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FARMING METHODS AND SYSTEMS ANALYSIS

By Gary Erisman, Ph.D., C.S.P.
Private Farmer

Dr. David S. Pratt: The first speaker today is—I am very pleased, harkening back to some of the comments we heard this morning—someone who is involved as a stakeholder and a person directly involved in agricultural production. Gary Erisman was born and raised on a family farm in Stanford, Illinois. He got a bachelor's degree and master's degree, both from Illinois State University, one in agricultural education and the other in traffic and safety education. He went on to receive a Ph.D. in health and safety from the University of Illinois in Urbana, and then has gone on to become a Certified Safety Professional. He has had numerous experiences and has taught and been involved in occupational safety and health at the university level for a number of years. At the present time, and since 1980, he is an active farmer and also serves as a safety consultant in farming.
Dr. Erisman:

As I view it, my primary task as lead-off man for this session is to establish a perspective on the topic. It has been concluded for many years that accidents are a particular problem to those engaged in farming.[1] This conclusion has resulted from intuition and the use of epidemiology, the scientific method of studying epidemics in a particular population.

PROBLEMS WITH THE EPIDEMIOLOGY APPROACH

Epidemiology is a staple method of investigative evaluations of health problems. However, there are some problems with epidemiology when used to investigate accidents.

1. In epidemics, the agent (germ) is usually a constant, a single, identifiable organism with predictable properties. That finding is not true with accidents.[2,3] For example, all cases of chicken pox result from one organism. However, not all tractor accidents result from the same organism (tractor). Tractors vary in size, weight, ballast, age, etc.

2. Little can be done to change the germ. In epidemiology, most success has been achieved by reducing the human's susceptibility to disease through vaccination, administration of drugs, or education. However, data has consistently shown the most success in preventing accidents is achieved through changing the agent or environment through redesign.[4,5,6]

3. In epidemiology, the illness must manifest itself. It is an "after the fact" method of problem solving. When compared with alternative methods, it is an inefficiency.

4. Perhaps the biggest problem with epidemiological studies of accidents is that they rarely tell us the most crucial information. Epidemiological studies answer the questions "who," "what," "where," "when." They do not answer "why."[3]

We have to resort to other techniques to answer the latter question. For example, we may find 70 percent of all farm accidents in Iowa occur between the months April and October.

However, that may be because of chance alone; that is the time span during which most farming activities are conducted. When we pool data from different states, it produces even more uninterpretable data; April has a different significance to farm activities in Iowa than it does to farms in Georgia.

The output of such studies is data, which serves as the basis of conjecture. It is little basis for scientific, effective countermeasure development.

Epidemiological studies of accident problems already in existence are of value to isolate problem areas that justify more in-depth investigation.

THE SYSTEMS APPROACH

A more proactive, modern technique to use with accident and injury control is referred to as the systems approach. It is the approach to accident control that has been used with considerable success in areas such as highway transportation systems, air travel and traffic control, and the space program.

We need to define some terms as we go along. I will use the systems method to try to establish a perspective on farm accidents. A system is defined as an orderly arrangement of components that act and interact to perform some task or function within a given environment.[7]

1. Note that a system is defined according to some task or function it is to perform. Examples include the digestive system of a human, the postal system, or an air traffic control system.

2. A system is made up of components that act or interact (the components are related); each component affects the function of other components, and ultimately, the output of the system.

When using the systems approach, the first consideration is to identify the purpose of the system. What is the system supposed to achieve? What is the system's output to be?

The second consideration is the development of a thorough understanding of how the system functions. How do the components or activities relate to each other? What happens to the system if one component fails? For example, it would be impossible for a physician to competently practice medicine unless he or she knows the systems of the body, the components of the systems, and how the systems interrelate. Extending this example, it is impossible to effectively use the systems analysis technique, without first gaining a thorough knowledge of the system in question.

Systems are designed and maintained on a two-priority basis. The first priority of a systems designer is to produce a system that will do the job for which it is intended. The second priority is to determine if the system will work within an acceptable degree of safety.

Systems can be evaluated using two types of criteria, systems criteria and human criteria.[7] I would like to use these two criteria in an evaluation of our American farming system.

Systems Criteria

Following the procedure set out, I must ask the question, "What is the purpose of the U.S. farming system?" From a national perspective, the purpose is to insure a reliable supply of food and fiber for our citizens and other people abroad. It can be argued that America's greatest natural resource is its capacity as a food factory. The climate, soil types, water supply, technology, distribution system, economic system, and creativeness of the farmers and workers, when put together, comprise the best collection of agricultural resources (components) in the world.

1. Each farmer in Japan produces enough food to supply himself and 3 others; in Russia, 11 others. But each American farmer produces enough to support himself and 114 others.[8]

2. The reliability of the American food machine is so high, it is largely taken for granted in this country. We have *never* known the starvation experience of European, Russian, and Asian countries during and after World War II. Nor do we know the famine that exists in a host of countries today.

3. Americans spend a smaller percent of their disposable personal income for food than in any other country in the world.[9]

4. American agriculture is big business. It makes up about 18 percent of all the nation's jobs (20 million jobs). However, only 19 percent of that 18 percent (3.8 million) are actually involved in farm production—farmers, hired labor, and workers in forestry, fisheries, and agricultural services.

5. The American production system has evolved from the hunter-gatherer system of our Native Americans, through slash and burn systems, largely through nomadic systems, and through the subsistence form of farming that predominated well into the 1950's. Since then, economic demands have brought a major shift from subsistence farming to a specialized, commercialized form that predominates today.

6. U.S. farmers produce a variety of commodities for domestic and export markets. The 1987 Census of Agriculture lists more than 200 different commodities produced in the U.S. If a single word were chosen to describe U.S. production, the best word would be "diverse".[9]

7. Each commodity produced represents a specific subsystem with specific operations equipment, timetables, labor, and marketing demands.

In addition, a majority of farms still combine two or more subsystems—one superimposed on the other—that usually have synergistic effects. Examples are hog-corn farms; cattle, corn, bean farms; etc. Each farm represents a unique subsystem of activities and risks, with no two exactly alike. Perhaps the greatest strength of the overall system is the creativity of the components; each farmer tries to build a better mousetrap.

