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Case Report

Fluoride failure: From Sandy City's water system incident to statewide ban and beyond

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ABSTRACT

In 2019, a fluoride overfeed in the drinking water system of Sandy City, Utah, USA, sickened residents, corroded pipes, and released lead and copper. Sandy operators changed practices immediately, state water regulators issued administrative orders in following years, and in 2025, due partly to the incident and partly to national mood, the Utah legislature banned water fluoridation altogether—the first such ban in the United States. This case study examines the incident's technical failures (in equipment settings, control logic, and hydraulics), procedural failures (in water sampling, record keeping, and public notification), and how changes in fluoridation practice and policy escalated from a single local event to the national stage.

1. Introduction

In many parts of the United States, drinking water has been fluoridated since the 1950s. Since 1976, the American Water Works Association—the drinking water industry's main professional association—has maintained a policy statement supporting fluoridation "as a public health benefit" (AWWA 2022). By 2006, 69 % of the U.S. population was receiving fluoridated water [1]. Proponents of fluoridation cite the low-cost oral health benefits, namely preventing tooth decay [2], while opponents speak against chemical risks, inconsistent doses, and unconsented mass medication through the water system [3–5].

In the state of Utah, two counties and one city had elected to fluoridate their drinking water, serving some 1.6 million people. The practice had been going well with the support of highly trained water operators, the county health departments, and the state drinking water authority. But in 2019, a major fluoride overfeed occurred in Sandy, Utah, a city of 100,000 people in Salt Lake County (Fig. 1), from the Paradise Valley Well (Fig. 2). Hundreds of people were affected over three days, and water quality was questioned for months. It was the largest fluoride overfeed event in the nation's history, setting off a ripple effect of changes leading in 2025 to the first statewide fluoridation ban in the United States.

Partly due to the Sandy incident, fluoridation in Utah went from accepted to questioned to banned in just a few years. This case study summarizes the incident, describes technical and procedural failures, and discusses resulting changes in fluoridation practices and policy escalating to the national level.

2. Incident summary

Technical information in this section comes from an incident investigation report [6], a water quality report [7], and a fact brief [8]. All are publicly available.

2.1. Intended fluoride operation

Fig. 3 shows the general process and equipment for fluoridation at the Paradise Valley Well. A 23 % hydrofluorosilicic acid solution (H_2SiF_6, hereafter the "solution") is delivered by truck to the well house and stored in a 3800 L (1000 gal) bulk tank. An operator must press and hold a manual switch to activate the transfer pump and move some of the solution to a 110 L (30 gal) day tank. When certain conditions are satisfied (described below), an automated feed pump feeds the solution at 0.023 L/min (0.006 gpm) into the flow of water coming from the well, which is typically 8300 L/min (2200 gpm). The fluoridated water continues into the distribution system through a 300 mm (12 in.) diameter pipe. All the fluoridation equipment is kept in a separate chemical room in the well house.

The design rules state, "The electrical outlet used for a fluoride feed pump shall have interlock protection by being wired with the well or service pump, such that the feed pump is only activated when the well or service pump is on. The fluoride feed pump shall not be plugged into a continuously active ('hot') electrical outlet" [9]. This interlock,

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Fig. 1. Location of Sandy, Utah, USA. The city, with a population of 100,000, is located in Salt Lake County, where fluoridation was required.

Fig. 2. Paradise Valley Well House. The facility contains a main/control room, a well/pump room, and a fluoridation room.

however, could be bypassed with the HAND mode.

The design rules further state, "In addition to the feed pump control, a secondary control mechanism shall be provided to minimize the possibility of fluoride overfeed. It may be a day tank, liquid level sensor, SCADA control, flow switch, etc." [9]. The facility had a day tank, a scale (for solution mass), a SCADA control, a shower/eyewash interlock, and other protections. Still, an overfeed occurred.

The on-site programmable logic controller (PLC) was programmed such that the feed pump, when in AUTO mode, will activate only with these conditions, in this order:

1. The well is on
2. No high Fl_2 gas is detected
3. No alarm is active for leaks in the bulk tank
4. No alarm is active for leaks in the day tank
5. No alarm is active for low level in the day tank
6. No alarm is active for the feed pump
7. No alarm is active for the shower/eyewash station

The feed pump also has a HAND mode for priming and testing, which bypasses the condition that the well be on, and an OFF mode. On site, the modes are controlled though the PLC's touchscreen interface. Fig. 4 compares the two modes.

