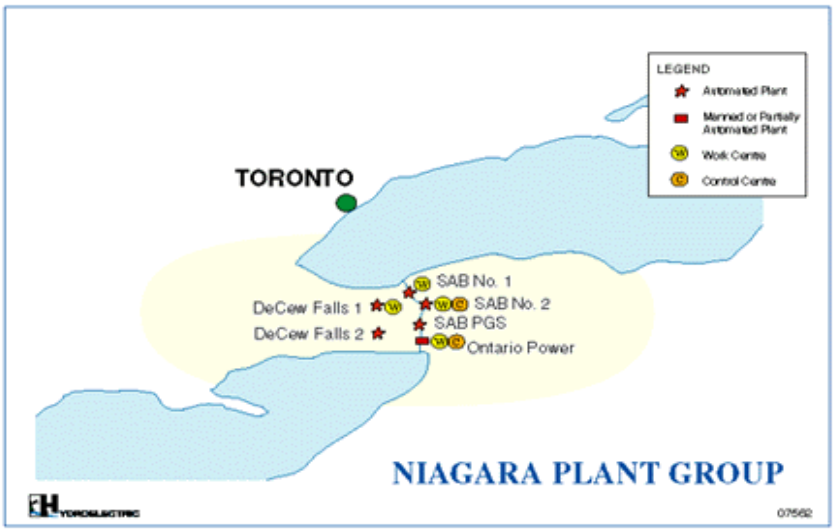
I would like to thank Kelly Peterson of ASI Group Ltd. St. Catharines Ontario for her contribution to this presentation.

Kelly Peterson of ASI Group and her colleagues have spent a great deal of time at our plants in the past few years assisting and providing input during the re-building of our Sodium Hypochlorite Treatment Systems. They also provided valuable assistance troubleshooting problems that arose through the monitoring work that they did for us.

Special thanks also to my colleagues at the Niagara Plant Group who worked hard to design and rebuild these systems in the Niagara Plant Group from the ground up.

1.0 Niagara Plant Group Location and Facilities



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Thank you for the opportunity to talk about the Re-design of the Sodium Hypochlorite Treatment Approach for Zebra Mussels at the Niagara Plant Group.

Niagara Plant Group is located in Ontario, Canada in the Niagara Peninsula, in and near Niagara Falls. We currently operate 5 hydroelectric generating stations with a capacity of about 2340 MW which is about 30% of the total Hydroelectric capacity in the province or about 10 percent of the total electrical generation in the province.

Niagara Plant Group has had an ISO 14001 registered Environmental Management System in place since 1998, and a management system registered to OHSAS 18001 Health and Safety Management System in 2002. Our efforts to re-build these treatment systems and the results achieved support elements of the MS policies to continually improve, prevent (reduce) pollution and work safely in a injury free workplace.

1.0 Niagara Plant Group Location and Facilities

Sir Adam Beck #2

Sir Adam Beck #1

DeCew #2

Pump Generating Station

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Three of the plants are located along the Niagara River: Sir Adam Beck 1 (SAB1) constructed around WW1, Sir Adam Beck 2 (SAB2) and Sir Adam Beck Pump Generating Station (SAB PGS) both constructed in the 1950's. Our DeCew Falls 2 plant draws water from the Welland Canal was constructed in the 1940's.

Sir Adam Beck #2 with its 1360 MW capacity, is the largest plant in the OPG Hydroelectric portfolio.

The Pump Generating Station is a type of hydroelectric generating station in that water is pumped into a reservoir during low demand times, and then used for generation during high demand times.

2.0 Original Treatment Approach 1992-2002

- **Chlorination systems were first installed in the early 90's to mitigate the quickly spreading threat from zebra mussels.**
- **OPG had no previous experience with this type of equipment/operation – A generic system design was employed and rolled out to "at risk" plants**
- **The typical treatment period was 180 days (June to November) each year**
- **Various treatment approaches were used, continuous shock at start and end of the year and daily periodic treatment through the remainder of the year in the 2 to 5 ppm concentration range**
- **There was no system in place to check on effectiveness of treatment other than monitoring chlorine concentration levels**

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•In Ontario, Zebra Mussels spread into the Great Lakes about 1988.

