FORMALDEHYDE AND PARAFORMALDEHYDE IN LABORATORIES: HAZARDS, REGULATIONS, AND SAFETY

CONTENTS

1.0 INTRODUCTION

Formaldehyde is a colorless, highly reactive, flammable gas with a strong irritating odor. In many research and clinical laboratories, formaldehyde is commonly found as formalin, a saturated (37%) formaldehyde solution. If a protocol calls for 10% formalin, it is roughly equivalent to 4% formaldehyde. Another common form of formaldehyde in laboratories is paraformaldehyde, a white crystalline powder of polymerized formaldehyde. Paraformaldehyde is a flammable solid that readily depolymerizes to formaldehyde when heated or mixed with water.

The human body is continuously exposed to low concentrations of endogenous formaldehyde (i.e. produced as a byproduct of normal metabolism), as well as smaller quantities from dietary sources (reference). This natural formaldehyde exposure is not innocuous, as it is implicated in the development of some age-related diseases. Formaldehyde is a highly reactive chemical, capable of modifying or destroying many biological molecules, including proteins and DNA. This reactivity is useful, for example it enables formaldehyde to fix and preserve biological specimens, but it also gives formaldehyde potent acute and chronic health hazards. Formaldehyde is an important workplace hazard; furthermore, it is a wider public health concern on account of traces being released into the air from various sources including furniture, composite wood products, building materials, consumer products, and more.

Formaldehyde is a Cal/OSHA Article 110 regulated carcinogen in the workplace. Other formaldehyde exposures are regulated by Cal/EPA. See this California Department of Public Health formaldehyde fact sheet for general information on regulation, health hazards, and safety controls. Useful hazard information is also to be found on the NJ Dept. of Health formaldehyde fact sheet.

Acute exposure can be irritating to the eyes, nose, and throat while chronic exposure may cause cancer of the nose and sinuses as well as some types of leukemia and lymphoma. In addition, formaldehyde solutions have been associated with decreased fertility and adverse reproductive effects.

Formaldehyde is a potent sensitizer. Susceptible individuals may develop an immunological memory to formaldehyde-protein adducts formed in the human body as a result of formaldehyde exposure, especially when exposure is repeated.

Once sensitization has occurred, subsequent exposure to miniscule quantities of formaldehyde triggers an immune response, which may manifest as an attack of dermatitis (itchy skin rash) and/or occupational asthma (wheezing, difficulty breathing, chest tightness, coughing). Sensitization is largely irreversible, and sensitized individuals may have to permanently discontinue working with formaldehyde.

Researchers and laboratory personnel may be exposed to formaldehyde vapors emitted from formalin and paraformaldehyde solutions, or from contaminated materials. Common exposure examples include weighing paraformaldehyde outside of a fume hood, vapor emission during preparation of solutions, and exposure to formaldehyde while preserving or handling preserved specimens. Formaldehyde gas can build up in the airspace above solid paraformaldehyde due to slow depolymerization at room temperature; therefore, paraformaldehyde containers must never be opened outside of a fume hood. Paraformaldehyde dust is also a potent health hazard if inhaled or if it enters the eyes. Exposure risks can be reduced by making sure proper engineering safety controls are used, best working practices and procedures are followed, and appropriate personal protective equipment (PPE) is worn.

Paraformaldehyde sometimes dissolves slowly in water and some workers use heat to speed up the process. This process may release large quantities of formaldehyde and must never be conducted outside of a fume hood. Please refer to this article for further information, including a quick and safer procedure for paraformaldehyde dissolution/depolymerization.

Principal investigators (PIs) and supervisors are required to assess the hazards of all work with formaldehyde-containing materials to determine and implement appropriate precautions and controls. The assessment must include the type, form, concentration and volumes of the chemicals used, as well as best practices and procedures, engineering controls, personal protection equipment, decontamination and cleaning, spill response, waste handling, and emergency procedure in the event of a potential exposure or other emergency. Based on the assessment, appropriate safe working practices shall be incorporated into a written formaldehyde-specific standard operating procedure (SOP). To aid PIs, EH&S will make a generic formaldehyde SOP available online, which can be modified as needed to reflect particular hazards or processes in a specific lab. The SOP shall be reviewed by new lab members, and annually by all lab members during annual laboratory-specific safety training. Applicable safety data sheet(s) (SDS) shall be reviewed by all new formaldehyde users, and should preferably be re-reviewed annually, with a focus on the health and physical hazards of the associated chemical. All formaldehyde users shall be apprised of signs and symptoms associated with possible exposure. New formaldehyde users should be given hands-on training by the PI, or training may be delegated to a lab member the PI deems appropriately experienced and knowledgeable.

