WHAT ABOUT WATER IN A WtE PLANT?  
Strategies to optimize process and cooling water operation in a WtE plant

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Executive summary

There is a growing awareness of the effects of climate change, water and energy shortage as well as the fragility of our energy supply. This awareness has led to an increased interest in innovative, cost-effective solutions and improvement of the efficiency of Waste-to-Energy (WtE) plants.

Specific knowledge to do so can be found in experiences gained with traditional thermal power plants. For both thermal power plants and WtE plants, water plays a crucial role. To guarantee energy production and efficiency, the following items are among others a direct result of optimization of the water quality of both process- and cooling water:
- minimization of efficiency loss
- prevention of heat transfer loss
- prevention of forced outages
- prevention of corrosion damages.

WtE plants tend to use contractors to safeguard and optimize their process and cooling water. Although it may seem that there is a cost advantage, there are also clear disadvantages. One of them is the lack of control by the plant chemist on the total process as it has become dependent on the contractors vision and expertise. Therefore the quality and conditioning of the process and cooling water is dependent on the quality and expertise of the contractor(s). To optimize the efficiency of the plant, specific know-how and expertise is a necessity. Also, by combining a good monitoring system (early warning) combined with the basic knowledge of the process operators, one can fulfil
an important role in safeguarding the water and steam quality. This is important as the chemist is not always present.

By means of practical cases at WtE plants and thermal power plants in several western European countries, the advantages, disadvantages and the lessons learned of different water strategies will be discussed. The practical examples include waterside corrosion of process & cooling water and biofouling in cooling water systems.

**Introduction**

There is a growing awareness of the effects of climate change, water and energy shortage as well as the fragility of our energy supply. This awareness has led to an increased interest in innovative, cost-effective solutions and improvement of the efficiency of Waste-to-Energy (WtE) plants. This development will lead to challenges for WtE plant operators since there is a dual role in place namely the role of waste disposal and the new role of a power and steam producer. For the latter special attention is required of the reliability of the plant. Here corrosion risk management plays an important role, in particular in the hearth of the plant. An often overlooked (or less considered) aspect is the influence of the water quality in the WtE plant. In the mean time the plant chemist who is mostly responsible for both process and cooling water, has many other tasks in a WtE plant. Therefore WtE plants tend to use contractors to safeguard and optimize their process and cooling water.

The development where the plant chemist is taking on more tasks and is not able to tackle the water quality sufficiently is also a development in the present Power Industry. The difference in this industry is that a plant chemist can rely on an available competence centre and/or on available knowledge and experience to adopt the best water strategy to ensure reliable operation. In most cases the power industry can call upon the support of a biologist, which is necessary when dealing with biofouling of cooling water systems.

**Why is water important**

Before discussing the different water strategies adopted by several WtE plants, power plants and operators of industrial boilers the crucial role of water will be dealt with here. A direct result of optimizing the water quality of both process- and cooling water are:
- minimization of efficiency loss
- prevention of heat transfer loss
- prevention of forced outages
- prevention of corrosion damages.
This optimization will guarantee energy and steam production and efficiency. For cooling water systems the control of biology is evident. For example figure 1 shows the effect of clogging of a condensor tube that leads to increased flow resistance and corrosion attack. From this example and many others like it, biology can have a direct effect in:

- the fouling of screen (debris) bars
- an increased flow resistance
- the clogging sieves and condenser tubes
- an increased heat transfer resistance by “Biofilms”
- a risk of corrosion, pitting, Micorbiological Induced Corrosion (MIC), erosion-corrosion

Figure 1 Clogging of heat exchanger tubes leads to increased flow resistance and risk for erosion/corrosion

While biology plays a key role in open and closed cooling water systems, in closed cooling water systems the water quality (pH, precipitation, additives etc.) also plays a key role in reliable operation. The role of water quality is no different for process water which is often considered to be the blood line of every steam / power generating unit. In the water-/steam cycle it is important to form a protective oxide layer to safeguard the underlying carbon steel. This magnetite layer is formed and maintained by correct conditioning of the water-/steam cycle. The choice of conditioning depends on the materials used and process conditions (pressure) and the water quality. For low pressure boilers (<80 bar) a solid alkalizer is usually used in the drum while for high pressure boilers (>80 bar) only volatile conditioning treatment is used. Incorrect conditioning can lead to the formation of a porous magnetite layer and/or the continuous formation of this layer that can eventually lead to leaking pipes, clogging, iron transport in your system (clogging of feedwater pumps) etc.

