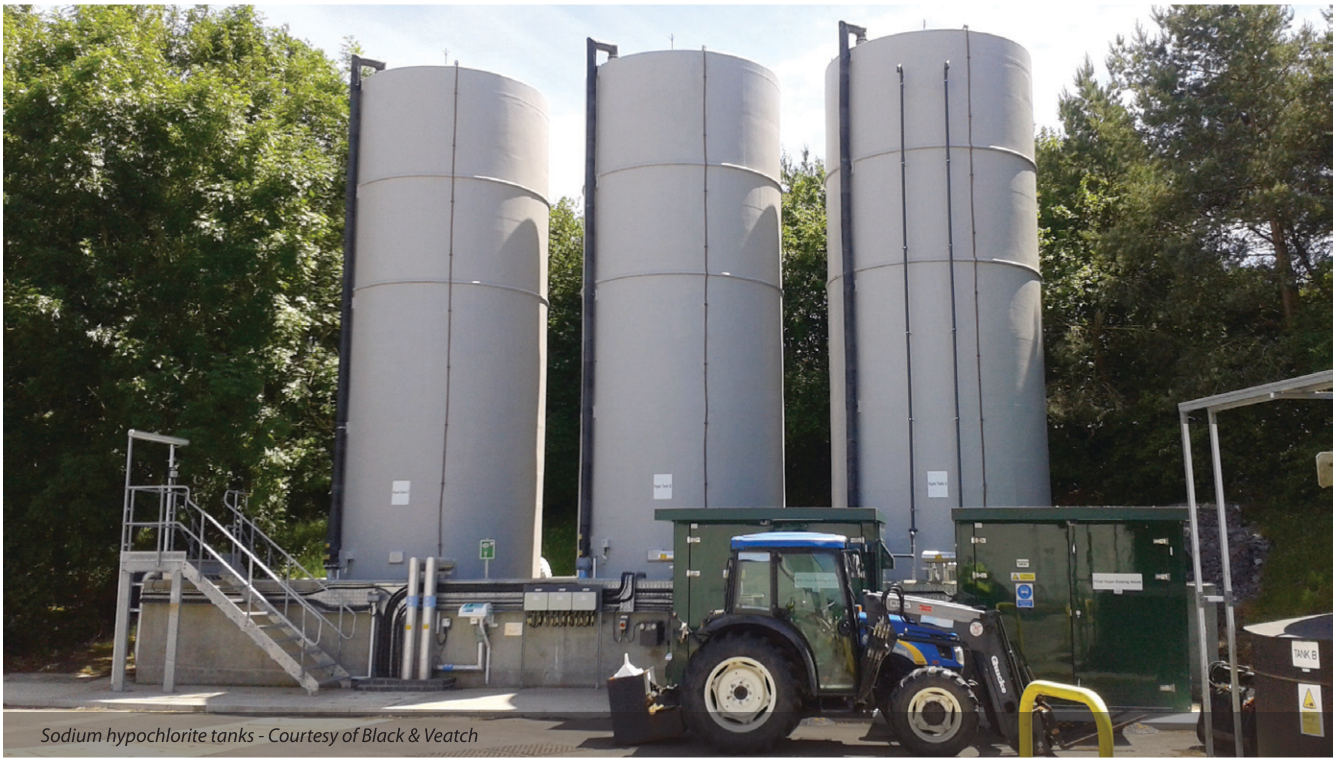
Purton WTW Electrochlorination Plant

design and installation of a new chlorination system to prevent the invasion of extended colonies of zebra mussels

by Mark Gilding BEng CEng MICE MIWater

Purton WTW is located approximately 5km north of Berkeley in the village of Purton, Gloucestershire. The Bristol Water Ltd (BW) owned WTW abstracts raw water from the Gloucester and Sharpness Canal to the north of the treatment works and at maximum output can produce 165Ml/d to serve the population of Bristol. The Gloucester and Sharpness Canal watercourse has been invaded by extended colonies of zebra mussels that attach themselves to hard surfaces such as the intake screen, the intake pipeline, and the pipeline to the head of the treatment works reducing hydraulic capacity of the system. Zebra mussels are non-native freshwater molluscs that originated in Eastern Europe. They clog waterways, cause natural lake ecosystems to deteriorate, and impose a financial burden on water companies. Seasonal zebra mussels in the abstracted water are controlled by heavy doses of chlorine at the intake and a bulk chlorine system has been in use at Purton WTW since the works was commissioned in 1974 with up to 25 tonnes of bulk liquid chlorine stored on site.



Sodium hypochlorite tanks - Courtesy of Black & Veatch

Drivers

The liquid chlorine plant was defined by the Health and Safety Executive (HSE) as an installation falling within the 'Control of Major Accident Hazards (COMAH) regulations. The system was therefore subject to thorough regulations pertaining to this type of installation. The nature of these requirements combined with concern over the single source supply for chlorine prompted BW to look for alternative means of generating chlorine to treat the Zebra Mussel problem.

