

Reuse of water in the circular economy – Innovation for urban water treatment

Full report www.r3water.eu



Test and demo site Hammarby Sjöstadsværk

www.aqua-q.se



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AQUATRACK® & Ozone Polishing

Online optical monitoring of contaminants and ozone polishing

Aqua-Q has developed two separate novel standalone technologies for safe reuse of effluent water:

- 1) On-line real time optical (laser) contamination monitoring and automatic sampling system for effluent water coming out of MBR, MBBR and SBR process. The system, AQUATRACK® - Early Warning System with automatic sampler, is now EU ETV certified, No. VN20160017.
- 2) Composed an automatic, self-contained modular ozone polishing system for online or batch application to eliminate pharmaceutical residues and pathogens present in treated wastewater (effluent) from MBR, MBBR, and SBR process.



Both these innovative technologies are performing well as standalone and have been demonstrated successfully. The idea is now to combine these technologies on a digital platform so that it can internally exchange, gather information from each other and will act on demand. Ozone polishing will be actuated on demand by AQUATRACK® to remove contaminants from effluent and provide safe and clean water for reuse.

The novel ozone polishing system is used on the effluent water from the MBR process and differentiates from other waste water treatment technologies where they use high doses of ozone either in the beginning or in the middle of the MBR process which creates by products. Our ozone polishing step is at the last end of the WWTP, MBR process and needs less ozone and less need for a granulated active carbon filter (GAC) to absorb the biproducts. We look for research cooperation.

Both technologies are patented.

Technology 1 - AQUATRACK®



AQUATRACK® is a real time online monitoring and sampling system for pathogens in treated wastewater for reuse and reclaimed water. The system consists of multiple conventional water quality sensors including an optical laser sensor which detects all possible forms of variations caused by contamination (natural, human error, process failure) in reclaimed and recycled water.

The system can communicate wireless and access data remotely. The software creates a dynamic fingerprint of effluent water based upon the micro contaminants/micro particles/micro debris in the effluent water. When the fingerprint deviates the system automatically captures relevant water sample that can be analyzed for positive identification of pathogens.

AQUATRACK® is now EU ETV certified for monitoring and sampling of drinking water, reuse and reclaimed water.

Addressed problems and challenges

The main source of contamination comes from purified or insufficiently purified wastewater, both industrial and small-scale private sewage discharge. It pollutes rivers, lakes, water bodies, and coastal waters and creates potential risk of microbial contamination in drinking water, bathing water, groundwater, etc.

The emerging environmental problem in the developed countries is pharmaceutical residues in purified or insufficiently purified wastewater both from municipality and industries.

To solve the above-mentioned problem of contamination in the effluent water many new different technologies/processes are being developed like MBR, MBBR etc. These membrane technologies have well defined cut off. The effluent discharge is used for reuse and reclaimed water in agriculture or ground water recharge.

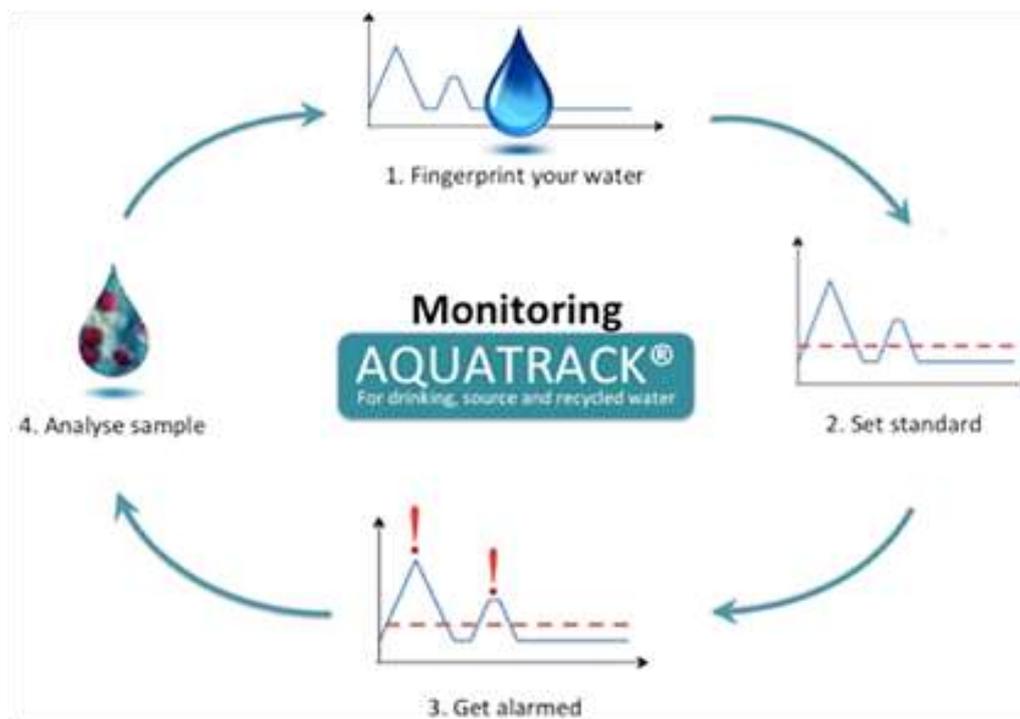
In the R3Water Project Aqua-Q developed a novel user-friendly, intelligent real time on-line monitoring and sampling system, AQUATRACK®, which is used for real time quality monitoring of the effluent from a MBR process in Stockholm and now in Spain. The aim is to give the management of a treatment plant early warning for sudden changes/deviations in effluent water quality. These changes are having high probability of microbiological growth due to contamination that is harmful to environment, rivers, lakes and contains also drug residues among other organics.

