UV LAMP BREAKAGE AT MELBOURNE WATER DISINFECTION PLANT

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ABSTRACT

An incident occurred at one of Melbourne Water's ultraviolet radiation (UV) disinfection plants in which a UV lamp and sleeve broke and fragments of quartz entered the water supply system. A burst in the reticulation pipework had caused a rapid change in flow and pressure through the duty UV chamber, resulting in UV lamp and sleeve breakage.

The UV plant is located alongside a 2100 mm conduit which transfers water between two major reservoirs. The UV plant gets its raw water from a 375 mm diameter main which tees off the conduit at the site, and flows through two parallel inline strainers into a pressure reducing station. The UV plant, consisting of three UV units, is then connected in parallel before the main continues to supply the township.

Melbourne Water has undertaken a root-cause analysis which identified a need for a surge analysis of the burst failure and a Computational Fluid Dynamics model to investigate the effect of the rapid change in flow and pressure on the UV lamp quartz sleeve. The model has confirmed the hydraulic scenario of the incident and the required mitigation measures for the future.

The key purpose of this paper is to increase awareness to this potential risk. The paper provides incident facts and a discussion on mitigation strategies that Melbourne Water is implementing.

KEY WORDS

Ultraviolet Disinfection, UV Disinfection, Ultraviolet Lamp, UV Lamp, UV Lamp Break.

1.0 INTRODUCTION

The UV Treatment Plant can treat up to 10.6 ML/d and runs continuously as it receives its water via gravity feed from the Upper Yarra Reservoir via the Yarra-Valley Conduit. The primary process consists of ultraviolet radiation disinfection (UV). The raw water that feeds into the plant is from a closed catchment, and while the risk of contamination is low, it requires disinfection suitable for pathogen inactivation with short contact times.

Water passes through a stainless steel chamber containing an arc-tube which emits UV light that treats the water. The arc-tube is oriented within the chamber such that it is mounted in a quartz sleeve and water is capable of passing the sleeve on all sides. UV light is efficient at inactivating microorganisms like protozoa which can't be effectively treated using chlorine. The intensity of the UV transmission and dimensions of the chamber determine the optimal water flow rate for effective treatment. In the event of low or no flow conditions, the chamber can overheat and a temperature sensor within the chamber will shut down the unit.

The secondary disinfection is chlorine disinfection (using sodium hypochlorite solution) which provides a disinfection residual downstream of the plant (when the water is in the water distribution system).
The plant also consists of several 'by-pass' points which can be used in the event of

extreme emergency (eg. bushfire) or if part of the plant needs to be taken offline.

In March 2015, there was a burst in the retailer's DN375 water main. The burst damaged the duty UV unit's sleeve, lamp and seals, which resulted in the lamp and sleeve breaking into fragments.

2.0 DISCUSSION

The UV treatment system consists of three medium pressure UV chambers which run on a duty/standby system, with up to two chambers in operation at any one time. Lamps are rated to >38 mWs/cm^2, with an intensity of 45 mW/cm^2 and a transmissivity of 80% at the end of the lamp life (with one chamber offline). UV dose, which must be above 30 mWs/cm^2 to achieve the appropriate inactivation of pathogens, is administered based on the measured intensity of the UV light, transmissivity and contact time in the chamber i.e. flow rate through the chamber. If the dose is less than 30 mWs/cm^2 for more than 10 minutes, an incident must be declared and appropriate action taken. While transmissivity is a set value, flowrate and intensity are measured. Alarms exist for globe outages and globes are replaced annually. In situations were the UV plant has completely failed, or is unavailable, sodium hypochlorite will be used as the primary disinfection method.

Following the discovery of the UV lamp breakage, an incident management team was established which performed the following operations:

- Safety: the immediate risk was the potential for on-site personnel to inhale mercury. Sampling conducted on the area surrounding the UV lamps found there was no cause for concern. There was also a risk of electricution due to the power supply having contact with sprayed water in a flooded room. The bund was full of water, and created overflow as a result of the additional water release.. The risk of electricution was found to be minimal due to the control box being sealed. Future recommendation is that the control cubicle should be placed outside of the room.
- Alarms: The first alarm sounded at the treatment plant was a generalised 'UV fault alarm'. This alarm did not adequately prepare the operators for the hazards on site. The second alarm that arised was a 'smoke detector alarm' which indicated that there could be a fire, but the operator opened the door to a flood. These two alarms alerted operators to an incident occuring at the UV plant, but did not allow for adequate preparation for the risks involved.
- Notification: the Department of Health and the affected retail water company were immediately notified. All internal Melbourne Water stakeholders were also notified.
- Investigation: a root-cause analysis and additional controls investigations were performed.
- Risk Assessment: An risk assessment was conducted in conjuction with the Department of Health which confirmed that the quartz and minute amounts of mercury would not have entered customer. The risk assessment is discussed in more detail in section 2.3.
- Response: The lead operator, in conjunction with the maintenance provider, were on-site overseeing all repair works and collecting mercury and quartz samples. There was excellent communication between the area manager, lead operator and technical support to facilitate getting the plant operational.

2.1 UV Lamp Breakage Causes

Lamp sleeves are vulnerable to fractures which can occur due to improper handling, internal stress and external mechanical forces such as wiper jams, water hammer, resonant vibration, and impact by objects.

Following investigations and consultations with various organisations and individuals, the cause of UV lamp breakage was found to be a burst main downstream of the plant that resulted in a significant increase in flow rate through the system.