It is important, at this point, to make a distinction between the system's purpose from a national perspective, and the purpose of the system from the producer's perspective. From the farmer's perspective, the purpose of the system is a means of earning a living, or supplementing income.

True, there are many secondary motives—pride of ownership, a way of life, perpetuation of the heritage, etc. But the primary purpose, to earn a living, should never be allowed to become obscured.

1. Farmers seek to bring about an optimum mix of land, labor, and capital inputs to maximize output, which is ultimately measured in dollars.

This technique of mixing inputs is the basis of doing business in America. It is referred to as entrepreneurship, "the ability of one to organize, manage, and assume the risk of a business or enterprise" (dictionary). Thus, to enter farming is to voluntarily expose ourselves to risks, economic and personal. There is evidence to suggest that people psychologically differ in their willingness to expose themselves to risk.[10]

That does not make them "bad" people. It adapts them to the demands of the job others could not perform successfully or happily. Other occupational groups of this type would include such people as astronauts, pilots, stock and real estate brokers, athletes, police officers, and fire fighters.

2. The most telling single statistic that depicts the system's performance for producers was released by the USDA recently.

In the middle 1970's, $0.34 of every food dollar was returned to the farm level. Today, that figure has been reduced to $0.24. The margin of profit per unit of operation continues to shrink. There is only one way to maintain or increase profitability under those conditions, operate or produce more units.

Usually, for one operator to increase in size, another must shrink. This may sound like Darwinism, but it is not that simple. A farmer may be extremely efficient.

With no opportunity to expand, however, i.e., no additional land to rent, he can be economically reduced to the point that his primary income must shift to off-farm sources. The enterprise is taken up by another, who remains economically viable. The result is that the big get bigger. There are more and more part-time farmers. The middle-sized operations continue to disappear.[9]

3. The trend in farm size leads to another finding with implications for safety.

> The trend toward fewer, larger farms has reduced the number of family workers, but it has increased the average farm's hired-labor requirements.

Today, 50 percent of the hours worked on farms are worked by farm operators; 16 percent by unpaid farm workers, such as family members; and 34 percent by hired farm workers.[9] The trend toward fewer, larger farms has reduced the number of family workers, but it has increased the average farm's hired-labor requirements.

4. The trend toward fewer, larger farms in not necessarily a healthy one either for those engaged in farming or those dependent on the U.S. food system.

There is a point where concerns about quantity override concerns about quality. For example, one operator may operate more acres, but may do a poorer job per acre. Yields per unit may begin to dip a bit. These events are insidious and sometimes hard to measure.

The ultimate result is a detrimental effect on total system output. The system, in total, reaches a point of diminishing returns. It is not a situation of the operator's choosing, making, or desire. It is something the economic system is imposing on them. It is an event that ultimately will have to be addressed.

To summarize, based on an evaluation of systems criteria, the U.S. food production system is found to be extremely productive. It is also found to be changing toward fewer, larger components, which, in turn, threaten continued capacity to increase production.

Human Criteria

A second group of criteria can be used to evaluate systems. They are referred to as human criteria, and as identified by McCormick and Sanders,[7] are made up of 4 subcriteria.

1. *Human Performance Measures* elements such as individual demands on sensory, mental, and motor activities.

It is obvious, due to increased mechanization and specialization, that physical demands on farmers and other workers are being reduced. It is equally obvious, due to economic demands, that mental stresses are being increased.

The luxury of being able to survive a season of bad weather or inaccurate business decisions no longer exists for some operators. It resembles playing in a poker game with increasingly high stakes. Each year more and more producers find they have their whole stack of chips in the pot. There is no acceptable alternative to being correct. That is stress!

2. *Physiological Criteria* indicators of the effects of the work load on people.

Examples might include blood pressure, heart rate, respiration rates, chronic health problems, and others. I am unaware of studies that have attempted to compare the fitness to work of today's farmers and other workers with those of the past. I would postulate farmers today are less physically fit as a group than those 20 years ago.

- The average age of an American farmer today exceeds 50 years of age.

- Farm work has become more erratic. The subsistence farms of the 1950's required work every day year around. Today, with specialization, the *physical* demands are much more seasonal. Nevertheless, farmers today try to operate units that fully use their capacity (equipment). This trend tends to produce more pronounced periods of underwork and overwork. Partially offsetting are contributions from industry that reduce physiological demands, i.e., air-conditioned cabs, power assists, etc. Nevertheless, farming still remains among the most physically demanding of all forms of work.

3. *Subjective Criteria*: This critically important area refers to people's evaluation of the system.

> Thus, design is the most critical stage for the prevention of hazards and hazardous products.

It is often inaccurate. However, it is the perspective that drives decisions. From a national perspective, farming may appear to have the characteristics of farming 30 years ago. The public perception is often that of the farm when they left it. Little public understanding of the true dynamics of modern farming exists.[9]

By contrast, those directly involved in farming are acutely aware of the realities of modern activities. The opinion of many is that it is not as much fun, nor as enjoyable as it used to be. It is approached more as a cold-blooded, demanding, unforgiving business.

4. *Accident Frequency*: It should be noted that accidents are just one of several criteria used to evaluate a system.

The value of any system is contrasted with the cost to operate it. That statement may sound insensitive. It is an accurate assessment of the way the world works.

When viewed in the systems concept, an accident represents one form of system failure. When the system breaks down, output is reduced or stopped. Systems are designed to minimize or eliminate breakdowns in any form.

Farming ranks at or near the top of the list of accidental deaths per 100,000 workers exposed to risks.[1,10] These findings have been documented by more than one source.

Translated into system terms, this documents a system that breaks down more frequently because of a specific reason (injuries) than most other systems. Further, it documents that consequences of this systems failure are more serious than others. The breakdown involves a death or serious injury.

The question is, "Why?" That is a question for which we do not have a definite scientific answer. In my evaluation, we have a great number of opinions, conjecture, and over-generalization. We do not have defendable data. That finding is the direct result of the inadequacy of the epidemiological methods primarily used to study the problem.