2.2. Conditions before incident

The well and fluoridation system had not operated since July 2016, some two and a half years before the incident. Other water sources were sufficient and the well was not needed during that time. The equipment was maintained and ready to go, and if the PLC allowed, the feed pump would run, in AUTO. The feed pump was set to dose 0.023 L/min (0.006 gpm) to achieve 0.7 mg/L in the finished water.

The emergency shower/eyewash station has a spring-loaded flow sensor that registers when water is flowing. Sometime before December

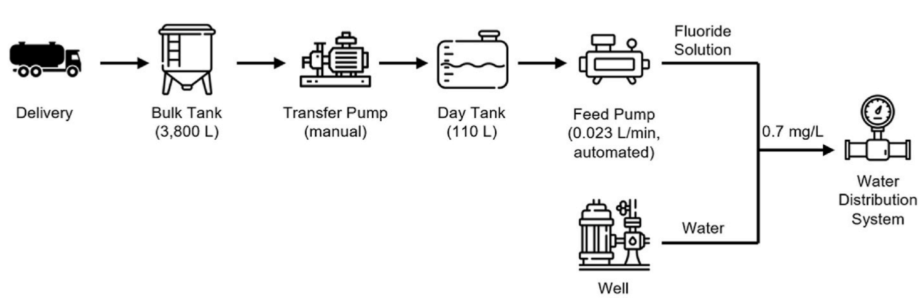

Fig. 3. Fluoridation process at Paradise Valley Well.

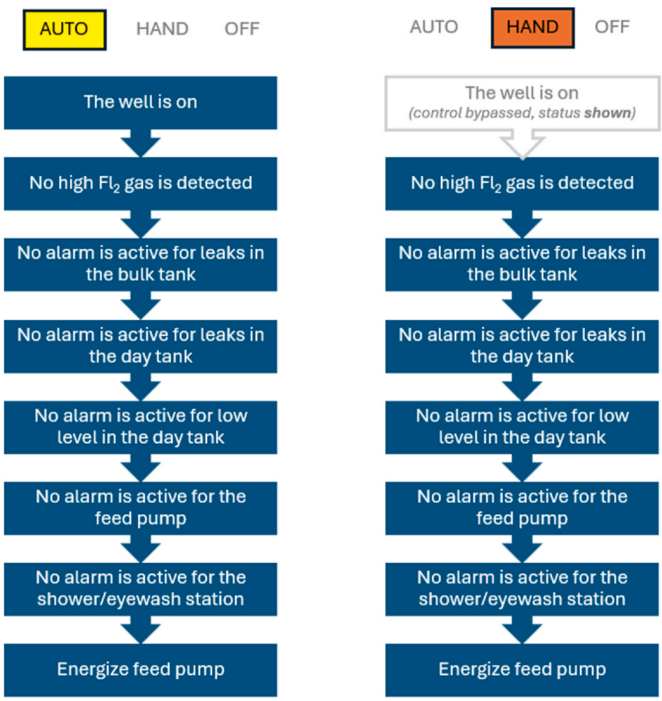

Fig. 4. Fluoridation logic for AUTO and HAND modes. HAND mode, intended only for priming and testing, bypasses the condition that the well be on.

2018, the spring became stuck in the open (flowing) position, with no actual flow, locking out the feed pump and sending an alarm. The alarm was not visible on the PLC display main screen, so operators did not know the sensor was faulty or that the alarm was active. In January 2019 the flow sensor returned to the closed position, but the hidden alarm remained active.

In December 2018 a contractor was on site to upgrade the PLC. During the upgrade, the feed pump was turned to HAND mode for testing. It was not returned to AUTO. The feed pump status was not visible on the PLC display. With the well offline and no feed pump running (because of the shower/eyewash alarm), operators did not suspect the setting was left in HAND mode. After January 2019, the only remaining condition to activate the feed pump was to clear the shower/eyewash alarm.

