Herbicide Bioassay Study Guide

SCST Herbicide Bioassay working Group

Introduction

This study guide was developed to aid in preparation for the Society of Commercial Technologists' Certified Genetic Technologist (CGT) exam for herbicide bioassay testing. The exam is a minimum of two parts: the general molecular genetics written exam and the herbicide bioassay written exam. You have the option (if you qualify) to take three other exams: immunoassay, PCR, and electrophoresis. If you pass the molecular genetics exam and one or more of the other exams, then you will need to take the practical exam for up to four areas.

This study guide is a work in progress. Thus far there are sections on the basics of herbicide bioassay testing, symptoms of non-trait (non-tolerant) seedlings, and one on safety. The "basics" section includes information on the herbicides themselves (mode of actions, etc.), the traits, and testing methods. This study guide is meant to expand on an already good source of information: chapter 14 of the SCST Seed Technologist Training Manual. Information on this manual, how to qualify for the Certified and Registered Technologist exams, and how to study for the exams can be found on the SCST web site (www.seedtechnology.net) or by contacting Anita Hall, Executive Director of the SCST. Comments and suggestions about this study guide can be sent to Anita who will forward them to the Herbicide Bioassay Testing Working Group.

Herbicide Bioassay Testing – terminology, methods, troubleshooting

AI

Active Ingredient. The AI is the chemical component of the herbicide that is phytotoxic (kills plants). The chemical name and amount of AI must be listed on the herbicide label. Other compounds may also cause toxicity, but the AI is the basis for the herbicide.

Adjuvant (to a herbicide)

An adjuvant is a compound that enhances the effectiveness or application of the herbicide. It can improve the herbicide's activity by helping it stick to the leaf surface better, changing the osmotic potential, or encouraging the plant to grow faster and therefore take up more chemical. Spray adjuvants are generally grouped into two broad categories—*activator adjuvants* and *special purpose adjuvants*.

Special purpose adjuvants, such as compatibility, buffering, antifoam and drift control agents, may widen the range of conditions under which an herbicide may be applied. *Special purpose adjuvants*, such as surfactants, crop oil concentrates, nitrogen fertilizers, spreader-stickers, and wetting agents will typically enhance the performance of the herbicide. Surfactants, mixed in with the herbicide prior to application, can improve transport of the herbicide's active ingredient into the plant. The AI (active ingredient) in an herbicide must move from an aqueous environment into one (plant's cuticle) comprised of lipids/lipophilic molecules, before it can accomplish its task.

Weed control may be improved with the use of additives, but crop injury may be increased also. For this reason, carefully follow label directions regarding the use of additives. It is also important to consider the adjuvant when designing or troubleshooting a bioassay.

Bar Gene

The Bar gene, isolated from *Streptomyces hygroscopicus*, codes for the enzyme Phosphinothricin N-acetyltransferase (PAT). It can give resistance to glufosinate herbicides (Liberty).

BXN

Bromoxynil is active against dicotyledenous plants by blocking electron flow during the light reaction of photosynthesis. It is a nitrilase gene from *Klebsiella pneumoniae* subspecies *ozaenae*. The bacterial nitrilase enzyme catalyzes the breakdown of bromoxynil into non-phytotoxic compounds

CP4 EPSPS

CP4 EPSPS, enzyme 5-enolpyruvyl-shikimate-3-phosphate synthase, is naturally produced by an *Agrobacterium* species (strain CP4) of soil bacteria. CP4 EPSPS is essential for the functioning of that bacterium's metabolism biochemical pathway. CP4 EPSPS is unaffected by glyphosate-containing herbicides, (Roundup) so introduction of the CP4 EPSPS gene into crop plants (e.g., soybeans) makes those plants essentially impervious to glyphosate herbicides.

Herbicide Label

The label must contain the identity of all ingredients or chemicals contained in it, the amount of AI, the name and address of the manufacturer, physical hazards, health hazards, 1st aid measures, handling and storage, safety, stability, toxicity, ecological information, and disposal method.

Herbicide-Tolerant Crops

Cultivated crop plants that have been altered to be able to survive application(s) of one or more herbicides by the incorporation of certain gene(s), via either genetic engineering or traditional breeding techniques. For example, the CP4 EPSPS gene has been inserted, via genetic engineering, into crops (e.g., soybean, canola, cotton, corn/maize, etc.) to make them tolerant to glyphosate herbicides. Corn has also been transformed with the PAT gene to have resistance to glufosinate herbicides. Other corn lines, such as those with the IT or IR genes, are tolerant to imidazolinone herbicides. Imidazolinone tolerance has been developed via traditional breeding techniques.

