



Accidental Mixing: Dangers, Incidents, and Prevention

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Agenda

- Theory and Resources
- Review of Incidents
- In-Depth Look at Select Incidents
- Prevention Strategies
- Group Discussion

THEORY AND RESOURCES

Definition

Accidental Mixing:
the unintended combination of
two or more incompatible
chemicals

Sodium Hypochlorite Reactions

Acids/
Acidic
Compounds

+ Sodium
Hypochlorite



Chlorine Gas

Ammonia

+ Sodium
Hypochlorite



Chlorine Gas +
Explosive Compounds

Organics
(Fuel)

+ Sodium
Hypochlorite



Chlorine Gas +
Explosive Compounds
+ Chlorinated Organics

Unintended Consequences

Chlorine Gas is considered a toxic inhalation hazard (TIH) chemical

Chlorine Exposure Thresholds in ppm

0.2 – 0.4 ppm	Odor threshold (decrease in odor perception occurs over time)
1 – 3 ppm	Mild mucous membrane irritation, tolerated up to 1 hour
5 – 15 ppm	Moderate irritation of the respiratory tract. The gas is very irritating, and it is unlikely that any person would remain in such an exposure for more than a very brief time unless the person is trapped or unconscious
30 ppm	Immediate chest pain, vomiting, dyspnea (labored breathing), cough
40 – 60 ppm	Toxic pneumonitis and pulmonary edema
430 ppm	Lethal over 30 minutes
1000 ppm	Fatal within a few minutes.

Sodium Hypochlorite Reactions

Metals
(Steel,
aluminum,
bronze, brass,
Inconel[®],
Monel[®], etc.)

+ Sodium
Hypochlorite



Non-violent release of
oxygen gas; formation could
cause overpressurization of
closed vessels or systems



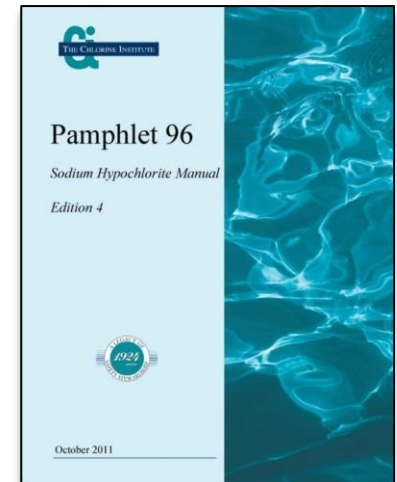
Sodium Hypochlorite Reactions



Sodium Hypochlorite Resources

- CI Pamphlet 96) *The Sodium Hypochlorite Manual*
- CI HYPO-VIDEO) Handling Sodium Hypochlorite Safely
- CI Sodium Hypochlorite Incompatibility Chart
- CI Customer Checklist
- Euro Chlor GEST 96/218 - Safe Use of Sodium

CI materials listed here are available from the Chlorine Institute: www.chlorineinstitute.org