HAZARD EVOLUTION

Perhaps the greatest single value of the use of the systems approach is the prevention of the problem before the problem manifests itself in the form of an injury. I will discuss one example of its use.

When we view the development of any device, i.e., hammer, screwdriver, or tractor, we find that in each stage of movement, an opportunity for degradation from design criteria exists. Examples are incorrect assembly, repair, and wear.

It has long been recognized that the safety of a device can be no better than it is found to be at the design stage. Thus, design is the most critical stage for the prevention of hazards and hazardous products.[5,6,7]

When products are found to have preventable hazards resulting from design inadequacies, it suggests that two further evaluations are in order:

1. The academic preparation of the engineers and the content of the curricula through which engineers are or have been prepared, and

2. The degree to which administrative environments encourage or reward contributions toward sound systems and human factors design.

SUMMARY

The U.S. production system is a model of productivity when viewed from the outside. Economic trends have left much to be desired to producers and others who work in the system and make the system work.

Accident frequencies suggest a high frequency of system breakdowns that must be addressed. System approaches should be used to evaluate why these breakdowns are occurring. What system modifications can be made to reduce the system failure rate?□

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ERGONOMICS

By Professor Stephan Konz
Department of Industrial Engineering, Kansas State University

Dr. David S. Pratt: We have another presentation that I think is going to shed some important light on agriculture from a perspective that we, unfortunately, seldom hear from very much, and that is ergonomics. Dr. Steve Konz is going to speak next. He received his Ph.D. in Industrial Engineering from the University of Illinois. He has been at Kansas State University since 1964. He has been a prolific writer and contributed to the scientific literature with over 170 publications, and he has a book that is very popular, *Work Design: Industrial Ergonomics*,* which is currently in its third edition and was just recently re-offered in 1990, and it is used at more than 25 American universities. We are, indeed, delighted to have Dr. Konz with us today to talk about *Ergonomics*. Dr. Konz:

SUMMARY

Ergonomics deals with the interaction of man and machine in a physical and social environment. For agricultural safety, two ergonomic recommendations are:

1. Focus on unsafe conditions, not unsafe acts.

2. Redesign rather than use training or warnings.

ERGONOMICS

Overview

The word *ergonomics* was coined by Professor Murrell in Wales in 1949 from the Greek words *erg* (work) and *nomos* (laws, rules).[1] Thus, it referred to the study of work. Over the years, the meaning has broadened to the study of the interaction of people and their environment. The work environment is just one possible environment.

One aspect of ergonomics that has received considerable attention is the study of the characteristics of the individual person. When focused on a person's dimensions and strengths, this is called anthropometry. When focused on the cardiovascular and muscular systems, this is called work physiology.

Information flows from the man to the machine through controls. Information flows from the machine to the man through displays.

Thus, it was logical that much of the early work in ergonomics focused on controls and displays. Note that displays include not only instruments (active displays) but also letters and number arrangements such as text, tables, and graphs (passive displays).

The man and machine are in a physical environment (visual, noise, climate, chemical). Therefore, ergonomists also study these variables.

Most ergonomists attention has been focused on the visual environment. Ergonomists' interest in noise and climate (temperature, humidity) has focused on the degradation of performance due to noise and climate.

Finally, this activity occurs in a social and organizational milieu. The person interacts not only with machines but with other people. This area presents many challenges as people are much more difficult to modify than machines.

One of the basic philosophies of ergonomics is the primacy of people over machines. The idea is to adjust the machine, not the man.

This is in contrast to a common engineering philosophy of designing a machine, then assuming the personnel department will be able to find someone to be able to run the machine. Thus:

- Adjust the machine to the man, not the man to the machine.

An alternative statement is:

- Adjust the procedure to the person, not the person to the procedure.

PROFESSIONAL BACKGROUND OF ERGONOMISTS

As might be imagined, the professional background of ergonomists is very diverse. As a very broad split, ergonomists are divided into those interested in product design and those interested in occupational ergonomics.

The ergonomists interested in product design, however, usually are not designers or engineers but staff consultants to designers. Very commonly, they will have a background in psychology— usually a M.S. or Ph.D.

The ergonomists interested in occupational ergonomics include consultants. More commonly, they include industrial engineers, medical practitioners, and safety specialists. These occupational ergonomists tend to have a small amount of training in ergonomics (50 to 100 classroom hours) grafted onto a basic specialty such as industrial engineering, industrial hygiene, occupational medicine, etc.

The occupational ergonomists tend to have BS degrees. (During the 1950's and 1960's, ergonomics was the province of the Ph.D. In the 1970's, it changed from a science to a technology. Ergonomics knowledge was obtained by those with M.S. and B.S. degrees. In the 1990's, training materials are beginning to appear for blue-collar workers.)

There are many professional homes for occupational ergonomists in the USA. The largest ergonomics society, the Human Factors Society (HFS), has "technical interest groups" for Safety (582 members as of January 1, 1990) and Industrial Ergonomics (506 members). They are the second and fourth largest of the seventeen interest groups in the HFS.

The Institute of Industrial Engineers has an Ergonomics Division of about 1,050 members. The International Foundation for Industrial Ergonomics and Safety has about 300 at their annual meetings. There is considerable interest in ergonomics in other organizations (National Safety Council, American Society of Biomechanics, etc.).

Ergonomics is widespread outside the USA. There are 18 countries that have an ergonomics society belonging to the International Ergonomics Association (IEA), as well as some countries that have not yet joined the IEA. Total membership is about 15,000.

AGRICULTURAL SAFETY AND HEALTH CHALLENGES

As a broad generalization, safety and health problems can be divided into three categories:

1. Injury: An accident causes an injury. The time frame is short—a "sudden event." An example would be a hand mangled in a power takeoff or a burn from a grass fire. It enters government statistics for deaths, lost worktime, medical treatment other than first aid, loss of consciousness, restriction of work or motion, or transfer to another job.

2. Cumulative trauma: The body (muscles, ligaments, joints) suffers "insults" over a time period usually measured in months or years. Examples would be carpal tunnel syndrome, back injuries, or hearing loss. In general, the problem is due to a "physical" agent (weight, noise, vibration) or motion of the human body itself. In government records, cumulative trauma (also called repetitive strain, occupational over-use syndrome) is considered an illness. Back problems, however, are considered injuries.