EH&S can assist PIs and supervisors with hazard assessment, as needed. Please contact EH&S Lab Safety at labsafety@usc.edu for assistance.

2.0 FORMALDEHYDE REGULATIONS, EXPOSURE LIMITS, AND AIR MONITORING

Formaldehyde use has written regulatory standards that must be followed in all workplaces, including USC laboratories. Cal/OSHA has set the permissible exposure limits for formaldehyde. These limits are very low, and violation can result in fines. It is the responsibility of the PI or supervisor to ensure that all required protections are in place and understood by workers. The regulated exposure limits for formaldehyde are defined and summarized in the text below; this includes the specific Cal/OSHA requirements given in Title 8 California Code of Regulations Section 5217. EH&S will provide exposure monitoring, when needed, and can advise on local exhaust ventilation and other safety controls appropriate to minimize or eliminate potential exposure.

Please see Appendix 1 at the end of this document for information on the relationship between Cal/OSHA regulations *§5217 Formaldehyde* and *§5191 Occupational Exposure to Hazardous Chemicals in Laboratories* and their scope and applicability in research labs.

Please refer to Appendix 2 for information on formaldehyde reporting requirements.

3.0 REGULATORY DEFINITIONS

Action Level (AL): An airborne level calculated as an eight-hour time-weighted average, which initiates certain required activities such as exposure monitoring and medical surveillance.

Ceiling Limit (C): The maximum concentration of an airborne contaminant to which a worker may be exposed for any time period, no matter how brief.

Permissible Exposure Limit (PEL): The maximum permitted 8-hour time-weighted average concentration of an airborne contaminant to which workers may be exposed. The PEL, which is based on scientific evidence, is designed to reflect a value at which almost all people can be exposed for 8 hours a day for an entire working career without any adverse health effects.

Regulated Area: Any area where airborne concentration of contaminant exceeds either the PEL or STEL. Access is restricted to trained authorized personnel.

Short-Term Exposure Limit (STEL): The maximum time-weighted exposure to a contaminant to which a worker may be exposed during a specified short time period (usually 15 minutes).

Time-Weighted Average (TWA): The average exposure to a contaminant over a given period of time, typically 8-hours for a PEL, and commonly 15 minutes for a STEL.

4.0 EXPOSURE LIMITS AND REQUIREMENTS SUMMARY

Table 1. Formaldehyde Regulatory Exposure Limits and Cal/OSHA Requirements

Formaldehyde Airborne Concentration	Type of Limit	Exposure Duration	Cal/OSHA Requirements
0.1 ppm	[not named]	not specified	§5217 (n)(1): "*...where the employer can show, using objective data, that employees are not exposed to formaldehyde at or above 0.1 ppm, the employer is not required to provide* [formaldehyde] *training*" At USC, everyone who works with formaldehyde shall at a minimum be trained on its safe use as part of lab-specific safety training provided by PIs and supervisors. (This is the same requirement as for all hazardous materials usage.) Individuals who do not work with formaldehyde, but who may spend time in a workspace where formaldehyde is present, do not need formaldehyde safety training if exposure levels are below 0.1 ppm (which should be the case in normal labs using appropriate safety controls).* Individuals who may be exposed to formaldehyde concentrations above 0.1 ppm will require formaldehyde safety training, which may need a higher level component in addition to the basic internal lab-specific training. Contact injuryprevention@usc.edu for more information.
Below 0.5 ppm (8 h TWA) **and** below 2 ppm (15 min TWA)	Action level (AL) and STEL	8 h TWA and 15 min TWA	If employee exposure is below both the AL and STEL then no special requirements apply (aside from the training requirements covered above). **For typical research lab operations there is no valid reason the AL or STEL should ever be exceeded provided lab personnel are properly trained and using appropriate safety controls (e.g. chemical fume hoods) in accordance with a satisfactory SOP.** USC occupational health will conduct formaldehyde exposure monitoring in representative labs conducting typical formaldehyde procedures to objectively determine that exposures are below the AL and STEL, in accordance with the CAL/OSHA regulation *§5217. Formaldehyde*.