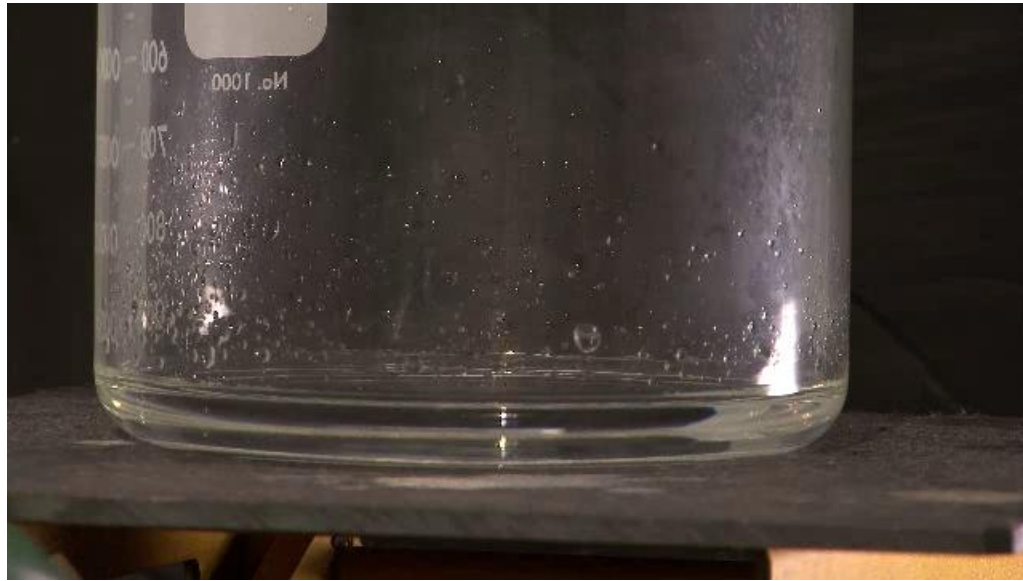
Hydrochloric Acid Reactions

Caustic Soda/
Alkalies

+ HCl



Heat, splashing of
solution



Hot, uncontrolled,
splattering liquids
pose a threat to the
chemical handler

Video – Caustic + HCl

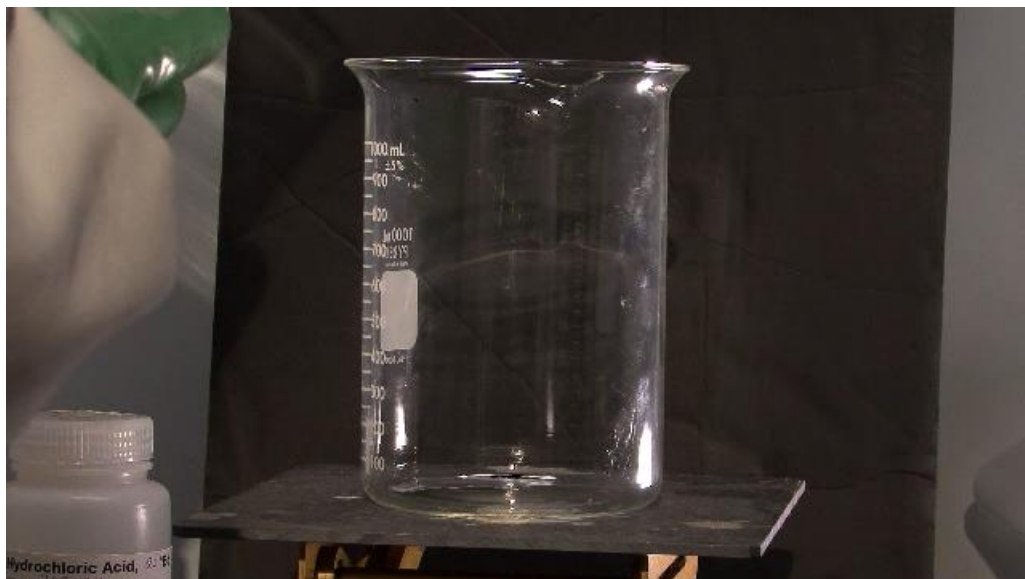
Hydrochloric Acid Reactions

Metals

+ HCl



Hydrogen Gas (H_2)



- Concentrated H_2 is flammable between 4% and 75%
- A hydrogen gas-rich atmosphere can become an explosion hazard

Video – Aluminum Foil + HCl

Hydrochloric Acid Resources

- CI Pamphlet 98) *Recommended Practices for Handling Hydrochloric Acid in Tank Cars*
- HCL-VIDEO) *Safe Handling of Hydrochloric Acid*
- CI Pamphlet 150) *Recommended Practices For Handling Hydrochloric Acid in Bulk Highway Transports*
- CI Pamphlet 163) *Hydrochloric Acid Storage and Piping Systems*