3. Illness: An organ of the body is injured, generally by a chemical or a biological agent. The time period is variable, with times of minutes (acute) for skin irritants and allergies to years (chronic) for silicosis and occupational cancers.

Note that the present government statistics do not have this division into three categories. Present statistics are divided into injuries and illnesses.

Most of the cumulative trauma problems are in the illness category although back problems are considered injuries. Figure 2 shows how cumulative trauma has become a larger percent of reported illnesses.

Table I gives, for agriculture, injury and illness statistics for 1988 (last data available). A key point is that, although cumulative trauma is increasing in importance among illnesses, total injury cases (per 100 workers) are about 20 times more frequent than total illness cases.

ERGONOMICS FOR AGRICULTURE

As pointed out in the previous section, the major problem of safety and health is safety. Although ergonomics has a broader orientation than just safety, two ergonomics concepts will be discussed in relation to safety.

Table I. Injury and illness statistics per 100 full-time workers for agriculture in 1988.[2]

	Agricultural Production	Agricultural Services	Forestry
Injury			
Total cases	11.7	9.2	11.9
Lost workday cases	6.1	5.0	6.3
Non-fatal cases without lost workdays	5.6	4.2	5.5
Lost workdays	108	91	136
Illness			
Total cases	0.54	0.45	0.47

Focus on unsafe conditions, not unsafe acts. Most accidents and injuries can be considered to be a result of either unsafe acts or unsafe conditions. For example:

• A farmer is injured when a tractor tips over on a slope. The injury could be considered to be from the tractor having a

McCarthy et al.[4], after reviewing 400 papers, reported that there is very little evidence that warnings work—that is, change behavior. Any cigarette smoker emphasizes this point. There are literally thousands of warnings about the dangers of smoking. Yet, people continue to smoke. The acronym Present, Read, Understand, Memory, Act, Effective (PRUMAE) points out some of the challenges.

P (Present): The warning must be present. If the warning is in an instruction manual, which has not been seen, the warning cannot work. If the warning originally was a label on a machine, but the label is gone, there is no warning.

R (Read): The next problem is to get the warning read. People find many excuses not to start reading material. (If all else fails, read the instructions.) If they start, they often skip many parts of the text. We are surrounded by a barrage of messages in newspapers, TV, billboards, etc., and learn to filter them out. Most injuries concern rare events so there is no reinforcement from not following the warning. (Remember how in "Peter and the Wolf," Peter ignored repeated warnings about the wolf and nothing happened to him for a long time until the last time.) Try to make the warning "stand out" of the background.

U (Understand, comprehend): The reader may not understand the warning language (e.g., a Mexican reading English). Even if the reader "knows" the language, the words may be "too big." Pictographs are an attempt to reduce this problem. Unfortunately, some of them are as intelligible as written Chinese. That is, pictographs are another language that you may not understand. Understandability can be improved with grammar and layout of the message. The warning can be divided into four statements: signal, hazard, consequence, instruction. For example: "DANGER, HIGH VOLTAGE WIRES CAN KILL, STAY AWAY"; or "WARNING, CONTAMINATED WATER, ILLNESS MAY RESULT, DO NOT DRINK." The "hazard" statement is the most important. The "Signal" word and the "Consequences" may be redundant information to informed users.

M (Memory): Once motivated to input the information to the brain, the person now must commit it to long-term memory. Then, upon need, retrieve it. Easier said than done.

A (Act): Upon retrieving the information from the brain, the person now must translate this into action. An important point is the cost of compliance. For example, complying with a warning "Don't use broken door" was 94 percent if another door was adjacent, 6 percent when another door was 50 ft. away, and 0 percent when another door was 200 ft. away. Reducing the cost of compliance (reducing the cost/benefit ratio) should improve compliance.

E (Effective): The person then needs the necessary ability to do the desired behavior and then the skill and training to do it effectively.

For a warning to work, all six steps must succeed.

Box 1. Warnings.

high center of gravity or from an unsafe act of the farmer (farmer makes too sharp of a turn).

• A farmer is injured on a power takeoff. The injury could be considered due to an inadequate guard or an unsafe act (farmer fails to maintain the guard).

• A farmer falls from the second floor of a barn. The injury could be considered due to an inadequate railing or an unsafe act (farmer tripping over tools on the floor near the edge).

To reduce future accidents and injuries, the best approach is to consider all accidents as due to unsafe conditions. That is, the "machine" is at fault. The "machine" should adjust to the "man," not the converse. If the man had "problems," then the "machine" or procedure should adjust, not the man.

Psychologically, the "machine is at fault" approach results in a positive approach to solving the problem. If a "man is at fault" approach is used (i.e., the accident was due to an unsafe act), the problems of changing human behavior seem so overwhelming that often nothing is done.

There is a need for research on how to get people not to commit unsafe acts. Why do people do things that they know are unsafe? And, an even more difficult problem, how can their behavior be changed?

FOCUS ON DESIGN RATHER THAN USE TRAINING OR WARNINGS

A safety challenge can be reduced by warnings, training, or design. For example, a farmer could fall into a silo. One possibility is to warn the farmer against falling into the silo. The second possibility is to train the farmer not to fall into the silo. The third possibility is to redesign the procedure or machine to prevent falls.

• Warnings

Box 1 discusses warnings in more detail.[3] The key point is that warnings do not work well. Many things have to occur for the warning to work.

Another problem with a warning is that it is a temporary solution, not a permanent solution. That is, each person exposed to the danger must be warned and the warning must be repeated over time, or it is forgotten.

• Training

Training can be effective, but it is expensive since everyone exposed to the danger must be trained. It is difficult to give training to "visitors" and "bystanders." Another problem of training is that it is temporary and must be repeated over time, or it is forgotten.

• Design

Designing out the problem is the best approach because it is a permanent solution. For the silo problem, design solutions might be a safety harness or railings.

