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Water Disinfection (Part 1): Chlorination *(continued)*

(continued from the previous newsletter)

In Osorno's last newsletter (Water Disinfection Part 1: Chlorination), the history of water treatment by chlorination was covered, including its advantages and disadvantages. This newsletter considers additional aspects of chlorination, as well as complementary water disinfection processes.

Chloramination

When a water source contains ammonia or amines, the process of chlorination results in the formation of chloramines. It has become popular in North America to add a small amount of ammonia at the water treatment plant to deliberately induce chloramine formation. Chlorination results in a multitude of toxic disinfection by-products (DBPs) (see previous newsletter: Water Disinfection Part 1), while chloramination leads to lower concentrations of toxic DBPs - trihalomethane (THM) and haloacetic acids (HAA). Unfortunately, chloramination is substantially less effective at disinfecting water. The World Health Organization (WHO) states "*... monochloramine is about 2,000 and 100,000 times less effective than free chlorine for the inactivation of E. coli and rotaviruses, respectively.*" (http://www.who.int/water_sanitation_health/dwq/S04.pdf).

For treatment plant operators, an easily obtainable indication of disinfection quality is to measure the oxidation-reduction potential (ORP) of the treated water.

Interesting fact: The so-called "chlorine smell" of swimming pools or water from the tap is not the smell of chlorine but chloramine. As explained in the previous newsletter (Water Disinfection Part 1), free chlorine only exists for a very short time in water. It is hypochlorous acid and its anion hypochlorite that are erroneously called "free chlorine."

Chlorine and UV

Hypochlorite is quickly decomposed by UV light. This explains why "chlorine" is deactivated so rapidly in outdoor pools exposed to full sunlight, and more slowly in indoor pools by the UV component of fluorescent lamps.

In municipal waterworks, a UV system is often added to a chlorination system, often promoted as "multi-barrier disinfection". This is counterproductive because the UV light in fact cancels the effect of chlorination. This leads to a paradoxic situation that disinfection quality improves when UV disinfection is switched off.

If UV light must be used due to regulatory requirements, it must be the first treatment step, since all chemical disinfectants including "chlorine" are de-activated by UV light.

Chlorination in Wastewater (Sewage) Treatment

Disinfecting wastewater effluent helps protect fish and other aquatic biota, as well as municipal drinking water supplies from waterborne diseases. Many wastewater treatment plants use chlorination to disinfect their effluent prior to discharge. As with water

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treatment, chlorination of solutions with organic compounds leads to the formation of disinfection-products, many of which are toxic. Chlorinated wastewater effluent has caused lethality in fish and invertebrates downstream of wastewater treatment plants. For this reason, chlorinated wastewater effluent was added to the List of Toxic Substances covered by the Canadian Environmental Protection Act in 1999. However, there are effective and safe ways to disinfect wastewater effluent that don't involve chlorination.

For further information on the List of Toxic Substances can be found at: http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=9554670A-1

Shock Chlorination

Shock chlorination is a method that normally is not applied in treatment of potable water other than for disinfection of the distribution system (pipe disinfection), wells, and swimming pools. In all these cases, there are better alternatives available. Please watch out for our upcoming newsletters on “Well Maintenance” and “Pool Water”.

Chlorine Residual

One of the reasons for the widespread use of chemical disinfectants such as hypochlorite in its various forms is that they provide a “residual” level of protection against waterborne pathogens. A chlorine residual is a low level of chlorine remaining in water after its initial application. For any chemical disinfectant added to water, there is a certain amount that is “consumed” by the raw water, for example during oxidation of naturally occurring substances such as organic compounds, iron and manganese salts. The “consumed” amount is lost for disinfection.

In the case of chlorination, there is an additional loss of disinfectant due to reaction with organics, in addition to the oxidation that chlorination shares with other chemical disinfectants. This reaction with organics is the reason why the chlorine-typical DBPs (THMs, HAA) are formed. Only chlorination leads to the formation of these DBPs causing a further loss of disinfectant.

The chlorine residual is the concentration that remains after these losses occur in water disinfection. By monitoring the chlorine residual throughout a drinking water distribution system, water treatment operators can quickly identify points at which the residual declines or disappears. Unfortunately, the lifetime (persistence) of hypochlorite in water is only moderate; the residual may disappear by itself in lines with insufficient water flow. Chlorine residuals are typically measured with what is called the DPD test, details of which will be described in the upcoming newsletter “Water Disinfection (Part 4): Testing Crucial Parameters”.

There are alternative methods of water disinfection which provide a more persistent residual, and therefore greater protection from waterborne pathogens. These will be covered in the upcoming newsletter “Water Disinfection (Part 2): Chlorine Dioxide”.

Summary

The serious health effects of chlorination are summarized here: “*In 1976, chloroform, a trihalomethane (THM) and a principal DBP, was shown to be carcinogenic in rodents. ... Further concern was raised in epidemiology studies suggesting a weak association between the consumption of chlorinated drinking water and the occurrence of bladder, colon, and rectal cancer.*” (“*Drinking Water Disinfection Byproducts: Review and Approach to Toxicology Evaluation*”, Environmental Health Perspectives 107, 207 (1999)). To receive an electronic version of this document, please contact Osorno.

In upcoming newsletters, Osorno will provide information on safe alternatives to chlorination.

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