All materials listed here are available from the Chlorine Institute:
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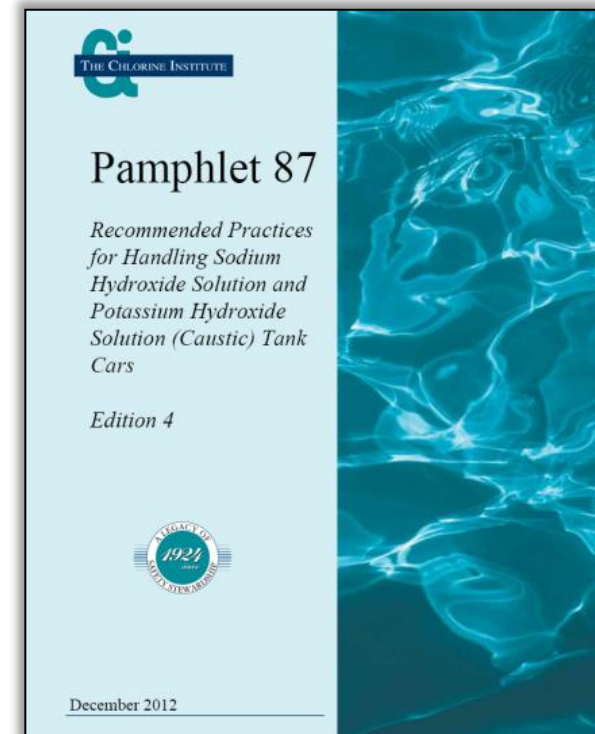
Caustic Reactivity

- Caustic reacts with pure metals or alloys of aluminum, zinc, and tin and may generate flammable hydrogen gas. **The reaction of caustic with aluminum is particularly vigorous**
- Caustic will also rapidly attack and destroy leather and wool



Caustic Resources

- CI CI Pamphlet 87) *Recommended Practices for Handling Sodium Hydroxide Solution and Potassium Hydroxide Solution (Caustic) in Tank Cars*
- CI CI Pamphlet 88) *Recommended Practices for Handling Sodium Hydroxide Solution and Potassium Hydroxide Solution (Caustic) in Bulk Highway Transports*
- CI CI Pamphlet 164) *Reactivity and Compatibility of Chlorine and Sodium Hydroxide with Various Materials*
- CI CI Pamphlet 65) *Personal Protective Equipment for Chlor-Alkali Chemicals*
- Euro Chlor GEST 12/406 - Best Practices in the Production and Handling of Caustic Soda/Potash



Caustic Trailer Accidental Mixing Video



Audience-Specific Wall Charts

- Wall Chart 6) Preventing Accidental Mixing Events [Driver/Carrier Focus]
- Wall Chart 7) Preventing Accidental Mixing Events [Customer Focus]
- Double-sided charts detail both manager and driver/operator best practices

Wall Chart 6



Wall Chart 7 (draft)



Other Resources

- CI's Accidental Mixing Video
- Other publications that address prevention:
 - CI Pamphlet 17) *Packaging Plant Safety and Operational Guidelines*
 - CI Pamphlet 49) *Recommended Practices for Handling Chlorine Bulk Highway Transports*
 - CI Pamphlet 66) *Recommended Practices for Handling Chlorine Tank Cars*
 - CI Pamphlet 87) *Recommended Practices for Handling Sodium Hydroxide Solution and Potassium Hydroxide Solution (Caustic) Tank Cars*
 - CI Pamphlet 88) *Recommended Practices for Handling Sodium Hydroxide Solution and Potassium Hydroxide Solution (Caustic) Cargo Tanks*
 - **CI Pamphlet 96) *Sodium Hypochlorite Manual***
 - CI Pamphlet 98) *Recommended Practices for Handling Hydrochloric Acid in Tank Cars*
 - CI Pamphlet 150) *Recommended Practices for Handling Hydrochloric Acid in Cargo Tanks*
 - CI Pamphlet 170) *Hydrogen Chloride, Anhydrous (AHCL), Refrigerated Liquid (UN 2186), Tank Car & Cargo Tank Handling Manual*
 - [CI HCL-VIDEO\) Handling Sodium Hypochlorite Safely](#)
 - [CI HYPO-VIDEO\) Handling Sodium Hypochlorite Safely](#)
 - Euro Chlor Safety video - [Best practices for loading and unloading chlor-alkali chemical products](#)