AQUATRACK® is designed to monitor effluent quality 24/7 after MBS, MBBS, SBR and conventional treatment process and collection of water sample when there is high risk for pathogens in the effluent discharge.

Applicability and pre-requisites

Applicability process of AQUATRACK® is user-friendly and follows the 4 simple steps, see picture below:

- 1) Connect a side flow of the effluent water to the inlet of AQUATRACK® and get a fingerprint of your water stream and always access the water quality changes on the local monitor or get the results wireless.
- 2-3) Decide a highest amount of water quality variations of your process water and get alarmed when variation occurs.
- 4) The variation that trigger the alarm is automatically sampled and stored for further analysis.



4 steps of the applicability process of AQUATRACK®

- Monitoring of wastewater effluent from MBR, MBBR, SBR and after conventional waste water treatment process.
- Monitoring and quality control of industrial water treatment process
- Monitoring of drinking water reservoir, networks, source/lake water

Pre-requisites:

- The equipment needs to be placed inside a room having normal room temp and 230/240 V AC electrical plug with floor drain. A partial constant flow of about 4-5 l/min of the effluent to be monitored with an open/stop valve at a pressure of 2-3 bar.

Features and benefits

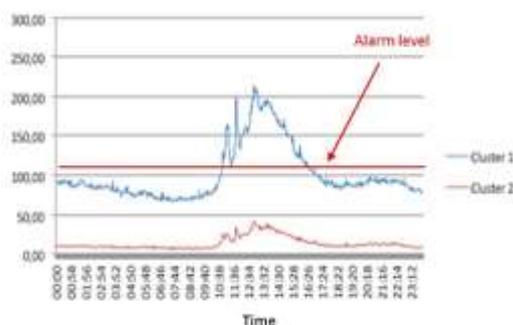
Benefits of AQUATRACK®:

1. Most cost effective and accurate monitoring system for immediate detection of MBR, UF, NF and RO filters break through and alarms operator for the event with time and date. Records all incidents. Clear economical benefit.
2. Creation of individual fingerprint of different non-contaminated water helps preventing building of biofouling by identifying contamination in time.
3. Early warning to an operator of a treatment plant for micro particles/micro debris exceeding the set limits in the effluent. Always generate alarm when there is deviation from stable water quality.
4. Operator can establish periodic pollutant profile (e.g. daily/monthly/yearly profile of micro contaminant presence in water) and hence optimize treatment process.
5. Captures automatically water sample for biological & chemical analyses: i.e. water sample captured right at the time of the observed anomaly gives high confidence on analysing results.
6. Helps protecting the environment in a sustainable way. Safe re use of treated waste water brings value in life.

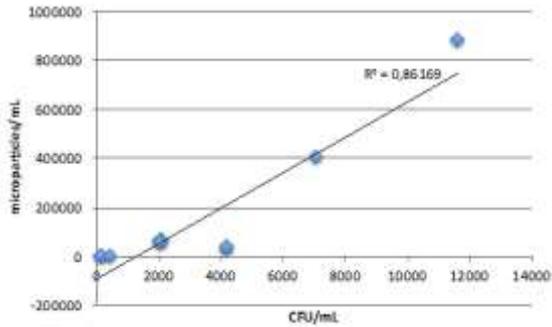
Operation and maintenance

- AQUATRACK® can be easily installed without making any changes to the existing treatment process. Installation starts working from day one (plug and play).
- Maintenance is simple and does not require much time.