Figure 2 Pictures of boiler pipes with extensive oxide layer growth
However compared to industrial boilers and power plants, WtE plants refurbish their boiler house completely every couple of years due to fire sided corrosion. The perception is that by doing so the risk of leaking pipes, corrosion, heat transfer loses etc. caused by inadequate water quality would be minimized. However when considering the water-/steam cycle the regions which run risk are the locations where the (feed) water temperature is 150 °C. Therefore feed water pumps and economizers can have a raised risk level (figure 3+4).

Figure 3 Process water: left corrosion of piping – right iron deposits on feed water control valve

What adds to the growing awareness of process water quality is the development and trend that WtE plants will transfer from low pressured to high pressured boilers. In high pressured boilers the water quality is even more important to ensure reliable operation. Here the influence of a thick porous magnetite layer (due to bad water quality) can result in a heat flux which can increase the rate of fire sided corrosion of boiler tubes and ruptured pipes.

Figure 4 Water-/steam cycle

Experiences utilizing different water strategies – cooling water

Depending if a plant has an open cooling water system, an open recirculating cooling water system or a closed cooling water system different strategies are adopted. For the open cooling water system the control of biology (macro-fouling) could be realized by:

- a continuous and/or shock chlorine dosing regime
- **Pulse-Chlorination**: optimized hypochlorite dosing
- **Thermal treatment (Thermoshock)**

These options are usually combined with biofilm (micro-fouling) control techniques like the use of bucky balls like Taprogge. Several industrial sites have experienced that continuous and/or shock dosing don't always lead to the desired effect of combating biology, in particular for macro fouling (e.g. mussels, oysters and barnacles). These organisms are one of the most difficult to mitigate in a cooling water system. Mussels and oysters have the ability to close their shells during a dosing and switch to an anaerobic metabolism. During this period they do not experience any effect of the dosing. After a chlorine dosing they will open up again to restart their filtering activity.

While thermoshock on the other hand is dependent on the site attributes it can also be less effective for certain oyster species, since some of them have a higher thermal resistance. Also thermoshock cannot reach all area's of the cooling water system (inlet). It is a known that chlorine is the most effective detergent against biofouling.

In 1998 the Dutch Power Industry contracted KEMA in developing alternative methodologies for the chlorination procedures to reduce the amount of chlorine, without loss of effectiveness in fouling control. Reducing the amount of chlorine saves the environment, reduces energy use and maintenance costs of the Electro Chlorination Plant. The result was Pulse-Chlorination and this optimized technique is now considered BAT by the IPPC Bref document for cooling water.

With Pulse-Chlorination a pulse of chlorine is dosed into the cooling water system when the bivalve is ±100% open. Once the dosing is stopped and the bivalves opens again slowly (recovery period) and a new pulse chlorine dosing is started. The results of an optimized chlorination regime utilizing Pulse-Chlorination is illustrated in the pictures made available from the E-ON power plant on the Maasvlakte (Netherlands).

![Figure 5 Pictures taken at E-ON power plant Maasvlakte (NLD) – on the left before Pulse Chlorination and on the right after Pulse Chlorination](image)

Once Pulse Chlorination has been adopted on a site, the plant chemist/operator will monitor the effectiveness of their chlorination regime by utilizing biofouling monitors.
Another development is the use of modelling tools to ensure the effectiveness of chlorination. Sodium hypochlorination dosing is a very viscose liquid which does not mix very well with sea water. To optimise this mixing the dosing structure can be optimised using Computational Fluid Dynamics. This modelling tool aids us in getting a good insight in the effect of optimising dosing structures. This saves expensive trial and error in practice.