It may help acceptance of design solutions to focus on the annual capital cost rather than the initial capital cost. For example, railings may cost $500 but then last 25 years. Give the cost as $20 per year rather than $500.□

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PERSONAL PROTECTIVE EQUIPMENT

By Richard A. Fenske, Ph.D., M.P.H.
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Dr. David S. Pratt: The next speaker is Dr. Richard Fenske. Dr. Fenske received both his Master's in Public Health and his Ph.D. from the School of Public Health at the University of California at Berkeley. Following his preparation there, he spent six years on the faculty at Rutgers University in New Jersey and worked with the Agricultural Experiment Station in New Jersey. Recently, and I must say to the lament of the agricultural community of New Jersey, Richard has left and is now with the University of Washington, School of Public Health and Community Medicine. Dr. Fenske is going to talk about *Personal Protective Equipment*. Dr. Fenske:

I am going to talk about—and I was a little daunted by being the only person to talk about a subject this broad—personal protective equipment. I have done research in this area, but as all of us who do research know, we know a lot more about the particular problems that we have studied than the general issues that might be raised by all of the farming activities in the United States.

As a result, this talk is going to focus more or less on applicators and, perhaps, field workers and their exposure to pesticides and the use of protective equipment under those circumstances as opposed to, say, the use of such equipment in silos or in swine confinement and all the other kinds of activities that are involved.

The pesticide application problem and the residue problem with harvesters tend to be, in some sense, generic—not that there are not differences across the regions. The processes have some similarities, and we are able to make some general statements about the use of personal protective equipment during these kinds of activities.

WORKER PROTECTION STRATEGIES IN THE AGRICULTURAL WORKPLACE

I am going to start out by discussing a lot of options other than personal protective equipment. In industrial hygiene and in occupational health in general, we tend to talk about controls of exposure or hazards in terms of a hierarchy that involves engineering, administrative controls, and personal protective equipment.

This hierarchy is actually explicitly addressed in the Occupational Safety and Health Act, and this point has already been made earlier—that the best solution is to engineer the hazard out of the process, if we can do that. Increasingly, regulators have turned to personal protective equipment because given the kinds of risk assessments that are being produced for pesticide applicators and field workers, under current practices, it would appear that many compounds could not be registered if we were not using personal protective equipment.

I am going to be a little bit critical of this point of view, but at the same time sympathetic to the dilemmas that are faced by regulators and by farmers who have a pressing need for certain chemicals to be registered at the present time. Let us go through these options before we get into our main subject.

Engineering Controls

Regarding engineering controls: we have already had some examples of closed mixing and loading systems. I think this is an understandable concept. If we can avoid direct contact of the worker with chemicals, we are going to reduce the hazard.

We can have applications conducted with closed tractor cabs. If these types of systems are used properly, they do tend to reduce exposure among the workers. We can also have changes in the way in which we conduct the applications.

Quite a bit of research is going on in the way of agricultural engineering, attempting to get more of the material on the target and less as drift and on areas of the environment where we are not interested in having the compound. We can also make innovations in formulation.

Microencapsulation comes to mind as a good example of a formulation technology that gets the active ingredient out there, but in a much less hazardous form. So there are many opportunities, if we are creative, to reduce the hazard before we ever have to worry about personal protective equipment.

Administrative Controls

In terms of administrative controls, I think one that is given a lot of lip service but, I know from my own experience, does not get much funding is integrated pest management. That is selective use of agricultural chemicals and the use of other kinds of pest management processes. This, obviously, reduces the hazard of chemical exposure.

I might add to this list alternative cultivation practices. One of the interesting points in the earlier talk had to do with the evolution of farming practices, from subsistence to specialization. With that specialization comes the need to use increased amounts of chemicals, given monocultural agricultural systems.

I think a lot of farmers actually are taking a second look at this. Mixed cultivation, rotation of crops and such, is a means of reducing the use of chemicals. It is cost-effective in some cases, and it certainly reduces the hazard.

> So there are many opportunities, if we are creative, to reduce the hazard before we ever have to worry about personal protective equipment.

Product substitution: EPA is trying to find safer substitutes for the kinds of compounds that we use in the agricultural work place, but given the review process and the complexities of the regulatory process, we know this is very difficult. Also, at this stage in the game, to create a new chemical, a chemical manufacturer has to invest literally tens of millions of dollars prior to that compound coming onto the marketplace.

It is a very risky game at this stage for chemical manufacturers, and we have seen a thinning out of the industry. A number of agricultural chemical companies have disappeared from the scene in the last five to ten years because of this kind of pressure.

Of course we have worker education and training, something I think is being discussed quite a bit in this (conference). We are going to talk a little bit more about how important that is for personal protective equipment. It is a control that can be exerted to reduce hazards that can be quite effective. Of course, when you are talking about agricultural field workers, people who enter fields that have been treated and may come into contact with the residues, we do have a formal administrative control called a re-entry interval. I believe, EPA is changing the name of the reentry interval to restricted entry—a period of time during which no one is allowed into a field so as to allow residues to decay to an acceptable level as judged by a risk assessment process.

Personal Protective Equipment

Our third and, one should say, final resort: In general in industrial hygiene, it is considered that personal protective equipment is the final resort and also a temporary resort.

No one may consider that temporary may mean years of time to bring a new engineering control into the marketplace to avoid the use of these things, but I think philosophically we need to treat personal protective equipment as a stop-gap measure, however necessary it may be today, and try to look beyond the use of this equipment to some process that does not require the need for this equipment.

The first question to ask about personal protective equipment is, "Can we make equipment that does the job?" I think the answer is—with American ingenuity behind us—yes, we can. We have seen it done.

For workers conducting some mechanical operations on the moon, their protective equipment is doing a very good job of protecting them from absolutely nothing. In this sense that is profound, for without these suits there would be a hazard, indeed.

We put these same kind of suits on workers right here on earth. If you can imagine yourself working for eight hours a day under these circumstances, I think you can immediately see some of the problems associated with protective clothing. Cumbersome, etc. We will detail some of these.

Now, in the agricultural work place, unfortunately a farmer's view of farm work is this. I point out this fellow who is dressed like a true westerner. This is a picture in South Dakota. (Slides are not illustrated.)