•At that time, systems had to be designed quickly to deal with the risk, so there was little time to fine tune the systems to operate well with our four different generating stations that had different physical characteristics.

•In Ontario, these treatment systems also operate under special permits called "Certificates of Approval"

2.0 Original Treatment Approach 1992-2002

Over time, common problems emerged…….

•Leaking PVC piping, piping breakages, pump break downs, dysfunctional automatic operation

•Over time health and safety problems emerged, labour intensive operations ($$)

•Fluctuating concentrations and breakdowns resulted in effective treatment ….

Water Cooled Transformer Piping at DeCew in 1999

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•The Initial treatment system that was installed was really a temporary one as the thinking was that some other form of treatment would eventually be identified to replace it

•It did not take long before PVC piping became brittle, pumps broke down and the automatic system became dysfunctional

•Many other technologies have been evaluated by OPG over the years, but sodium hypochlorite is still the favoured and most effective approach in our operating environment

•Over time, because the systems broke down a lot, there was not much “continuous” treatment taking place. The system often ran for a few days, then broke down, requiring repairs. The “temporary” system was becoming a very labour intensive system to operate, and ultimately a system that resulted in ineffective treatment

3.0 Improved Zebra Mussel Management

2001- 2002 A new approach…..

•"Prototype" new system at Decew #2 Plant

•Prototype Philosophy:

- **Redesign from ground up**
- **Get it right on our smallest system-then carry experience to large plants**
- **Satisfy safety, environmental, operational and cost concerns**
- **Clarify accountibility for operation and maintenance**
- **Adhere to KISS (NB)**

•Develop "best practices" chlorination strategy and revise permits accordingly to allow for a flexible approach

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•To start our re-design process, we looked at other companies and other plants in our fossil and nuclear facilities to see what worked well for them, and what did not work, to come up with shopping list for new piping, pumps and analyzer

•The new prototype philosophy promoted automation and low maintenance requirements to reduce human intervention and operating costs. Main Components:

•**Piping**: Had to be resistant to corrosion from Sodium Hypochlorite. We used schedule 40 carbon steel piping that was coated with a plastic (PVDF, PolyVinyliDene Fluoride) lining. The lining forms a polymer barrier with the steel piping preventing it from corrrosion. Brand names included Kynar and Haler. This type of piping is highly resistant to corrosion, and has good strength and abrasion resistance.

•**Pumps:** Had to be resistant to corrosion from Sodium Hypochlorite, pumping capacity in the 0 to 6.6 liter per hour to treat in the 0.5 ppm range at 50 PSI into the service water lines in the plant. Desirable features include an off-gassing capability for Sodium Hypochlorite. Selected Prominent Gamma/L dosing pumps.

•**Analyzer:** Desired a low maintenance analyzer that measured chlorine in the 0-2 ppm range. Selected Prominent Dulcometer D1C Chlorine Analyzer and Controller

3.0 Improved Zebra Mussel Management

2003 Moving Forward…

Treatment Strategy

•NPG started to work with ASI Group Ltd. (ASI), a full service engineering and environmental technology company that is recognized as an international industry leader in the research and design of programs for zebra mussel control

•ASI's treatment effectiveness monitoring program showed that the existing treatment equipment and strategy was ineffective (0% mortality of adult mussels in the bioassay @PGS after 59 days of operation)

Chlorination Systems

•Decew prototype operated reliably – system operated for 74 days for from September 9th to November 21st, 2003, however, only 65% mortality of the adult mussels in the bioassay was observed after 74 days of treatment indicating only partial control of infestation was obtained.