2.3. Pipeline hydraulics

Unrelated to fluoridation, but nonetheless important, is the discharge pipe connecting the well house to the water distribution system outside. When the well is offline, the pipe is full but no water is flowing. However, the pipe slopes downhill. If a liquid denser than water enters the pipe (say, hydrofluorosilicic acid solution with a specific gravity of 1.2), it would sink under the static water and flow downhill by gravity (Fig. 5). It is this hydraulic condition that would allow a dense liquid to migrate to and spread in the water distribution system.

2.4. Overfeed incident and response

In February 2019, a winter storm caused a communication failure at the Paradise Valley Well, triggering an alarm. An operator cleared the alarm—and, unintentionally, all other alarms, including the shower/eyewash alarm. All logic was now satisfied to activate the feed pump. Over the next three days, 53 L (14 gal) of the solution was fed into the system without any well water to dilute it. Fig. 6 shows the progression of logic that enabled the feed pump to start and Fig. 7 shows a timeline of selected events.

The city received nine water quality complaints, including illnesses, in the area and operators responded. They found the feed pump running and immediately shut it down. They flushed several hundred thousand liters of water through nearby fire hydrants, instructed residents to flush their premise plumbing, and collected water samples. The city used its advanced metering infrastructure (AMI) to see which homes had been flushed and followed up at ones that had not. A forensic hydraulic model later showed that up to 270 homes may have received water far over the 4 mg/L maximum contaminant limit (MCL) for fluoride [10].

2.5. Procedural failures

The subsequent investigation identified the technical failures described above but also revealed numerous procedural failures.

A central challenge was poor communication among Sandy City leaders, the Salt Lake County Health Department (SLCoHD), and the Utah Division of Drinking Water (DDW). (As in most states, DDW has

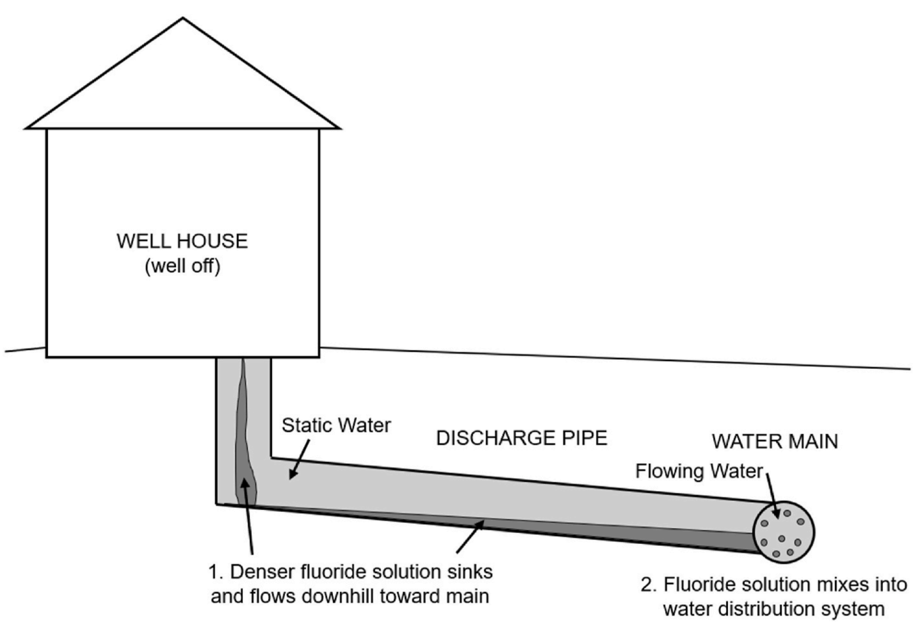

Fig. 5. Conceptual profile of discharge pipe to water distribution system. The slope enables a dense fluoride solution to sink and flow into the main.

