

TOXICITY OF HERBICIDES TO LIVESTOCK

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With more widespread use of herbicides in California and other western states, the possibilities of poisoning livestock through negligence have increased. Though the actual losses have not been great, the toxicity of such herbicides as sodium arsenite, sodium chlorate, borax, and sodium dinitro-ortho-cresylate (Sinox) is of practical interest. Some livestock producers have hesitated to use herbicides on their ranges and pastures; they have ascribed to all such "weed killers" the extremely poisonous properties of sodium arsenite. This attitude is understandable because sodium arsenite was long the only common herbicide, and is still the main active ingredient in many proprietary weed killers. Nevertheless, some of the chemicals are entirely safe, under ordinary conditions; and there is no need for the poisoning of livestock by any herbicide if the user takes precautions.

Although there is considerable published information on the effects of sodium arsenite and other long-used arsenicals, and of sodium chlorate, the data are scattered and not always readily available. Until now, little has been written concerning the toxicity of such newer herbicides as borax, sodium dinitro-ortho-cresylate, and ammonium sulfamate.

This paper draws on the literature as well as our own experiments. It does not describe the preparation and application of herbicides, since these procedures are covered in bulletins and circulars available through county agents, agricultural commissioners, and the Agricultural Experiment Station.

FACTORS DETERMINING THE EXTENT OF HAZARD

Before discussing the individual herbicides, we will survey the following factors, which may determine the hazard to livestock:

The Inherent Toxicity of the Chemical.--Naturally, such well-known poisons as sodium arsenite should not be used as foliage sprays on ranges, pastures, or other lands to which livestock have access. Relatively nontoxic chemicals, such as borax, may be safely used.

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Attractiveness or Repellency.--Some poisonous herbicides, including sodium arsenite and sodium chlorate, have a salty or brackish taste that apparently attracts stock and therefore increases the risk.

Other chemicals, including ammonium thiocyanate and sodium dinitro-ortho-cresylate, are repellent. Although poisonous, they have been used in pastures without ill effect, because animals have refused to graze there until the chemicals have decomposed or been leached out by rain.

Method of Application.--Chemicals that present hazard on vegetation may sometimes be relatively safe on bare soil, provided they are not attractive. Thus the arsenic trioxide (white arsenic) on firebreaks in national forests has caused no fatalities.

Reaction of Herbicide with Vegetation.--The toxicity of some herbicides to animals is apparently reduced by a reaction between the chemical and the vegetation. Thus sodium dinitro-ortho-cresylate is less toxic when consumed on sprayed vegetation than when given as a drench.

Season of Application.--Chemicals applied during the rainy season are soon washed off the vegetation or leached out of the surface soil, whereas applications during the dry season may remain accessible for months.

Rate of Application and Size of Treated Area.--Recommendations are usually given in pounds of chemical per unit area of land surface, or can be converted to these terms. Thus, one can compute the number of toxic doses for a given species of animal on a treated area. Then, from the animals' grazing habits, and from the density of vegetation, one can estimate the average probability of a toxic dose. Heavy applications over extensive areas are obviously more hazardous than lighter ones over smaller areas.

The Situation Where Applied.--In a livestock-producing region, there is some danger in treating weeds anywhere with poisonous chemicals. A gate may accidentally be left open, or stock may break through a fence. Obviously, extreme caution must be exercised in treating grazing lands, hayfields, roads used as stock driveways, and banks of streams or ditches that supply drinking water.

AMMONIUM SULFAMATE

Ammonium sulfamate ($\text{NH}_4\text{SO}_3\text{NH}_2$)³ has been applied mainly in an experimental way. Since it may yet be developed commercially as an herbicide, data were secured on its toxicity to livestock.

Herbicidal Dosage

Experimental work indicates that on deep-rooted perennial weeds, dosages of 4 to 8 pounds per square rod are required. As a contact spray for killing only the aboveground organs of weeds, 1/2 to 2 pounds per square rod will usually suffice.