Formaldehyde Airborne Concentration	Type of Limit	Exposure Duration	Cal/OSHA Requirements
0.5 ppm	Action Level (AL)	8-hour TWA	If employee exposure is above either the AL or the STEL, this triggers periodic employee exposure monitoring and medical surveillance (§5217). When needed, this will be conducted by EH&S Occupational Health (injuryprevention@usc.edu). (For additional requirements if exposure is found to be above the STEL, see below in table.)
2.0 ppm	STEL	15-minute TWA	
0.75 ppm	PEL	8-hour TWA	**Workers shall NOT be exposed above the PEL or STEL.** Cal/OSHA requires implementation of work practice and engineering controls to lower exposure below the PEL and STEL, to the extent feasible. If these controls cannot feasibly reduce the exposure below the PEL and STEL, or during the period while effective controls are being installed, or during maintenance periods when safety controls are not fully functional, respiratory protection will be required, and signed regulated areas have to be implemented which only authorized trained personnel may enter. Furthermore, exposure levels which trigger respiratory protection and regulated area requirements also trigger State reporting requirements (§5203; see Appendix 3 for more information)..
2.0 ppm	STEL	15-minute TWA	
N/A	Ceiling	Instantaneous	Cal/OSHA does not specify a ceiling for formaldehyde.
* Examples of personnel who do not directly work with formaldehyde but spend time in spaces where formaldehyde is present, and who are highly unlikely to be exposed to concentrations above 0.1 ppm, include students doing dissection in the anatomy labs, and non-research staff (e.g. custodians) transiting through regular labs.			

5.0 REQUIREMENTS

5.1 SOP

All labs that use any form of formaldehyde/paraformaldehyde shall have a satisfactory formaldehyde SOP. It is strongly recommended the SOP be based on the EH&S Formaldehyde SOP template to ensure that key safety considerations are not omitted. The template should be modified as appropriate to reflect experimental procedures or safe working practices which are specific to the particular lab. The individual with overall management responsibility for the lab (usually the PI) shall review and approve the SOP. Lab personnel shall review and sign the SOP before commencing any work with formaldehyde or paraformaldehyde. The SOP shall be re-reviewed annually.

The formaldehyde SOP is a key safety document. The PI is ultimately responsible for the contents of the document, training staff on the document, and implementing safety practices specified in the SOP.

5.2 Training

All personnel that use any form of formaldehyde/paraformaldehyde must do lab specific formaldehyde safety training. At a minimum, lab personnel should be trained on the contents of the lab-specific formaldehyde SOP. This training shall be completed by new lab personnel before they start working with formaldehyde-containing materials and shall be refreshed annually. PIs shall keep internal training records.

EH&S may make additional formaldehyde safety training available, and may opt to make this a requirement for higher-hazard formaldehyde workers or all formaldehyde workers. EH&S training may supplement but not replace lab-specific formaldehyde safety training.

New lab personnel who are inexperienced in the safe handling of formaldehyde/paraformaldehyde should additionally receive hands-on training and supervision to ensure safe working practices are understood and adhered to.

The PI retains ultimate responsibility for the content and quality of internal safety training; however, PIs are free to delegate the provision of training to suitably knowledgeable and experienced personnel (e.g. lab manager or senior postdoc).

5.3 Engineering Safety Controls

Engineering safety controls in the context of formaldehyde safety basically means local exhaust ventilation. Chemical fume hoods provide the most assured protection from formaldehyde vapor and paraformaldehyde dust. Please refer to Table 2, below, for a general overview of the ventilation requirements of different types of work with formaldehyde/paraformaldehyde.

NOTE: Paraformaldehyde is not just a dust hazard, but also emits formaldehyde vapor. Containers of paraformaldehyde shall not be opened outside of a fume hood.

Totally exhausted biosafety cabinets are designed to provide protection from volatile chemical hazards and may be used in lieu of a chemical fume hood; however, chemical fume hoods provide more assured protection. If work with concentrated formaldehyde solution (e.g. 37% solution) or large quantities is to be conducted then a chemical fume hood should be used. Note that totally exhausted biosafety cabinets are uncommon in most USC laboratory buildings. The most common variety of biosafety cabinet at USC is the type which discharges air back into the lab via a HEPA filter. These biosafety cabinets do NOT provide any protection from volatile chemical hazards and shall NOT be used in lieu of a chemical fume hood.

NOTE: Biosafety cabinets are classified according to a scheme in *Biosafety in Microbiological and Biomedical Laboratories* (BMBL) published by the CDC; see Appendix A Parts 3 and 4 for more information on the types, the degree of protection they afford, and their limitations.

