Plasma Water Disinfection, and IIoT Pumps Utilized in Water Disinfection Opportunities

Introduction

Declining fresh water supplies is one of the most ominous and persistent challenges we are globally facing. The UN World Water Development Report 2019 states that over 2 billion people live in countries that suffer from high water stress. It then further refers to estimates that approximately 4 billion people experience severe water scarcity at least one month out of the year. The report further allocates that sector-wise, the largest water consumption is undisputedly agriculture. Agriculture is responsible for 69% of annual water withdrawal, followed by industry and energy sector at 19% and households at 12%. Globally more than 80% of all wastewater is discharged to the environment without being treated. Climate change is predicted to amplify the extremes, rendering wet areas wetter and dry areas dryer, which accelerates the water stress growth rate in the latter. Compared in numbers, insufficient access to clean water and inadequate sanitation are reported to grossly outweigh the attributable deaths resulted from droughts, floods, earthquakes, epidemics and conflicts.

Water can be contaminated in many ways. Some of the most notable forms of water pollution are nutrients, which is well attributable to the large share of water consumption by agriculture. Other types of pollution causing acute problems consist of aqueous bacteria and viruses (poor sanitation), and biologically active chemical residues like pharmaceuticals and crop protection agents. For pharmaceuticals, especially when concerning groups of chemicals that are endocrine disruptors and antibiotics. It has been reported, even in popular media, that hormonal medication residues like female contraception agents, can have dramatic effects on the fish population when ending up in aquatic environments. As for antibiotics, over-use combined with improper discarding and irresponsibly discharged industrial wastewaters, can amplify bacterial resistance and it seems that currently bacteria are developing immunity faster than we can modify and produce new antibiotics. Discovery of ‘super- bugs’ that are resistant to antibiotics are reported in public media frequently, and certain still effective antibiotics, like vancomycin, have been generally restricted under hospital use only. Immunity of bacteria towards antibiotics is one of the biggest threats we are currently facing, and pharmaceuticals in the environment are promoting just that. It should be noted that not only careless discarding delivers medical substances to the environment, but also that normal and responsible consumption provides an important route as well: going through the body, some pharmaceuticals and their biologically active metabolites, exit naturally. This means that in addition to appropriate education on how expired or unused drugs should be discarded, the need for proper technology to destroy them in wastewater streams is evident.

Speaking of water treatment, we may typically think about municipal wastewater treatment plants (WWTPs). Contemporary WWTP typically consists of mechanical removal of solids (primary treatment) and biological treatment of dissolved organics and nutrients (secondary treatment), often coupled with chemical addition for coagulation/flocculation at some part of the process.

Sometimes the overall process is extended with tertiary treatment, which can be hygienization or further polishing of the effluent from residual dissolved organics using e.g. membrane separation, UV irradiation or ozonation.

Tertiary treatment is also required to remove any pharmaceuticals that go through the WWTP unaffected. Indeed, while some common pharmaceuticals like ibuprofen (non-steroidal anti-inflammatory painkiller) can be well degraded in a biological process, others, like carbamazepine (anti- epileptic drug), can even increase in concentrations during the biological process (this peculiar problem is due to certain metabolites of the parent compound being restored to the original chemical structure during biological treatment). It thereby becomes evident that with a huge range of possible pharmaceutical compounds and their many active metabolites and transformation products, we need non-selective processes to take care of them all. It is also important to realize that chemical analyses can generally only detect what we are looking for, meaning that if we do not look for 'everything', we are not aware of all the pollutants present. Looking for everything is of course not feasible. In other words, the problem is that we cannot send samples to the lab and say, "please find all the pharmaceuticals in there", but instead we need to specify and list all the compounds we need to analyze. The longer the list, the higher the cost, and all compounds need to have an analytical method created to enable identification and measurement of concentration. This further emphasizes the need for non-selective tertiary processes.

The mechanism by which dissolved organic compounds are degraded is generally based on oxidation. A number of processes and technologies have been developed to provide oxidants for water purification in such a manner, and each one has their assets and drawbacks. Typical assets can be energy efficiency, low maintenance costs, low investment cost, safety, efficacy etc. Their opposites make the typical drawbacks and finding a technology to only meet the assets is a great challenge. Oxidation is frequently done with ozone, hydrogen peroxide, chlorine compounds, and some very elaborate combinations utilizing those together with catalysts, UV-light, electric discharges, and low-voltage electric current.