REVIEW OF INCIDENTS

Recent Accidental Mixing Incidents

Year	Materials Mixed	Incident Description	Quantity Released/Marked	Source
2011	sodium hypochlorite (NaOCl) + hydrofluorosilicic acid (HFS)	Water treatment tank	into HFS	DOT
2012	sodium hypochlorite		HFS and plant gases	DOT
2014	sodium amide		part	DOT
2014	sodium hydrated peroxide (KAl(SO ₄) ₂)		a marked roughly read the gases which injured the driver and each was released.	DOT
2015	sodium hypochlorite + hydrochloric acid	bleach onto truck (HCl) and delivered about 60 gallons into bleach (60 gallons) at customer site. ER called and plant evacuated.		DOT

Long listing of incidents included as an appendix to this presentation

Commonalities in Incidents - Equipment

Inadequate Marking

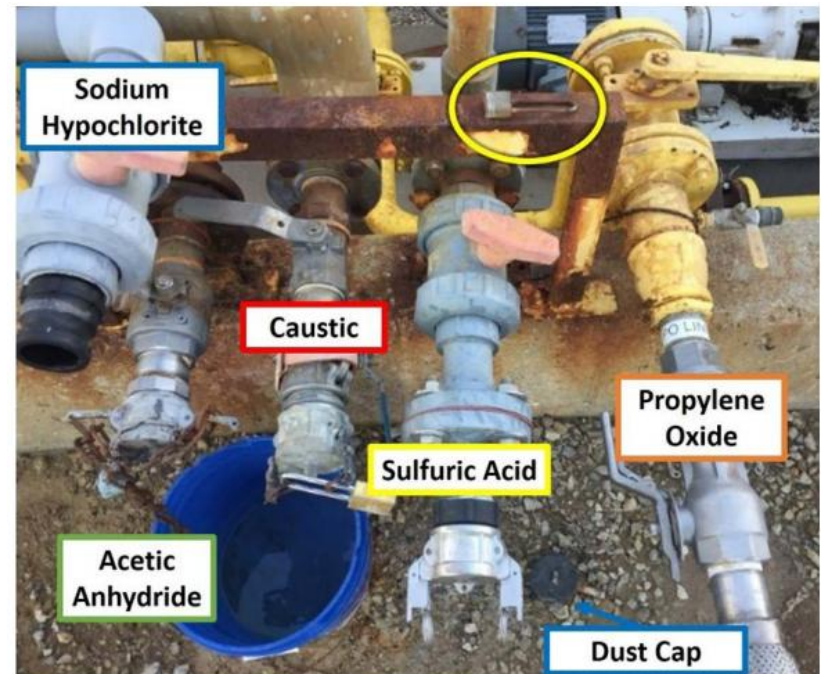
- Storage tanks, fill lines, or connections not labeled/marked correctly or marked at all



Commonalities in Incidents - Equipment

Connections

- Connections for all of the different product storage tanks look the same, are in very close proximity, and all may not be locked to prevent access



Commonalities in Incidents - Equipment

Dedicated Equipment

- Not having dedicated pumps for different products (mini-bulk delivery)



Commonalities in Incidents – Behavioral Factors



Supervision/Attention

- Driver left unsupervised to make connections and delivery
- Plant operators or driver not completely paying attention
- Poor weather conditions, time of day or other factors that may cause driver or operators to rush;