•Replacement projects initiated at SAB#1, SAB#2 and Pump GS patterned on the DeCew prototype

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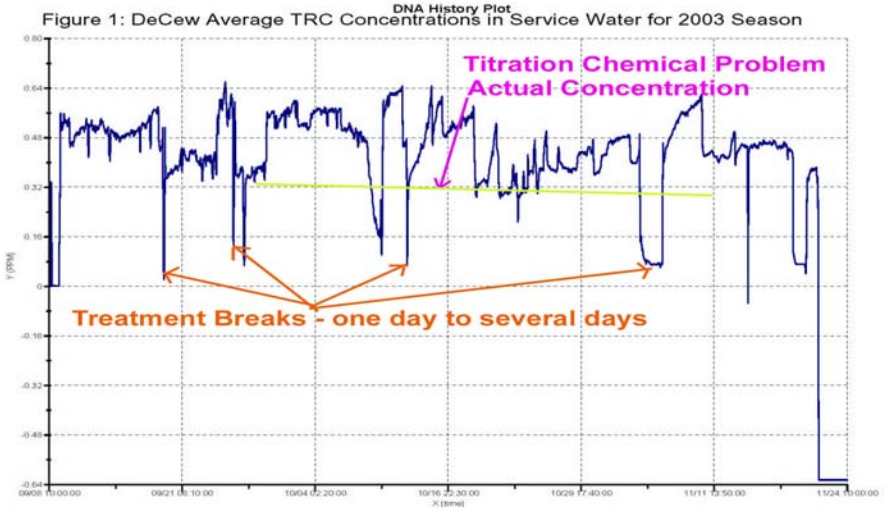
DeCew # 2 Prototype – Results of First Year Treatment 2003

•While the new DeCew system operated relatively reliably, it still took 74 days to achieve only a 65 % mortality. More analysis to follow on the next slide.

•Through monitoring work by ASI Group at our remaining plants in 2003 that were still operating with old equipment, we had confirmation that we had many problems in achieving effective treatment. Our Pump GS was a good example where in 2003 after treating for 59 days, we killed 0% of the 100 zebra mussels in that were placed in our biobox. The old approach was obviously flawed.

3.0 Improved Zebra Mussel Management



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Analysis

•Original target treatment concentration of 0.5 ppm might have been slightly too low to achieve an optimum kill rate – **Action – Increase target concentration slightly**

•During the treatment, we had several interruptions in treatment, some lasting several hours, others lasting days. These breaks, even after a few hours appear to be enough to allow the Zebra Mussels to “catch” their breath and hang on much longer **Action: identify the cause of the interruptions, and come up with a solution to minimize their occurrence**

•Chemicals used for titrating to check the calibration of the analyzer were bad and resulted in an actual treatment at a much lower concentration than actuality.(see yellow line) **Action: resolve problem with chemicals to insure that this is not a problem**

•Water temperature contributed to a longer treatment time due to the naturally lower metabolic rates of Zebra Mussels. **Action**: Target treatment when water temperatures are warmer to reduce treatment times.

3.0 Improved Zebra Mussel Management

New Chlorination Systems-Status

•In 2002 a new treatment system was installed at Decew #2. It operated for the first time in 2003.

•In 2003 a new treatment system was installed at our Sir Adam Beck 1 and Sir Adam Beck 2 plants

•In 2004 a new treatment system was installed at Pump GS

•Extensive negotiations were required with our Ministry of Environment to achieve a flexible, consistent and practical Certificate of Approval that fit planned treatment strategies and equipment and that also met the regulators requirements

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3.0 Improved Zebra Mussel Management

2004

Treatment Strategy– ASI Recommends a New Approach

- 24 hour a day treatment at low concentration (0.4-0.8 ppm) for a short period (10-21 days) with a target concentration average of 0.65 ppm within the system
- chlorine levels must not fall out of this range over the treatment period for more than a few hours
- focussing treatment during warm (>20 C) water temperatures
- targeting August/September so that mussels can not re-establish before winter, and those that do will grow slowly over the winter while water is cold so as to pose minimal risk till next season's treatment
- application of this approach be consistently used at all our plants
- seeding live adult mussels in a container in a biobox to monitor treatment effectiveness in the form of a bioassay with treatment continuing until 100% mortality of the adult mussels in the bioassay is achieved
- Minimum treatment of 10 days to insure complete kill

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At our end of season review at the end of 2003, ASI Group made a number of recommended changes to fine tune our treatment approach to make it more effective.