Quartz sleeves are capable of withstanding continuous positive pressures of more than 120 psig but can break at negative pressures of just 1.5 psig, which can result from line breaks or accidental dewatering of the reactor. It is therefore important to assess whether installing air release valves, air/vacuum valves, or combination air valves to prevent air pockets and negative gauge pressure conditions is necessary.

Other identified engineering and administrative improvements that can prevent UV lamp breaks were:

- Lamp sleeve fractures during service could allow water to enter and create a temperature difference between the hot lamp and water. Thus, special care needs to be taken when servicing and replacing UV lamps.
- Temperature differences can also occur due to the orientation of the lamps with relation to the ground, and the optimal orientation is to have the lamps parallel to the ground.
- Purchasing UV lamps with a high quality quartz may increase the sleeve tolerance.
- Prevent debris from entering the UV reactor by placing barriers prior to the reactors such as screens, baffles or low-velocity collection areas.
- Introduce temperature and flow sensors that alarm at critical conditions, causing the UV reactors to shut down and stop water flow.
- Surge analysis to determine if there is a potential for water hammer damage or if pressure relief valves are needed.
- Introduce comprehensive UV operator training and an equipment maintenance program in respect of this incident.
- To protect the reactor, adequate circuit breakers should be specified.
- Routine maintenance and inspection should continue to be carried out by staff.

Improvements that can prevent unsafe water from entering the water supply system:

- Installing strainers and low velocity collection areas downstream of the reactor.
- Installing isolation valves that are activated by an alarm to isolate the potentially unsafe water.

2.2 UV Reactor Elevation within the Treatment Plant

Dewatering of the UV reactor has been known to cause negative pressures which can lead to breaking of the UV quartz sleeves. The plant’s UV system elevation is such that the reactor’s inlet and outlet streams are both lower than the UV reactor (see Figure 1). This is not a favourable arrangement as it makes the reactor susceptible to dewatering. A reduced dewatering option would be to either have both reactor inlet and outlet above the reactor, or the inlet lower and outlet above the reactor.

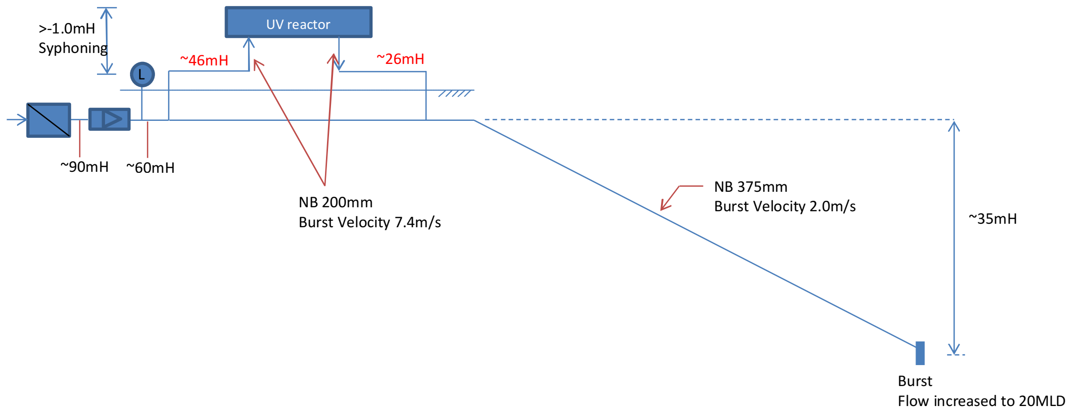

Figure 1: ***The Current UV System Elevation at this Treatment Plant: To the left is the raw water entering the treatment plant from the main conduit, and to the right is the treated water going into water supply. The diagram shows the elevation from the main burst location.***

2.3 Risk Assessment

An extensive risk assessment was undertaken in conjunction with the department of health to determine the risks to public health as a result of the incident. The risk assessment determined that there was no risk to public health from either the small amount of mercury released from the UV lamp or from the quartz fragments. This conclusion was based on the multiple control barriers present between the contaminant and the consumer, which included:

- Very low levels of mercury released were below health limits as per the Australian Drinking Water Guidelines.
- The proximity of the burst location to the treatment plant coupled with the time of day (midnight) and the high flows at the burst location would have resulted in a turnover of three pipe volumes making it extremely likely any contaminant would have been expelled from the drinking water system.
- Elemental mercury is insoluble in water making it more likely to have been flushed out.
- Topography of the zone would assist in moving any contaminants to the burst location.
- Water quality samples were taken throughout the supply zone with all mercury level results below a detecable limit.

In addition to the barriers above, the risk of the quartz fragments was also minimised:

- Customers are tapped to water mains through ferrules located on the top of mains. Quartz fragments would travel along the bottom of the water main due to their density.
- Normal operating velocity would not re-suspend these fragments.
- Customer meters have approximately 1 mm mesh within the meter assembly providing a barrier.

Based on the risk assessment, it was agreed between Melbourne Water, The Department of Health and the retailer that there was no risk to the customer. Regardless, a number of follow up actions were completed which included:

- Extensive flushing of the zone.
- Ice pigging of affected mains.
- Swabbing of the low point where any particles still remaining would have accumulated.

3.0 CONCLUSION

UV lamps have the potential to break. This paper exists to share this experience in the hope that others may learn from the findings and prevent UV lamp breakage from occuring in other UV plants.

In particular, it is necessary to identify all potential events that can lead to UV lamp breakage in all UV plants. In addition, there should exist a UV lamp breakage contingency plan, which includes investigating the appropriate measures to prevent quartz and mercury from entering the reticulation system in case a breakage does occur.

4.0 ACKNOWLEDGEMENTS

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