Since oxidation requires oxidants, it is easy to conclude that strong oxidants are preferred together with low cost. The most feasible oxidant is called hydroxyl radical (OH-radical), and it is so peculiar that any process utilizing OH-radicals has been called an advanced oxidation process (AOP) since 1987.

Ozonation in water purification has been around for more than a hundred years, and it has been studied in numerous studies to be very effective in destroying pharmaceutical residues from wastewater. The asset of ozonation systems is the very high oxidation potential of ozone, but a typical drawback is high capital investment plus quite a high operational cost from electricity consumption; ozone is generated on-site with ozone generators that employ electric plasma discharges to convert oxygen into ozone, which is then sparged to the treated water.

A second evolution of this approach was the development of plasma technologies that bring the electric discharge into a direct contact with the water, but these attempts have not reached a successful commercial scale for wastewater treatment. Generating the discharge directly where the water is skips the sparging operation needed in ozonation, but a more important property of plasma processes is the generation of OH-radicals from the water itself when it is hit by the plasma, making these processes AOPs. This approach has been studied in many different configurations to overcome deficiencies in ozonation in order to make the process less expensive and more powerful. The major hurdle for plasma technologies has been scalability within reasonable simplicity and cost. In this paper, we give a preview of the Flowrox Plasma Oxidizer plasma water treatment system that overcame these problems.

Flowrox Plasma Oxidizer: Plasma Water Treatment Technology Overview

Plasma Water Treatment

Flowrox Plasma Oxidizer utilizes non-thermal plasma for water treatment. The system contains an electrode stack that generates special types of electric discharges to create an ambient temperature plasma field inside a reactor. The treated water is then allowed to pass through the plasma volume with high specific plasma-water contact surface area. Maximizing the contact surface area allows for abundant OH- radicals to be formed on the interface, contributing to effective oxidation of dissolved pollutants.

Intuitively, generating electric discharges to treat water may sound energy intense, but the basis for the Flowrox Plasma Oxidizer process is in an accurate focus of electric energy to the point where it is needed on a molecular scale, which translates as a sophisticated means of igniting the desired oxidation reactions at minimal energy input. Various reactor configurations with different kinds of plasmas have been studied for water treatment applications and generally it has been observed that a straightforward gas-phase discharge, brought in contact with liquid water, is a better solution than attempting to breaking the discharge through water with submerged electrodes. Again, intuitive as it might be to create the plasma right through the water for ultimate contact, this approach suffers inevitable energy losses as it relies on water vaporization to form a conductive pathway for the discharge propagation. Flowrox Plasma Oxidizer combines the very high plasma-water contact surface area with the advantages of a simple gas-phase electric discharge.

Plasma, often referred to as the fourth state of matter, is basically ionized air or some other gas or gas mixture. Ionization of air enables an electric current to pass through it. In perhaps more colloquial words, plasma basically means electric discharge, such as a lightning strike, what you see inside fluorescent lights, or the spark between a car engine spark plug’s terminal. It is convenient and important to separate types of plasmas into thermal and non-thermal ones. Thermal plasmas are very hot, like lightnings and welding arcs (up to thousands of degrees), whereas non-thermal plasmas remain closer to ambient temperatures. The thermodynamic difference stems from molecular movement: in thermal plasmas both electrons and ions in the gas are energized, while in non-thermal plasmas only electrons are. For water treatment purposes, there is no reason to spend energy in energizing ions, which means that non-thermal plasmas are preferred. The reason is because only high-energy electrons are needed for generation of OH-radicals in a very straightforward reaction:

$$e^- + H_2O \rightarrow e^- + OH + H$$

The equation describes how an electron (e-) colliding with a water molecule (H_2O), with a very high energy, splits it into an OH-radical and what is called atomic hydrogen (H). The atomic hydrogen is scavenged by ambient oxygen to form a hydroperoxyl radical, also an oxidant, and the OH-radical will react instantaneously with surrounding substances. Since the radicals are formed from the treated water, it can be said that in plasma treatment the water actually purifies itself! Due to the high reactivity of the OH-radical, it is inherent that many of these will be consumed in useless decay reactions. On the other hand, it also means that residual OH-radicals are not found in the treated water through the output of the reactor. As the efficiency of the Flowrox Plasma Oxidizer process lies in the appropriate focus of energy into heating electrons and not ions, the efficacy is based on the sheer abundance of the OH- radicals on the plasma-water interface.