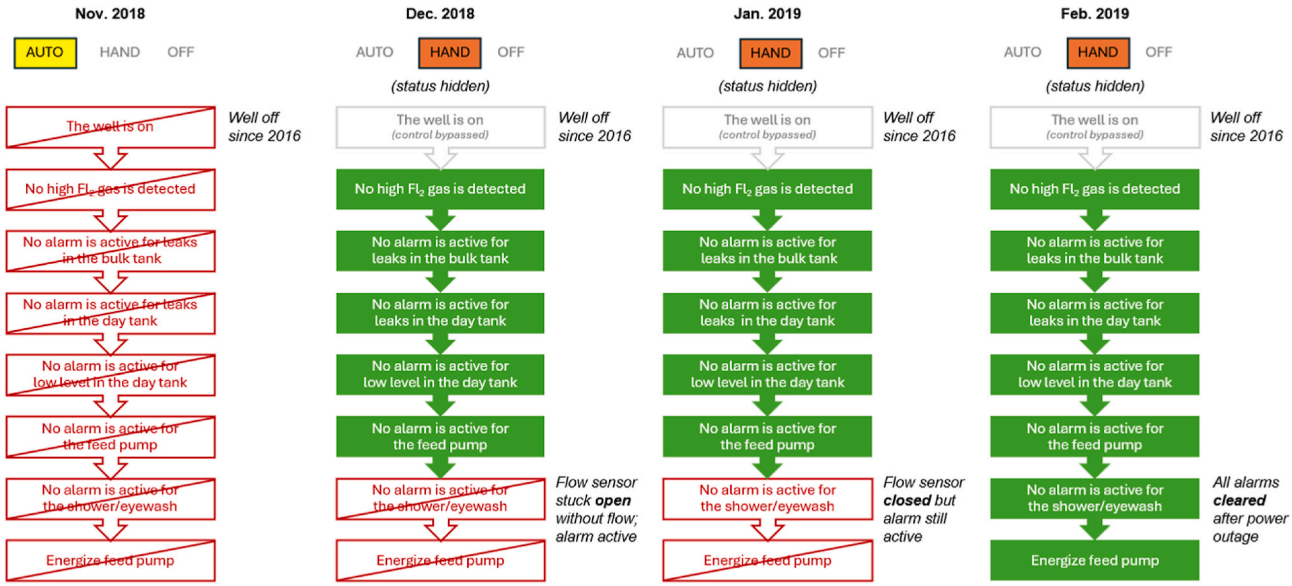

Fig. 6. Progression of fluoride logic leading to the overfeed. In the first three cases, the feed pump was locked out for different reasons: AUTO mode required the well to be on; the shower/eyewash flow sensor was active, and the shower/eyewash alarm was active. In the final case, all conditions were satisfied.

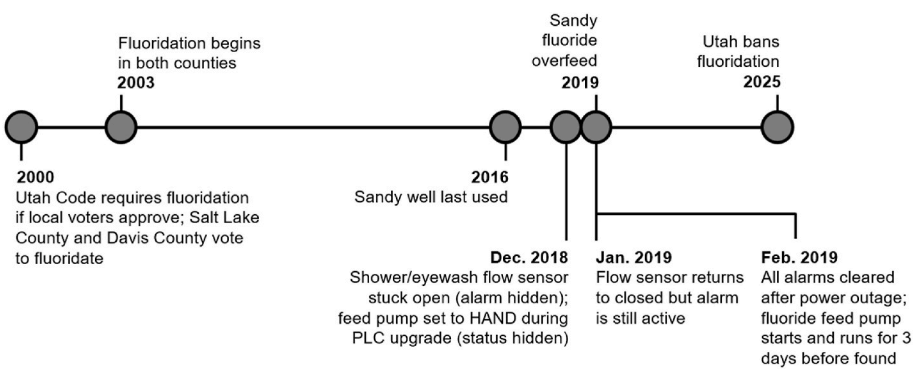

Fig. 7. Timeline of selected events concerning fluoridation in Utah and the Sandy incident.

primacy for administering the Safe Drinking Water Act on behalf of the U.S. Environmental Protection Agency.) Although Sandy City operators responded promptly to early complaints, they did not immediately notify external authorities because they did not know the seriousness of the situation. Early interactions among agencies revealed uncertainty over roles, expectations, and protocols, slowing a coordinated response. For example, DDW and SLCoHD disagreed with the city's defined area for public outreach and directed Sandy to expand it twice in the days that followed. The absence of a pre-established emergency communication pattern hindered a unified response.