Imazethapyr (IMI)

Imidazolinone herbicides are active against the enzyme acetohydroxyacid synthase (AHAS), also known as acetolactate synthase (ALS). AHAS is an enzyme found in bacteria, certain other microorganisms and plants. This enzyme catalyses the first step in the biosynthesis of the essential branched chain amino acids isoleucine and valine. Herbicide induced AHAS inhibition results in a lethal decrease in protein synthesis.

Herbicide Antagonism

When two or more herbicides are mixed together, there can be a reduction in the activity of one or both of the herbicides on target plants. This is known as herbicide antagonism.

Herbicide Bioassay

This bioassay is an efficacy test performed on plants or seeds that screens for tolerance to a specific herbicide. The plants/seeds are exposed to the herbicide and, after a period of growth time, are rated as tolerant or susceptible. Whereas PCR looks for presence of the desired DNA and an ELISA finds the protein coded for by that DNA, the bioassay determines the actual effect or activity of the gene in a living plant.

The bioassay typically requires less special equipment than other genetic tests and can be relatively easy to integrate into a conventional seed lab. For mixing the herbicide solutions, labs should have appropriate ppe (personal protective equipment), a magnetic stir plate, dedicated containers of various sizes and graduated cylinders. Separate areas, germination containers and carts for each different herbicide used are also necessary. Plastic sheets or trays can be used to protect countertops and avoid contaminating evaluation areas. Sprayers and greenhouse/growth chamber space will be needed if the spray test method will be used. Standard herbicide bioassays methods include: substrate imbibition, presoak or seedling spray.

Herbicide Negative Trait Check – Control plants/seeds that are sensitive to the specific herbicide used in the test.

Herbicide Positive Trait Check – Control plants/seeds used in a bioassay that are tolerant to the herbicide used in the test.

Herbicide Nomenclature and Formulations

Each herbicide has at least one trade name and/or common name and a chemical name. Roundup^{tm} is a trade name. Glyphosate is the chemical name.

The amount of AI can vary dramatically with each formulation. Certain herbicides may be packaged for bulk farm use, ready to use home gardener use, or combined with other herbicides for a more complete package. It is critical to know the percent AI in the formulation used for a bioassay, or results may not be accurate.

Because there is often more than one formulation of a particular herbicide, selection and application of various products can be somewhat confusing. Herbicides are made available in various liquid or solid formulations, depending upon the solubility of the active ingredient in water, and the manner in which the product is applied (i.e. dispersed in water or applied in the dry form). Formulation type is listed on the herbicide label and may be designated by a letter or letters following the trade name.

An herbicide label must a list of all ingredients and the amount of active ingredient contained in the product. For liquid formulations, amount of active ingredient contained is expressed both as a percentage of the total ingredients and as the number of pounds in a gallon of product. Active ingredients contained in dry formulations are expressed only as a percentage by weight. Several formulations and abbreviations are listed below.

Emulsifiable concentrate (E or EC) - a liquid formulation containing various emulsifiers that aid in dispersion of the active ingredient in water.

Water Soluble (S, AS, or WS) - usually a liquid formulation containing the active ingredient, water, and sometimes a surfactant and antifreeze agent.

Oil Soluble (OS) - a liquid formulation containing the active ingredient dissolved in oil or some other organic solvent. These herbicides must be applied in an oil-based carrier such as diesel fuel or kerosene.

Liquid Flowable (F or LF) - a thick liquid with a slurry-like consistency containing the active ingredient, water, and stabilizers to help active ingredient stay in suspension. Spray tank agitation is necessary to keep flowable formulations from settling out of suspension.

Wettable Powder (W or WP) - a dry powder containing the active ingredient, a diluent, usually bentonite or attapulgite clay, and surfactants. Spray tank agitation is necessary to avoid settling.

Dry Flowable (DF) - a dry formulation consisting of herbicide-impregnated granules that easily disperse in water. Dry flowables are easier to handle and measure than wettable powders. Spray tank agitation is necessary to avoid settling.

Granules (G) or Pellets (P) - a dry formulation consisting of the active ingredient coating or adhered to some type of inert granule such as clay, vermiculite, or sand. These formulations are applied just as they are purchased with no mixing.