Another important oxidant formed in the process is ozone. Ozone is produced from the oxygen in the ambient air, and indeed, the process efficiency can be ramped up with an accessory oxygen concentrator coupled to enrich the inside oxygen concentration. Enriched oxygen concentration has been observed to even double the plasma oxidation energy efficiency. However, while important, ozone plays a secondary role in the oxidation process as the OH-radicals are generally attributable to 60-80% of the oxidation work. The roles of these oxidants depend on the composition of the wastewater; OH- radicals can react with compounds that exhibit a refractory character towards oxidation with ozone.

Flowrox Plasma Oxidizer Technology

The original motivation for direct plasma treatment of water was to create a fundamentally more economical alternative to conventional ozonation. The core idea was to generate the oxidants right where the water is and harness the power of OH-radicals, whose formation is a notable benefit when the plasma is brought in contact with water. It was also considered important in the early design phase that the system should be very robust, tolerate harsh conditions, have no moving parts and exhibit no electrode erosion attributable to electric discharges. These features were finalized into the current Flowrox Plasma Oxidizer design and the result is really a low maintenance system that has only stainless steel in contact with the water, no moving parts and zero observed electrode erosion. Another distinctive feature for Flowrox Plasma Oxidizer is its ability to tolerate high conductivity waters, which is not an obvious feature for a system that brings electric discharges together with water. Flowrox Plasma Oxidizer can be operated with no extra chemicals, using only electricity. As an accessory product, the unit can be equipped with an electricity driven oxygen concentrator, which can boost the overall energy efficiency considerably: enriching the oxygen concentration from ambient to 60% can double the efficiency.

The first generation Flowrox Plasma Oxidizer is a 2-kW system, a single unit being capable of treating 1-25 m3/h depending on the application. The system is a plug-n-play unit with connection ports for inlet, outlet, drainage, and power. The treated water is fed from the top, allowed to pass through the plasma reactor and exit through the outlet port. The unit is illustrated in Figure 1.

Figure 1. Flowrox Plasma Oxidizer 2 kW unit.

Flowrox Plasma Oxidizer Applications

Flowrox Plasma Oxidizer technology has been tested in the treatment of various waters, wastewaters, process waters, cooling waters and simulated model solutions. Testing has included monitoring of specific target compounds as well as collective parameters of general interest, such as color, odor, COD, BOD, TOC etc. The technology has also been piloted for drinking water disinfection which is one of the most promising tasks while enjoying parallel benefits from simultaneous odor and color removal.

The majority of suitable applications deal with the destruction of organic pollutants. Some inorganics may also be well susceptible towards a reaction with the oxidants: metals can be removed from organometallic complexes and oxidized to a higher valence state, nitric and sulfuric species can be oxidized into nitrates and sulfates etc. Aromatic hydrocarbons and other organic pollutants, with unsaturated double bonds in their molecular structure, are facile targets for plasma oxidation. The simplest structures are often the most refractory ones, such as low molecular weight organic acids like formic and oxalic acid. Conveniently however, these kinds of compounds may often be environmentally benign and easily biodegradable. While these guidelines can be useful for estimating process applicability against given pollutants, it is important to understand that they are generalizations among typical scenarios and essential exceptions.

Phenol is a typical model substance used in studies of new oxidation technologies to provide a point of comparison in performance and energy efficiency. Flowrox Plasma Oxidizer technology has proven remarkable performance in phenol degradation yielding 88 g/kWh removal efficiency in operation with ambient air and an even more impressive yield of 138 g/kWh at enriched oxygen atmosphere (initial concentration 100 ppm). Another study for furfural removal from 500 ppm yielded 133 g/kWh efficiency in basic solutions and 182 g/kWh in acidic ones, which demonstrates very high figures and gives an example of the effect of pH on efficiency. It is worth pointing out, however, that on the contrary to the experiences with furfural, high pH is often beneficial for the oxidation energy efficiency due to certain pH dependent ozone reaction pathways, which emphasizes that the water quality is usually the major variable. A large group of other pollutants with cyclic molecular structures are pharmaceuticals, most of which have one or more cyclic moieties in them. A large group with many individual compounds tested for plasma treatment as pharmaceuticals are discussed in more detail at a later paragraph.

