# FLUORIDATION OF THE NORTHERN PENINSULA AREA WATER SUPPLY

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# FLUORIDATION OF THE NORTHERN PENINSULA AREA WATER SUPPLY

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**ABSTRACT**

In late 2003, a decision was made by the five Indigenous councils of the Northern Peninsula Area (NPA) to fluoridate their common water supply. SunWater, as the contracted operator of the NPA water treatment facility, was asked to construct and commission a suitable fluoride dosing system as an augmentation to the existing treatment plant.

A risk assessment undertaken during the preliminary design phase of the project identified a number of key issues relating to the implementation of a new treatment process in a small and isolated community. Assessment of options to manage these issues culminated in the decision to construct a dosing facility that utilised fluorosilicic acid as its source of fluoride.

This paper examines the criteria used to select the source of fluoride and its associated dosing system, the issues experienced in establishing and commissioning the system, and the management measures taken to resolve the problems encountered.

## 1.0 INTRODUCTION

The NPA is located at the tip of Cape York in far north Queensland, and is comprised of three Aboriginal and two Torres Strait Islander communities that utilise a common water supply. Water is extracted from the Jardine River and pumped to the township of Bamaga where it is treated through a microfiltration process. Treated water is then pumped to a high level reservoir and gravity fed to each of the five communities.

An extensive consultation process led by Queensland Health and the Department of Aboriginal and Torres Strait Islander Policy (DATSIP), combined with dental surveys across the area conducted by the Department of Defence through Army Aboriginal Community Assistance Program (AACAP), culminated in an agreement from each of the Councils to add fluoride to their water supply.

SunWater has operated the water treatment facility and reticulation area in the NPA under contract to DATSIP since it was constructed and commissioned in 2000. Following the decision to fluoridate, DATSIP commissioned SunWater to construct a suitable fluoride dosing facility as an augmentation to the existing treatment plant.

## 2.0 DISCUSSION

### 2.1 Chemical Treatment Options

Initial scoping activities revealed three commonly available sources of fluoride for application to water supplies, these being:

**Sodium fluoride (NaF).** This is a powder-based form of fluoride, and is the most common source of fluoride utilised in Queensland water supplies.

**Sodium silicofluoride ($Na_2SiF_6$).** Another powder-based form of fluoride used utilised widely throughout Australia, although not currently used in Queensland.

**Fluorosilicic Acid ($H_2SiF_6$).** A liquid based form of fluoride that is also commonly used throughout Australia (RMIT-University, 1999).

The form of fluoride utilised in the water treatment process largely dictates the design of the dosing facility that must be adopted to apply the chemical, with notable differences between the powder based plants and acid (or liquid) based plants. As there are no quantifiable health benefits of one form of fluoride over another, the process for determining the form of fluoride to be utilised in the NPA was driven largely by the designs of commercially available dosing equipment.

## 2.2 Design Criteria

A risk assessment was undertaken during the preliminary design phase of the project to identify issues requiring active management and costing into the project budget. The risk assessment revealed a number of fundamental issues that related directly to the dosing system, thereby providing some key criteria for its selection:

***Reliability -*** The majority of supplies and materials utilised in the NPA are shipped in from Cairns, as roads into the area are rugged and impassable during the wet season. Consequently there are significant delays associated with accessing spare parts and other inventory for corrective maintenance exercises. In addition, travel to the site by service technicians from major centres requires connecting flights from Cairns via a regional flight service with limited availability, and accommodation in the area is restricted and expensive. Subsequently reliability of the system was a critical factor in plant selection.

***Capital and operating costs -*** Costs varied significantly depending on the form of fluoride utilised and the associated dosing equipment. For smaller systems such as the NPA, acid based plants tend to have lower capital costs (due to their simplistic design) and higher operating costs (due to the expense of the acid which is not commonly available in Queensland) in comparison to powder based plants.