Herbicide Formulations - Amino Acid Synthesis Inhibitors

Amino acid synthesis inhibitors act on a specific enzyme to prevent the production of amino acids. Amino Acids (AA), the building blocks for protein synthesis, are essential for plant growth and development. Sulfonylurea, imidazolinone, and sulfonamide herbicides inhibit the same enzyme, acetolactate synthase (ALS), blocking the production of three essential amino acids. Glyphosate blocks the synthesis of three amino acids by inhibiting a different enzyme. AA synthesis inhibitors are subdivided according to the enzyme that is inhibited: ALS inhibitors and EPSP synthase inhibitors. Injury symptoms are slow to develop and include a stunting or slowing of plant growth and eventual death. Symptoms are likely to show in the new plant growth first because movement of these herbicides is to those areas.

ALS Inhibitors - Translocated both apoplast (upward) and symplast (downward). They have soil and foliar activity. Tolerant corn hybrids should be labeled as "Clearfield" or with the designation "IR" or "IT" following the hybrid number.

> **Imidazolinones** - imazaquin (Scepter), imazethapyr (Pursuit), imazamox (Raptor), imazapyr (Lightning)
> **Sulfonylureas** - chlorimuron (Classic or Synchrony), nicosulfuron (Accent), primisulfuron (Beacon), thifensulfuron (Harmony GT), etc.
> Permit Lightning is a premix of imazethapyr (Pursuit) plus imazapyr for post emergence use in field corn hybrids that are resistant or tolerant to Pursuit and other imidazolinone herbicides.
> Synchrony STS is a 3:1 premix of chlorimuron (Classic) plus thifensulfuron (Harmony GT) for use only on STS soybeans (sulfonylurea tolerant soybeans).

EPSP Synthase Inhibitors - Non-selective, used for burndown applications or non-crop weed control. They are translocated both apoplastically and symplastically. They have no soil activity and are rapidly inactivated.

Examples: glyphosate (Roundup, Glyphomax, others),glyphosate-trimesium (Touchdown)

Glutamine Synthetase Inhibitors

The enzyme glutamine synthetase allows the plant cell to convert ammonia, a product of various plant processes, into amino acids. Glutamine synthetase inhibitors block the activity of this enzyme. The result is a buildup of phytotoxicic ammonia and a lack of essential amino acids, and an inhibition of photorespiration and photosynthesis, and, ultimately, plant death. Glufosinate, currently the only glutamine synthetase inhibitor, has only foliar activity. Translocation within the plant is limited. Primary symptoms of activity are a rapid necrosis of leaf tissue followed by plant death.

Example: glufosinate-ammonium (Liberty)

PAT Gene

PAT, a dominant gene, gives resistance to the glufosinate ammonium herbicides by coding for the enzyme *phosphinothricin acetyltransferase.* The PAT enzyme detoxifies phosphinothricin by acetylation into an inactive compound. The PAT gene is used by genetic engineers either as a marker gene or to confer resistance to the herbicide Liberty^{tm}.

The phosphinothricin (AI) in glufosinate herbicides causes inhibition of glutamine synthetase, an enzyme that catalyzes the synthesis of glutamine in the plant. It is the only enzyme in the plant that can detoxify the ammonia produced by plants during metabolic processes such as photorespiration and amino acid degradation. Without sufficient glutamine synthetase production, there is an accumulation of lethal levels of ammonium in susceptible plant tissue within hours of application.

Phosphinothricin

Phosphinothricin (PPT), is the active ingredient of glufosinate ammonium herbicide (Liberty). It inhibits glutamine synthetase, which results in the accumulation of lethal levels of ammonia in susceptible plants within hours of application.

Surfactant

Surfactant is an acronym for a “surface active agent”. They are often used for adjuvants in herbicides. Basically, surfactants reduce the surface tension between the spray droplets and the leaf surface so that the spray is absorbed.

Tolerance to Herbicides

Tolerant plants are typically able to rapidly degrade or deactivate the herbicide they’re exposed to, thereby escaping its toxic effects. Tolerance can occur naturally, through selective pressure by extensive exposure to an herbicide, by natural or induced mutations, or genetic engineering with a specific gene. Environmental conditions may affect a plant’s natural tolerance/sensitivity to an herbicide. Rotational use of herbicides with different modes of action or active ingredients, good mechanical weeding practices and using good sanitation practices can help prevent the development of tolerant weeds. The usefulness of an herbicide declines rapidly as more weeds become tolerant to it.

