Zebra Mussel Control

Zebra mussels were first introduced into the United States in 1986. They were discovered in the Great Lakes, where they were most likely carried in by the ballast water of ships coming from Europe.[1] Their arrival was notoriously conspicuous when water intake pipes all over the Great Lakes region started becoming clogged with their masses. Unlike native clam species, zebra mussels have byssal threads, which are adhesive proteinaceous threads. These threads allow the mussels to attach to hard substrates. The threads are produced by a special gland in the foot (the byssal gland) and are attached to byssal retractor muscles that can pull them into the animal. These threads also enable the mussels to pull closer to the surface, to which they adhere, making casual removal very difficult. Their ability to colonize in densities of 300,000 to 1,000,000 units per square meter has led to great difficulties for industries drawing water from infested areas. The zebra mussels soon form thick layers over top of each other inside of the piping, eventually leading to complete blockage if left untreated.

Various chemical strategies for controlling *Dreissena polymorpha,* the Zebra Mussel, have been implemented in water treatment facilities and power generating stations. These strategies depend primarily upon chlorine in various forms with exposure times ranging from 2 to 12 days. The use of chlorine generates trihalomethanes, which are potential human carcinogens. A non-carcinogenic solution is a 4.5 ppm aqueous alkylbenzyldimethylammonium solution, which results in approximately 100% zebra mussel mortality in 24 hours (LD 50 = 2 ppm). Alkylbenzyldimethylammonium chlorides consist of approximately 50% C_{14}, 40% C_{12}, and 10% C_{16}, and are commonly sold under the trade name “Zephiran Chloride®”. This product is primarily suited to long runs of pipe blocked with zebra mussels, or contaminated stationary water holding ponds and tanks. The concentration of quaternary ammonium compound necessary to control these macrofoulers is relatively non-toxic to surrounding phyto- and zooplankton.

To avoid mass zebra mussel cleanings every few months, a continuous application is needed to discourage zebra mussel veligers on newly cleaned pipes. The veliger stage of zebra mussels is the near-microscopic free-floating stage and is the most difficult stage to identify because of their small size. When these veligers absorb enough calcium from the surrounding water they become too heavy to float in the water column and begin to settle out. They attach to rocks, plants, and especially intake piping. Hydrogen peroxide has been proven effective at keeping piping free of mussels. It kills the small, attached mussels and prevents veliger settlement.

Hydrogen peroxide is specifically targeted at maintaining pipe integrity by selectively discouraging and destroying the post-veliger colonizing stage. It is ideally suited to use in water treatment facilities that pre-treat water for human consumption. Hydrogen peroxide eventually breaks down into harmless by-products of water and oxygen, with no harmful trihalomethanes produced.[2]

The economic benefits of hydrogen peroxide are unmistakable as well. When zebra mussels first invaded the Great Lakes, the city of Monroe, Michigan was completely shut down for two days. Their water treatment facility had been completely occluded by zebra mussels. Schools, businesses, and industries depending on the city's water source were forced to shut down as the treatment facility struggled to unblock its pipes.

The optimum usage of alkylbenzyldimethylammonium chloride and hydrogen peroxide follow in this design. The first application would be of alkylbenzyldimethylammonium chloride for a 24 hour time period to kill all sizes of zebra mussels. After this, a continual stream of low concentration hydrogen peroxide would discourage future settlement of zebra mussel veligers.

A current method of controlling zebra mussels is the “Ontario Hydro’s Solution.” An Ontario hydro plant solves the problem of zebra mussels by continuous application of liquid chlorine at 0.3 ppm during the four month breeding season.[3] However, established adult colonies do occur. These colonies are dealt with by a year end treatment of 2.0 ppm for two to three weeks.

Chlorine has many drawbacks when used for zebra mussel removal. The worst of these is the production of trihalomethanes, or THMs, which are carcinogenic by-products of chlorine’s reaction with zebra mussel bodies and extraneous organic material in the water column. Before the arrival of zebra mussels, water treatment facilities took great care to use only chlorine after the incoming water had settled and been filtered to remove the majority of organic material in the water. However, with the necessity of zebra mussel removal, facilities have been forced to sacrifice the safety of their customers to maintain their productivity. The EPA, OSHA, and other water-quality managing agencies are currently examining this questionable move. The EPA has already advised that companies minimize their THM production by limiting their use of chlorine.