Commonalities in Incidents – Behavioral Factors

Procedures

- Driver does not question or raise concerns with plant operator;
- Plant operators or driver do not follow proper procedure
- Plant has inconsistent filling procedures for each bulk tank
- Two different people making connections on each end and not verifying with the other



Commonalities in Incidents – Paperwork/Recordkeeping

- **Shipping Papers**
 - Shipping papers or tank labels may not be reviewed thoroughly



Commonalities in Incidents – Paperwork/Recordkeeping

- **Maintenance**

- Lack of appropriate records or signs indicating system is under maintenance and different procedure is required



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IN DEPTH LOOK AT SELECT INCIDENTS

Case Study:

Sodium Hypochlorite + Ammonium Sulfate

Series of Events:

- April 2, 2014, a driver was scheduled to deliver ammonium sulfate to an unstaffed water treatment facility in Kitchener, Ontario
- The ammonium sulfate is accidentally delivered into a sodium hypochlorite tank
- The reaction is so violent, there is damage to the roof of the multi-story building

Case Study:

Sodium Hypochlorite + Ammonium Sulfate

The Aftermath:

- There were concerns that nitrogen trichloride, a reactive byproduct was still present, days after the explosion occurred
- There were three organizations involved:
 - Subcontracted delivery company
 - Chemical supply company
 - Facility owners



Damage to the roof of the Greenbrook Pumping Station can be seen Thursday, the day after an explosion there.

Case Study:

Sodium Hypochlorite + Ammonium Sulfate

- The incident receives multi-day news coverage
- 12 days after the incident, there is speculation that the building will need to be demolished due to structural issues



Atchison, Kansas Incident (2016)



CSB

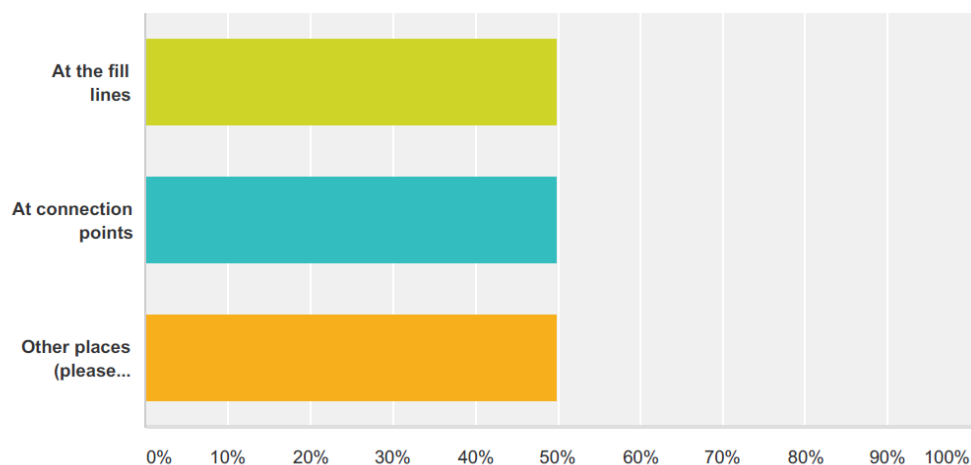
Partnership with the Chemical Safety and Hazard Investigation Board (CSB)

- CSB sought CI's expertise during investigation
 - CI Pamphlets
 - Member Survey
- CSB still wants to highlight proactive Industry activities

Bulk Liquid Unloading Survey

Q8 Where does your facility place these signs/labels?

Answered: 8 Skipped: 11



PREVENTION STRATEGIES

Safeguards - Drivers

- Empower drivers to refuse deliveries in unsafe conditions with upper management support
- Checklists
- Understand the nature/reactivity of the chemical
- Ask questions; double-check

Sample Paragraph in Customer Letter

- All bulk tanks and the unloading connection point, must be clearly & correctly labeled according to their contents.
- Bulk delivery drivers are not allowed to transfer product into unlabeled tanks or lines.