Effect upon Animals

At this station, two yearling wethers were given 1/2 ounce and 1 ounce of ammonium sulfamate by mouth with no ill effects. A third wether ingested 1/2 pound over a 5-day period with no ill effects. Dogs have tolerated relatively large repeated doses. Apparently, therefore, this herbicide is relatively nontoxic to animals.

AMMONIUM THIOCYANATE

Ammonium thiocyanate (NH_4CNS) and sodium thiocyanate⁴ (NaCNS) are occasionally used as temporary soil sterilants for perennial weeds, and as contact sprays for general weed growth on uncropped land. Ammonium thiocyanate is toxic, and presumably the sodium salt also.

Ammonium thiocyanate is a colorless, odorless, hygroscopic, crystalline solid, with a cold, slightly salty taste. The technical grade used in weed killing may be purple-brown, with some insoluble impurities.

Herbicidal Dosages

From 3 to 8 pounds of ammonium thiocyanate is applied per square rod for deep-rooted perennial weeds. Since it acts on such weeds primarily through the soil, one may either dissolve it in water and spray it, or broadcast the crystals uniformly. The results are not affected by removal of the aboveground portions of the weeds. These portions are killed by spraying with 1/2 to 2 pounds of the chemical per square rod.

Repellency

In a certain experiment, cattle, sheep, and a horse refused to feed on plots recently treated at

³Manufactured by E. I. du Pont de Nemours & Co., Inc., and sold under the name "du Pont Weed Killer." Company addresses at Wilmington, Del.; 2260 East 15th St., Los Angeles, Calif.; and 1400 Sixteenth St., San Francisco, Calif.

⁴Sodium thiocyanate is the active ingredient in Aero Brand Weed Killer, manufactured by American Cyanamid and Chemical Corporation, 30 Rockefeller Plaza, New York, N.Y., and Azusa, Calif.

rates of 1, 2, 3, 4, and 5 pounds per square rod. The cows did not graze on treated plots even several weeks after treatment, rain having fallen in the interval. According to reports, a cow refused to eat hay and ground grain and silage sprinkled with the salt, and other cows and calves refused to eat crystals from a dish. Apparently, therefore, this herbicide presents no hazard.

Lethal Dose

The lethal dose for cattle is about 8 ounces. No data on sheep are available.

ARSENICALS

Arsenic Trioxide (White Arsenic or "Arsenic")

White arsenic (As_2O_3) is a white, amorphous or crystalline powder, with a bitter taste. At ordinary temperatures it dissolves slowly in water, attaining a concentration of about 2 per cent. The resulting solution is arsenious acid (H_3AsO_3), of which arsenic trioxide is the anhydride.

White arsenic is an effective soil sterilant; 4 to 8 pounds of the dry powder per square rod is spread on the bare surface. It appears to be non-attractive, and no livestock poisoning has been reported where all vegetation was removed beforehand.

Sodium Arsenite

Arsenious acid reacts with sodium hydroxide (soda lye) to form sodium arsenite. Sodium arsenite weed killers are usually prepared with 1 part sodium hydroxide to 4 parts of arsenic trioxide. It is customary to characterize them by the arsenic trioxide assay. Thus an 8-pound sodium arsenite solution contains the equivalent of 8 pounds arsenic trioxide per gallon; or 50 per cent by weight, as such solutions weigh about 16 pounds per gallon. Similarly, a gallon of a 4-pound sodium arsenite solution is equivalent to 4 pounds of arsenic trioxide, assays around 32 per cent of that compound, and weighs about 12.6 pounds per gallon.

Sodium arsenite is very soluble in water, and even in low concentration is highly toxic to plants. Contact sprays containing 0.5 to 1 per cent of arsenic trioxide are used on mixed vegetation. The volume may vary from 1 to 6 gallons of solution per square rod, giving a range of 0.04 to 0.5 pound of arsenic trioxide.