Aside from carcinogenic by-products, chlorine leads to an undesirable taste residue in water treated for consumption. Chlorine is unfavorable because of its interactions with plant equipment as well. Chlorine attacks rubber gaskets as well as pump and pipe integrity over long-term use.

Recently the federal government has raised concerns about MX, a relatively unknown chemical by-product of chlorination. A Finnish study linking MX and cancer in rats prompted the National Toxicology Program of the U.S. National Institutes of Health to announce a two-year study on the health consequences of the chemical in both rats and mice.[4] Scientists will study whether both animals react the same way to MX and five other by-products of drinking water disinfection. The Finnish study found that more than 50% of rats receiving the highest doses of MX developed cancer or tumors of the thyroid, compared with about 22% in a control group.

As the Zebra mussel population continues to increase, the problem will continue to increase and many more plants will have to control these pests. If plants begin using liquid chlorine as a treatment they will begin to pollute the river and lakes that they are drawing cooling water from.

Water intake pipes all have a steel grating which functions to keep debris from entering the pipe. The goal is to design a system using hydrogen peroxide to prevent zebra mussels from colonizing on the inside of intake pipes and on the pipe grating. The system can also be used for a one-time kill using alkylbenzyldimethylammonium chloride. This is accomplished by making a portion of the grating out of perforated stainless steal tubing. A solution of one of the toxins is passed through the tubing and jetted out of the perforations into the counter-current flowing intake water. The jets disperse the toxin evenly to concentrations of 3.0 parts per million (ppm) for hydrogen peroxide, which is run continuously, and 4.5 ppm of Zephiran chloride that is run for a period of 24 hours.

A design can be seen in Figure 1. The feed pipe is split into three smaller streams that run vertically across the intake.

The zebra mussel toxin can be stored in a tank and diluted with water before being sent to the grating. This can be seen in the Process Flow Diagram, Figure 2.

