Suggested Practices for Fluoride Design

Purpose of Design and Operational Standards

Between 1976 and 1992, the U.S. Public Health Service Center for Disease Control (CDC) documented 15 cases nationwide of fluoride overfeed events. There were likely many more that were unreported. Of these 15 cases, 6 episodes were from community water supplies (CWS) and 9 were from school water supplies. The 6 CWS overfeed cases include Harbor Springs, Michigan (detailed below) but not Portage, Michigan or Hooper Bay, Alaska (also detailed below). Of the 15 total cases documented, the apparent causes were mechanical failure in 6 cases, electrical failure in 3 cases, and operator error and/or installation mistakes in the remaining 6 cases.

Detailed Case Studies

Harbor Springs, Michigan - 11/22/77

Four persons became ill with nausea and vomiting after drinking municipal water. One person sought medical care and was hospitalized overnight. Mechanical control of the fluoride metering pump malfunctioned resulting in a maximum concentration of fluoride being fed of 42.6 mg/L.

Portage, Michigan - 7/3/91

An overfeed occurred at the Amberly Wellfield sometime between July 1, 1991 and July 3, 1991. The confirmation of the overfeed came on July 5, 1991 with the results from an analysis of a sample collected at Amberly School reporting 92 mg/L of fluoride. The sample collection was initiated by a report filed with the Kalamazoo County Human Services Department regarding children at the school becoming ill on July 3, 1991. It was determined that a solid state well control card short circuited, falsely indicating that the well was operating, activating the fluoride feed pump. There was not a redundant feed pump electrical activation mechanism such as a flow switch wired is series with the feed pump. The wellfield was actually out of service at the time of the overfeed for repairs to chlorination equipment. Approximately 44 pounds of hydrofluosilic acid were pumped at the injection point which is located outside the wellhouse in a pit. Due to the distribution configuration, it is believed that the entire volume of lost acid was pulled into the school. No serious health effects were reported possibly because chlorine was also overfed simultaneously, producing an unpalatable taste.

Hooper Bay, Alaska - 5/21/92

Hooper Bay is a small village on the Bering Sea populated predominately by Alaska Natives. The water system does not serve individual homes, but rather, serves a 1675 gallon holding tank from which residents then carry the water to their homes. One person died as a result of this event and it is estimated that 296 people became sick. Peak concentration of fluoride was estimated at 150 mg/L, though records are not adequate to determine this absolutely. Fluoride concentration was measured at 58 mg/L on 5/27/92, several days after the suspected peak. There were many factors which contributed to this event. The operator lacked formal training and could not correctly perform fluoride tests. Required monthly reports of fluoride measurements had not been submitted to the state for over two years. High fluoride concentrations (up to 20 mg/L) were also documented in 1991, with apparently no successful corrective measures. Major electrical and mechanical defects were identified. The control system was unreliable and did not activate the water pump consistently. The fluoride pump performed four times faster than expected when tested, and because of improper electrical wiring, could be activated independently of the water pump. Under certain conditions, the fluoride could be siphoned into the water well, and it is believed that siphoning also contributed to this overfeed.

New Baltimore, Michigan - 8/24/95

An overfeed occurred August 24, 1995 during the midnight shift when the plant was shut down. The overfeed was discovered the following morning during routine inspection of the fluoride day tank, when the operator noted the missing acid. The fluoride feed point is on the filter influent line. There is no pressure on this line while the plant is shutdown. A failed single anti-siphon valve on the metering pump is the presumed cause of the overfeed even though inspection of the anti-siphon valve did not reveal any obvious defects. Feed rates exceeded 4 mg/L during the event. However, it was estimated that plant tap fluoride levels did not significantly exceed 4 mg/L as a result of the dampening effect of the reservoir.

St. Joseph, Michigan - 12/24/98

A recent repair to the fluoride rotodip feeder box produced filings which apparently lodged in an elbow of the rotodip feeder return line. A transfer pump supplies fluosilicic acid continually from two bulk tanks at a lower level to the rotodip feeder when the plant

is operating, and the excess acid overflows to a box in the rotodip feeder, which supplies the aforementioned return line. When the return line became restricted due to the repair filings, the rotodip overflow box backed up, causing overflow into the rotodip feed box which supplies the routine feed line. The peak fluoride feed rate during the event was approximately 14 mg/L. This was only an estimate because there is no day tank or routine daily volume or weight measurements for fluoride used (in addition to the rotodip feeder volume calculation). However, the peak was dampened via the plant reservoir, and 5.1 mg/L was the maximum concentration detected at the plant tap.

