ILLUMINATING THE TOXICITY OF FIREWORKS

Charlotte Means, DVM, MLIS, Diplomate ABVT & ABT
ASPCA Animal Poison Control Center, University of Illinois

Welcome to **Practical Toxicology**, brought to you in partnership between *Today's Veterinary Practice* and the ASPCA Animal Poison Control Center (APCC) (aspcapro.org/about-animal-poison-control-center). This column provides practical clinical information about diagnosing and treating pets that have been exposed to potentially harmful substances.

The APCC:

- Provides 24-hour diagnostic and treatment recommendations by specially trained veterinary toxicologists
- Protects and improves animal lives through toxicology education, consulting services, and case data review
- Developed and maintains AnTox, an animal toxicology database system that identifies and characterizes toxic effects of substances in animals
- Works closely with human poison control centers to provide animal poisoning information
- Offers extensive veterinary toxicology consulting to organizations in industry, government, and agriculture.

If treating a patient that requires emergency care for poisoning, call the APCC at **888-426-4435**.

It is Fourth of July weekend, and you are prepared for the many unscheduled appointments, from patients with gastroenteritis due to downing hot dogs to those suffering from noise phobia. However, the patients you end up seeing are neither fearful nor full of food.

In the exam room, Mrs. Smith explains that her dog ate firecrackers. A technician takes a phone call and reports that Mr. Jones is coming in—his dog ingested sparklers. Then the whole Doe family arrives with their dog: while walking by the river this morning, Fido chewed on remains of the municipal fireworks.

Should you worry about these patients? Hospitalize? Refer? How do you treat?

FIREWORK INGREDIENTS

Fireworks are a class of low explosive pyrotechnic devices that contain many different ingredients (**Table 1**, page 66). To produce combustion, fireworks require a:

- **Binder:** Typically dextrin and rarely contributes to toxicity
- **Fuel:** Typically *black powder* (gunpowder), a mixture of sulfur, carbon (charcoal), and potassium nitrate (saltpeter); *aluminum powder* (flash powder) may be used for brighter explosions
- **Oxidizing agent:** Produces oxygen to support fuel combustion; includes nitrates, chlorates, or perchlorates
- **Reducing agent:** Burns the oxygen provided by oxidizing agent; frequently includes both sulfur and charcoal
- **Regulator:** Controls the speed of the reaction, with various metals used
- **Coloring agent:** Provides color but does not contribute to combustion.[1]

Chemical reactions during the combustion process affect kinetics, bioavailability, and toxicity of various ingredients[2-4]; therefore, spent fireworks can have different compositions than unused fireworks.

TYPES OF FIREWORKS

Common fireworks include firecrackers, smoke bombs, sparklers, snakes, and bottle rockets (**Table 2**), and these are the types of fireworks your patients will most likely ingest.[4,5]

Charcoals: Not All the Same

Charcoal (carbon) in black powder is composed of partially pyrolyzed (partially decomposed) cellulose from soft wood. **Activated charcoal** (activated carbon) is made specifically for medical use (ie, decontamination of the gastrointestinal [GI] system) by heating common charcoal in the presence of a gas—a process that creates many internal pores, which help trap chemicals within the activated charcoal.

LEGALITY OF FIREWORKS

Most states and cities have stringent regulations regarding the purchase and use of fireworks, and differentiate between fireworks available for purchase by consumers versus licensed pyrotechnicians.

The United States government uses the United Nations explosives shipping classification system to categorize fireworks: **Class 1.3G** includes most display fireworks, which require a Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) permit to purchase. **Class 1.4G** consists of consumer fireworks, which can contain a maximum of 50 mg of explosive material.

Illegal consumer fireworks, such as M-80 and M-100 firecrackers and cherry bombs, are sometimes sold as legal consumer fireworks. To

TABLE 1.
Ingredients Commonly Found in Fireworks

INGREDIENT	USE	EFFECTS AFTER INGESTION
Aluminum	Silver and white flames and sparks (common in sparklers)	Poor oral absorption; little risk of toxicity
Antimony (antimony sulfide)	Glitter effects	Poor oral absorption; poisoning is very rare
Barium (barium chlorate, barium nitrate)	Green color; can help stabilize other volatile elements	See **Table 3**, page 68
Beryllium	White sparks	Poor oral absorption; inhalation can cause lung cancer
Calcium (calcium chlorate)	Orange color; used to deepen other colors	Poor GI tract absorption; however, calcium chloride is corrosive and can cause oral/esophageal ulceration and GI hemorrhage. See **Table 3** (Chlorates)
Cesium (cesium nitrate)	Indigo color	Toxicity is of minor importance
Chlorine	Component of many oxidizers in fireworks	Toxicity is of minor importance
Copper (copper chloride, copper halides)	Blue color	Copper salts are locally corrosive
Iron	Gold sparks	The amount of iron in fireworks is generally minimal; toxicity is of minor importance
Lithium (lithium carbonate)	Red color	While toxicity is of minor importance, vomiting is common
Magnesium	White sparks and improves brilliance	Toxicity is of minor importance
Phosphorus	Glow-in-the-dark effects; may be a component of the fuel	*Red phosphorus* (safety matches) is an insoluble substance and nontoxic in oral ingestions, whereas *white phosphorus* (fireworks) can cause severe gastroenteritis and cardiotoxic effects
Potassium (potassium nitrate, potassium perchlorate)	Violet color; black powder explosive used to oxidize firework mixtures	Animals with normal renal function have minimal toxicity consisting of GI signs
Rubidium (rubidium nitrate)	Violet color	Toxicity is of minor importance
Sodium (sodium nitrate)	Gold or yellow color	See **Table 3** (Nitrates)
Strontium (strontium carbonate)	Red color; used to stabilize firework mixtures	Toxicity is of minor importance; mild vomiting and diarrhea may be seen
Sulfur (sulfur dioxide)	Component of black powder	Vomiting and diarrhea are common after ingestion
Titanium	Silver sparks	Poor oral absorption; heavy dust exposures can cause coughing and dyspnea
Zinc	Smoke effects	Zinc salts can cause vomiting, diarrhea, and GI ulcers; however, firework ingestions rarely cause zinc toxicosis