About the same dosage applies for an acid-arsenical spray solution effective against certain deep-rooted perennial weeds. Besides sodium arsenite, the solution contains 5 per cent by weight of concentrated sulfuric acid.

Sodium arsenite also sterilizes soil, and is used at the same rates as the dry white arsenic. Thus 4 pounds of arsenic trioxide per square rod is provided by 1/2 gallon of 8-pound sodium arsenite solution or 1 gallon of 4-pound solution.

Sodium arsenite causes most of the arsenical poisoning in livestock. It is highly poisonous,

very soluble, and attractive (probably because of its brackish sweet taste). Cattle and sheep have been killed by eating soil treated with the poison, and by gnawing the bark from shrubs drenched with solution.

Arsenic Pentoxide and Arsenic Acid

Pentavalent arsenic compounds (arsenates) are less toxic to plants than the trivalent compounds (arsenites), and are more expensive. They are therefore less used than the arsenites. Nevertheless, in special cases arsenic acid (HAsO_3) and arsenic pentoxide (As_2O_5)--which forms arsenic acid in solution--have a definite value. In Australia, South Africa, and the southwestern states of this country arsenic pentoxide is generally regarded as a specific for prickly pear.

Crude arsenic acid and concentrated sulfuric acid may be mixed to form an acid-arsenical translocated spray, ready for use when diluted with water.⁵

Though arsenic acid is not generally considered to be so attractive as sodium arsenite, and Australian stockmen are said to treat prickly pear with it without removing livestock, one should avoid spraying it in the presence of grazing animals.

Precautions

Although it is probably impossible to protect livestock completely where arsenical compounds are used, the following precautions reduce the hazard:

1. Never treat vegetation with either soluble or insoluble arsenicals without first removing livestock.
2. Burn off the arsenic-treated vegetation or plow it under as soon as you can do so without interfering with the results of the treatment.
3. Be sure that the smoke from arsenic-treated vegetation does not drift over plants which may later be grazed, and that it does not reach persons or animals. Volatilized arsenic may cause poisoning if inhaled.
4. If burning or plowing is not feasible, do not return livestock to the area until several inches of rain have fallen. Even then, arsenic retained on the vegetation in an insoluble form may not have been leached out.
5. In sterilizing soil with sodium arsenite or arsenic trioxide, first remove all vegetation. Wherever possible, use arsenic trioxide rather than the soluble, attractive sodium arsenite.
6. Apply arsenicals to soil only during the rainy season, so that they will be exposed on the surface for a minimum time.

⁵Pentox is such an acid-arsenical preparation, manufactured by the California Spray Chemical Corporation, Richmond, Calif.

7. Fill depressions or drain them. Livestock have been fatally poisoned by rain water from depressions on arsenic-treated soil.

Fatal Dose

The fatal dose varies according to the solubility of the particular compound, and according to the animal's condition. The insoluble arsenicals are less toxic than the soluble ones. The approximate fatal dose of arsenic trioxide is 225 to 500 grains⁶ for a cow; 150 to 225 grains for a horse; and 10 to 15 grains for a sheep. The fatal dose of sodium arsenite, in terms of the arsenic trioxide assay, is 30 to 60 grains for a cow; 30 to 45 grains for a horse; and 6 to 10 grains for a sheep.

Symptoms of Poisoning

Sudden onset with staggering, trembling, and prostration is followed by death in 3 or 4 hours. Great distress is shown by colic, groaning, restlessness, and fast breathing. When the amount of arsenic ingested is less, cattle have severe, painful, bloody diarrhea with loss of appetite, grinding of the teeth, redness of the eyes, and prostration. In this type of poisoning, death may be delayed for 2 to 7 days.

Treatment

In cases of suspected arsenic poisoning, call a veterinarian immediately. While awaiting his arrival, keep the animals quiet; allow them no water; give strong black coffee (8 ounces to 2 pints three times daily for horses and cattle, according to age and size, and 2 to 8 ounces for sheep); give mineral oil as a laxative, whether the animals are purging or not. Freshly precipitated ferric hydroxide is no longer recommended for arsenic poisoning. Instead, sodium thiosulfate (hypo) is administered by mouth and intravenously.