Organic acids like formic, oxalic, acetic and succinic acids are also popular model compounds. They exhibit lower reaction rates with oxidants and for these properties provide good subjects for scientific studies. In practice they are seldom a problem due to natural biodegradability and overall harmlessness. These low molecular weight substances are typically more refractory than the heavier and aromatic hydrocarbons, and while the Flowrox Plasma Oxidizer technology has shown comparatively high oxidation rates with those as well, few practical applications are encountered in industrial operations. Yet, while low weight organic acids may not be a very interesting target for pollutants, in many cases an effluent stream that requires further COD reduction may very well contain organics in this form. COD reduction in turn is a very common and increasingly sought-after operation for further polishing of WWTP effluents, and most Flowrox Plasma Oxidizer pilot projects so far have focused on COD reduction. COD can be removed with plasma oxidation from municipal WWTP effluents, pulp and paper industry wastewaters, and for example textile industry wastewaters at very high yields. A recent project demonstrated a remarkably low energy consumption of 4.7 kWh/kgCOD for 50% COD reduction from a biologically treated wastewater effluent at a mere 0.7 kWh/m3 Flowrox Plasma Oxidizer plasma energy dose.

Pharmaceuticals compose the widest single group of chemicals studied for degradation of various waters with the Flowrox Plasma Oxidizer technology. More than 30 chemicals have been observed from municipal, hospital and institutional wastewaters. The technology has been proven to substantially cut the pharmaceutical load to the environment when installed either to a point source such as a hospital sewer line before connection to municipal network, or at the end of an WWTP to serve as tertiary treatment. Higher number of pharmaceuticals with higher concentrations occur in point sources like hospital sewage, which make it a convenient place to cut the content before it’s diluted in the network. Even the complex mixture at a very high COD characteristic to untreated hospital sewage has been observed to be a feasible medium for Flowrox Plasma Oxidizer treatment, as the results have shown that regardless of the composition, the pharmaceuticals occurring in nano- to microconcentrations are almost or completely degraded below analytical level of detection at 0.1-1 kWh/m3 plasma energy dose. Since the transformed species are not visible in analyses, unless specifically determined, further studies have been conducted to ensure that possible transformation products are also affected: indeed, any identified transformation products, including those from partial oxidation in the beginning of the process, have been observed to degrade further and even completely mineralize into CO2 and water, which is seen as TOC reduction.

Fuel additives like MTBE and dissolved oil residues pose great hazards for aquifers and are known to render ground water undrinkable following spill accidents. Flowrox Plasma Oxidizer oxidation has demonstrated very high efficiency in destroying both dissolved oil fraction and MTBE at a very acceptable energy consumption. The non-selective process readily oxidizes any such compounds, producing safer water for reuse or disposal.

Color removal is another typical task for an AOP. While high color and turbidity naturally exclude processes relying in UV light, plasma treatment is insensitive towards turbidity because the oxidants are produced on the gas side of the liquid surface and no light transmission through the liquid media is required. Color removal can be thus very efficient, the efficiency depends on various treatment parameters and the composition of the color itself. Figure 2 below visualizes color reduction in plasma treatment of various wastewaters.