As an independent party KEMA has experienced that different WtE plants in the Netherlands use a combination of outsourcing and their own operators. For continuous and/or shock dosing a supplier of hypochlorite is usually contracted. For Pulse-Chlorination a combination of outsourcing and own operators are used. The effectiveness of the Pulse-Chlorination is usually monitored by operators. This early warning systems enables operators / plant chemist to be aware and knowledgeable of the effects of dosing on the biology. Any other changes in biology due to intrusion of a new species to local waters can be identified in a timely fashion. While for outsourcing the operators are dependent on the knowledge and expertise of the staff of the contractor and can therefore be unaware of new biological threats. Also here the contractor's best interest is to sell their commercial products.

For an open recirculation and closed cooling water systems the key is to maintain the water quality by controlling the solubility products (nutrients, scaling and salt formation). This can be done by:

- utilizing different anti-scaling agents and additives to combat organic and inorganic precipitation
- maintaining water quality standards (pH regimes, \( \mathrm{O}_2 \) concentrations etc.) to prevent corrosion of carbon steel and to prevent organic and inorganic precipitation
- blow downs to prevent organic and inorganic build up
- utilization of biocides. The combination of organic matter, nutrients and high temperatures are ideal environments for microbiological activity. This can again lead to MIC.

On the market there are many different products available from different suppliers, which also posses different chemical functional properties. It is therefore difficult for an operator / plant
chemist to judge and compare the effectiveness of all these different products in their system. Next to that one must determine the correct dosing regime of the product. Some industrial boiler operators, WtE and power plants outsource this activity to a supplier which often offers cheap labour to monitor the effectiveness of their own products. To counterbalance this conflict of interest these industrial sites and plants opt to play and challenge the supplier with her competitors. Unfortunately this can lead to a constant change in suppliers and chemicals utilized to "safeguard" the water quality or a decrease in outsourced work aimed at safeguarding/monitoring the water quality. Here specific site knowledge and experience from one supplier is lost while the other supplier would have to go through the learning curve. Another option utilized is to have an independent review help raise the awareness and knowledge at both supplier and the operators/chemist of the plant. Constant monitoring of the water quality by the operators / plant chemist (or independent party) thereafter remains an important feature that will help safeguard water quality.

**Experiences utilizing different water strategies – process water**

Over the last years there has been a disturbing development in all industrial sectors and that is the gradual loss or unavailability of experienced personnel. This effect is noticeable in the way process water is safeguarded in industrial boilers, power plants and WtE plants. This *can* and *has* led to unexpected outages due to poor water quality which otherwise would have easily been safeguarded.

As an independent party KEMA has seen different conditioning regimes used for low pressured boilers in WtE plants (and industrial boilers). Typical conditioning regimes for low pressured boilers seen in WtE plants include All Volatile Treatment (AVT = ammonia) with phosphate or alkali dosing in the boiler. There are different suppliers on the market that offer commercial products with added features to these original bulk chemicals (primarily the phosphate products). In practice these commercial products are not necessary and one can condition the water-/steam cycle on basic chemicals. Here it is important to realise that the boiler suppliers have their specifications and in most cases they refer to phosphate conditioning. This conditioning regime is preferred by suppliers since these boilers are supplied world wide, and not every where in the world the water quality is the same. While in most western (European) countries the feed water quality is of higher standard due to the use of currently advanced demin water treatment plants.

Commercially available organic products used for conditioning are also used for low pressured boilers (<80 bar). The main disadvantage of this material is that it degrades to organic acids and CO$_2$ which in turn are a risk for the water-/steam cycle. Some users have positive experiences. For example at least one plant in the Netherlands utilizes a commercially available organic product to condition their process water. So far according to the operators they have good results. Here the plant chemist / operator monitor the water quality themselves. This is an important factor in
ensuring the water quality. The plant used to run on AVT and alkali and the operators/chemist were therefore familiar with conditioning regime(s).

While for example in Belgium the use of hydrazine is still utilized in some plants, it is totally phased out (prohibited by law) in the Netherlands. Also the risk of using an oxygen scavengers like hydrazine, is that the absence of oxygen all together in the water-/steam cycle can have an adverse effect on the corrosion rate on the carbon steel. For oxygen is needed to form the protective layer magnetite.

