Agricultural Gases, Liquids, Vapors, and Veterinary Drugs

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1. Introduction

A wide range of gaseous and liquid hazards exists in agriculture (1,2) [Table 1]. Virtually all of the gaseous hazards exist in one form or another in general industry from which we can anticipate health effects. While we know of their existence in agriculture, only a few of these hazards have been surveyed in farm settings. We do not know how frequently (on the average) farmers are exposed to individual agents. We do not know the range of concentrations of such exposures. We do not know the extent of the health effects except for the occasional severe case report or fatality. And if we reallyt did know these parameters, we face yet another challenge, how to translate into "agricultural hygiene" the industrial hygiene paradigm of Anticipation, Recognition, Evaluation, and Control learned in general industry over the past 50 years. As we begin to apply this paradigm, another challenge is to understand the limitations of rote transferral of this paradigm from general industry to agriculture without also understanding its nature and its culture.

This presentation will begin with a review of some of these agents, their sources on the farm, and some of the limitations of the traditional hierarchy of controlling these hazards either at their source, along the pathway of the exposure route, or at the receiver (in this case the farmer or farm worker). A discussion of health effects will be minimized except for agents which are by-and-large unique to agriculture.

2. Definitions

I feel obliged to define a few terms and concepts ingrained into industrial hygiene folklore. The first [Fig. 2] is the paradigm of anticipation, recognition, evaluation, and control. Historically, this process began with the recognition of adverse health effects existent within a working population. Today, we can anticipate (and hopefully avoid) adverse health effects based on toxicology or prior experiences in other work settings. To evaluation the degree of risk, we have developed a system of "performance based" exposure limits guidelines (guidelines called Threshold Limit Values [TLVs] and their regulatory equivalents called Permissible Exposure Limits [PELs]) whose goal is to prevent adverse health effects by keeping exposures and doses to acceptably low levels without specifying the method or "work practices" to achieve those levels.

The second [Fig 3] is a concept that adverse health effects are the culmination of an often complex chain of events beginning with the agent emanating into the working environment from a sometimes nebulous source and traveling through a physical pathway to create either an airborne, dermal, or even oral dose; the dose is generally dependant upon the duration of exposure and the degree of personal protection being used by the worker; the agent may act at the site of contact or be absorbed into the body and be transported to some biological target organ where it acts toxicologically to create a clinically identifiable effect.

Over the years, a hierarchy of control options has been inculcated into the profession whereby controlling the source is the preferred option, controlling the pathway between the source and worker is the second option, and controlling the receiver is the third and least preferred option. Hygieniests believe that respirators or other forms of personal protective equipment are not a quick cure-all, contrary to popular belief. And even when they are recommended, good practice dictates (and OSHA now requires) that the respirator should be selected based on the measured level of exposure.

3. Gases and Vapors

The following history of silo gas is representative of the fragmented progression of anticipation, recognition, evaluation, and control of a potentially common agricultural health hazard. [Fig 4] Occupational hazards associated with silo gas were first reported in 1914 via case studies of four fatalities of farmers working in and around their freshly filled silos. Their deaths were attributed to carbon dioxide (3). It was not until the 1950's (30 to 40 years later) that investigations revealed the presence and importance of nitrogen dioxide (4-6). The major portion of toxic NO_2 appears to be produced from organic nitrates, aggravated by the addition of heavy nitrate fertilizer and/or drought conditions (6). The process of NO_2 production begins within hours of ensilage, peaks in three to seven days, but may last for up to two weeks. Levels of NO_2 as high as 200 ppm have been reported tseven days after filling (6-7); this is well over its current TLV of 3 ppm (with a 5 ppm STEL). Our broad understanding of the magnitude and frequency of this hazard is limited by a lack of systematic environmental surveillance and poor reporting of farm injuries and fatalities. Our understanding of its overall impact on the health of farmers is further limited by the difficulty in diagnosing non-fatal cases of the disease due to the multiple and usually latent phases of its clinical manifestations (8-10). Thus, the severe and fatal cases of silo fillers disease that are reported probably represent the tip of the proverbial iceberg.