Trait

A trait is a specific phenotypic characteristic of an organism, such as insect or herbicide resistance. Many traits are the result of the expression of a single gene, but some are polygenic (result from simultaneous expression of more than one gene). For example, five genes control the level of protein content in soybeans. In genetic engineering, a trait is the expressed characteristic of the gene introduced into the plant. For example, plants transformed with the Cry1Ab gene are expected to be resistant to insects such as the European Corn Borers. The PAT gene codes for an herbicide resistance trait, specifically, glufosinate.

Types of Herbicides:

Broad Spectrum – Kills all plants exposed to it. Non-selective. Non-discriminatory. Many broad-spectrum herbicides have surfactants that are also phytotoxic.

Post-Emergence – Applied to plants in field after the crop has germinated. These may interrupt photosynthesis or have growth regulatory properties. Post-emergence herbicides often require adjuvants.

Pre-Emergence – Applied to the soil prior to planting, or at planting, but before the crop has germinated.

Mode of action –The sequence of events from absorption of the herbicide to death of the plant. Herbicides can be growth or hormone regulators (often broadleaf killers), amino acid synthesis inhibitors (used for perennial and annual weed control), lipid synthesis inhibitors (usually kill grasses, not broadleaves), seedling growth inhibitors (pre-emergence), photosynthesis &/or pigment inhibitors (systemic or contact, grass or broadleaf), or cell membrane disruptors (contact herbicides).

Systemic Herbicide – Mobile herbicides. They translocate from the site of absorption or application to other parts of the plant. Roundup has strong systemic activity.

Contact Herbicide – Non-mobile herbicides. Typically disrupt cell membranes. Because they must contact the plant tissue in order to be active, they often must be applied post-emergence. Some can also have some systemic action. Contact herbicides often cause “burn down” type symptoms. Liberty^{tm}, if painted onto a small area of a sensitive leaf, will kill only the area painted, not the whole plant. However, when applied to a sensitive plant as a total spray, the entire plant is rapidly killed.

Some events that have been approved for use in the US:

Crop	**Event**	**Herbicide gene**	**Gene Source**	**Herbicide Trait**	**Method of Transformation**	
Soybean	GTS-40-3-2	ESPS	CP4-ESPS	glyphosate -	Microprojectile Bombardment	
Soybean		STS		Sulfonyurea - Synchrony	Conventional breeding	
Corn	IMI -IT		Single Dominant gene	Imizethapyr – Pursuit, Lightning etc.	Conventional – mutation breeding	
Corn	IMI -IR		Recessive gene	Imidazolinone- Pursuit, Lightning etc.	Conventional – tissue culture, somaclonal embryo variation	
Corn	T25	Pat	*Streptomyces viridochromogenes*	glufosinate- Liberty	Direct DNA transfer with protoplasts	
Corn	Bt11	Pat	*Streptomyces viridochromogenes*	glufosinate - Liberty	Direct DNA transfer with protoplasts	Also has Cry1Ab gene
Corn	GA21	mEPSPS	CP4-ESPS	Glyphosate- Roundup	Microprojectile Bombardment	A modified maize ESPS
Corn	NK603	ESPS	CP4-ESPS	Glyphosate- Roundup	Microprojectile Bombardment	
Cotton	RR			glyphosate		
Cotton	BXN	BXN	*Klebsiella pneumoniae*	Bromoxynil - Buctril	Agrobacterium tumefaceans vector	
Cotton	STS	nitrilase		Sulfonyurea - Synchrony	Conventional Breeding	
Flax	STS			Sulfonyurea - Synchrony	Conventional Breeding	
Canola/ Rape	GT200	2 genes		Glyphosate- Roundup	Agrobacterium tumefaceans vector	
Canola/ Rape	HCN28, HCR1	PAT	*Streptomyces viridochromogenes*	Glufosinate - Liberty	Agrobacterium tumefaceans vector, interspecies cross pollination	TransformedBrassica napus, crossed to B. rapus
Canola/ Rape	IMI		mutagenesis	Imidazolinone- Pursuit, Lightning etc.	Haploid mutagenesis, selection	
Sugar Beets	T120-7	PAT	*Streptomyces viridochromogenes*	Glufosinate - Liberty	Agrobacterium tumefaceans vector	
Rice	PWC16	Clearfield		Imizethapyr – Pursuit, Lightning etc.	Chemical mutagenesis	
Rice	LLRice	Bar	*Sreptomyces hygroscopicus*	Glufosinate - Liberty	Direct DNA transfer	

Herbicide test troubleshooting.