In several water-/steam cycle reviews KEMA has identified typical pitfalls familiar in both industrial boilers and WtE plants namely:

- a focus on lab measurements instead of online measurements
- detection limits of lab equipment are not suitable for the water-/steam cycle
- divided responsibilities
- use of commercially available online equipment
- no procedures / or not following procedures for upstart and shut down
- risk of dependency on experience and knowledge of suppliers/contractors
- data collection system not effectively used

Operators and plant chemists conduct different lab measurements to determine the quality and composition of bottom ash, waste water and cooling water. From this background and lab orientated focus the same strategy is then automatically adopted for the processing water. The danger here is that process water is close to demin water or better, and therefore most measuring equipment are inadequate for process water. The lower detection limits are too high. Also the influence of air ingress has a negative influence in the measurements taken by the laboratory.

Some WtE plants choose to divide the tasks internally and at the same time outsource other tasks. For example at one plant were three different internal departments and one external supplier responsible for the demin plant. Here the risk is that no one feels responsible, while one central person/department should be responsible.

Maintaining the protective oxide layer in any water-/steam cycle is essential to ensure reliable operation. Sudden temperature changes, like the cold up start of a plant, have shown that the protective layer will detach from the carbon steel and deposit elsewhere. This not only exposes the carbon steel to corrosion but also adds to an increase in clogging. This topic clearly illustrates the dual role operators face. For a quick start-up ensures waste throughput, while a gradual (hot) start-up would ensure and safeguard the water-/steam cycle.

The drain on knowledge and experienced personnel is not only felt in the power industry or the WtE plants, but also at suppliers and contractors. Here again the same applies for closed cooling water
systems the operators are dependent on the knowledge and expertise of the staff of the contractor. In most cases it is just that single person coming by to conduct measurements and fulfil a routine task. Also here the contractor's best interest is to sell their commercial products.

Over the years new online equipment have been developed like the degassed cation conductivity, oxygen monitor, and a pH monitor based on specific and cation conductivity. New equipment can help safeguard the water quality. Unfortunately the basic cation conductivity (which is 3,5 times more sensitive than specific conductivity) is not always evident in many industrial and WtE plants.

Monitoring with adequate and frequently calibrated online equipment and trending helps operator/plant chemists identify cooling water ingress. During many reviews it has become apparent that the limit values of the data collection systems are set to low and therefore important information is lost.

To conclude it is also well known that the plant chemist is not always present when one of the critical parameters (pH, conductivity, etc.) is out of spec. Here a known strategy in the power industry is to utilize a Chemical Support System (CSS) which can instruct the operators directly on which actions are needed and necessary. The CSS is a software programme that is directly linked to the DCS system. By combining this tool together with external independent reviews and courses focused on process and cooling water operators and chemists alike can raise their awareness and knowledge needed to safeguard the water quality.
Conclusions

WtE plants tend to use contractors to safeguard and optimize their process and cooling water. Although it may seem that there is a cost advantage, there are also clear disadvantages. One of them is the lack of control by the operators and plant chemist on the total process as it has become dependent on the contractors vision and expertise. Therefore the quality and conditioning of the process and cooling water is dependent on the quality and expertise of the contractor(s). To optimize the efficiency of the plant, specific know-how and expertise is a necessity. Also, by combining a good monitoring system (early warning) combined with the basic knowledge of the process operators, one can fulfil an important role in safeguarding the water and steam quality. This is important as the chemist is not always present. Another tool is the use of an independent party that can help raise the level of water quality awareness and fulfil an independent view on conditioning regimes.

A clear choice must be made with regard to the pay-offs and risks involved when operating a WtE plant. The dual role that operators face when deciding for a quick or gradual (hot) start-up was illustrated as an example to either safeguard the water-/steam cycle or maximize throughput.

Developments in new tools like Computational Fluid Dynamics (CFD) modelling, automated monitoring equipment and assisted Chemical Support Systems (CSS) can help assist operators and plant chemists safeguard the reliability of a WtE plant.