A few systematic surveys have recently been made of chronic gaseous hazards in modern semi-enclosed animal production buildings. Mulhausen (11) found that air quality in poultry barns frequently exceeded exposure limits of 25 ppm for ammonia [NH_3] during fall and winter and sometimes even exceeded its STEL of 35 ppm; H2S was undetected. Donham et al (12-13) surveyed similar swine barns and found 50% exceeded the TLV for ammonia; many of these buildings also exceeded the TLV for CO_2, H_2S, and CO (from un-vented space heaters). [Fig 5]

At these concentrations ammonia by itself would only be a strong irritant to the eyes, nose, and throat. However, in both poultry and swine farm settings, it may be important to consider the simultaneous presence of both ammonia and organic dust aerosols at levels often in excess of 5 mg/m^3. The hypothesis here is that the pulmonary damage caused by ammonia could be considerably greater if the gas were adsorbed onto a respirable-sized aerosol.

In addation to hydrogen sulfide, mercaptans and organic acids (such as methyl- and ethyl-mercaptan, carbonyl-sulfide, skatole, and propionic, butyric, and valeric acids) have been identified in the gases emanating from the anaerobic decay of manure typically stored in a pit under most hog and some dairy barns (14-15). It should be acknowledged that under normal barn conditions, hydrogen sulfide is not at levels of great health concern (12-13). However, when the manure is agitated prior to pump-out to be returned to the fields as fertilizer, it is rapidly released into the air above the frothing liquid (16-19). During agitation, the author has measured levels of H_2S as high as 300 ppm at pig breathing height and 1500 ppm in the pit. Manure gas deaths often involve multiple victims during futile rescue attempts (17,20). As was the case with silo gas, manure gas deaths even as recently as 1989 are sometimes mis-diagnosed as asphyxiation from methane (20).

Control of agricultural respiratory hazards should rely first on reduction at the source, second on ventilation or some other physical barrier to its movement, and third on personal protection. Control of the source of most of the above agents will require further research before the process of gas generation is sufficiently understood to be reduced or avoided. High rates of ventilation of farm shops or animal confinement buildings is often resisted by operators who prefer to conserve heat in cold winter climates; and if too much ventilation were installed without consideration of make-up air requirements, high levels of CO could be drawn back down heater exhaust vents. As in any other industry, the use of respirators should be considered a temporary and supplemental protection; but in agriculture there are no trained persons available to assist in the selection, fit, or maintenance of respirators. Thus when purchased at all, respirators are selected without knowledge of measured levels of exposure, often without even the benefit of an adequate "work practices" evaluation as shall be discussed below.

4. Liquids

Pesticides are formulated as solids (such as granules and wettable powders), liquids, and gases and vapors (mostly fumigants). Pesticides can present a hazard to applicators (21-23), to harvesters re-entering a sprayed field (24-25), and to rural residents via air, water, and even food contamination (26-28). Toxicologically, the major field-use pesticides can be broken down into six major chemical groups shown in Table 2. Most of these agricultural chemicals present dermal hazards either from absorption directly through intact skin and/or from dermatitis. Some of these insecticides are also used indoors especially in greenhouses were exposure is often higher (29). Two additional groups of non-field agricultural chemicals: one is fumigants (such as phosphine (usually aluminum phosphide or Phostoxin) or a volatile organic like carbon disulfide or ethylene dichloride) used in produce storage areas, and the other is disinfectants (such as chlorine, quaternary ammonia compounds, organic iodides, and cresol-based compounds) used in indoor animal production facilities (2). Certain of these chemicals present respiratory hazards particularly when used in combinations; other of these liquied chemicals present a risk of contact or an allergic dermatitis (30).

While a review of pesticide toxicities is being presented separately, they are presented here because they demonstrate an approach to anticipation, recognition, evaluation, and control quite different from general industry.

Some level of anticipation was available from the time of registration, but much of that interest was directed toward consumers rather than users who are exposed at much higher levels. Given that starting point, it is unfortunate that the recognition of hazards to users has often been a protracted process, in some ways no better than the history of many chemicals used in general industry. However, evaluation of exposure, when it finally started to be conducted, was not site or user specific but was conducted in response to more recent EPA pesticide registration requirements. EPA then promulgated what amounts to a "use practices standard" in the form of label instructions which specify the ways the chemical can be safely and legally used. The implication is that if all users follow these instructions, exposure will be sufficiently low to prevent adverse health effects. This process contrasts sharply with general industry where employers are expected to assess their own employees exposure to "assure a workplace free from recognized hazards."