Positive trait check not tolerant to herbicide –

Herbicide concentration may be too high
Wrong formulation used
Wrong herbicide may be used
Contamination with another herbicide or growth inhibitor may have occurred
Sample is nonviable or has poor vigor
Incorrect control may have been used
Growth conditions may have been wrong for test

Negative trait check does not show sensitivity to herbicide

Incorrect herbicide may have been used
Wrong formulation or amount of herbicide may have been used
Herbicide stocks may be expired
Herbicide may contaminated
May have needed an adjuvant
Herbicide may have been improperly mixed or prepared
Wrong check sample may have been used
Growth conditions for test may not have been appropriate

Test sample growth is irregular - causes

May have improper or uneven growth conditions – (check reps)
Herbicide concentration may have been too high
May have contamination from other herbicide
Herbicide may have been improperly mixed
Test may be incorrect for sample
Seed quality and vigor may be poor or variable
May have disease present that interferes with plant growth

Symptoms of Non-Trait Seedlings

This section lists the symptoms (characteristics) of non-trait seedlings when exposed to a herbicide in a herbicide bioassay test. Testing methods fall into four main categories: substrate imbibition (seed exposed to herbicide throughout the test), seed soak (seed exposed for about sixteen hours to herbicide), spray (seedlings sprayed in greenhouse or in the laboratory), or a combination of imbibition and seed soak methods. The following descriptions along with images of these seedlings may be found on the SCST web page.

- **Substrate Imbibition and Seed Soak Methods**

Herbicide Trait	**Seedling Type**	**Description**
Round up Ready®	Monocot	Short, stiff primary root; shoot short and pale
	Dicot	Short primary root often “off-color”; primary leaves may be “crossed”
Liberty Link®	Monocot	Short primary root; necrotic mesocotyl (“halo” effect)
	Dicot	Short primary root
Clearfield®	Monocot	Reduced primary root development
	Dicot	
STS®	Dicot (soybean)	Roots unaffected; small, crossed primary leaves
BXN®	Dicot	Reduced root development; lesions on hypocotyl

Spray Methods

Round up Ready®

Corn: Plant first appears stunted, twisted, and wilted, then turns reddish or brown with necrotic lesions and dies.

Soybeans: Plant is severely stunted. Stems and leaves turn reddish brown and necrotic lesions on leaves, stems and hypocotyls. Leaves curl under and the plant dies.

STS®

Soybeans: Plant is stunted and pale green with dark red veination on underside of leaf. Petioles also turn dark red.

Liberty®

Corn: Water soaked, dark areas appear at leaf margins and tips, expanding to leaf base. Plant is stunted, turns yellow, and dies. The sprayed plant shows typical “burn down” symptoms.
Note: if Liberty is applied (painted) onto a small portion of the leaf, only that portion of the leaf will die. If sprayed to the point that Liberty runs off the leaf, or if sprayed over large areas of the plant, the plant will die.

Safety Considerations for Herbicide Bioassay Testing

Chemicals (herbicides) are a major part of herbicide bioassay testing. This goes without saying, but all that goes with this testing from a safety standpoint may not be as obvious. There are safety aspects that may vary from lab to lab and aspects that personnel from all labs must be aware of and follow. All herbicides used in bioassay testing are safe to use if one follows precautions laid out in the Material Safety Data Sheets for each herbicide. In this section, we will take a look what information is available on a MSDS and how make use of this and other safety information.

Material Safety Data Sheets

MSDS' all contain the same categories of information, but the format may vary by distributor of the herbicide. MSDS' contain the following information:

chemical name or names
ingredients
physical characteristics
reactivity
handling and storage
contact information of the manufacturer
limits of exposure
fire and explosion data
health hazards
protective apparel/precautions

Distributors should send a MSDS with any order of a herbicide or other chemical. Otherwise one may be obtained from the distributor's web site or from elsewhere on the Web. A MSDS should be read through completely, but special attention should be made to the following information. The physical characteristics section contains information on the flash point (temperature at which the chemical will ignite), pH, odor, boiling point and other information. Two terms to be aware of for this section are Threshold Limit Value (TLV) and Permissible Exposure Limit (PEL). TLV indicates an exposure level under which most people can work consistently day after day with no harmful effects. PEL is a person's permitted exposure level during an eight-hour workday.