Safeguards - Customers

- Label all hose connections and storage tanks
- Lock out unloading valves
- Double sign off that the connection has been properly made (by both driver and customer)



Safeguards - Suppliers

- Offer training
- Periodically inspect your customer's facility
- Encourage drivers to raise safety concerns and questions; follow-up appropriately
- Incorporate safety policies regarding bulk deliveries that empower drivers by providing strong management support and buy-in

DISCUSSION

Accidental Mixing Discussion

- What measures do you have in place to prevent accidental mixing?
- How do you train and empower drivers?
Employees?
- What kind of customer requirements do you have for receiving the first shipment?
Subsequent shipments?

The Chlorine Institute Mission is Safety

Thank you for your attention!!!

CI exists to promote safety

Visit us online: <http://chlorineinstitute.org>

Email questions: techsvc@CL2.com



APPENDIX

Recent incident at customer – Accidental Mixing

Description	What, Where, Why, How- Learnings
Title: Unloading of HCl in wrong tank at customer Date event: 4th of July 2025 Site: at customer Summary: A truck with HCl was unloaded in the wrong tank with Nitric acid, leading to a dangerous combination that is known as Royal water. A special firm was called, and the fire department was also on site. During the disposal of this Royal water, the pressure became too high, and the tank exploded. With this explosion, the tank lid flew through the air and landed far away from the tank in a meadow. Luckily, no people got harmed.	Why did it happen? The customer has 2 sites opposite each other on the same road. The driver was new to this site and arrived at what was later established as the wrong site. He told the gatekeeper that he needed to unload HCl, and the gatekeeper let him through and said that he had to wait for the operator. The operator arrived, and the driver wanted to hand over the papers. The operator said that this was not needed and that the driver needed to unload the truck. The driver insisted that the operator would stay with the unloading, since this was his first time at this customer. The operator told the driver to move the truck to the unloading place and opened the doors for unloading. The coupling didn't fit, and the driver asked for a connection coupling. The operator told the driver that he had no coupling, so the driver looked in his own truck and found the coupling that could be used. After connecting the hose, the unloading started, and the operator went away. The driver told him to stay at the unloading, but the operator left anyway. After unloading, the driver looked for the operator to disconnect the hose again. He found another operator who said that the first one had gone home. The second operator said that he had no time to help with the disconnection, and the driver had to do this himself. After disconnecting, the driver went to the operator, and he signed off the CMR. Later that day, the other site called where the HCl was, and at that moment, they found out that it was unloaded in the wrong tank. Learnings and Actions to share Gate entry is important and should be the first check on correctness. The operator should always check the papers, and the unloading should start after both the driver and the operator have checked that they unload at the right tank.

Recent incident at customer – Accidental Mixing

- Video/media coverage of the incident



Recent Accidental Mixing Incidents

Year	Materials Mixed	Brief Description	Source
2011	sodium hypochlorite (NaOCl) + hydrofluorosilicic acid (HFS)	Water treatment plant employee instructed driver to offload bleach into HFS tank. The reaction released hazardous gases which injured 11 people. Quantity released is unknown. It is uncertain if the storage was properly labeled/marked.	DOT
2012	sodium hypochlorite (NaOCl) + hydrofluorosilicic acid (HFS)	Water treatment plant employee instructed driver to offload bleach into HFS tank. Driver repeatedly questioned the unlabeled storage tank to confirm and plant employee assured it was the correct tank. The reaction released hazardous gases which injured the driver and several plant operators. Quantity released is unknown. It is uncertain if the storage was properly labeled/marked.	DOT
2014	sodium hypochlorite (NaOCl) + ammonium sulfate ((NH ₄) ₂ SO ₄)	Driver delivered ammonium sulfate to unmanned water treatment plant and accidentally unloaded into bleach storage tank. Reaction was so violent it blew part of the roof of the building. There were no injuries. Quantity released is unknown.	DOT
2014	sodium hypochlorite (NaOCl) + hydrated potassium aluminum sulfate (KAl(SO ₄) ₂ ·12H ₂ O, common name is alum)	Plant operator instructed driver to offload bleach in what turned out to be a marked “alum” tank. It is suspected that plant personnel did not thoroughly read the shipping papers. The reaction released hazardous gases which injured the driver and plant operator. Just over 1,000 lbs of bleach was released.	DOT
2015	sodium hypochlorite (NaOCl) + hydrochloric acid (HCl)	Driver loaded wrong tote onto truck (HCl) and delivered about 60 gallons into bleach tank (about 700 gallons) at customer site. ER called and plant evacuated.	DOT