Controls under these circumstances have also differed from general industry. It can be argued that the registration process is itself a form of controlling the source, screening out chemicals deemed too hazardous for agricultural use and restricting certain others to "licensed users". In that sense, a form of hazard communication was adopted by agriculture a little before general industry. However, the EPA registration and labelling process has yet to address the machinery controlling the pathway of exposure. When it comes to personal protection, control has for a long time been mis-directed at airborne versus the dermal route of exposure; and those respiratory controls which are specified were established without a decision logic common to general industry for over 30 years (31-32). I am happy to report that EPA is currently developing a respirator selection decision logic at least consistent with a "use practices standard."

One might ask why is a "use practices standard" versus a "performance standard" approach used in agriculture. The one asking the question must not be a farmer. Even if the administrative and support structure were in place to conduct on-site monitoring at each farm or "place of employment," the activities, working environments, and chemical exposure levels in <u>most</u> agricultural settings vary sufficiently by season, day, and by even hour as to make such measurements moot. Which is not to say that measurements and even performance standards have no place in agriculture. For instance, work in animal production facilities is amenable to the application of traditional TLVs, environmental monitoring, and respirator selection criteria. "Use practice standards" have their own limitations: they must account for many variables, thus often making them overly restrictive conducive to low compliance. It remains a challenge for the future to define the conditions favoring either form of standard or if either is even adequate.

The other category of agricultural chemicals are the fertilizers. Anhydrous ammonia is the most heavily used fertilizer in production agriculture. Anhydrous ammonia is hazardous to the skin and especially to the eyes because it is highly hygroscopic, highly caustic, and extremely cold (-28 °F under pressure). Almost any eye contact with this chemical will result in permanent blindness (33). Inhaling high concentrations of ammonia can result in severe damage to the upper respiratory tract, resulting in bronchiectasis as a possible sequelae (34). Most of the occupational injuries from anhydrous ammonia occur because of faulty couplings, bleeder valves, shut off valves, broken hoses, or plugged applicator tips. In addition to an established program of preventive maintenance, a pro-active hazard communication for both commercial and private applicators is essential to establish consistent wearing of eye protection and ensuring the availability of clean water to flush eyes and skin in case of contact.

In addition to their fire hazard and intrinsic toxicity, many of the liquids involved in agriculture can produce dermatitis [Table 3]. Compared to other occupational groups, farmers have a proportionately higher prevalence of skin diseases (35-36).

Irritant contact dermatitis is perhaps the most common type of agricultural dermatoses (35-39). Irritant substances are ubiquitous and include ammonia fertilizers, several pesticides, soaps, petroleum products and solvents. Avoidance schemes must include work practices to eliminate or reduce exposure to the most irritative substances and/or the use of personal protection equipment.

Allergic contact dermatitis is typified by poison ivy or poison oak reactions. These are exquisite sensitizers as are certain herbicides and pesticides (2). These reactions are more difficult to control, because susceptable farmers are exquisitely sensitive to very small amounts of the offending liquids.

5. <u>Veterinary Drugs</u>

Veterinary drugs are broadly divided into two classes of biologicals and antibiotics. Biologicals are made from living products to enhance the immunity of an animal to a specific infectious disease or diseases. Users of biologicals are at risk of either accidental inoculation or splashing the product into the eyes, mucous membrane, or broken skin. Users at risk include not only veterinarians and their assistants, but also farmers, ranchers, and their employees except for certain diseases for which a government regulated control program is in effect (e.g. brucellosis, rabies, pseudorabies). (2) The most frequent reports of occupational illnesses associated with biologicals involve veterinarians either splashing brucellosis strain 19 in their eyes or accidental inoculations. Symptoms may include infection, inflammation, severe localized swelling and pain, or/and an allergic reaction. The infection mimics the acute infection seen from acquisition of the disease directly from either cattle or swine. Disability may last for days to weeks in the worst cases (40).

Other products that have been associated with occupational illnesses include Newcastle disease vaccine, contagious ecthyma vaccine, Jhone's disease bacterin, Escherichia coli bacterins, and erysipelas vaccines. Newcastle disease and contagious ecthyma (orf) vaccines are live products used in chickens and sheep, respectively. Workers may contaminate their eyes with Newcastle vaccine as it is being applied inside poultry buildings via a nebulizer, resulting in a moderate conjunctivitis with influenza-like systemic symptoms. Orf vaccine can cause the same pox-like lesions at the site of inoculation as a naturally acquired infection. Both of these diseases are self-limited and disability will only last for a few days, unless the orf lesions are numerous (41-42). Injuries induced by the bacterins for Jhone's and E. coli, and most erysipelas vaccine are limited to the inflammatory response induced by the adjuvants.