BORAX

Borax ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$), a white, odorless, crystalline compound of brackish taste, is used for Klamath weed (Hypericum perforatum) on range lands; also, to a lesser extent, for sterilizing uncropped areas where the poison hazard from arsenic, a more permanent sterilant, is objectionable.

For soil sterilization, borax is generally applied dry, because its solubility is relatively low. It may, however, be converted to the more soluble sodium metaborate by dissolving 1 part lye (sodium hydroxide) with 4 parts borax. Sodium metaborate thus prepared is occasionally used to prevent seed formation in Klamath weed, as dry borax is ineffective during the dry season when the weed is producing seeds.

⁶There are 437.5 grains in an ounce avoirdupois.

Sodium chlorate is sometimes added to borax to increase the herbicidal efficiency. For this purpose, 1 pound of sodium chlorate per square rod is generally recommended.

Herbicidal Dosage

Between 6 and 8 pounds of borax per square rod is applied to Klamath weed, either as the dry, granular product, or in metaborate spray. For general soil sterilization the dosage usually runs from 8 to 15 pounds per square rod.

Effect upon Animals

Borax poisoning has not been reported in domestic animals. At this station, each of four aged ewes ingested an ounce of borax daily for 15 days without ill effects. Autopsies, a week after the final dose, showed no lesions that could be attributed to the borax.

CARBON DISULFIDE

Although the vapors of carbon disulfide (CS_2) are toxic when inhaled, there is apparently no hazard to livestock where the chemical is applied as a soil fumigant for killing perennial weeds. The liquid is injected into the soil to a depth of 3 to 8 inches; and the vapors emanating from the surface are dissipated by air movement.

SALT

Common salt (sodium chloride) is effective as an herbicide only in extremely heavy applications. Conceivably, therefore, salt-starved animals may obtain an injurious amount. They should be adequately supplied beforehand with salt blocks or licks.

Herbicidal Dosage

For controlling deep-rooted perennial weeds and for sterilizing uncropped areas, 1 pound per square foot (275 pounds per square rod) is usually recommended.

Fatal Dose

The lethal dose of salt for horses is 4.4 to 6.5 pounds; for cattle, 3.3 to 6.5 pounds; for sheep, 0.5 to 1.0 pound.

Symptoms

The most obvious symptoms of salt poisoning are diarrhea, diminished milk flow, lack of appetite, red and dry mouth, colic, frequent urination, and blindness; also weakness and paralysis of the hind legs. Give mineral oil and stimulants.

SINOX

Sinox,⁷ a proprietary preparation, contains 30 per cent of sodium dinitro-ortho-cresylate as the active ingredient. This compound is an orange-yellow, water-soluble, crystalline salt, with a bitter, slightly astringent taste.

Herbicidal Dosage

Sinox is a selective spray, which affects only broad-leaved weeds having nonwaxy leaves and stems--not grasses or other plants having water-repellent surfaces. It is used mainly for controlling weeds among the cereals, flax, onions, garlic, peas, and other field and vegetable crops from which livestock are ordinarily excluded. In addition, however, it is effective against thistles and other undesirable growth on ranges and pastures, and on roadsides, ditchbanks, and railroad rights-of-way. In these places, to which livestock may have access, the dosage employed is 1 to 5 gallons per acre. The required amount of concentrate is diluted with water before spraying.

Repellency

To test the repellency of Sinox, sheep were placed in enclosures where part or all of the vegetation had been sprayed. The results show that sheep largely avoid sprayed vegetation as long as untreated vegetation is equally available, and this repellency persists until after a rain. According to field observations, cattle are similarly repelled. If only sprayed vegetation is available, sheep will graze, though reluctantly. The resultant slight rise in temperature soon subsides, and no further symptoms are apparent.