Public notification efforts faced additional complications. The initial public notice, drafted by DDW and required under federal and state regulations, was altered for unknown reasons by Sandy City staff before distribution, omitting key warnings like "Do Not Ingest." The omissions undercut the urgency of the message and confused residents. Moreover, door-to-door delivery was inconsistent and no record was kept of which homes were contacted. Several affected residents learned about the issue only through neighbors or media. As the notification area expanded based on additional sampling and hydraulic modeling, the gaps in early outreach became more apparent.

The city's initial sampling response reflected a similar lack of coordination. Field crews collected some water samples only after extensive flushing, likely underestimating peak fluoride concentrations. No field kits were available to provide real-time feedback on fluoride, pH, or metals, delaying efforts to define the incident's extent and severity. Initially, the city relied on a local water district's laboratory, but as testing piled up due to exhaustive sampling, samples were rerouted to a commercial lab. There were simply too many samples to be tested efficiently. Delays in processing and reporting further slowed communication with DDW and the public: laboratory emails went to Sandy or DDW but not both; some samples were missing dates or locations; and early fluoride results from the field were recorded on forms meant for, and labeled as, chlorine residual.

The gaps were compounded by a lack of documentation throughout the response. No meeting notes were taken during early interagency coordination calls, despite the urgency and complexity of the situation. Without a written record of decisions, responsibilities, or timelines, misalignments persisted for days. While procedural failures did not cause the overfeed, they significantly hindered the agencies' ability to effectively respond.

2.6. Hydraulic modeling

During the incident, Sandy staff ran a trace simulation in its existing winter-scenario EPANET hydraulic model to determine the initial extent of contamination. The early modeling helped the city define the affected area and eliminate unaffected areas to accelerate response. Animations from the model were shown in news broadcasts as the situation unfolded

Table 1
Contaminant concentrations before and after flushing.

Contaminant	Regulated Level (mg/L)	Maximum Observed Level before Flushing (mg/L)	Observed Level after Flushing (mg/L)
Fluoride	4.0	150	1.5
Lead	0.015	0.40	0.006
Iron	0.30	3.8	0.15
Arsenic	0.01	0.035	0.00
Manganese	0.05	0.47	0.00
Aluminum	0.20	2.7	0.00
Copper	1.3	25	0.70

Data from WQTS [7].

[11].

Later, the investigation team developed a "forensic" hydraulic model to recreate water system behavior during the incident. Data from the city's SCADA system, AMI records, and water samples informed an ultra-calibrated EPANET simulation of both hydraulic and chemical transport. The forensic model confirmed the timing, location, and magnitude of fluoride contamination and, retroactively, provided estimates of fluoride concentrations before physical samples were taken. While forensic hydrology has been applied to flood events [12,23], hydrologic/hydraulic models are generally oriented toward the future or toward "what if" scenarios. This may be the first use of modeling to reconstruct in detail a real drinking water contamination event.

2.7. Water quality after incident

Field and laboratory samples indicated that fluoride (MCL 4.0 mg/L) reached 150 mg/L during the incident. After flushing, field and laboratory samples measured between 0.5 and 1.5 mg/L. High concentrations of hydrofluorosilicic acid lowered the pH of the water to between 3.8 and 5.9 during the incident, which returned to about 7.0 after flushing. Coincident with the low pH, metals were released, and hundreds of water samples were analyzed. Lead, iron, arsenic, manganese, aluminum, and copper exceeded their regulated limits at first but returned to normal after flushing (Table 1).

Even with the fluoride flushed out, copper continued to leach from premise plumbing for months. Almost a year after the incident, a corrosion study plan was approved and sampling continued monthly and then quarterly in the affected area. In May 2021, the final water quality report concluded that the metals concentrations had stabilized well below their regulated limits and that the incident had no lasting negative effect on premise plumbing.

3. Practice and policy changes

3.1. Sandy actions

Sandy faced enforcement actions from DDW through an Administrative Order in March 2019. In January 2020, the final investigation report [6] recommended 42 actions across five categories for Sandy to implement. The key ones included:

- Update the standard operating procedure (SOP) for well shutdown to include shutting off the fluoride system.
- Replace the digital control for the feed pump with a manual switch.
- Audit PLCs for hidden alarms.
- Remove command to "clear all" alarms; allow clearing only individual alarms.
- Install external alarms (visible/audible) on fluoride facilities.
- Visit each fluoride facility every day.
- Check fluoride controls after power outages or PLC maintenance.
- Install automated pH and fluoride probes downstream of the injection site.
- Provide handheld pH probes for field sampling.
- Update operator training for fluoride handling.
- Sample strategically rather than exhaustively to expedite results.
- Keep notes in interagency meetings.
- Update emergency response plans.
- Clarify public notice procedures.