Control of these hazards again resides largely in "use practice standards," good animal handling techniques and facilities to prevent the uncontrolled and untimely movements of stressed animals (43). The use of pneumatic syringes, lock-on needle hubs, and multiple dose syringes will also help reduce injuries. Eye protection is indicated in many instances. A full face respirator is recommended while aerosolizing vaccines such as Newcastle, but the other 7 components of a full respirator program are rarely instituted.

Antibiotics are products derived or synthesized from living organisms, mainly mold species of the genus streptomyces. Antibiotics are used to treat infectious diseases therapeutically or to improve the rate of gain and feed efficiency in cattle, swine, and poultry. Again not only veterinarians but also livestock producers and feed manufacturers and formulators are exposed to these agents via aerosols of antibiotic containing feeds within livestock buildings or via aerosols or direct contact while preparing feeds either on the farm or in feed manufacturing plants. The two main occupational hazards are allergic reactions and the development of antibiotic-resistant infections.

The main products used as feed additives include penicillin, tetracycline, sulfamethazine, erythromycin, and virginiamycin. These same products plus many more are used therapeutically. Penicillin is the primary agent that may induce an allergic reaction manifest in the form of a skin reaction from direct contact, or possibly a systemic reaction from inhalation or inoculation. A variety of these agents may induce development of resistant organisms in the gut flora of exposed individuals. In one case, a severe resistant salmonellosis was traced to animal contact by people who were treated with antibiotics for a condition unrelated to salmonella (44).

Again the importance of antibiotics as an agricultural health hazard is unknown either in terms the frequency or the magnitude of exposure levels or health effects. It seems that the evaluation of risk from antibiotics is amenable to air sampling and the development of "performance" oriented exposure guidelines. Control should strive toward removing as feed additives those antibiotics used for humans and rotating the use of those still added. Other prudent control measures where antibiotics are used include enclosing feed formulation, grinding, mixing, and storing operations; utilizing general dust control procedures in animal feeding operations; supplemented by dust masks.

6. Conclusions

The industrial hygiene paradigm of Anticipation, Recognition, Evaluation, and Control can, in principle, be applied to agriculture with the following translations.

- Anticipating health and safety hazards in agriculture is the prospective application of dose-response knowledge generated either in the laboratory or in other industries.

- Recognizing health and safety hazards in agriculture requires the interest and commitment of farmers, farmer groups, local community organizations, manufacturers, and governmental agencies to survey both the farming environment and the health status of farmers.

- *Evaluating* health and safety hazards in agriculture can in most cases use existing surveillance technologies, but new ways must be developed to interpret surveillance data from the farm setting for farmers.

- *Controlling* health and safety hazards in agriculture must go beyond "hazard communication" to modify the sources and interrupt the pathways of exposure before the farmer with or without personal protection is dosed.

Organizationally the hazards from gases, liquids, vapors, and veterinary drugs are not uncontrollable. By and large, we can anticipate the health effects of individual agents, and we know how to measure both the agents and their effects in a population. We have just not utilized these skills in agriculture as yet, probably both because of the cost of surveillance studies in such a scattered and diverse population and because of the perception that "agriculture" was not interested in someone intervening in their affairs. We are at the dawn of the age where the interest and funds are being put into agricultural health and safety. I hope that in our rush to study and improve the statistics upon which future preventive health and safety decisions will be made, that sight is not lost of agriculture as way of life. Kelly Donham and I recently have been referring to agricultural hygiene as the application on farms of industrial hygiene principles learned in general industry (2). We like to think (with tongue in cheek) that agricultural hygiene as a growing opportunity. The open question is, is it going to be easier to train industrial hygienists about farming than it will be to train farmers to be agricultural hygienists?