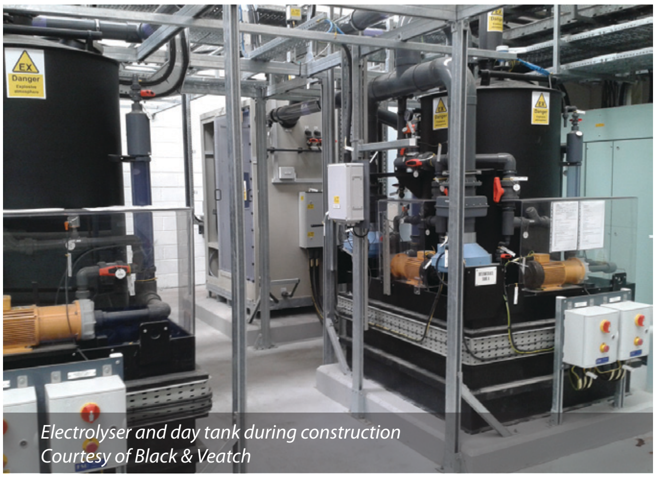
Whilst the liquid chlorine option was viable in terms of total expenditure, the more concerning aspect was the greater demands which had been placed on this type of installation by current safety legislation. Even where storage levels are kept below the relevant COMAH tier limits, expectations in relation to standards of risk minimisation and preparedness for a major accident are similar. Operators of such sites are also required to demonstrate to the HSE that the risk has been reduced *'as low as is reasonably practicable'* (ALARP); therefore other options needed to be considered by BW.

Black & Veatch was commissioned to carry out a feasibility study to review all available options for dealing with zebra mussels. Following the conclusion that chlorine treatment was still the most appropriate control measure a design was developed to produce sodium hypochlorite on site through the installation of an electrochlorination plant. The project was then delivered as a design and build contract by Black & Veatch, including detailed design, construction and commissioning of the new plant.

Current facility description

The original works treatment process at Purton WTW comprised screening, pH control, clarification, rapid gravity filtration, super and de-chlorination. This was supplemented in 1993 with the addition of pre and post ozone systems installed with granular activated carbon filtration to improve taste and odour. There was a further upgrade to the works in 2012 with the inclusion of ultraviolet treatment and now only marginal chlorination of the final water is practised. The bulk chlorine system provided the dosing for both the Zebra mussel control at the intake and the marginal final dose.

Zebra mussels removed from the Purton WTW intake
Courtesy of Black & Veatch



Electrolyser and day tank during construction
Courtesy of Black & Veatch

New MCC for electrochlorination plant
Courtesy of Black & Veatch

Table 1	Maximum	Average
Intake chlorine dose (summer)	2.5 mg/l	2.5 mg/l
Intake chlorine dose (winter)	0 mg/l	0 mg/l
Disinfection chlorine dose (summer)	2.0 mg/l	1.5 mg/l
Disinfection chlorine dose (winter)	2.0 mg/l	1.5 mg/l

Table 1: Design chlorine doses

Table 2	Maximum dose	Average dose
Intake chlorine dose (summer)	575 kg/day	575 kg/d
Intake chlorine dose (winter)	0 kg/day	0 kg/day
Disinfection chlorine dose (summer)	330 kg/day	248 kg/day
Disinfection chlorine dose (winter)	330 kg/day	215 kg/day

Table 2: Required chlorine capacity at maximum plant flows

The common practice of using chlorine or any other disinfectants/oxidants is to maintain a trace level of oxidant to prevent veligers (larva) or adult mussels from becoming attached to the structure of concern. Studies have shown that chlorine applied in a continuous flow-through mode to maintain a residual of 2.5mg/l would kill 90% of the mussel population.

The amount of chlorine required to control the seasonal zebra mussels is far greater than that needed to provide final marginal chlorination on the Purton WTW site. The primary concern associated with this volume of chlorination is the formation of undesirable halogenated organic disinfection by-products (DBPs) such as trihalomethanes (THMs) and haloacetic acids (HAA).

To avoid these issues BW had previously investigated chlorine dioxide (ClO_2) dosing at the intake. However, due to the use of costly chemicals with further storage issues, it was decided to proceed with chlorine for the removal of Zebra mussels and aerators have been installed in the raw water reservoirs for the purpose of stripping out THMs formed during the chlorination process.

What is electrochlorination?

The process involved in electrochlorination is the desalination of water to produce a chlorinated solution. This happens when salt water (brine) is inserted into electrolyser cells where one side is a cathode, the other is an anode.

As the water flows through the anode/cathode channel, energy is applied as a low voltage DC current and the electrolysis process is triggered. The sodium hypochlorite (NaOCl) is instantly produced as well as a byproduct of hydrogen gas (H_2). The hydrogen gas is vented off to the atmosphere from an intermediate tank and the sodium hypochlorite is then transferred to bulk storage tanks as the finished product.