My experience in working with farmers throughout the United States is that this is their image of themselves, not of the previous slide of a hazardous waste worker or some other kind of specialist in chemical hazards, because the use of agricultural chemicals, which are acutely or chronically toxic, is only one relatively small part of the job of being a farmer. I think we have some farmers in the room who can attest to that.

These workers would much prefer to be dressed like this during their work, or with short sleeves, or whatever and leather boots: all the things we tell them they cannot do when they are working with pesticides. That is the reality, and I think it is quite a legitimate point of view. I would rather work like this than work in the kind of gear that I showed you before.

Now, we can dress workers up to wear equipment, and they can use it properly. That is clear. We have gloves; we have a nonwoven coverall; and we have a mixing process here going on. But we know that lots of workers would rather dress like this when it is 90°F, 90 percent relative humidity in Florida, in July.

You can see the open shirt, no gloves, no rubber boots—just jeans. Mixing. Loading. Exposure under these conditions with an open loading system like this is inevitable. The issue is a balance between protection and comfort. It is very hard to persuade workers in these environmental conditions that protection is more important than comfort.

We can get workers to put on suits, but sometimes they do not wear their gloves. In some cases we can get people just loading, putting on their respirator but seeming to be totally oblivious to the fact that some of these compounds go through the skin and the dermal route of exposure is a very important one.

Here we have someone dressed in his street clothes with no gloves, loading 50-pound bags of an organophosphate insecticide—I might add with the propeller blade running. I use this in class. How many things are wrong with this picture? So we do have problems in education and communication, in awareness of hazards.

Here we can have someone who looks like he is dressed up just about as well as we are going to do it: rubber gloves, a full coverall, respiratory gear, some kind of cap anyway—but then we find him doing some strange things. He only wants to use a portion of his bag.

He has ripped open the bag, measured out a wettable powder in the breeze, and turned out to be the highest-exposed person in the study we were conducting, despite all his protective gear on. He is doing something that he should not be doing, but no one is going to go there and enforce any regulation on him.

Then we have people right here in the state of Iowa who will tell me that since they are just mixing an herbicide, and it is not toxic—and they mean acutely toxic, of course—that they do not need to wear gloves or protective clothing.

Then we have people out on the bean buggies spraying herbicides in the soy bean fields who are dressed without a thought to personal protection. Here we have to consider that this young woman is a pesticide applicator who is trying to get a suntan at the same time, working quite a bit at odds with our idea of personal protection from skin exposure.

We have a wide range of people to consider and to protect, and we should remember—I think it is obvious from this conference's emphasis—but these children are pesticide workers. They are agricultural workers too, exposed to pesticides in the fields behind them.

They are ready to go out and do some harvesting and will inevitably come into contact with pesticide residues. All of these people in some way or other have to be helped, and protective clothing is not necessarily going to do the job.

PERSONAL PROTECTIVE EQUIPMENT

Limitations

Here are some of the limitations that I see as important for using protective equipment. In general, whatever it is gloves, respirators, or these whole-body garments—it is uncomfortable. That decreases your ability to do and enjoy the work that you are supposed to be doing.

If you are wearing a respirator, it puts stress on your respiratory system, which can be a problem. You lose dexterity when you use gloves.

A whole-body garment that is nonwoven cannot breathe, and can cause heat stress. All of these things are very well known, but I am recounting them because I think they are all important to keep in mind.

Use Requirements

Some people would argue that it is easier to use protective equipment than to do the administrative or engineering control. In fact, if you have a good protective equipment program, it is not easy at all. You have to deal with training your personnel. That is not a one-time thing. It is a continuous process.

You have to determine that people are using the equipment you have given them, using it properly. The equipment has to be maintained.

Somebody has to be made responsible for the maintenance. Is it the worker? Is it the employer? Who takes care of this? Equipment has to be replaced.

A judgment has to be made about when it is replaced. That judgment is often made on the basis of economics rather than on the basis of safety. We have a whole host of things where is unclear whose responsibility it is for all of these items. That is a problem in itself.

Selection Criteria

Let us look at respiratory protection first and then we will go to other kinds of protection. When a respirator is required on a pesticide label, a process has gone on at the regulatory level.

A toxicological evaluation of a particular compound has been conducted. A permissible exposure limit has been calculated. To some extent, an estimate of what people are actually exposed to has to be generated. If it appears that one needs a respirator—that the hazard is sufficient to require a respirator—then it has to be decided what kind of respirator deals with the particular associated hazard.

Is it an aerosol? Is it a vapor? Are we talking about large dust particles? This all is a complicated regulatory process, but we have it pretty well worked out.

Respiratory Use Requirements

Now, at the use level, there are some very important things to remember, and again, they complicate the use of protective clothing. When someone is using a respirator and conducting labor, they need to be tested in terms of their respiratory capacity to make sure that that respirator is not going to put excessive stress on them. The issue of fit testing, which is commonplace in industry in a work place that is well-defined and may have an industrial hygienist on staff, is very problematic out in the agricultural work place.

Who does the fit testing? Most farmers do not know how to do fit testing. Fit testing actually can become quite a sophisticated process. My experience is that there is no fit testing in practice going on in agricultural workplaces. So, if the respirator does not fit, it is not an effective means of reducing hazard.

Then we have the inspection and maintenance of this equipment. Most farmers and farm employees are not in a position to decide if a respirator is no longer in good condition.

Finally, one problem with the kind of cartridges that are traditionally used on pesticide respirators, for example, is that you never know when they are saturated. They have a finite capacity, and a lot of farmers change them once a season.

Some do it by smell, which is a real problem because the hazard usually occurs prior to the odor threshold. We do not have a good system for that.

All of the responsibility for these things is placed on people who are very busy doing something quite different; they are producing food. They are dealing with crops. They are mechanics.

They are all the other things that we have talked about, and here they are also having to be experts and specialists in protective clothing evaluation. It is a big problem in terms of a realistic expectation that we place on people.

CHEMICAL PROTECTIVE CLOTHING

If we turn to what I am calling chemical protective clothing, where we are talking primarily about garments that cover the skin and attempt to put a barrier between chemicals and the skin.