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Table 1. Typical toxic agricultural Liquids, Gases, Vapors,

Ammonia	(from urine, urea, and anhydrous)
Carbon dioxide	(animal respiration and combustion)
Carbon monoxide	(combustion sources)
Hydrogen sulfide	(manure gas)
Nitrogen dioxide	(from fresh silage)
Oxygen Depletion	(Asphyxiation in confined spaces)
Pesticides	(primarily dermal absorption hazards except fumigants)
Welding	(fumes and gases)
Fuel storage	(leaks and fires)
Fuel and waste oil	(skin cancers and dermatitis)
Liquified Propane [LP] gas	(fires)
Liquified anhydrous ammonia	(dermal injury)

Table 2. Major groups of field-use agricultural pesticides

Insecticides	Common commercial names
Organophosphates	Counter, Parathion, Guthion, Lorsban, Rabon
Carbamate	Temik, Furidan, Lannate, Sevin
Organochlorines	Dieldrin, Lindane, Chlordane
Herbicides	
Phenoxy-aliphatic acids	2,4-D, 2,4,5-T, Trioxone
Bipyridyls	Paraquat, Diquat
Triazines	Atrazine, Bladex, AAtrex
Other/miscellaneous	
Thiocarbamates (fungicides)	Thiram, AAtack, Nabam, Maneb, Zineb
Arsenicals (herbicides)	Paris Green, cacodylic acid
Acetanilides (herbicides)	Alachlor, Lasso, Ramrod
Dicarboximides (fungicides)	Difolitan, Captan
Dinitrotoluidine (herb.)	Amex, Prowl, Treflan

Table 3. Skin Conditions of Agricultural Workers
[adapted from ref. 2]

Classification of Skin Condition	Agents (examples)
Irritant contact dermatitis	Ammonia Fertilizers Animal Feed Additives Vegetable Crops & Bulb plants Insecticides, Herbicides, Fumigants
Allergic contact dermatitis	Herbicides, Insecticides Antibiotic Feed Additives Plants
Photo-contact dermatitis	Creosote Feed Additive Plants containing Furocoumarins
Sun-induced dermatoses	Sunlight
Infectious dermatoses	Cattle, Swine, Sheep
Heat-induced dermatoses	Moist, hot environments
Arthropod-induced dermatoses	Chiggers, Bees, Wasps

Table 4. Veterinary drugs potentially hazardous to users.

Biologicals

- Brucellosis strain 19
- Newcastle disease vaccine
- Contagious ecthyma (orf) vaccine
- Jhone's disease bacterin
- Escherichia coli bacterins
- Erysipelas vaccines

Antibiotics

- Penicillin
- Tetracycline
- Sulfamethazine
- Erythromycin
- Virginiamycin

The Agricultural Hygiene Paradigm

- Anticipation is the prospective application of dose-response knowledge generated either in the laboratory or in other industries.

- Recognition requires the commitment of farmers, interested farm groups, and governmental agencies to survey both the farming environment and the health status of farmers.

- Evaluation must develop new ways to interpret surveillance data from the farm setting for the agricultural population.

- Control includes not only "hazard communication" but also modified sources and interruptions in the pathways of exposure before the farmer with or without personal protection is dosed.

NH_3:

Source: urine (urea) - wet floors, slats, gutters, etc.

Anticipated Health Hazards:

Irritating to eyes, nose, trachea (wet body parts)	10-15 ppm
TLV = recommended exposure limit (for gas)	25 ppm
Adsorbed to an aerosol may provoke bronchitis, asthma, or other pulmonary effects	<20 ppm

H_2S:

Source: anaerobic manure digestion

Anticipated Health Hazards:

Threshold of odor detection	0.1-0.2 ppm
Offensive odor (rotten-eggs)	3-5 ppm
TLV = recommended exposure limit	10 ppm
Olfactory paralysis (cannot be smelled)	25-100 ppm
Serious eye injury (gas eye)	50-100 ppm
Bronchitis (dry cough)	100-150 ppm
Pneumonitis and pulmonary edema	200-500 ppm
Rapid respiratory arrest (death)	>1000 ppm

Mercaptans and organic acids associated with hydrogen sulfide from manure.

- Methyl-mercaptan
- Ethyl-mercaptan
- Carbonyl-sulfide
- Skatole
- Propionic acid
- Butyric acid
- Valeric acid

CO:

Source: improperly adjusted heaters or no make-up air

Anticipated Health Hazards:

TLV = recommended exposure limit	50 ppm
Induces spontaneous abortions in swine	100-150 ppm
Asphyxiation dependent upon duration of exposure	
	2-3 hrs at 500 ppm
	<15 mins >2000 ppm