No chemicals other than salt (sodium chloride (NaCl)) are used throughout the entirety of the process. Although the actual chemical processes involved are complex, they can be simply represented by the following equation:

$$\underset{(salt)}{NaCl} + \underset{(water)}{H_2O} + \text{Energy} \longrightarrow \underset{(sodium\ hypochlorite)}{NaOCl} + \underset{(hydrogen)}{H_2}$$

Project scope

Outline sizing of electrochlorination equipment for Purton WTW was based on a maximum design flows of 165Ml/d (average 120Ml/d) and the maximum chlorine doses given in Table 1 (see bottom left). For the purpose of the design, summer is taken to be the months when chlorine is dosed to the intake for zebra mussel control i.e. from the beginning of April to the end of October; winter is taken to be the period November through to the end of March. The resulting design capacities for the chlorination system are summarised in Table 2 (bottom left).

The new electrochlorination plant is designed to provide a maximum chlorine demand of 745 kg/day to dose the Purton WTW intake and also provide the marginal final disinfection dose.

The new plant comprises two electrolysers each sized to generate the equivalent of 372.5kg/day chlorine in the form of sodium hypochlorite (NaOCl). These operate as duty/standby during winter months (just for final dosing) and as duty/assist when chlorination for zebra mussel control at the intake is required. The electrolyser units are located within an existing building and forced ventilation has been installed to ensure no change in ATEX category of the existing building due to the presence of the hydrogen gas by-product. To supply the DC power for the electrolysers two large rectifiers were installed within a separate room in the existing building. These rectifiers produce a large amount of heat during operation and as part of the design the team developed a system for using this excess heat to provide heating to other areas of the chemical building reducing operating costs of the current heating system.

The sodium hypochlorite is stored within 3 (No.) storage tanks (each 83m^3 to provide a total volume of 249m^3 (48 hours storage) based on the sodium hypochlorite concentration of 6g/l). The PE lined GRP tanks utilise a pressure type level indication and local tank contents indicators combined with an overflow detection system.

The tanks are situated within a bunding system to retain any leaks due to tank or pipework failure. The individual tanks are also valved so that they can be isolated from one another for maintenance or during the winter period when a lower volume of product is required.

To provide the brine for the electrolyser units there are 2 (No.) GRP salt saturator tanks each sized for 40 tonnes. They are designed for bulk delivered salt allowing for 1 month storage under all operating conditions. The tanks are located within a bunded area and are fitted with a dust arrest system and low level contents detection.

The brine is pumped to the electrolysers through a set of duty/standby brine pumps located within their own kiosks. One issue that had to be addressed was that bromate is formed during the electrochlorination process due to the presence of bromide in the salt used to produce the brine fed to the electrolysers.

This is simply overcome by specifying and procuring high purity, low-bromide salt to minimise bromate formation.

The sodium hypochlorite dosing pumps are located adjacent to the bulk storage tanks and are mounted within their own kiosks. There are 2 (No.) duty/standby pump arrangements, one dedicated to the intake and one dedicated to the final dose. The existing intake dosing sparge and final dosing lance arrangements were reused as part of the scheme.

As the final chlorine dose is critical to the operation of the WTW there have been a number of failsafe systems built into the design. These include the provision of duty/standby pumps at all stages of the process and crossover valving on all pipework to ensure the failure of a single item of equipment will not interupt the final chlorine dose.

As a final back-up system there is also a valved connection to the bulk storage tanks so that they can be filled using diluted 14% concentration hypochlorite if there is a failure of the electro-chlorination system, including power failure. Due to the volume of water required for the electrochlorination process a new motive water system was also designed and installed as part of the Purton WTW electrochlorination scheme.

Completion

The final installation had a changeover valve arrangement to allow a staged commissioning process without adding additional risk to the WTW process. The new plant was fully commissioned in June 2014 enabling BW to decommission and remove their bulk chlorine storage system.

When the plant had been in operation for a number of months there was evidence that the replacement of chlorine with sodium hypochlorite has provided a marked reduction in caustic dose that is required for pH correction, providing a significant saving in chemical costs for the WTW.

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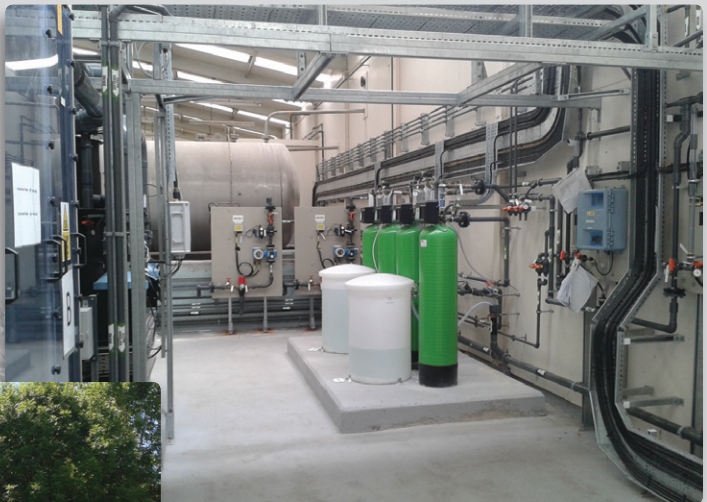

Brine tanks - Courtesy of Black & Veatch

Salt saturator tanks - Courtesy of Black & Veatch