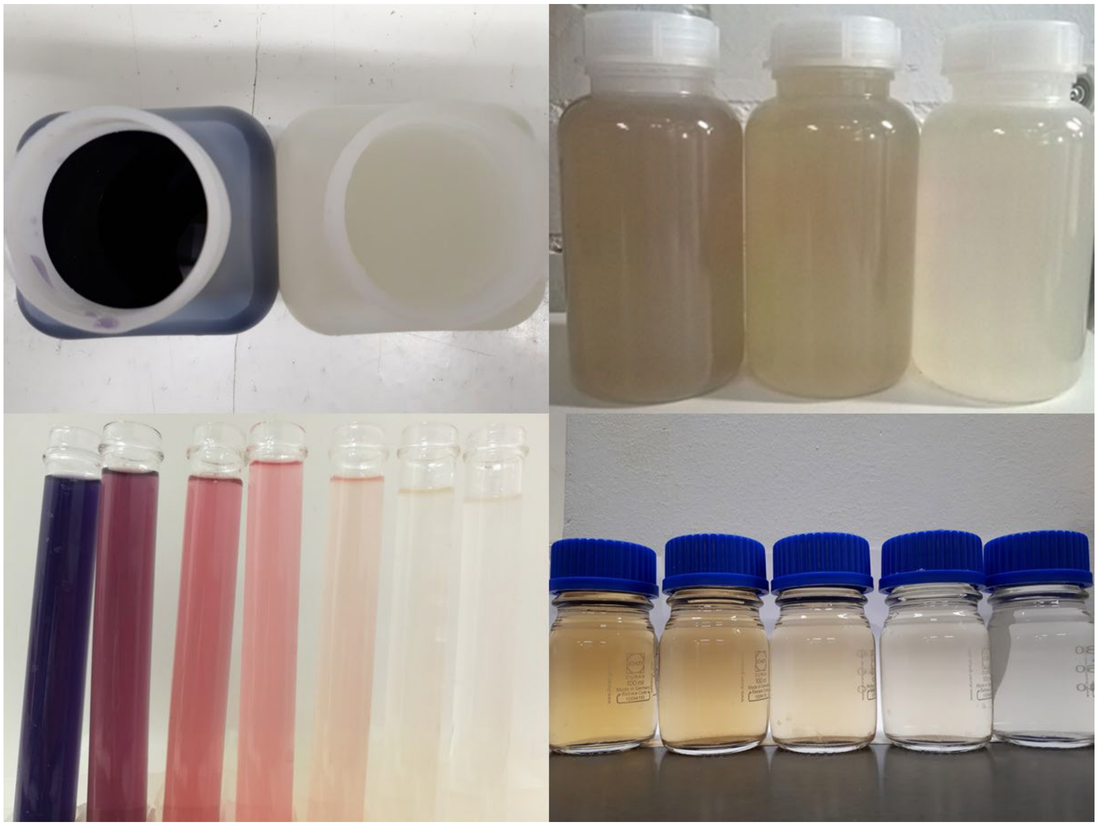

Figure 2. Color removal by Flowrox Plasma Oxidizer plasma treatment. Left: textile industry wastewater; top right: high turbidity industrial wastewater; bottom right: biologically treated wastewater effluent.

One of the most potential applications for plasma treatment is disinfection of drinking water. The parallel benefits complementing disinfection include destruction of organic micropollutants, removal of odors and residual color (e.g. humic acids). In a previous project the system was used for a full year- around disinfection of a drinking water in a city waterworks station. During winter, a modest 0.01 kWh/ m3 plasma energy dose was enough to keep the water disinfected. More difficult conditions in summer,0.03 kWh/m3 was observed to ensure proper effect.

The Industrial Internet of Things Is Going to Change the World Dramatically

Pick up any magazine today and there are typically multiple articles discussing the industrial internet of things (IIoT) or digitization. Digitalization has been around for many years already, it just hasn't been adopted by the industry. Early adoption was done in airplane engines and other vital equipment. Only a few years ago companies were not ready, or still contemplating how, to tackle the subject of digitalization. But the number of companies planning and implementing utilization of digital solutions is growing rapidly. In 1995 there were only about 1 million devices connected to the internet of things. By 2015 there were already 10 billion devices connected, and by 2020 it is estimated there will be some 50 billion devices connected. The amount of information we collectively are gathering today is immense. In the past two years the industry has generated more data than the past data history of the planet combined. Companies that are fully invested in digitalization are claiming some very large gains.

"Some claim they are gaining one additional month of production per year."

Other benefits of digitalization include reduced cost of maintenance and significant fuel, energy and chemical consumption. The real value lies in being able to decipher and use all that information. Data without intelligent systems to help decipher this information cannot be utilized efficiently. A typical DCS or SCADA system is kind of a black box. The traditional control system takes hold of the facility's process, but most do not have intelligence such as machine learning or artificial intelligence incorporated (AI).

Flowrox offered to a mining company in Finland its Malibu Smart Filter Monitoring solution. The mine had three vertical pressure filters processing zinc from their thickeners. The pressure filters were not new and had been operational for many years. The mine agreed to purchase a Smart Cube and installed it to begin monitoring the three filters. There was no other instrumentation installed but rather the Flowrox Smart Cube began collecting data from all the instrumentation already on these automatic pressure filters. Engineers at Flowrox worked with the owners and developed key performance indicators (KPI) that the owners wanted to be able to see. Check out Figure 5 below.

Figure 5. KPI chart developed with input from customer to display key performance indicators as well as alarms on the machines.