Recent Accidental Mixing Incidents

Year	Materials Mixed	Brief Description	Source
2015	sodium hypochlorite (NaOCl) + Nalco Trasar 3D T265 corrosion/scale inhibitor	Driver mistakenly pumped bleach into inhibitor tank, which lacked standard company marking.	DOT
2015	sodium hypochlorite (NaOCl) + sulfuric acid	Customer personnel initially was not on site at time of delivery. Weather conditions were poor (heavy rain) and the facility had closed. The driver had a code for gate access but it wasn't work. After some phone communication and customer employee showed up on site to assist with gate access, which took about an hour.). The driver was hospitalized and incapacitated, so he couldn't provide information after the incident. Per video surveillance and phone records, driver conducted visual inspection of receiving tank and walked around the tank, then proceeded to connect and deliver bleach into marked acid tank with DOT corrosive label with UN 2796. After noticing a problem, he walked across the street but returned twice to the connection point at the trailer with and without an escape respirator. After the second attempt, he walked back across the street.	DOT
2016	sodium hypochlorite (NaOCl) + ferric chloride	Driver and customer reportedly verified bulk hook-up to proper fittings. After transfer began, driver walked transfer hose lined and realized it was connected to the wrong tank. Bleach was transferred into "ferric chloride tank #2" instead of "sodium hypochlorite tank #2." 5 people were sent to the hospital for observation and later released.	DOT
2016	sodium hypochlorite (NaOCl) + hydrochloric acid (HCl)	Driver connected and unloaded HCl into bleach tank. Driver sent to the hospital for treatment. <i>No contributing factors provided in report other than "human error."</i>	DOT

Recent Accidental Mixing Incidents

Year	Materials Mixed	Brief Description	Source
2016	sodium hypochlorite (NaOCl) + sulfuric acid	Delivery of sulfuric acid was scheduled. Driver arrived early so night shift operator accepted delivery and escorted driver to Mod B building. Operator unlocked and removed dust cap from sulfuric acid line while driver donned PPE and retrieved the hose at the truck. The operator then returned to the building and did not watch driver make the connection. Driver connected to first fill line (which was unlocked and accessible) assuming it was sulfuric acid and began transfer. Operator shift change occurred inside building when transfer began. Soon after, greenish-yellow cloud emitted from bleach tank. Conflicting stories on whether the operator pointed out the sulfuric acid line to the driver. Connections for several bulk tanks in very close proximity and not clearly marked.	CSB case study
2017	sodium hypochlorite (NaOCl) + hydrochloric acid (HCl)	Driver connected and unloaded HCl into bleach tank. He immediately turned the valve off after noticing vapors releasing. Driver sent to the hospital for treatment. <i>No contributing factors provided in report, but it did note corrective actions (review SOPs, hazard analysis review, and retrain driver and customer on verifying connections/product).</i>	DOT
2018	sodium hypochlorite (NaOCl) + hydrofluorosilicic acid (HFS)	Driver verified with customer operator where to connect and operator said yes. After connection and beginning transfer, driver went to check on the flow and then back to truck to turn off flow where he noticed vapors releasing from the vent pipe outside. The bleach had been delivered into an HFS tank.	DOT
2018	sodium hypochlorite (NaOCl) + phosphate	Driver and customer employee were at "Well #6." The driver connected to tank and both left the property without detecting any release. Another customer employee returned to the well and encountered the releasing vapors. Turns out the driver connected to a phosphate tank. That person was sent to hospital for treatment and later released.	DOT