***Operator health -*** A major concern associated with the operation of a fluoridation facility is the exposure of operators to fluoride compounds. While fluoride compounds can cause acute poisoning, chronic poisoning is more likely from workplace exposure (QLD Health, 2000). A regular intake of fluorine above 6 mg/day is likely to result in toxic effects that are collectively known as fluorosis. In water treatment facilities this generally occurs through the regular intake of sodium fluoride dust via the lungs (QLD Health, 2000).

***Queensland Health Code of Practice for the Fluoridation of Public Water Supplies (the COP) -*** The COP defines the operational criteria needed to meet the main technical, workplace health and safety, and environmental requirements of Queensland's fluoridation legislation. It also identifies how fluoridation plants are to be established and operated in a safe manner to satisfy these criteria (QLD Health, 2000). The COP was the most significant criteria in the design process, and was utilised in the establishment of the specification to the dosing equipment supplier and in the design and construction of the fluoride dosing room, which was purpose built.

After considering these key criteria, fluorosilicic acid was selected as the preferred fluoride source for the NPA facility. The reasoning for this selection process was as follows:

***Reliability.*** The system selected was comparatively simple and presented fewer mechanical processes that could potentially fail, notably through the absence of bag loaders and mechanical mixers typically associated with powder based plants.

***Cost.*** Capital costs of acid plants were generally lower than powder based plants, again due in most part to the absence of bag loaders and mechanical mixers. Chemical costs of acid were higher than powder (approximately 20% more based on the quotes obtained during the planning phase), however the plant would need to be operated for 25 years before the combined operating / capital costs tipped in favour of a powder based facility given the relatively small volumes of water being treated (averaging 4 ML/day).

Powder based plants also present an additional cost in the disposal of the bags in which the chemical is supplied. Due to their contamination with fluoride powder, the bags are deemed a regulated waste, and would need to be transported to Brisbane for disposal.

***Operator Health.*** The use of a liquid product avoided the dust issues associated with powder-based plants, and this was a *major* factor in plant selection. Acid fumes were a consideration, however this was effectively managed through the installation of appropriate mechanical ventilation.

***COP Compliance.*** Given that the facility was being designed from scratch, achieving compliance with the COP was relatively straight forward for both powder and acid plants, with no advantage to either system.

### 2.3 NPA Fluoridation System Design

The plant utilises 20% solution fluorosilicic acid which is delivered to the facility in 1000 L bulky bins. The bins are connected directly to the dosing skid, and 30 L batches of acid are transferred to a header tank via a transfer pump. This acid is then released to one of two 120 L day tanks (duty and standby) and filled with water to generate a 5% solution.

This dilution process was specifically designed into the facility to provide higher flow rates through the dosing pumps, thereby facilitating more accurate dosing at lower plant flows. Water demand in the NPA varies between 1 and 6 ML per day depending on the season, and problems have been experienced in the past with chlorine dosing pumps both priming and accurately dosing at lower flow rates.

Both day tanks are mounted on loss of weight scales required under the COP to measure the weight of chemicals used on a daily basis. Duty and standby dosing pumps deliver the diluted solution into the treated water main via a common suction line from both day tanks.

System operation is largely automated via an independent PLC which controls the batching process and transfer between day tanks, and fluoride dosing rates which are controlled from online analyser measurements. The only aspect of operations that is not automated is the filling of the header tank, which is controlled manually via the switchboard. This manual intervention has been built into the system to prevent possible overdosing resulting from PLC failure.

## 2.4 Issues Encountered

The following is a brief overview of some of the key problems that were encountered during commissioning and initial operation of the NPA fluoridation facility. Many of the issues outlined here are relatively simplistic in nature, however they resulted in disrupted operations and required considerable effort from both the supplier and operator to identify and resolve.

***Issue 1 – Fluoride concentration spikes during the plant backwash process.***

Problem: The NPA water treatment plant utilises a micro-filtration process that filters water through polypropylene fibres to remove contaminants. These fibres require relatively frequent backwashing in order to dislodge built up sediments, resulting in the plant stopping, backwashing, and recommencing operation every half hour or so.