Regulatory Selection Criteria

We go through a similar kind of regulatory selection criteria with a toxicological evaluation and exposure scenario, making sure that the particular material matches the kind of exposure. There is an infinite variety of combinations of material and hazards. One material is fine against one chemical, but is readily penetrated by another. EPA has worked on a very complicated process in the last few years, but they would be the first to admit that there is a lot more that needs to be done.

Cost and availability: A lot of farmers do not know what is out there. Also, it looks like it has a pretty high price tag, especially the nonwoven coveralls that have become popular.

They are supposed to be throw-away garments. It is very tempting not to throw those garments away but to use them over and over again, because they can be expensive.

Worker acceptance: It is fine to give a worker one of these garments, but he may not be wearing it if he is under your supervision. Once he is out of sight he may not be wearing this garment properly. We have seen plenty of evidence of that out in the field with zippers pulled down, coveralls with the top part tied around the waist —all sorts of ingenious ways of keeping cool under the kind of work that these workers do.

Testing

If you are interested in research for a lifetime here is an area where there is plenty of work. We have all agreed that there is no such thing as an impermeable garment, and it is a very important concept to get across.

This breakthrough is a function of time. Some garments may be impermeable for days or weeks, but they are not infinitely impermeable, and breakthrough time has become a primary criterion for testing garments.

We have standard laboratory tests, which are actually quite good for testing breakthrough times. Whether this simulates field conditions or not—actual use conditions—is open to question. We only have limited field performance tests, and we need more of that kind of work if we are going to say to farmers, "Wear this garment. It will reduce the hazard that you face." I think there is a serious question at this point as to whether we can make that statement or not for very many garments.

FIELD PERFORMANCE EVALUATION

Orchard Applicator Exposure

What I would like to show you is some work that we have conducted down in Florida the last few years—a very short summary of it—that gives you a couple of examples of why I am expressing skepticism about the use of chemical protective clothing. We conducted a study under EPA sponsorship in the citrus orchards in Florida.

But this is the kind of application process called an air-blast applicator—a tractor-pulled rig that has 1,000 gallons of material that is sprayed to basically saturate these trees to provide complete coverage. It is a very high exposure potential situation for the worker who is sitting there in an open cab and can end up taking a shower.

We were specifically testing a couple of nonwoven coveralls to see if they could improve the situation for these workers. Workers did not like them very much, but they were willing to wear them for our half-day study period. We found some problems with these garments very quickly.

They were not designed to step on and off tractors. One gentleman, within 30 minutes of wearing this garment, ripped it. He is about 40 minutes from his home base. So if he does not have any spare clothing, he has a problem. He has less protection than he would have had had he just been wearing his regular clothes.

Another fellow had the same problem. He was reaching up to work some equipment. It turns out that these garments do not have a lot of play in them. They are used to working in cotton, so maybe this is a problem that can be addressed eventually, but it certainly was a startling one for us to see for these workers.

We use a technique that introduces a fluorescent material into the spray system and then allows us, under black lights and darkened conditions, to see patterns of exposure on the skin. We saw some interesting ones here—and unexpected ones.

Here you can see that this worker was not wearing gloves and there is material on his hands. This person was wearing a long-sleeved garment and look at this material that goes up here. You can see the material goes all the way up to the elbow, and yet he is wearing a longsleeved garment.

This person is even more impressive. We had material on his hands, quite a bit on the forearm. Here is the elbow. Material went up the elbow. We actually saw material down around the armpit of this worker—material that was being blown right up the sleeve of these garments.

I do not know if you noticed in the previous slides, but these garments have rather large sleeves. They are made as one-size-fits-all.

Of course, having an open sleeve allows a certain amount of ventilation, since the garment does not breathe, but it also allows a lot of material to be blown right up the garment and onto the skin. We also saw cases of actual breakthrough of these garments.

You can see here material that went down through the neck, but here is material on the upper arm that was quite isolated and was evidence that the garment had broken through—and this was in about a two-hour spraying period. He might wear this garment for eight hours a day. So the breakthrough is happening relatively early.

When we use this fluorescent technique, we develop an exposure score when we attempt to quantify this. I show you this as a baseline for four types of garments: a work shirt, a woven fabric that is a cotton coverall, and two different types of nonwoven fabrics that we were testing.

We measured the exposure to the head, and we saw that, more or less, these workers were getting the same type of exposure. We had controlled the conditions, and we expected to see this. This more or less confirms it. This is the head exposure, and you can see that it is substantially higher than the exposure to the torso—the trunk of the body. But, again, the exposure in this region seems to be very similar.

Look what happens when we take a look at the forearms, which are the white bars, and the upper arms, which are these other bars. We have an actual increase in exposure as we move from a work shirt up to these nonwoven garments. That is simply a quantitative verification of what you saw in those slides.

In the cases where people were wearing these nonwoven garments, sleeve openings allowed substantial material to move up and deposit on both the forearms and the upper arms. You can see the same trend. So, actually, the woven garments proved to be more protective under these particular conditions.

Now, you can seal up the sleeves and you can prevent these problems, but unfortunately most of the garments are designed without any kind of seal on them; and most farmers are unaware of this kind of problem.

When we looked at exposure to the thighs, using patches above and below the clothing, here again we found something very interesting. Although for the work shirt material—I guess this was for the torso—there seemed to be a little bit more penetration. We could not make any distinction, between the cotton coveralls and the nonwoven coveralls.

What is important is that all of these garments were breaking through. There were measurable residues of pesticides underneath virtually all of these workers after a two-hour application period, and that is a small fraction of their normal application period.

The problem that I see, and I am going to illustrate it with another study, is that the workers believe, because we tell them, that they are receiving protection by wearing these garments. This study at least suggests that under these particular conditions, they were not receiving any greater protection, and for the arms they were actually receiving less protection than if they had been wearing cotton garments.