This was a drastic departure from how we used to do the treatments where:

•Systems broke down all the time - we never got a long period of treatment in

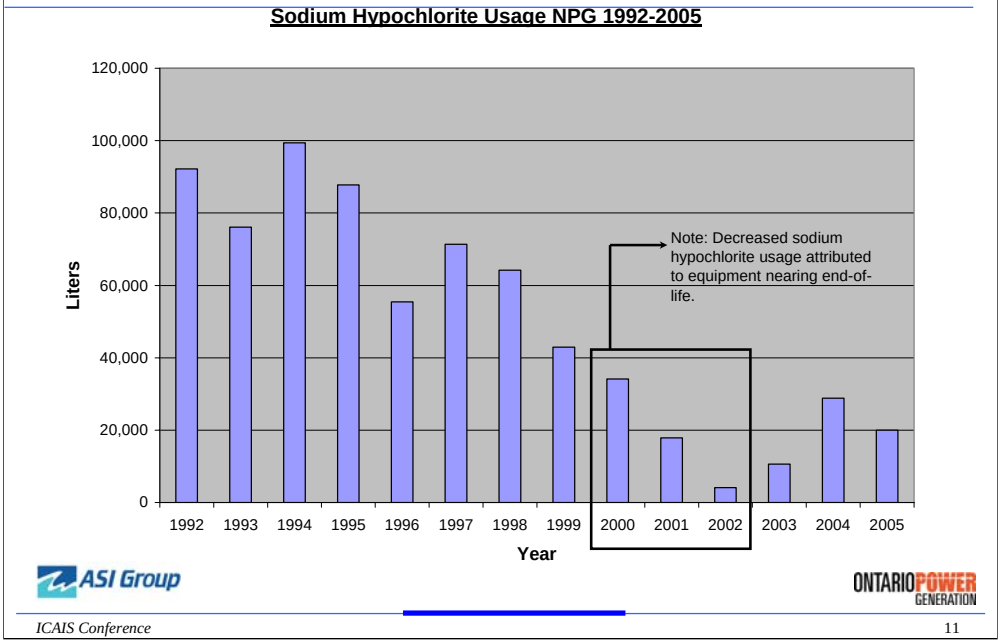
•Our chlorine treatment concentrations fluctuated wildly

•When we did get the systems running, the duration was sometimes as long as 180 days

•In latter years, sometimes we did not get treatment running at all,or it did not start until October or November when treatment was very ineffective

•No body ever thought to ask - how much is enough sodium hypochlorite ? The monitoring using live adults in a bioassay is critical to knowing how effective your treatment is, and when you can shut down

4.0 Treatment Performance 2004, 2005



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•In 2005, you can see we used about 20,000 liters of sodium hypochlorite

•This is a far cry from the 80,000 to 100, 000 liters of the early 1990's

•You might think though that it is not that much lower than in 2000 (35,000) or 2001 (18,000) - that is true.

•It is actually higher than 2002, 2003

•The numbers behind the graph tell the story

•In 2002, only PGS and DeCew treated - SAB 1 and SAB 2 had so many problems they did not treat at all. They were also preparing to install their new systems

•In the late 1990's and early 2000's the volume of treatment was actually dropping at all the plants because the systems were breaking down so much

•the breakdowns contributed to much less effectiveness of treatment

•We feel that the 20,000 liters usage of sodium hypochlorite for all the plants will likely be the range that we will discharge with effective treatment in the future

4.0 Treatment Performance 2004, 2005

ASI's Mussel Monitoring Program Objectives:

1. Track and determine the seasonal peaks of free-floating larvae (veligers and post veligers) and the infestation rates of settlement stage larvae at the in-plant biobox locations at each facility to help optimize the timing of the treatment program.