Flowrox made a digital twin of the environment as well as the auxiliary equipment feeding the pressure filters. The KPI page was then formed in the reports tab of the digital environment. The data that the Smart Cube is collects is sent to the cloud via LAN connection, WIFI or cellular data. TLS encryption is utilized so the data is safe and highly unlikely of being hacked. TLS is the same encryption utilized by much of the internet banking industry. The way that Malibu works in this case, is that it is slave to the normal operating system. So, Malibu can only collect data but not make any changes to the control of the machinery.

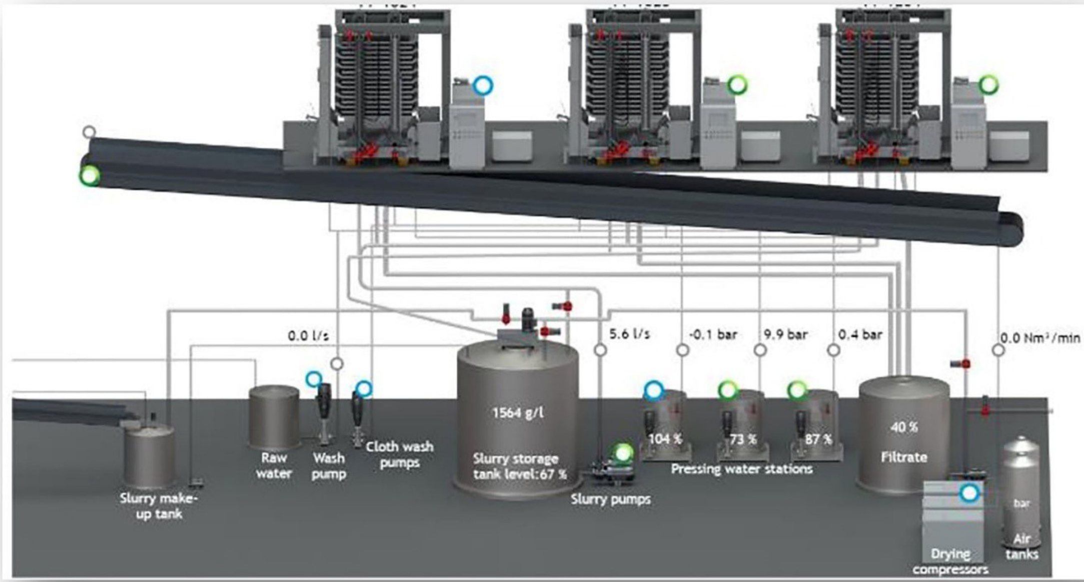

Figure 4. Depicted above is the digital twin image along with all the auxiliary equipment that supplies services to the machine. In this image two of the filters have green circles by the machine. This indicates those machines are operational at that time.

After a short time of monitoring, it was detected that machine 2 was producing significantly more tonnage than machines 1 and 3, with shorter cycle times. Further detection was made that machines 1 and 3 were waiting as much as 4 hours per day on auxiliaries feeding the fillers. The pressing water tank and slurry storage tanks were recharging and thus the filters had to wait on them to refill. Plant personnel had no idea this situation was occurring. From their control system they were led to believe the filters utilization rate was very high, but machines 1 and 3 had a utilization rate that was only 40 – 50%. This mine's main product is zinc production and it is in high demand. Producing more without additional investment was highly sought after.

Filter 1 was producing 7,149 kilograms per hour and filter 1 and 3 were producing 5,975 and 4,642 kilograms respectively. If filters 1 and 3's performance were improved to the level of filter 2, then 3,681 kilograms more per hour would be produced. Based on a 24-hour operation, that would increase production by 88,344 kilograms per day. The annual production increase based on a 300 day per year run rate would be 26,503,200 kilograms per year. With zinc's current price of $1.26 per US pound, that would mean they would be able to sell $73 million more per year. There was a lot of incentive to find solutions to the problems they did not even know they had before deploying an IIoT solution. Flowrox Malibu does not replace the traditional control system but rather is an inexpensive IIoT solution to bring further intelligence to users with its integrated machine learning and AI.

There were other benefits found as well. The plant manager said he would take several Excel files from the control system every Monday to produce last week's production figures. He said this task would take approximately two hours in totality. Now with the information produced from Malibu he could see production rate hourly if he so desired to. He and others could visit and view the digital twin imagery, KPI chart and various other reports directly from their smart phones, tablet or PC instantly. Malibu can also house a document management system so that all drawings, maintenance manuals, repair videos, how to videos, and any other valuable information are right there for analyzing. So, a maintenance person can watch a repair video on their smart phone while they perform the actual repairs on a filter.