Fatal Dose

For sheep the fatal dose is about 10 cubic centimeters (1/3 fluid ounce) of Sinox concentrate as a drench. However, even greater amounts are not fatal when consumed on sprayed vegetation.

Symptoms of Poisoning

On receiving fatal doses by mouth, sheep manifest the symptoms within a few minutes: increasingly rapid breathing, trembling, frothing at the mouth, involuntary passage of urine and manure, a temperature as high as 100°F, and death in convulsions in 7 to 15 minutes. Given less than fatal doses, sheep show depression, lack of appetite, and fast breathing for 24 hours. Chronic poisoning is possible; it leads to failure of proper growth and development, and eventually to death.

⁷Sinox is manufactured by Standard Agricultural Chemicals, Inc., 1301 Jefferson St., Hoboken, N.J., and Davis, Calif.



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SODIUM CHLORATE⁸

Sodium chlorate (NaClO_3) is a colorless, odorless crystalline solid of salty taste, very soluble in water. Because it decomposes with the release of oxygen when heated, it presents an extreme fire hazard when combined with combustible cloth, wood, or dry weeds; such combinations ignite readily, sometimes spontaneously. The residue after decomposition of sodium chlorate is sodium chloride, or common salt.

Herbicidal Dosage

The main herbicidal use of sodium chlorate is in controlling deep-rooted perennial weeds. The dosage is varied between 1 and 10 pounds per square rod, according to the weed species, soil type, season, and other local conditions. Application is either by distributing the dry crystals over the area, or by dissolving in water and spraying. In either case the vegetation may be left standing, or it may be removed and the chemical applied directly to the soil.

In spraying mixed vegetation on uncropped areas, including roadsides, railroads, and gravel paths, the dosage may be as little as 1/4 pound per square rod on very small, tender weeds, or up to 3 pounds on tall, rank growth.

Attractiveness

Sodium chlorate definitely appeals to cattle and sheep. Because of its salty taste, salt-hungry animals prefer sprayed vegetation to unsprayed. They will also lick the soil surface where the dry chemical has been applied. They may take unpalatable, poisonous plants more readily after spraying. Conceivably, sodium chlorate spray may induce the formation of toxic substances in plants--for example, hydrocyanic acid in Johnson grass.

⁸Sodium chlorate is the principal active ingredient in Atlacide, manufactured by the Chipman Chemical Co., Inc., Bound Brook, N.J., and Palo Alto, Calif.

Preventive Measures

The following precautions will minimize the poison hazard:

1. Salt the animals liberally several days before treating the area with sodium chlorate.
2. If the chemical is applied dry, break up all lumps, and spread the material evenly, avoiding piles.
3. Treat perennials immediately before a rain, so that the chemical remains on the surface a minimum time.
4. Where more than 5 pounds per square rod is required, divide the application, waiting until rain has dissolved the first portion before applying the second.
5. Place opened containers where livestock cannot reach them.

Fatal Dose

For sheep, the fatal dose is 2 to 3 ounces, single dose; for cattle, 1 ounce daily for 2 weeks, or 2 ounces daily for 3 days.

Symptoms of Poisoning

Acute sodium chlorate poisoning is manifested by severe jaundice, labored breathing, depression, prostration, weakness, lack of appetite, blood in manure, and death in 2 to 5 days; chronic poisoning, by poor condition, dullness, and poor appetite. There is no satisfactory treatment.

SULFURIC ACID

Sulfuric acid (H_2SO_4) is used as a contact and selective spray, and as the penetrating agent in acid-arsenical translocated sprays. Because of its high acidity and its oxidizing and dehydrating properties, the concentrated acid is a caustic poison. The caustic properties are much less pronounced, however, at the dilutions used on weeds; and the acid is rendered innocuous by reaction with plant tissues in the killing process. The same considerations apply to hydrochloric, nitric, and phosphoric acids, which are less often used than sulfuric, because of their cost.