2. Evaluate the effectiveness of the treatment programs during each facility treatment by monitoring adult mussel bioassays daily.

3. Monitor chlorine levels at biobox locations daily during the treatments and compare the results to in-line chlorine monitoring system measurements and the performance of portable TRC test equipment to ensure adequate concentrations are maintained within the system.

Goals/Purpose of mussel monitoring often referred to as the integrated approach to mussel control.

4.0 Treatment Performance 2004, 2005

2004

Bioassay Results

- DeCew NF23 treatment **12 days** and **100 % mortality** in 8 days
- Pump GS treatment **21 days** and **98 % mortality**
- SAB 1 treatment **22 days** and **98 % mortality**
- SAB 2 treatment **24 days** and **98-100 % mortality**

2005

Bioassay Results

- DeCew NF23 treatment **10 days** and **100% mortality** in 6 days
- Pump GS treatment **7 days** and **100% mortality** in 7 days
- SAB 1 treatment **9 days** and **100% mortality** in 9 days
- SAB 2 treatment **13 days** and **100% mortality** in 11 days

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This slide illustrates the increased success and control in 2005, shorter treatments and greater success. Also highlights the importance of effectiveness monitoring by ensuring that you only treat for as long as you have to therefore no use of excess chemical and no more partial control, only complete control.

Overall “Treatment Days” in 2005 dropped to 39 days as compared to 79 “Treatment Days”in 2004.

Treatment in 2005 was more focussed during August/September and also benefited from having some of the problems encountered in 2004 worked out.

The proof is in the results

•the bioassay consists of 100 live, full grown zebra mussels harvested from the great lakes, and placed inside a plastic mesh cage in an aquarium style box in which treated water flows through constantly

•The zebra mussels when harvested, are acclimatised in a lab, before being seeded and again in the plant before treatment starts -

•The thinking is, if you can kill these very robust adults in the ideal slower moving water environment of a biobox, then any zebra mussels within your system will certainly be dead

4.0 Treatment Performance 2004, 2005

Dead Zebra Mussels Found in Unit Coolers after 2004 treatment at our Pump GS

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•The results of an effective treatment after years of ineffective treatment could cause problems – take precautions

•At our Pump GS plant, we had a tremendous flush of dead shells, some of which ended up in the manifold entrance to the generator coolers

•Our coolers had extra capacity so we were fortunate that we did not have any over heating issues develop

4.0 Treatment Performance 2004, 2005

2004 Treatment Results Pump GS Piping

Before **After**

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Pipe on the left was filled with live zebra mussels in the 1 to 1.5 cm range. It was located upstream of a water cooled compressor at Pump Gs

Compressors only run periodically, and piping in their vicinity likely represents an ideal environment for zebra mussels to grow

The same pipe after 21 days - there were no zebra mussels left inside the pipe

This is the ultimate bioassay – a removable section of pipe where water flow is only periodic.

4.0 Treatment Performance 2004, 2005

TRC Quality Results 2004 & 2005

•Results revealed that greater control of TRC residuals were obtained within the service water system from 2004 to 2005 with significantly fewer discrepancies between the in-line analyzer and titrator results

Location	2004 # of Analyzer Readings with >5% Discrepancy with Titrator Results	2005 # of Analyzer Readings with >5% Discrepancy with Titrator Results
DeCew NF23	0	0
SAB 1	7	1
SAB 2	27	15
PGS	10	5

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These results show that tighter control over analyzers can help to reduce treatment duration as shown in previous slide.

The majority of discrepancies during both years are a direct result of suspect titration chemicals that were no longer effective due to warm plant temperatures and cross contamination with droppers etc.

By insuring chemicals used for titration are effective, we know exactly what is being put into the service water and therefore, therefore no under or over dosing.