Through additional monitoring it was detected that when air consumption increases dramatically it is a clear sign that either diaphragms or rubber seals have failed on the filter. Produced air is the costliest input to a pressure filter. In the past this increase in air consumption would go unnoticed by the control system. With Malibu it can be detected and alarmed immediately. Appropriate plant personnel will receive an e-mail or a text with which exact filter has the issue. Another filter issue that Malibu detected was a spike in the pressure of the pressing water system. This spike was quite high and could lead to ruptured diaphragms, blown out seals or in the worst case a damaged metal plate pack. If the plate were damaged it could result in a $500,000 or more repair and three months or more in downtime of the filter.

Since the mine is experiencing and seeing the benefit of IIoT solutions, they have asked Flowrox to provide smart monitoring of three additional filters as well as smart monitoring of their thickeners.

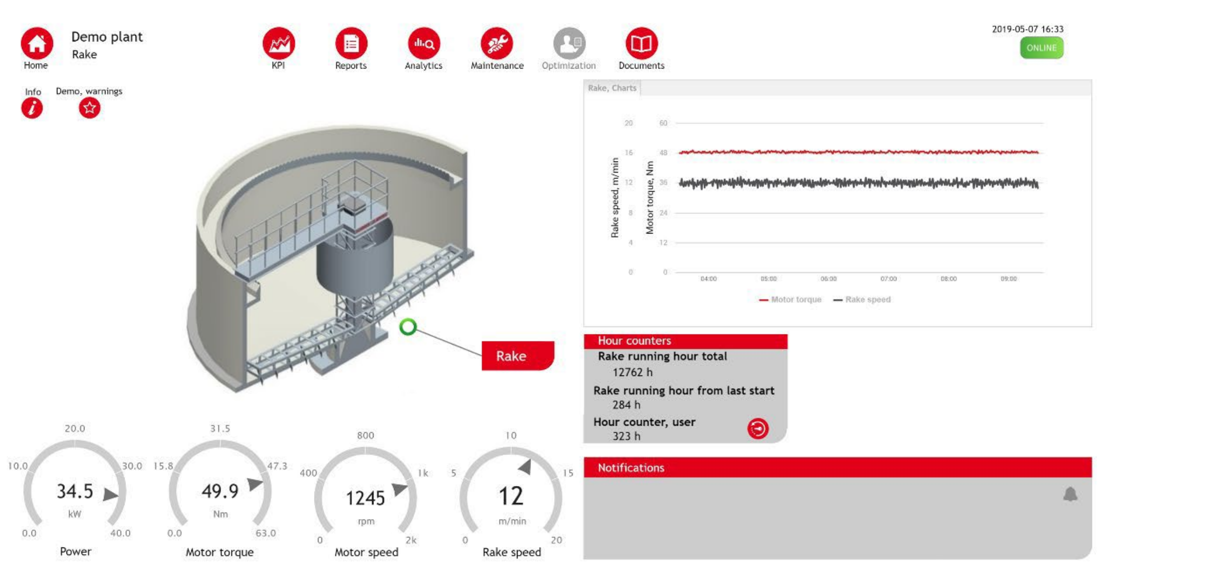

Figure 6. Thickener monitoring at mine in Finland.

Producing Fresh Water with Better Pumping Techniques

David J. Silverman, P.E., Process Manager for PSI Process and Equipment explains the approach to selecting chemical feed pumps.

“Our most recent application was for a groundwater utility feeding lime to raise pH. After reviewing various types of pumps, we thought hose pumps would be a good option because of the abrasiveness of lime and the potential for small chunks of lime to be present in the feed, since with hose pumps only the hose is in contact with the medium and the rollers can crush small chunks of lime. So, we reviewed literally every hose pump on the market.”

They had tried many types of pumps with limited success- at that time, they were using diaphragm pumps; they were spending a lot of time rebuilding their chemical feed pumps and just didn’t have the manpower to keep up, so they were looking for an alternative. We offered to do a trial with another type of pump and they agreed.

Hose pumps vary in several design aspects, such as the number of rollers, the construction of the drive, and the design and manufacturing of the hoses. We believed that fewer rollers would provide a more consistent feed. After reviewing all manufacturers, we recommended the Flowrox LPP-D pump. It has a single eccentric roller, and we sized the pump so it would run at a relatively slow speed, to reduce hose wear but also so that it would provide a consistent, steady feed; hose pumps can experience a brief backflow as the roller passes the outlet, so fewer revolutions means fewer pulses and more consistent feed. We also used Flowrox’ high-torque drive to ensure it would withstand higher pressures seen during peak demand.