During commissioning of the fluoridation facility it became rapidly apparent that this intermittent operation was generating large fluctuations in fluoride concentrations. As the plant stopped to backwash, so too did the fluoride plant a short time thereafter. Because the fluoride plant did not stop in the same instant that the primary treatment facility stopped, a small volume of concentrated fluoride entered the treated water main. When the plant operation recommenced, this spike was sent through to the on-line fluoride monitor, exceeding the safety threshold of 1 ppm, and subsequently shutting the fluoride plant down. When the fluoride levels had fallen to an acceptable concentration, the fluoridation unit recommenced operation, only to be shortly disrupted by another backwash cycle that set the same chain of events into motion once again.

This process is graphically illustrated in Figure 1 below from a SCADA screen dump which shows the plant flow rate (black line) and corresponding fluoride concentration spikes (red line) following the backwash process

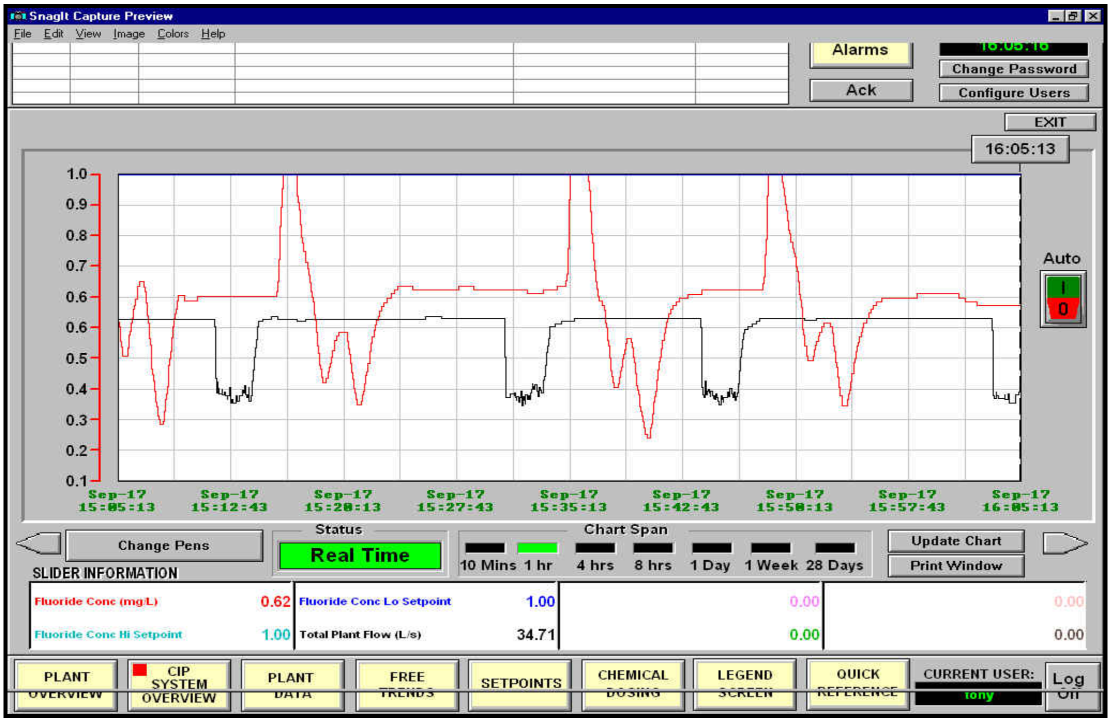


**Figure 1:** ***SCADA Screen Showing Fluoride Concentration Spikes Following Backwash***

Solution: To negate the impacts associated with small spikes of fluoride travelling through to the online analyser, a contact tank and recirculation pump were installed. This tank receives all water from the sampling line and mixes it prior to entry into the analyser, delivering a homogeneous solution that eliminates small chemical concentration variations and provides an averaged (and more constant) measurement of chemical dosage rates.

This solution also eliminated a secondary issue of inadequate chemical mixing in the treated water main prior to extraction at the sampling point, which was later found to be compounding the fluctuations in the fluoride concentration. The installation of the contact tank not only resolved this issue, but also generated more constant results from the existing online pH and residual chlorine analysers that had been suffering from this same problem to a lesser extent since construction of the primary treatment plant.