4.0 Treatment Performance 2004, 2005

ASI Recommends the following for continued success:

1. Continued monitoring of intake densities of free-floating larvae and in-plant densities of settlement stage larvae.
2. In-plant bioboxes should remain operational throughout the entire year.
3. Continued implementation of treatment programs when water temperatures are above and are expected to remain above 15°C.
4. Treatment duration should occur for a minimum of 10 days.
5. Continue to refine the current procedures for handling, storage and use of titrator chemicals to ensure analyzers are calibrated to true TRC readings

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1. Free-floating larvae provide indication of reproduction of surrounding mussel population and provide an indication of when settlement may be expected based on developmental stages of larvae observed in the headwater samples. Settlement stage monitoring at the bioboxes tracks the infestation status of the service water system between treatments. Data from 2003 to 2005 illustrates that mussel densities entering the plant and settling within the plant fluctuate significantly from year to year. Tracking these fluctuations allows OPG to determine how severe infestation within the plant is during a given year to determine if more than one treatment is required or treatments are only required every other year.
2. Allows infestation within the system to be accurately determined. Can also provide information regarding growth rates of mussels over the winter and spring which may have implications in the timing of treatments.
3. ASI experience reveals 100% mortality of mussels in bioassays can be expected to occur in 10 days at 15 C, when water temperatures are lower, treatments are longer more $$
4. If complete mortality occurs prior to 10 days ASI recommends continuing the treatment for added protection.
5. Issues with chemicals in 2003, 2004 and 2005. If we can eliminate this problem will have better control of TRC within system and optimize the outcome.

These contrasted greatly to how we did our treatment at the time

4.0 Treatment Performance 2004, 2005

Summary

1. The integrated approach to controlling mussel infestation the OPG NPG adapted beginning in 2003 has been extremely successful in assisting with the optimization, evaluation and timing of treatment strategies.

2. Adult mussel bioassays used to evaluate the success of the treatments has proved critical in determining the endpoint of each treatment.

3. TRC analysis by ASI as an independent quality check of the functioning of OPG's portable test equipment and in-line monitoring equipment has proven efficient in optimizing residual chlorine levels within the system.

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1. Integrated approach involves the inclusion of monitoring to evaluate the success of treatments, and optimize treatment timing to ensure that the infestation status of the system is constantly monitored. Eyes open approach to control, allows you to have an idea of what is going on in the system at any given time.
2. Results from 2003 highlight this point with only partial control at DeCew, 65% mortality in after 74 days of treatment, 0 mortality after 59 days of treatment at PGS.
3. Continual problems with chemicals. Independent checks catch problems immediately to helps to ensure treatment not extended if levels are too low and proves that readings being obtained are accurate which gives a better idea of what might be leaving the plant at the outfall.

5.0 Problem Encountered and Resolution

Bad Chemicals Used with Titrations for Calibration

- OPG uses Wallace and Tiernan Titrators to check calibrations of our analyzers
- As part of the titration, phenylarsenoxide (PAO), PH4 buffer and potasium Iodide solutions are used
- Each year over the past 3 years we have discovered through independent quality checks by ASI that one or more of the titration chemicals was suspect resulting in erroneous calibrations and treatment at lower concentrations than was expected

- **Considerations**:
  - Minimize cross contamination of chemicals
  - Store chemicals in amber bottles
  - Keep the chemicals cool, or replace frequently when in use even if well before the expiry date

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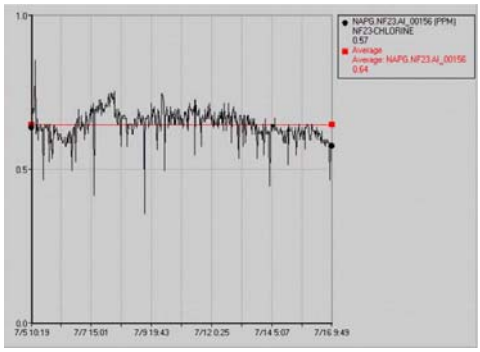
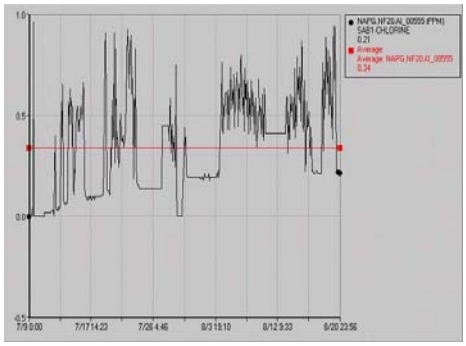
5.0 Problem Encountered and Resolution