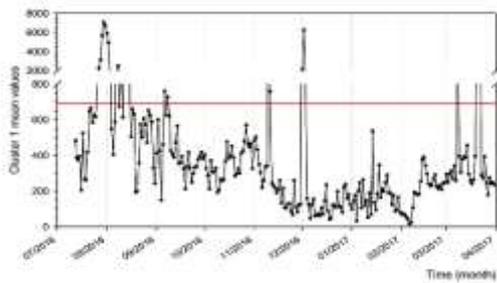
Results



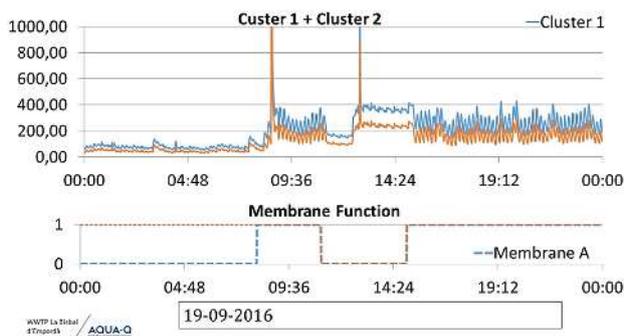
This graph represents an overview of level of contaminants as fingerprint in the MBR effluent water and is represented in two clusters. Cluster 1 represents bacteria size and cluster 2 represents size of parasites. This graph also indicates that at about 10.30 am some anomaly happened and that anomaly returned to normal around 16.30 pm. 10.30 to 16.30 was a critical period for the process.



The graph illustrates a real-time example of AQUATRACK® monitoring of treated wastewater. The increased values triggering the automatic sampler is plotted against the number of Heterotrophs (Total Count) measured by MBS MultiReader. A correlation of 86% between the triggered alarms and bacteria count was found.



Overview of average mean values collected by AQUATRACK® from July 2016 until April 2017 from MBR effluent at WWTP La Bisbal d'Empordà, Spain.



Variations during one day of the effluent quality from MBR process at WWTP La Bisbal d'Empordà, Spain.

Perspectives for the future

The ETV verification shows that AQUATRACK® can be used to keep continuous track of biological contaminants in drinking water, source water, and treated wastewater (MBR effluent). It can also be used to keep record of contaminants (e.g. micro-debris, biological contaminants, planned/unplanned discharge of wastewater treatment plant).

This performance can be considered as an important feature of an environmental monitoring technology.

Information from AQUATRACK® can be used to make intelligent decisions about the amount and kind of disinfection, hence avoiding over-disinfection and thus saving money.

AQUATRACK® can establish daily, monthly, and seasonal contamination patterns which can be used to improve the efficiency of a treatment process, thus saving electricity and chemical costs.

AQUATRACK® gives real-time warning of possible contamination events, which can help to avert epidemics, and costs & liabilities associated with epidemics.

AQUATRACK® can be claimed as an innovative and novel early warning system of monitoring and sampling for pathogen detection in drinking water and reclaimed water.

Technology 2 – Ozone polishing system



Aqua-Q has developed and composed a modular ozone polishing system and has successfully demonstrated that in a cost-effective way with a minimum dose of ozone both pharmaceutical residues and pathogens can be totally removed beyond the limit of detection.

This online ozone polishing pilot system is fully automatic and self-contained. Only a partial flow of effluent water from MBR process and 230 – 240 V AC electric plug is required for plug and play.

Local industrial regulations have to be maintained to comply with government regulations.

Addressed problems and challenges

Water pollution/contamination from pharmaceutical residues are the major environmental challenge in aquatic environment in many developed and emerging countries. Drug residues from human and animal consumption through the sewage system reach lakes and rivers that have become a global environmental problem. Current drugs collide with the requirements of sustainable development. Pharmaceutical consumption in society is increasing. 50-60% of this consumption ends up in our water environment. Many of these drugs are found in our drinking water, source/lake water, aquatic life, bathing water, and ground water etc.

Even though the concentrations of these pharmaceutical compounds are low concentrated (nanograms per litre levels), no one really knows exactly the long-term exposure adverse consequences affecting human health and aquatic life.

Scientists still arguing about the current state of the various drug substances that can interact with each other and form hazardous substances. Therefore, there is the need to develop methods to eliminate these dangerous drug residues in each treatment plants before discharging the effluent water to nature or using it as reclaimed water. Stringent legislation and control is required.

To solve this challenge, sophisticated technologies have been developed and are commercially used in the treatment of wastewater (both municipal and industrial) like MBR (Membrane Bio Reactor) and MBBR (Moving Bed Bio Reactor) etc.