At the time of the report, many of the recommendations had already been completed and Sandy was working with regulators on the rest.

A Stipulated Consent Order from DDW in January 2021 fined Sandy $37,200 and ordered continued monitoring and the completion of the corrosion control study. It also stated that the Paradise Valley Well would need a new operating permit if Sandy intended to use it again.

3.2. Fluoride training and awareness

While fluoride safety training had been offered to Utah water operators, the offerings seemed to become more frequent in the two years after the incident. Fluoridation was also the topic of new presentations at conferences of the Intermountain Section of the American Water Works Association and the Utah Chapter of the American Public Works Association during that time.

3.3. Statewide fluoridation ban

In 2000, the Utah Code was amended to require fluoridation if a majority of voters supported it. That same year, residents of Salt Lake County and Davis County voted to fluoridate their water (Fig. 7). Fluoridation in those counties began in 2003.

But by 2025, a call to ban fluoridation grew in Utah. Spurred by the memory of the Sandy incident, pandemic-era resistance to public health interventions [13], a 2024 lawsuit against the EPA [14], and an anti-fluoride agenda by U.S. Health and Human Services Secretary Robert F. Kennedy, Jr. [15], Utah lawmakers passed a bill in March 2025 to prohibit fluoridation. The bill, H.B. 81, repealed Section 19-4-111 of the Utah Code allowing fluoridation and replaced it with contrary language: "A person may not add fluoride to water in, or water that will be introduced into, a public water system" and "a political subdivision may not enact or enforce an ordinance that requires or permits the addition of fluoride to water in, or water that will be introduced into, a public water system" [16]. Naturally occurring fluoride within the MCL is still allowed, but fluoride may not be added.

Dentists and other professionals, backed by the American Dental Association and the American Medical Association, protested the bill, saying it would lead to further tooth decay in the local population, especially among children [17]. To compensate, the bill contained provisions allowing pharmacists to prescribe oral fluoride treatments [16]. Water utilities, however, welcomed the ban because the equipment, processes, and safety requirements for chemical handling were onerous and expensive. The fluoride ban greatly simplified their operations. By May 2025, they had stopped fluoridating, began to decommission their fluoride equipment, and were relieved of a major burden.

Utah residents were surveyed in the weeks after the bill was passed. About 47 % of registered voters said they approve the fluoride ban, while 37 % said they were opposed and 15 % said they did not have an opinion [18].

The Sandy incident played a particular role in Utah's fluoridation ban. At legislative hearings the issue was heavily debated and the Sandy incident was often invoked. Sandy residents spoke in favor of the ban, including a 17-year-old boy who described acute and lasting symptoms he attributed to consuming the contaminated water [19]. Without the Sandy incident, Utah would probably still be fluoridating its water.

3.4. Nationwide policy momentum

Utah was the first state to ban fluoridation. Florida followed in May

2025, and Kentucky, Louisiana, Massachusetts, Nebraska, and New Hampshire have proposed bans [20]. At a news conference in Utah in April 2025, Kennedy, Jr., called for all states to ban fluoridation and for the Centers for Disease Control, which he oversees, to reconsider its longstanding endorsement of community water fluoridation [21]. The resistance to fluoridation in Utah—which was originally intended as a public health benefit but has since been questioned—is yet another example of the unintended consequences in water resources engineering that Sowby and Hotchkiss [22] discussed.

4. Discussion and conclusions

The 2019 Sandy fluoride overfeed illustrates how technical failures, when combined with procedural gaps, can lead to widespread public health and infrastructure consequences, even in a well-regulated, professionally operated water system. While the root cause lay in specific equipment flaws and alarm management methods, the broader implications extend to emergency response, interagency coordination, and public trust.