Steady vs. Fluctuating Concentrations



DeCew July 2004: 12 Days 100% mortality



SAB 1 July/Aug 2004: 22 days, 98 % Mortality

•Fluctuating concentrations, what ever the cause, can extend the treatment period dramatically

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5.0 Problems Encountered and Resolution

Off gassing of Sodium hypochlorite

- At both our SAB 2 and SAB 1 plant, vent lines were incorporated into the design for the sodium hypochlorite tank as well as locations along the length of the sodium hypochlorite supply lines
- In both cases, we experienced some small spills/leaks as a result of gas accumulating in the vent tube and actually pushing the sodium hypochlorite out of the vent. This occurred even though the top of the vent pipe was at least 3 ft above the top elevation of the supply tank and line
- The fix in both cases was to extend the vent piping further and to also expand the diameter of the tubing near the top to break any “bubbles” of chlorine gas that may accumulate

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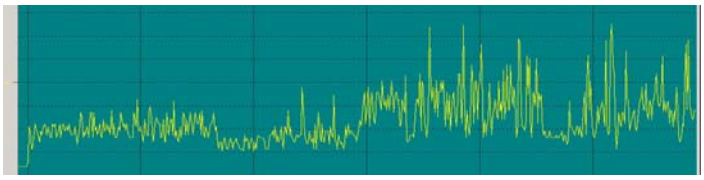
5.0 Problems Encountered and Resolution

Variable concentrations of sodium hypochlorite in treated water

- One of the sources contributing to variation in sodium hypochlorite in service water were our automatic coolers that were using the service water to cool generator units during the summer months
- These units are automated, and came on and off on a frequent basis making it difficult to get a “stable concentrations”

Consideration:

- We opted to remove the automatic setting for our coolers and set them to “full” to eliminate this variable



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5.0 Problems Encountered and Resolution

Water Temperature:

- Treatments carried out late in the season, October and November took much longer to achieve a 100 % kill, and often did not achieve a complete kill.

Consideration:

- Carry out treatments in August and early September when water temperatures are high (over 20°C) and metabolic rates of Zebra Mussels are also high
- Treatments in 2005 were almost all completed before or in 10 days and all achieved a 100 % mortality.

5.0 Problems Encountered and Resolution

Sediment and Debris Clogging Analyzer:

- Summer thunderstorms, often bring heavier sediment loads which can foul up analyzer sensors

Consideration:

- During treatment, daily checks of the analyzer including cleaning if required are necessary to insure continued operation without breaks.

6.0 Summary of Results and Conclusions

- **Treatment has been reduced to less than 2 weeks a year from 10 to 25 weeks resulting in:**
  - A huge savings on labour costs ($200 - $400 K/yr)
  - A substantial reduction on amount of chlorine released to the environment (20 Kl vs. 85 Kl)
  - A reduction on chlorine purchase costs ($ 15 K /yr)
  - A reduced risk of non compliance with the Permits due to reduced treatment time
  - Reduced time of exposure to chlorine hazard by employees by reducing the treatment time and using superior materials that are much more resistant to corrosion
- **Effectiveness of treatment is confirmed through live zebra mussel bioassays which dictate when treatment can be shut down**

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•With this reduction, it means 70,000 liters less chlorine in the environment

•reduced treatment time means a much reduced exposure to risk of spills or exceedance of discharge limits in the Certificates of Approval