Even though following prioritised pharmaceutical compounds are found in the effluent from a MBR process (see below under Results).

Aqua-Q's innovative solution is online real-time monitoring and sampling of the contaminants (early warning) and in real time eliminating that by ozone polishing so that safe and clean treated wastewater can be reused without quick positive identification of type of contaminants.

Applicability and pre-requisites

To eliminate both the drug residues and pathogens in treated wastewater (effluent from MBR) Aqua-Q developed/composed a cost-effective self-contained ozone polishing process. Ozone is a strong oxidizing gas and spontaneously reacts with organic substances and eliminates pathogens.

Mixing of ozone gas and effluent water by creating micro bubbles and obtaining a stable ozone water solution is our key success factor. This innovative ozone polishing process treated effluent from the MBR at Hammarby Sjöstadsværk in Stockholm. The ozone polishing step removes totally drug residues

below the limit of present detection limit and totally inactivates bacteria and other pathogens found in municipal and industrial effluent water. The treatment also reduces the TOC and color of the effluent water. The ozone gas and the effluent water is mixed in a closed circulation tank. Once the dissolved ozone concentration has obtained the pre-determined value the water is discharged to outlet.



The water in the left glass can be used directly to replenish aquifers or artificial recharge and is safe for irrigation purpose. Thereby, the negative spiral of water scarcity in the world can be broken. Reuse of water creates a great opportunity for future.

This modular ozone polishing system is automatic and self-contained with oxygen generator, ozone generator, reaction vessel, off gas destruction, efficient mixing of gas and water with all the necessary instruments to monitor the process stability.

In combination with AQUATRACK® the ozone polishing technology is a power full tool to remove pharmaceutical residues and pathogens with real time online quality control for reuse of water. The patented novel process set-up is a future process system.

Pre-requisites:

The equipment needs to be placed inside a well-ventilated room having normal room temp 20°C and 230/240 V AC electrical plug with floor drain. A partial constant flow of about 14-16 l/min of the MBR effluent is fed to the system with an open/stop valve at a pressure of 2-3 bar. There should be an ambient monitor for ozone gas leakage.

Features and benefits

Ozone polishing is a most cost-effective system to eliminate both pharmaceutical residues and pathogens in the same treatment coming out from a MBR system.

- 1) Our ozone polishing cost effectively eliminates both pharmaceutical residues and pathogens in effluent water with minimum dissolved ozone 0.08 ppm.
- 2) Require no secondary treatment with active carbon as no by products are observed.
- 3) Our empirical experience confirms with that if we maintain stable treatment process no costly pharmaceutical analyses is required on regular basis for prioritized drug residues as above.
- 4) Properly applied at correct position on a waste water treatment process ozone is a most environmental and effective tool to decompose organic substances and pathogens in the effluent and can have GRAS status.

Operation and maintenance

- 1) As ozone, modular system is skid mount and complete with system set up only electricity 230 – 240 V AC is required.
- 2) Effluent water at room temp or if possible, lower temperature is required along with discharge possibilities.
- 3) Operation is plug and play.
- 4) The system complies with all national industrial standards including national environment regulations

RESULTS

The table and graph below illustrates some of our results of active pharmaceutical residual substances found in the effluent of MBR process that has been effectively removed by ozone polishing step below the limit of detection.

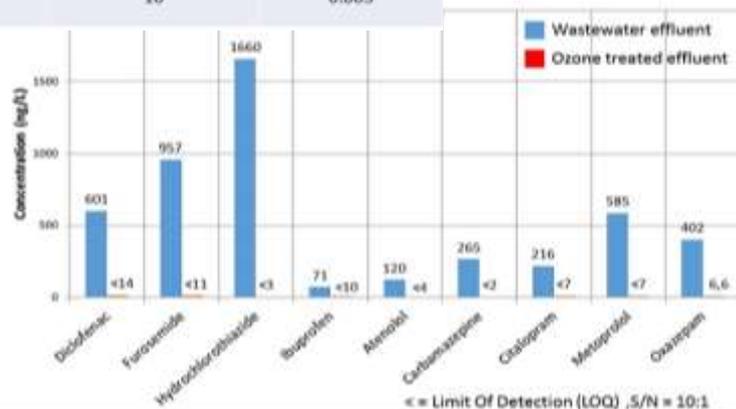
		Before ozone	After ozone
Substance	Mode of action	ng/L	ng/L
Diclofenac	Anti-inflammatories	601	<14
Furosemide	Diuretics	957	<11
Hydrochlorothiazide	Antihypertensives	1660	<2.8
Ibuprofen	Anti-inflammatories	71	<10
Naproxen	Anti-inflammatories	37	<4.6
Ramipril	Antihypertensives	<5.6	<5.6
Warfarin	Anticoagulants	6,9	<4.9
Atenolol	Antihypertensives	120	<3.7
Amlodipine	Antihypertensives	<3.6	<3.6
Bisoprolol	Antihypertensives	32	<5.2
Caffeine	Stimulant	17	<15
Carbamazepine	Sedatives	265	<2.1
Citalopram	Antidepressants	216	<6.5
Fluoxetine	Antidepressants	8,8	<6.0
Ketoprofen	Anti-inflammatories	68	<7.2
Metoprolol	Antihypertensives	585	<6.6
Oxazepam	Sedatives	402	6,6
Paracetamol	Anti-inflammatories	28	<11
Propranolol	Antihypertensives	68	<4.4
Ranitidine	Antulcers	72	<21
Risperidone	Antipsychotic	<22	<22
Sertraline	Antidepressants	<6.5	<6.5
Simvastatin	Lipid-regulating	<8.3	<8.3
Terbutaline	Asthma medication	13	<2.4
Analysed at IVL Stockholm		(<) lowest quantifiable limit (LOQ, S/N=10)	