Recommended Design Standards

1. Sodium fluoride, sodium silicofluoride and fluosilicic acid shall conform to the applicable AWWA standards and ANSI/NSF Standard 60.

2. Fluoride chemicals should be stored away from other chemicals to prevent contamination. Compounds shall be stored in covered or unopened shipping containers and should be stored inside a building. Unsealed storage units, feed tanks, or bulk tanks for fluosilicic acid should be vented to the atmosphere at a point above grade and outside any building. Bags, fiber drums and steel drums should be stored on pallets to prevent floor moisture from contaminating the chemicals. Bulk or feed tank containers should be of suitable strength and of non-corrosive materials.

3. Where provided, bulk storage tanks should be capable of storing 30 days supply. Adequate spill containment shall be provided for any bulk storage tanks. Transfer pumps should not be located within the containment area. A means to assess bulk tank liquid level should be provided.

4. Fluoride feed equipment shall include a feed tank (day tank) capable of holding no more than enough fluoride solution to meet maximum daily demands.

5. Scales or other loss-of-weight recorders, or liquid level indicators, as appropriate, accurate to within five percent of the average daily change in reading, shall be provided for fluoride solution day tanks. Spill containment shall be provided for day tanks.

6. Positive displacement pumps should be considered the standard method of feeding fluoride solution. In the event rotodip feeders are employed, the return line must be adequately sized, and an overflow which does not discharge to the feed line must be provided. Additionally, the rotodip feeders and any continuously running transfer pumps to the rotodip feeders, must be sized in accordance with the following item.

7. For greatest accuracy, feed pumps should be sized to feed fluoride near the midpoint of their range. Pumps should be designed to operate between 30-70% of capacity. Oversized feed pumps shall not be used because serious overfeeds can occur if they are set too high. Conversely, undersized metering pumps can cause erratic fluoride levels. Feed pumps shall be accurate to within five percent of any desired feed rate.

8. A graduated cylinder should be installed at the lowest point possible between the day tank and feed pump for purposes of calibrating the feed pump.

9. The fluoride feed point should be located where all of the water to be treated passes. However, fluoride should not be injected at sites where substantial losses of fluoride can occur, i.e., before large dose coagulation, before lime-soda softening or before ion exchange softening. Whenever possible, the fluoride injection point should be upstream of plant storage so that in the event of an overfeed, the concentration peak will be dampened. In a treatment plant, an ideal location may be the filter effluent line prior to the clearwell. Fluoride feed lines should be as short as possible and accessible throughout their entire length.

10. The point of application of fluoride, if into a horizontal pipe, should be in the lower one third of the pipe, ideally 45 degrees from the bottom of the pipe, and the end of the injection line should extend into the pipe approximately one third of the pipe's diameter. This will allow better mixing without sediments collecting around the injection point. The fluoride injection point should not be located at the top of the pipe because of potential air binding problems and to prevent pooling of acid on the bottom of the pipe, promoting corrosion.

11. For well supplies, the point of fluoride injection shall be on the discharge side of the check valve so the injection point is always under positive pressure. Attempts should be made to locate the injection point in treatment plants also at a place continuously under positive pressure. However, this may prove difficult in treatment plants that do not operate 24 hours per day. Redundant anti-siphon devices and an isolation valve as described in the following item will be considered acceptable anti-siphon protection for shift operations. Where open channels or open basins are utilized for fluoride application, a suitable air gap must be provided.

12. Redundant diaphragm type anti-siphon devices must be installed in the fluoride feed line. The anti-siphon device should have a diaphragm that is spring-loaded in the closed position. These devices should be located at the fluoride injection point and at the metering pump head on the discharge side. The anti-siphon device on the head of

the metering pump should be selected so that it will provide the necessary back pressure required by the manufacturer of the metering pump. Often these devices are integral to the pump and are part of a multi-purpose valve package which contains a back pressure valve, pressure relief valve, anti-siphon valve and feed valve. Further, an isolation valve must be provided on the fluoride feed line near the fluoride feed equipment, and shift operations must routinely close this isolation valve whenever the plant is shut down.

13. Suitable backflow protection shall be provided for all dilution water and bulk storage lines supplying the fluoride day tank.