“Flowrox was very accommodating with regard to the design. Instead of a conventional AC motor with VFD, this installation had DC drives. Flowrox’s engineers selected an appropriate motor and gearbox to work with this drive and deliver the flow range that was needed with plenty of reserve capacity.”

It’s important to carefully evaluate the discharge pressure, because in chemical feed applications there can be oscillation or pulsation, and the system pressure can vary diurnally or for other operational reasons. This is why, in this case, we recommended the high-pressure drive even though the pressure was nominally suitable for a low-pressure drive.

The current trial pump has been in service for five months. The operator notes, as we do, that the pH is very consistent, following a “flatline” pattern with essentially no variation, as we expected, due to the selection of the Flowrox pump. The trial continues and based on the results so far, we believe that the Flowrox pump is likely to outperform ALL the other pumps that have been tried over the years and represents a compelling value.

Package Pumping Systems Deliver Value and Improve Pump Reliability

Packaged pump systems were designed due to customer's needs and requirements. All too often a customer or contractor purchases a pump, installs it and starts it up. In many cases the installation, operating and maintenance instructions are not adhered to. The pumps are sometimes equipped with equipment or auxiliaries that are detrimental to that specific type of pump's performance. The idea behind a packaged system is to increase safety by incorporating both spill containment and in some cases, add pump covers to prevent unwanted spray from the pumps should something go wrong. The other aspect of packaged pump systems is to include all the auxiliaries on the packaged system to provide the pump the best environment to be the best it can be. Finally, the last advantage of a packaged pump system is that it arrives to the new owner factory tested and it is truly plug and play. Simply attach the feed piping, discharge piping and electricity, and the system is fully functional. No external contractors are needed to install a bunch of single components.

Figure 3. Two packaged pump systems that were manufactured so they can be wall mounted to conserve space. These systems have manifold, gauges, pressure relief, safety shut-off valves and the base of the unit functions as spill containment.

Conclusions

Fresh water is invaluable, and its declining availability poses immense threats with numerous side effects. As a primary element, the treatment of water will always be a topic of scientific works and continuous advancement, however the industry itself is often considered conservative. Better treatment results are required by increasingly strict regulations, which create pressure for water utilizing industries to consider their water treatment needs a bit further into the future.

Battling some of the most pressing issues in water security requires effective oxidation processes that reduce the load of various organic pollutants (e.g. pesticides and pharmaceuticals) to the environment, and enables the provision of clean and safe water for people around the world. New systems should be low-cost, reliable and efficient.

Flowrox Plasma Oxidizer is a first-of-a-kind direct plasma treatment system for water and wastewater, demonstrating a fundamentally new approach to water purification, thus representing a truly modern solution with a futuristic touch. The technology employs non-thermal plasma to generate ozone and hydroxyl radicals in a powerful and efficient manner. The solution is chemical free, utilizing electric energy to generate strong oxidants from air and the water itself. Unlike UV-relying systems, the process is insensitive towards turbidity and unlike chlorine and peroxide chemicals, Flowrox Plasma Oxidizer averts the need for chemical logistics, storage and use, as well as attributable safety procedures. Further assets include extremely low maintenance at no discharge-induced electrode erosion.

As an advanced oxidation process, Flowrox Plasma Oxidizer readily destroys dissolved organic pollutants from water while effectively removing color and odor. The solution is suitable for a wide range of industries and is feasible even for the removal of ozone-refractory substances. Further applications are found in disinfection and oxidation of dissolved inorganics like metallic, sulfuric and nitric species.

IIoT or digitalization is here and ready now. Many companies are grappling with which supplier of digitalization to get into bed with. I might suggest that you try one or even many. You don't have to roll it out plant wide and invest millions. You can start by making an individual asset intelligent by employing digitalization. Some great areas to invest in digitalization are when the issue revolves around safety or compliance. Other excellent targets would be assets that are constantly distressed, production bottlenecks, in distant, dirty, dark or dull locations.

Companies that have fully deployed digitalized solutions are performing in the top 25% of their peer group. Choose one, or many, and determine which works the best for you. For many years' productivity has failed to show significant improvements year on year. I believe digitalization is the first step in returning healthy productivity advancements.

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