So our conclusions from that study were obvious:

1. Nonwoven fabrics tear.

2. The garment design is the problem in terms of the arm exposure, all of these garments exhibit penetration.

3. These are important findings in terms of trying to evaluate these clothing articles realistically.

Greenhouse Applicator Exposure

The second study had to do with greenhouse application and was funded by NIOSH. We had a problem that we did not anticipate. We were traditionally looking at the applicator as spraying an aerosol. We were worried about the aerosol deposition. Would it penetrate the clothing?

We ran into a different problem—that the foliage in these greenhouses overhangs the benches. The worker comes into contact with that foliage, and we knew from other studies that the clothing gets some contamination on it. Here is a worker spraying in a greenhouse wearing blue jeans and a workshirt, and he is brushing up against that material when he bends over the bench.

We did our fluorescent tracer technique, and this is a real useful slide for male workers, when you point out to them exactly where they are getting exposed. It motivates them to think about what they are doing.

Also, if they wear this clothing home, this becomes their lap, and that is where their child sits. When you tell them this, they really do think about it, and we have seen some startling changes in behavior.

I think what we found that was even more interesting is that when you have a worker dressed up in one of these garments that is nonwoven and is advertised as protective, we see a breakthrough within one hour of spraying. These are the knees and the material is clearly associated with the height of the bench and the foliage where the contact is occurring.

You can see that it was very extensive, virtually all the way up to the top of the thigh, down to the knee, and halfway down the leg on both the front and the side of both of the thighs. This is a substantial body surface area, and when we talked to the worker about this, he had no idea that this breakthrough had occurred.

He is wearing basically a plastic garment. He is sweating underneath that garment. He is unaware that there is moisture traversing that garment and contaminating his legs.

We stopped him after one hour. He normally sprays three or four hours a day and uses this same garment all day and tends to use one garment for three days before he throws it away. This breakthrough is occurring in less than one hour. We clearly had a problem; the greenhouse where we did this work has certainly made some changes in terms of the protective clothing that they offer their workers. They were quite happy to find this out.

Our conclusions were that:

1. There is a particular hazard of contact with wet foliage.

2. The breakthrough can happen relatively quickly.

3. Workers are unaware of the breakthrough.

Unfortunately exposure is a very complicated issue. Unless we do these kinds of field studies, which tell us which clothes perform in what way under what particular conditions, it is difficult for us to give good advice to farmers regarding the use of chemical protective clothing.

AGRICULTURAL WORKER PROTECTION STRATEGIES

To sum up, I think that we can look at the problem in two different ways.

Adapt the Worker

We can adapt the worker to the work place—and in the greenhouse, unfortunately, given the economic constraints, we cannot convince greenhouse growers to move their benches further apart. It is very expensive to operate a greenhouse, and they want as many plants in that building as possible.

So, the worker is going to come into contact with that material. That is an example of where we cannot adapt the work place. The worker is going to have to somehow adapt to the work place.

Adapt the Work Place

There are, however, opportunities to adapt the work place to the worker. I would suggest as a general strategy that we think about it in these terms.

I think the commercial applicator whose livelihood depends on this and who, in a sense, becomes through practice an expert at the use of hazardous chemicals, is a legitimate candidate for requiring protective clothing and requiring a high level of training, knowledge about the use of the clothing and such—all the ingredients that I talked about that make personal protective equipment so complicated.

When it comes to these other groups—the owner applicator, our family farmer whom we talked about, or the worker who occasionally applies but is doing 90 other things on the farm, or the agricultural field workers who are walking into a field after spraying has been conducted and are assuming that it is safe because their employer told them they could—we have to develop, long-term strategies to adapt the work place to those workers to create a safe and healthy working environment for them.

We are a long way from that, I admit, and protective clothing can, under particular circumstances, serve an extremely useful role. I do not think it is going to serve us as a long-term strategy.

I am quite hopeful that with the kind of work that we have talked about in this conference and the kinds of initiatives that NIOSH has taken recently, we are going to see more work directed at solving some of these problems higher up on the scale—that is in the engineering and administrative sides—so that we can ultimately reduce our reliance on personal protective equipment.□

QUESTIONS

George Cook: I am George Cook, University of Vermont Extension System. Those slides showing the breakthroughs through this supposedly protective clothing—are there any recommendations as far as what people should use?

Dr. Richard Fenske: I want to clarify that what I have presented here are specific hazards that produced that. If you are thinking about greenhouses and the contact with wet foliage, people have gone to using—in Florida—overalls that are basically rubber or polyvinyl chloride. They are quite thick and are resistant to water penetration. That is one recommendation that we worked out with those commercial growers.

The EPA has spent the last five years developing a document for their use in terms of recommending personal protective equipment to users. I think EPA is going to have a data base that is primarily based on laboratory data but also a review of field studies. That is going to be our best evidence. Unfortunately, the answer to your question is that there are no guarantees that the use of this material that has been tested under particular circumstances may or may not be appropriate under other circumstances.

Thomas Seymour: Could you describe the fluorescent material you added into the material, as to its particle size and so on? Did it enhance penetration or permeation, or do you know, in looking at some of the material tests, whether it had any effect one way or the other on the performance of the material itself?

Dr. Richard Fenske: Well, we have not extensively tested that particular tracer compound with materials in a laboratory setting. We have done quite a few field studies with it. It is a fluorescent whitening agent that, in some cases in the past, has been added to plastics to make them bright or to laundry detergent. It is a powder. It is partially soluble in water. We mix it into the aqueous system. The fluorescent material and the active ingredient of the pesticide are being sprayed onto a surface, and we can only confirm that the pesticide penetrates through these garments by doing chemical analysis with samples underneath the garment. We have done such and found the pesticide. It is not necessarily true that this is an exact surrogate for any particular pesticide. We have approached it more from a generic point of view. But we have confirmed repeatedly that when we see this material going through a garment we, indeed, can find the active ingredient under that garment as well.

(inaudible): You are taking a sample of the material (inaudible) material (inaudible) pesticide (inaudible) look at how it penetrates as a mixture. Is here any synergism there to actually enhance permeation or is here any difference (inaudible) breakthrough (inaudible)?

Dr. Richard Fenske: That is certainly worth investigating. It has had a rather low priority because the concentrations we are using are very low. I think from a chemical point, having spoken with chemists about it, there was no feeling that there would be that kind of a effect.