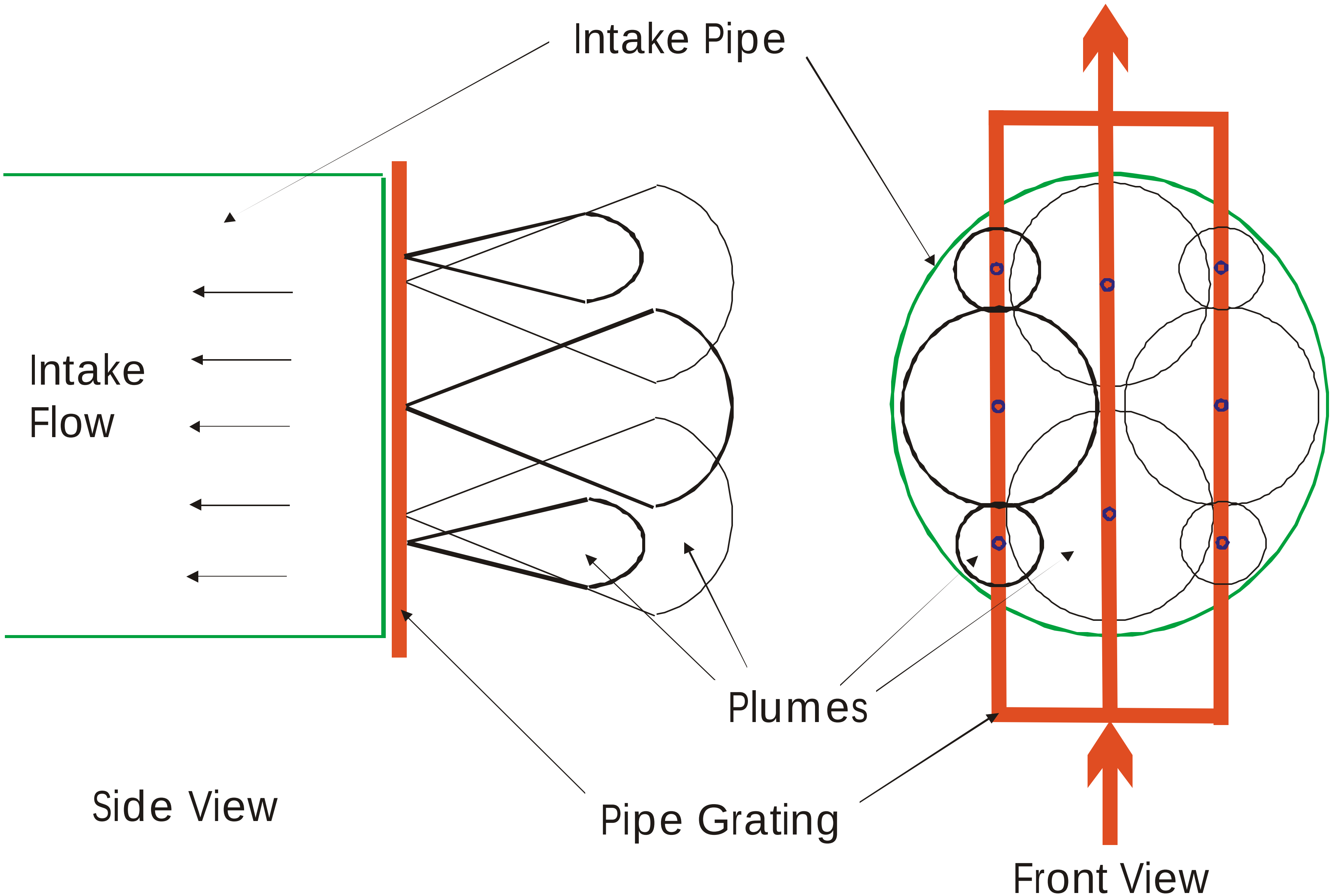

Figure 1: Optimum Jet Dispersion

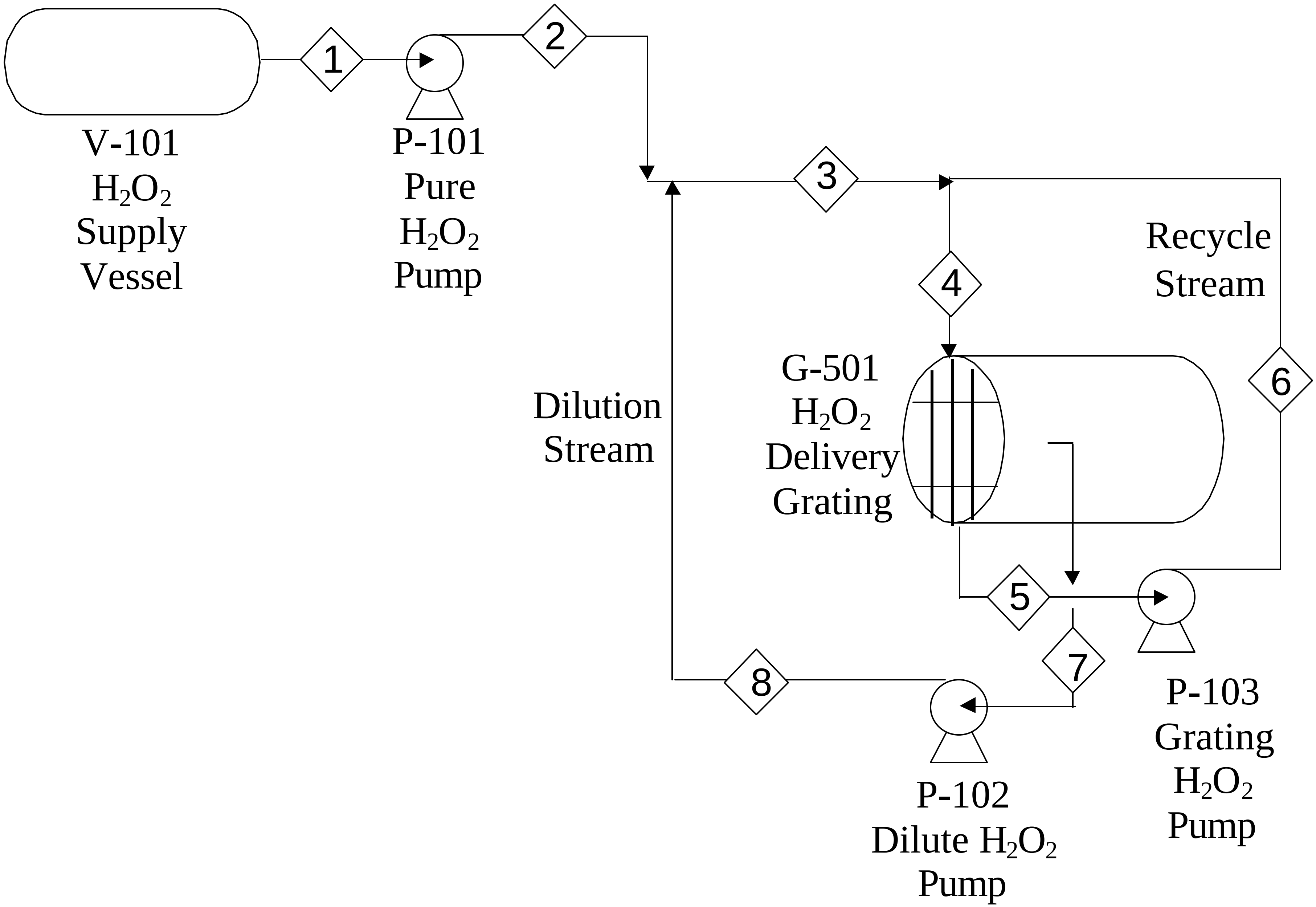

Figure 2: Process Flow Diagram for Zebra Mussel Chemical Removal

The toxin, either hydrogen peroxide or Zephiran chloride, is stored in V-101. For now, the continuous flow of hydrogen peroxide will be considered. The peroxide is gravity fed to pump P-101. Stream 3 is mixed with Stream 8, which is taken from the inside of the intake pipe in Stream 9. Stream 9 is taken from the inside of the intake pipe to prevent it from being colonized with zebra mussels. The purpose of Stream 9 is to dilute the peroxide feed and increase the flow rate. Pump P-102 brings the solution from the intake pipe up to the pressure required to mix with Stream 3. Stream 4 is mixed with the recycle, Stream 7. Stream 5 feeds the grating where the hydrogen peroxide flows out of the holes in order to dose the intake pipe with hydrogen peroxide at a concentration of 3.0 ppm. Streams 6 and 7 comprise a recycle loop that increases the flow rate in the grating in order to lower the pressure drop.

References Cited

1. Zebra Mussel Research Program. http://www.wes.army.mil/el/zebra/