***Issue 2: Loss of online analyser calibration during shutdown periods***

Problem: During the wet season, demand for water in the NPA can drop below 1 ML/day. As the distribution system is equipped with over 11 ML of storage capacity to cater for higher demand periods, this seasonally reduced demand can result in regular plant shutdowns exceeding 12 hours.

During the first wet season following commissioning of the plant, the online fluoride analyser started loosing calibration. After some discussion with the supplier it was determined that the ion selective electrode utilised in the analyser required constant immersion in water, and as sampling of water does not occur unless the plant is operational, the shutdowns were drying out the electrode. The supplier had apparently never encountered this problem before, as this was the first treatment plant they had experienced with such a variable mode of operation.

Solution: The newly established contact tank was equipped with a bypass valve that allowed water to be passed through the analyser when the treatment plant was not in operation, thereby perpetually submersing the electrode and eliminating the cause of calibration loss.

***Issue 3: The chemical dilution process***

Problem: To achieve the desired 5% acid solution, water is added to the 20% solution provided by the chemical supplier. The batching process utilised involves depositing the contents of the header tank (20% acid solution) into the day tank prior to filling the tank with water. Adding the water after the acid allows mixing of the day tank to provide a uniform solution for injection.

Following commissioning, QLD Health pointed out that adding water to acid is not a desirable practice due to the exothermic reaction that results, and that the preferred process is to add acid to water. However reversing the process to cater for this change would have eliminated the source of mixing, thereby requiring the addition of mechanical mixers which had been deliberately avoided for reasons outlined in section 2.2.

Solution: After some calculation it was determined that the risks associated with the mixing process were low, and agreement was obtained from QLD Health to leave the process as it was designed. However as a result of this experience, Queensland Health has indicated that it will amend the COP to eliminate this practice in the future.

***Issue 4: Leaking fittings and associated corrosion***

Problem: The fluoride plant suffered from a number of leaks that became evident shortly after operation commenced. These leaks led to obvious safety hazards for the operators, but also caused damage to the skid on which the plant was built. The skid was constructed largely of galvanised steel, including the electrical conduits, which offers little in the way of acid resistance and is expected to degrade significantly over the next few years.

Solution: All that could be achieved to resolve this issue was to repair the leaks by resealing all of the valves and fittings on the skid with Loctite 456. The specification to the supplier should have stipulated sealing of all joins with Loctite, and more importantly the construction of the skid in stainless steel and the provision of electrical conduits in PVC.

## 3.0 CONCLUSION

The selection of fluorosilicic acid as the source of fluoride for the NPA treatment facility overcame a number of the problems associated with powder based plants, notably the dust issues impacting operator health and the elimination of mechanical processes required to deliver the powder into solution. It also negated the regulated waste issues associated with disposal of powder bags, and kept capital costs to a minimum.

Aside from the leakage issues and associated corrosion, which could have been readily minimised through the use of appropriate construction materials and methods, there were no major drawbacks identified from the plant or disadvantages when compared to powder based options. To that end the selection of an acid based system proved to be the optimal decision for the small water supply in the NPA. However acid plants become less appealing as the size of the treatment facility increases due to the comparatively high chemical costs (particularly in Queensland), which would rapidly consume any capital cost savings that might be obtained where larger volumes of water are being treated.

The key issues encountered in commissioning and operating the facility were due to a mix of factors; some issues related to integration with the existing microfiltration facility, and others were a function of the plants design. However all of these issues could have been readily avoided had they been foreseen by stipulating the appropriate design criteria at the onset of the project. Hopefully this paper will provide some guidance to future designers of acid plants thereby enabling them to avoid similar issues.

## 4.0 REFERENCES

Ahokas, J.T et al (1999), *Review of Water Fluoridation and Fluoride Intake from Discretionary Fluoride Supplements,* RMIT-University, Melbourne.

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