One of the most significant takeaways is how an obscure combination of small, unknown failures—here, the misconfiguration of a feed pump, a faulty flow sensor, and a hidden alarm—can cascade into a system-wide crisis. Operators were unaware that the pump was in HAND mode and that an alarm was active. Although the dosing system included interlocks and controls to prevent unintended chemical release, the protections failed in combination because no such failure scenario was ever envisioned.

The emergency response revealed shortcomings in planning, communication, and execution. Despite swift operator action once the overfeed was discovered, fragmented coordination among city, state, and county officials delayed critical steps such as issuing accurate public notices and rapidly testing water quality. The failure to maintain meeting notes, track door-to-door notifications, or verify message delivery indicates a lack of procedural rigor. In retrospect, many of the failures could have been mitigated through pre-established protocols, clearer agency roles, and basic documentation practices.

The use of hydraulic modeling during and after the event emerged as a noteworthy innovation. Sandy's forensic model appears to be the first application of EPANET to reconstruct a real contamination event in detail. The ability to simulate chemical transport with time-aligned SCADA and metering data provided regulators and the public with essential clarity, especially when physical sampling had been delayed or rendered inconclusive due to flushing. The forensic approach may offer a new model for other utilities investigating operational anomalies.

Policy and practice changes followed the incident. Sandy implemented dozens of corrective measures—from hardware redesigns and SOP updates to real-time monitoring and expanded operator training. Many of the changes reflect best practices that other utilities might consider adopting proactively, even without an incident. Particularly valuable are the practices of removing "clear all" commands from PLCs, installing external alarms, and ensuring chemical systems are visited daily and checked after power disruptions.

The regulatory consequences extended beyond Sandy. While no new administrative rules were immediately promulgated by the state, enforcement actions under existing law were significant. These included fines, mandated training, and conditions on re-permitting affected facilities. Concurrently, there was an increase in fluoride-related trainings and conference presentations in Utah over the next two years, suggesting that the professional community responded with heightened awareness.

Ultimately, the Sandy fluoride overfeed became a political inflection point. The incident, combined with broader cultural skepticism toward chemical additives and public health mandates, contributed to Utah's landmark 2025 legislation banning the addition of fluoride to public water systems—the first such statewide ban in the United States. While the outcome is controversial and opposed by major health organizations, it demonstrates how localized but high-profile failures can ripple out to influence state and national policy (Fig. 8).

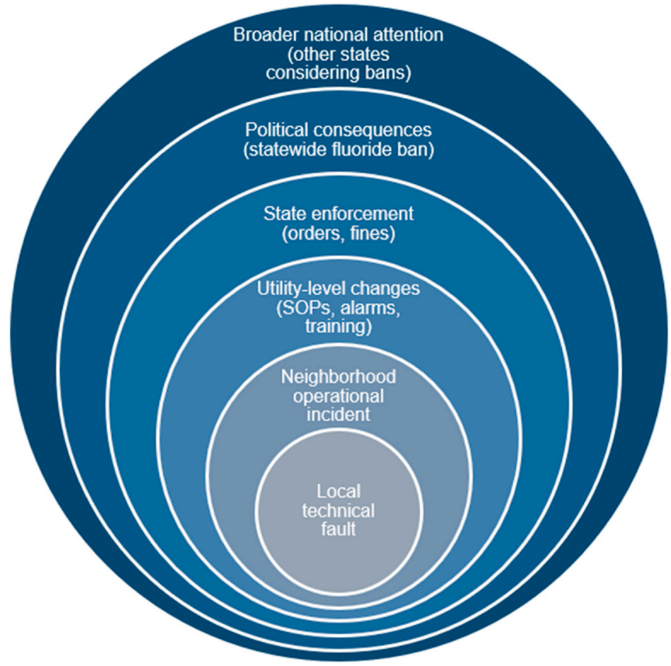

Fig. 8. Ripple effects of the 2019 Sandy fluoride overfeed, from local facility failure to national policy attention.

The Sandy case exemplifies how utilities and regulators must prepare for rare but high-impact events with both robust systems and practiced procedures. It also highlights the broader stakes of utility performance in maintaining public confidence and policy legitimacy.

Declaration of competing interest

The author declares the following financial interests/personal relationships which may be considered as potential competing interests: The author contributed to the original investigation report on the Sandy incident while employed full-time at Hansen, Allen & Luce.

Data availability

No data was used for the research described in the article.

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