TABLE 2.
Common Types of Fireworks

TYPE	INGREDIENTS	CONCERNS
Bottle rockets	Gunpowder	• Ingestion can result in GI irritation and intestinal foreign bodies. • Nitrates are of minor concern in monogastrics, such as dogs, but are of greater concern in ruminants (see **Table 3**). • While ingredients other than gunpowder may be used, clinical signs and treatment are generally the same.
Sparklers	Barium dinitrate Strontium carbonate Potassium perchlorate	• Ingestion causes GI signs in most patients and can also result in intestinal foreign body obstruction. • Barium causes severe hypokalemia, which leads to muscle weakness, cramping, and cardiac muscle dysfunction. • Amounts of barium and perchlorates are not likely to cause significant clinical signs unless many sparklers are ingested.
Snakes (also called *black snakes* or *glow worms*)	Potassium nitrate Carbon Sulfur Perchlorates Aluminum Strontium nitrate Barium	• In most cases, clinical signs are limited to gastroenteritis. • If more serious signs are present, potential for significant toxicity, such as barium toxicity, exists.[6]

add to the confusion, illegal and legal fireworks may share similar names. Legal fireworks can be identified by the:

- Manufacturer name on the item or box
- Provision of instructions for proper use and list of cautions.

Illegal fireworks should be reported to the ATF.[5]

CLINICAL SIGNS

In small animal practice, chlorate and barium result in the most problems associated with firework ingestion. As mentioned earlier, composition of spent versus unused fireworks can affect toxicity.

Unused (unexploded) consumer fireworks can cause gastroenteritis in dogs. **Unused display fireworks** can cause methemoglobinemia, along with vomiting, diarrhea, lethargy, abdominal pain, and salivation. Chlorates are not only local irritants, causing GI effects, but potent oxidizing agents that can oxidize red blood cells, causing hemolysis and methemoglobin formation.

Spent display fireworks from municipal displays cause more severe clinical signs. Often there is a significant amount of spent ash present, and the ash contains large amounts of more toxic firework components, such as barium (**Table 3**).

Illegal fireworks may be more likely to cause methemoglobinemia because they frequently contain high levels of chlorates (**Table 3**).

DIAGNOSIS

In most patients, history provides enough information to diagnose firework ingestion. However, if a symptomatic dog is presented with an unknown history, the potential differential diagnosis for methemoglobinemia includes ingestion of acetaminophen, onions or garlic, aniline dyes, naphthalene, and phenazopyridine. Hemorrhagic gastroenteritis can be caused by parvoviral enteritis, arsenic, and dietary indiscretion.

MANAGEMENT

If a client reports that the pet has ingested fireworks, try to determine:

- The brand of firework and amount (eg, one firecracker or a box)
- Whether firework was legal type of firework
- Where the firework was purchased: Illegal fireworks may be purchased from unauthorized firework stands, in other states or countries (ie, Mexico), from movie/TV production companies/suppliers, or through the Internet.

Frequently, the answers to these questions are unknown and treatment is based on clinical signs.

Emesis Induction

If the pet is asymptomatic and ingestion occurred less than 1 hour previously, emesis may be induced:

- If the fireworks contain barium, **magnesium sulfate** precipitates barium in the GI tract and prevents further absorption.
- If the fireworks contain chlorates, administration of **mineral oil** may prevent absorption as well as speed transit time through the GI tract. However, administer mineral oil with caution; if the oil is aspirated, lipid pneumonitis may occur.