Recent Accidental Mixing Incidents

Year	Materials Mixed	Brief Description	Source
2019	sodium hypochlorite (NaOCl) + sulfuric acid	Sulfuric acid delivered into bleach tank. Dedicated mixing plant had not been brought back into service after maintenance and the company failed to introduce effective records for the need to use the temporary manual system. The company had previously designed their system to eliminate the possibility of human error.	
2020	sodium hypochlorite (NaOCl) + fertilizer	Nursery's secretary showed driver where the bleach tank was (she pointed to the 800-gal tank). There were 3 tanks sitting next to each other – 275-gal empty caged tote; 800-gal tank with “yellow substance;” and 500-gal tank with “darker residue.” 800-gal tank had faded sticker that was difficult to read but tank was clear/translucent. Driver saw it was half full and thought it was bleach but told the secretary that the tank must be properly labeled before he could unload. She agreed and driver proceed to label the tank with UN 1791 and unload bleach into the tank. After about a minute, the driver saw fumes and immediately shut off the pump at the truck. Nursery owner ordered secretary to evacuate but other works to move out of the immediate area. Secretary told another worker to look at the tank. The driver told the secretary everyone should evacuate the building. Total of 15-20 evacuated with 1 exposure that was transported to hospital for treatment. Ends up the driver had actually delivered into a fertilizer tank.	DOT
2020	sodium hypochlorite (NaOCl) + sulfuric acid	Driver connected and delivered into sulfuric acid tank. No contributing factors provided in report.	DOT

Recent Accidental Mixing Incidents

Year	Materials Mixed	Brief Description	Source
2020	sodium hypochlorite (NaOCl) + hydrofluorosilicic acid (HFS)	Two drivers discussed what chemicals needed to be pumped and that a “dog” (PVC piping device) would have to be used. They decided to pump bleach first. Water used to wash out plastic bucket, which had residual HFS, and dog. Drivers donned latex gloves, face shield and Tyvek jack but had shorts and short-sleeved shirts. One worker hooked up dog to HFS line thinking it was the bleach line, went back to the truck where the other employee was. Both confirmed with each other to pump bleach. Bleach hose was then connected to the dog. 5 gallons of bleach was pumped into 100-gal HFS tank container about 50 gallons of product. After realizing the problem and during action to turn everything off, one driver ran back into the building to the lab to ask if the exhaust fans were on. That person (walked through the area of the reaction two additional times. He ended up dying due to high exposure. The report noted that a contributing factor was a lack of appropriate procedure for hooking up equipment, unrestricted access to all fill lines at all times, all fittings were the same size and shape, no color coding for lines, and no verification of correct hose being attached to correct line. Also, the drivers were left unsupervised while at water treatment plant (employees unlocked building and went back to what they were doing). The two drivers made the two different connections – one connecting at the truck and the other at the pump to the tote – and no true verification of the correct connections was done by the drivers.	OSHA inspection report?
2020	sodium hypochlorite (NaOCl) + sulfuric acid	Workers at health center accidentally mixed sulfuric acid and bleach. Three people sent to the hospital for treatment. <i>No contributing factors provided in media report.</i>	Media Report
2022	“granular chlorine” + hydrochloric acid (HCl)	YMCA did not follow industry standards for dosing pool, which is to close the pool for an hour, dilute the chemicals and place them directly into the pool. Workers added “granular chlorine” and later muriatic acid into the filtration system, rather than directly into the pool. The granular chlorine was not diluted. The pool was also not closed .	Media Report