2. Hydrogen Peroxide Online. http://www.h2o2.com/index.html

3. Zebra Home. Online. World Wide Web. http://www.schoolnet.ca/vp-pv/ces/e/zebra/zebrahom.htm#Life_Cycle.

4. “Chlorine In Water Can Cause Problems” *Greensboro News & Record*, 19 August 1997.

Other References

1. Welcker, Bonnie C.. “Development of an Environmentally Benign, Species-Specific Control Measure for *Corbicula fluminea*” *SCIENCE 21*, 2:1: pp 11, 25-27 Spring 1997.

2. G.N. Abramovich, *The Theory of Turbulent Jets*, MIT Press, Cambridge, p. 36, 1963.

3. Sparktec Environmental, Inc, http://www.sparktec.com/facts.htm.

4. Sparktec Environmental, Inc., Personal Correspondence, Jan 22, 2000.

5. Solomon Diving. http://www.solomondiving.com/.

6. N. P. Cheremisinoff and R. Gupta, *Handbook of Fluids in Motion*, Ann Arbor Science Publishers, p. 251, 1983.

7. S. Pai, *Fluid Dynamics of Jets*, Institute for Fluid Dynamics and Applied Mathematics, p. 96, 1954.

8. Nalepa, Thomas, and Donald W. Schlosser, *Zebra Mussel Biology, Impacts, and Control.* Ann Arbor, Michigan: Lewis Publishing, pp. 333-379, 1993.

9. Green, D.W. and R.H. Perry, *Perry’s Chemical Engineers’ Handbook*, (7th ed.), McGraw-Hill, New York, p. 6-21, 1997.