However, if the ingredients are known to be corrosive, do not induce emesis. Note that activated

TABLE 3.
Ingestion of Fireworks: Clinical Signs

INGREDIENT	CLINICAL SIGNS
Barium (barium chloride or barium nitrate)	• Barium salts are soluble, leading to rapid absorption. • Barium blocks the exit channel for potassium in skeletal muscle cells, sequestering the potassium in the cells; it also stimulates skeletal, smooth, and cardiac muscle. • The net result is severe hypokalemia, with: » Vomiting, diarrhea, hypersalivation, cyanosis, bradycardia, and dyspnea within 10 to 60 minutes after exposure » Tremors, seizures, paralysis, hypertension, and severe hypokalemia that may occur at 2 to 3 hours after ingestion » Progression to arrhythmias, respiratory failure, cardiac shock and, possibly, death in severe cases. • If no signs develop within 8 hours, toxicity should not be expected.[2,6]
Chlorates	• Chlorates, especially sodium chlorate, can cause vomiting, tachycardia, hemolysis, hyperkalemia (secondary to methemoglobinemia and hemolysis), methemoglobinemia, and nephropathy (secondary to hemolysis). • Methemoglobinemia may develop within an hour or, in rare cases, be delayed for 10 hours.[2]
Nitrates	• Monogastrics, such as dogs, generally only develop mild GI upset. • In ruminants, rumen micro-oganisms reduce nitrates to nitrites, which oxidize hemoglobin to methemoglobin, and severity of clinical signs correlates with the severity of methemoglobinemia.
Corrosive salts	• These salts may result in oral and/or esophageal ulcers.

charcoal does *not* bind to chlorates or heavy metals and, thus, is not recommended.

Critical Care

IV fluids can be used to maintain normal blood pressure and urine production, and saline diuresis increases excretion of barium. If the animal is cyanotic, oxygen is recommended. Oxygen saturation and electrolytes, especially potassium, should be monitored. In addition, obtain a complete blood count, measure liver and renal function (baseline and at 24, 48, and 72 hours), and assess urine output.

Chlorate Toxicity

Chlorates are slowly excreted unchanged from the kidneys and may damage the renal proximal tubules, causing renal vasoconstriction; renal enzymes may be elevated. Chlorates can also cause hyperkalemia.[4]

If chlorate toxicity is present, several options are available to assist in the conversion of methemoglobin to hemoglobin.

- **Methylene blue** (10 mg/kg IV as a 2%–4% solution); do not substitute new methylene blue for methylene blue.
- If methylene blue is unavailable, ***N*-acetylcysteine** (140 mg/kg IV or PO; then 70 mg/kg IV or PO Q 6 H for 5–7 treatments) can be tried.
- **Ascorbic acid** (vitamin C; 10–20 mg/kg IV, SC, or PO Q 4 H) aids in conversion of methemoglobin to hemoglobin and can be used as an adjunct treatment to methylene blue or *N*-acetylcysteine. However, if aluminum is an ingredient in the firework, do not use ascorbic acid because it enhances aluminum absorption.

Additional therapies include:

- Adding **sodium thiosulfate** (2–5 g in 200 mL of 5% sodium bicarbonate PO or IV) to mineral oil to inactive chlorate ions.
- Administering **sodium bicarbonate** (1–2 mEq/kg IV; titrate up as needed) to shift potassium extracellularly; then monitor acid–base status carefully.
- Using **blood transfusions** to treat hemolytic anemia.

Barium Toxicity

The primary treatment for barium toxicity is to correct profound hypokalemia.

- **Potassium chloride** (not to exceed 0.5 mEq/kg/H IV) can be used to treat cardiac arrhythmias, hypokalemia, and diarrhea caused by barium.
- If severe cardiac arrhythmias are present, **measurement of troponin I levels** is recommended, with subsequent echocardiography and cage rest, if needed.[2,6]

Corrosive Salts

If the ingested fireworks contained corrosive salts,

monitor for oral and/or esophageal ulcers, which may not be noted for 12 or more hours. However, oral and esophageal burns are rare in cases of firework ingestions.

- **Sucralfate slurries** (0.25–1 g PO Q 6–8 H) and **famotidine** (0.5–1 mg/kg PO, SC, IM, or IV) can be used to treat gastric irritation.
- **Proton pump inhibitors**, such as omeprazole (0.5–1 mg/kg PO Q 24 H), can also be used, especially for esophagitis.
- **Opioids** should be administered to address the pain of oral and esophageal ulcers, as needed.
- **Soft or liquid diets** should be fed. In patients with severe ulcers, an esophagostomy or gastrotomy tube may be required.
- A **broad-spectrum antibiotic** should be administered due to the risk for bacterial translocation.

PROGNOSIS & RECOVERY

Most patients that have ingested fireworks respond well to symptomatic and supportive care. Recovery usually takes 24 to 72 hours (10–14 days for oral or esophageal burns). Ingestion of fireworks is just one more reason to leave dogs safely confined indoors during celebrations that end with a bang.

APCC = Animal Poison Control Center; ATF = Bureau of Alcohol, Tobacco, Firearms and Explosives; GI = gastrointestinal

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CHARLOTTE MEANS

Charlotte Means, DVM, MLIS, Diplomate ABVT & ABT, is Director of Toxicology at the ASPCA Animal Poison Control Center (APCC). She received her DVM and undergraduate degree from Oklahoma State University and a master's degree in library and information science from University of Oklahoma. Dr. Means worked in small animal practice and as a clinical medical librarian before joining the ASPCA APCC.