Samples	RT	30°C	37°C	Organic carbon (mg/l)	Color at 410nm
Control	13*10 ²	16*10 ²	15*10 ²	12.5	0.008
Treated 1	0	0	0	10	0.005
Treated 2	0	0	0	10.5	0.004
Treated 3	0	0	0	10	0.005

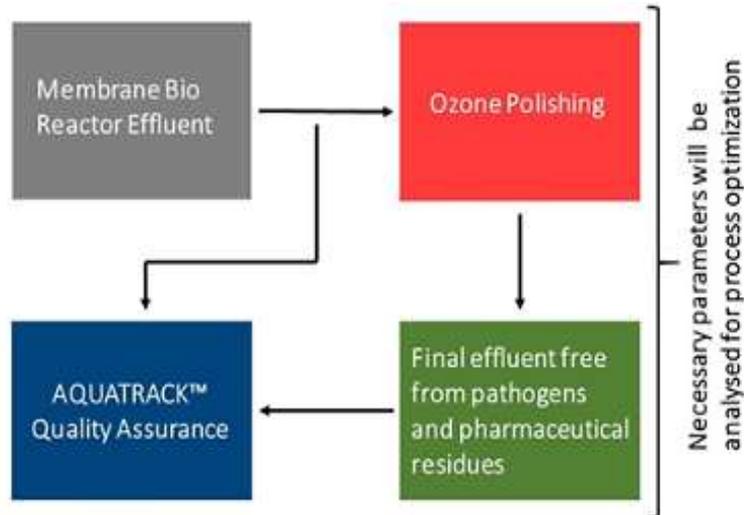
Removal of bacteria by ozone polishing.

This graph illustrates a few compounds.



Perspectives for the future

Reuse of water is essential in many parts of the world as population grows and demand for fresh clean and safe water increases. Reuse of treated wastewater with quality control provides hope and opportunity for people as water shortage has become a global problem not only in emerging countries but also in developed countries. There is a need for future new EU legislation to ensure high clean and safe reuse water standard not only a minimum standard for reuse of water as discussed today.



From innovative technology perspective, Aqua-Q strongly believes on future European standard for stringent quality control of reuse of treated wastewater for filling the aquifers, irrigation and other applications. Real time online monitoring of contaminants of effluent is necessary to protect environment and our common water bodies. Aqua-Qs contribution is a process set-up as shown in the scheme above which will ensure a cost effective combined process to monitor the contaminants in the effluent and eliminate the contaminants by ozone polishing the effluent.

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AWARDS



Received WssTP Water innovation SME award 2016.

The innovation was identified, as the best practice in the field of application with high market potential.

Aqua-Q, a Swedish SME, receives the World's most prestigious environmental National Energy Globe Award 2017 for its outstanding innovative achievement on real-time optical monitoring & sampling solution for quality control of drinking water & water for reuse & simultaneously removing pharmaceutical residues & pathogens in water by ozone polishing system.



Jury-Rating

Water is the most important premise for a healthy and good life. Recognizing contamination in an early stage can save lives and increase the possibility of finding solutions quickly. This project can improve the living condition of many people and prevent epidemics. It uses a minimum of energy and causes no emissions. It is a great contribution to humanity!

These international recognitions will encourage researchers, consulting groups, utility owners and investors to seize the opportunity to bring this technology into the global water market.