14. Vacuum testing for all anti-siphon devices and multi-purpose valves should be performed twice per year, or more frequently if based on the manufacturer's recommendations. All anti-siphon devices and multi-purpose valves must be dismantled and visually inspected at least once per year, or more frequently if based on the manufacturer's recommendations.

15. The fluoride solution feed pump should be located on a shelf not more than 4 feet higher than the lowest normal level of liquid in the carboy or day tank. A flooded suction line is not recommended in water fluoridation. The suction line should be as short and as straight as possible. There should be a foot-valve and strainer at the bottom of the suction line, and if necessary, a weight to hold it down.

16. The priming switch on the feed pump should be spring loaded to prevent the pump from being started erroneously with the switch in the priming position.

17. An in-line mixer or a small mixing tank should be installed in the finished water line from the water plant if the first customer is <100 feet from the fluoride injection point. This minimum distance of 100 feet assumes there are typical valves and bends in the water line that allow for adequate mixing.

18. Water used for sodium fluoride dissolution shall be softened if hardness exceeds 75 mg/L as calcium carbonate.

19. The fluoride feed system must be installed so that it cannot operate unless water is being produced. Further, redundant electrical activation of the fluoride feed is required to assure this is the case. For example, the metering pump could be wired electrically in series with the well pump or service pump. A second flow based device (such as a flow switch or pressure switch) could also be wired in series electrically with the feed pump to provide the required redundant feed pump electrical

activation mechanism. The electrical outlet used for the fluoride feed pump must have a nonstandard receptacle to prevent the possibility of the fluoride feed pump from being plugged into any continuously active (hot) electrical outlet. The fluoride feed pump may also be hard wired directly into the appropriate electrical circuit so that electrical source changes could be made only by deliberate action.

20. Personal protective equipment such as gauntlet gloves, chemical aprons, respirators, goggles, showers, eye wash facilities, etc. shall be provided for operators handling fluoride compounds. Deluge showers and eye wash devices shall be provided at all fluosilicic acid installations.

21. Provisions must be made for the transfer of dry fluoride compounds from shipping containers to storage bins or hoppers in such a way as to minimize the quantity of fluoride dust which may enter the room in which the equipment is installed. The enclosure shall be provided with an exhaust fan and dust filter which place the hopper under a negative pressure. Air exhausted from fluoride handling equipment shall discharge through a dust filter to the outside atmosphere of the building.

22. Provision shall be made for disposing of empty bags, drums or barrels in a manner which will minimize exposure to fluoride dusts. A floor drain should be provided to facilitate the hosing of floors.

23. A corporation stop valve must be provided on the line at the fluoride injection point when injecting fluoride under pressure.

24. A safety chain must always be installed in the assembly at the fluoride injection point to protect the water plant operator if a corporation stop valve assembly is used.

25. A permit is required from the reviewing authority before construction or installation of fluoride feed equipment.

26. An accurate device to measure the flow of water to be treated with fluoride must be provided.

27. Equipment shall be provided for measuring the quantity of fluoride in the water. Such equipment shall be subject to the approval of the reviewing authority.

Fluoride Monitoring/ Required OIC Visits

1. Daily visits by a properly certified Operator-in-Charge (OIC) are required to all systems that inject fluoride, regardless of size, and regardless of other department guidance regarding visits relative to system classification. "Daily" means at least five days per week.

2. Daily fluoride residual monitoring must be conducted by the water supplier at each point of entry where fluoride is injected. Parallel point of entry fluoride residual monitoring (with an outside, certified laboratory) shall be conducted at least once per year. Quarterly parallel monitoring is recommended and the reviewing authority may require this or even more frequent parallel monitoring. Monthly distribution system and raw water fluoride residual measurements should be conducted.

3. Operations such as treatment plants that are staffed for more than one 8 hour shift each day must collect a fluoride residual sample at least once per shift from the point of entry and from a location most indicative of the feed rate, if that is different. Additionally, these multiple shift operations must visually inspect the fluoride feed equipment at least once every shift and must record weight or volume measurements of fluoride used each shift.

4. As a minimum, daily volume or weight measurements and subsequent fluoride dosage calculations for each point of injection are required for all systems that inject fluoride.

5. Daily fluoride residual measurements and dosage calculations must be reported to the state in a form approved by the state and in accordance with Monthly Operational Report requirements.

6. Any fluoride overfeed events which result in a dosage of fluoride exceeding 4.0 mg/L must be reported to the state within 24 hours or as soon as possible.

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