The health hazards section is especially important. It gives information on the effects of acute (one-time) exposure and chronic (longer-term) exposure. Routes of entry, effects to skin, and effects to the eyes also are included. Important terms for this section are LD_{50} and $LC_{50.}$ LD_{50} (Lethal Dose 50) is the level (either oral or dermal) at which 50% of a population of rats died when exposed to the chemical. It is expressed as milligrams of chemical per kilogram of rat. The smaller the LD_{50}, the more hazardous the chemical (and visa versa). LC_{50} (Lethal Concentration 50) refers to the amount of chemical inhaled that killed half a population of rats. A section on first aid gives remedies for exposure to chemicals by skin, eyes, ingestion, and inhalation.

Chemicals can be handled safely if procedures in the handling section are followed. This section describes handling and storage precautions, protective equipment, and ventilation requirements. PPE (Personal Protective Equipment) is equipment and apparel that will shield all points of entry from the chemical. Eye protection involves safety glasses, goggles, or a face shield. There is a number of types of gloves (latex, vinyl, nitrile, etc.) available. However it is critical to wear the right glove for the job. Latex gloves are not sufficient for most aspects of herbicide bioassay testing. Coveralls or a lab coat usually are normally required. Respirators, ranging from a “dust mask” to a full-face respirator may be required. Employees must be properly trained in how to properly fit the respirator to their face, how to use it, and how to store it. An improper job of fitting a respirator can actually concentrate the chemical instead of protecting from it. When not worn, all respirators must be stored in a sealed container. It is a finable offense if OSHA discovers improperly stored respirators (i.e. hanging from a nail or lying on the floor near a garbage can, but in usable condition). Finally MSDS’ describes what chemicals to not store the herbicide near, and what to do if the chemical is spilled.

Disposal of Chemical Waste

It is important to know how to safely dispose of chemical waste – for employee safety, to protect the environment, and to protect the business from fines and/or lawsuits. Improper disposal of wastes or rinsate is a violation of federal law. *Ignorance* of proper disposal procedures will not protect a lab or a person from prosecution. Your state department of the environment or the Environmental Protection Agency (EPA) can be called. Garbage bags of herbicide-moistened towels or crepe cellulose paper and containers of waste herbicide must be clearly marked *without* using abbreviations. H_20 is not acceptable for water, buffer is not acceptable for buffer containing sodium azide. Containers of liquid, no matter for how short of time they will be used, must be clearly marked.

Standard Operating Procedures

Whether or not a lab is ISO-certified (International Standards Organization), each method involving herbicides or other chemicals should have a Standard Operating Procedure (SOP) developed for it. A SOP merely is a “how-to” for the method. It may start with a very brief description of the procedure and a list of equipment/supplies that are needed to conduct the method. This equipment is the actual testing equipment as well as personal protective equipment. Next the procedure is described in detail including whom to contact for general questions or for problems. The SOP should describe how to mix the herbicide stock solution (if there is one) and the working solution. A stock solution is an intermediate dilution of a herbicide. The stock solution is further diluted to get the working solution which is actually applied to the substrate or sprayed on the seedlings. SOP’s aid in analysts or technicians conducting testing safely and will help protect the lab from lawsuits.

Right-to-Know Laws

Right-to-Know laws are laws which protect the worker, emergency personnel, and the community from accidental exposure to chemicals. These laws have evolved into the Chemical Hygiene Plans used at many labs. Worker Right-to-Know means that employees have the right to know the properties and hazards of the chemicals they work with. Community Right-to-Know means the surrounding town or city has the right to know if there are chemicals being used within a lab which might negatively affect their health through accidental release. Finally Emergency Right-to-Know means that rescue personnel (especially firefighters have a right to know what chemicals or other substances are present which at a minimum would make a difference in how they fight a fire and otherwise might be a matter of their well-being. It benefits the lab and these groups when communication about chemicals is current and thorough.

Training

For each employee's well-being and for the good of the lab, it is important that all workers receive a well-rounded training in all applicable aspects of safety. Federal regulations require that all employees know what the initials MSDS stand for and how to use Material safety Data Sheets. Again, a lab can be fined if an employee doesn't know this information. OSHA occasionally inspects public and private labs. At minimum employees should be trained in using MSDS', proper use of respirators and other personal protective equipment, and conducting testing in a safe manner. Information is available in bookstores, via the Internet, or by contacting the appropriate state or federal agencies.

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