Table 2: Minimum Ventilation and PPE Requirements for Common Procedures using Formaldehyde

Procedure	Formaldehyde containing chemical	Ventilation	PPE (minimum)
Handling solid paraformaldehyde (e.g. weighing)	Solid paraformaldehyde	Fume hood or equivalent	Chemical splash goggles or safety glasses, disposable nitrile gloves,† lab coat
Preparation of solutions	Formaldehyde or paraformaldehyde	Fume hood or equivalent	Chemical splash goggles, double disposable nitrile gloves,† lab coat
Formaldehyde or paraformaldehyde solutions in pressurized systems	All	Local exhaust ventilation (fume hood, downdraft table, etc) at locations where formaldehyde may escape the system	Chemical splash goggles, disposable nitrile gloves,† lab coat. If high splash hazard, add face shield, impervious apron with sleeves
Fixing tissues or cells	≤ 4% formaldehyde solution (equivalent to ≤ 10% neutral buffered formalin) or ≤ 4% paraformaldehyde soln	Fume hood or equivalent; or well-ventilated area if small amounts and short task time*	Chemical splash goggles, disposable nitrile gloves,† lab coat
Placing sample in prefilled screw cap containers	Less than or equal to 4% formaldehyde or paraformaldehyde (≤10% neutral buffered formalin)	Fume hood or equivalent; or well-ventilated area if small amounts and short task time*	Chemical splash goggles, disposable nitrile gloves,† lab coat
Gross examination of fixed tissues	Less than or equal to 4% formaldehyde or paraformaldehyde (≤10% neutral buffered formalin)	Fume hood or equivalent, well ventilated area if small amounts and short task time*	Chemical splash goggles, disposable nitrile gloves,† lab coat
Microscopic examination of fixed tissues or cells	Less than or equal to 4% formaldehyde or paraformaldehyde (≤10% neutral buffered formalin)	Fume hood or equivalent, well ventilated area if small amounts and short task time*	Chemical splash goggles, disposable nitrile gloves,† lab coat. Safety glasses permissible when samples present no splash hazard (i.e. no liquid is present). After sample is placed in microscope, provided no eye hazards are in the vicinity, eye protection may be removed if needed to look into the microscope.
Blot assays	37% formaldehyde and diluted solutions	Fume hood or equivalent	Chemical splash goggles, double disposable nitrile gloves,† lab coat
Animal perfusions	Less than or equal to 4% formaldehyde or paraformaldehyde (≤10% neutral buffered formalin)	Fume hood or equivalent***	Chemical splash goggles, disposable nitrile gloves,† lab coat
Embalming	Less than or equal to 4% formaldehyde or paraformaldehyde (≤10% neutral buffered formalin)	Fume hood or equivalent***	Chemical splash goggles, disposable nitrile gloves,† lab coat
Specimen discard, waste chemical handling	All	Fume hood or equivalent	Chemical splash goggles, disposable nitrile gloves,† lab coat. If high splash hazard, add face shield, impervious apron with sleeves

Procedure	Formaldehyde containing chemical	Ventilation	PPE (minimum)
Spill cleanup (minor spill)**	All	Fume hood or well-ventilated area	Goggles, disposable double nitrile exam gloves† (or preferably Silver Shield™ or other suitable non-disposable chemical protective gloves), lab coat.
Spill cleanup (major spill)**	Cleaning major spills requires special training and respiratory protection and shall NOT be attempted by lab personnel. Cover the spill with absorbent (only if safe to do so without hazardous exposure), evacuate the lab, call DPS.**		

† Disposable nitrile gloves are a minimum standard of protection and offer limited resistance to formaldehyde/paraformaldehyde solutions. They are mainly suitable for short-term splash protection from dilute solutions; they are not suitable for protection from continuous contact, especially if solutions are concentrated. Appropriate glove selection for formaldehyde protection is covered in detail in the EH&S formaldehyde SOP.

* Permissible outside of a fume hood only if ALL the following are adhered to:

1. Well ventilated area
2. Small quantities (a few mL; 50 mL absolute maximum)
3. All liquid surfaces to be covered as far as practical
4. Short task time (≤5 mins)
5. Task not frequently repeated (average of once a day or less; not more than three times in any single day)
6. Fume hood is not easily available or is not practical
7. Safety protocol is written into a lab-specific SOP

** See Formaldehyde Spill Cleanup section

*** Animal perfusion and embalming may be conducted outside of a chemical fume hood (or fume hood equivalent such as a totally exhausted biosafety cabinet) ONLY if assessed and approved by EH&S Occupational Health. Exposure monitoring may be required as a part of the approval process. Note that suitable local exhaust provision is likely to be required, e.g. downdraft table. Please contact injuryprevention@usc.edu before starting work if work is planned to take place outside of a fume hood.

As noted in Table 2, above, there are certain conditions when non-fume-hood local exhaust ventilation (e.g. a downdraft table) may be a satisfactory engineering control to reduce formaldehyde/paraformaldehyde. However, these devices give less assurance of protection than a chemical fume hood; therefore, any proposed application of a downdraft table or other non-fume-hood type of local exhaust ventilation for controlling formaldehyde exposure should be assessed and approved by EH&S Occupational Health on a case-by-case basis before work commences. Please email injuryprevention@usc.edu for more information.

6.0 LABORATORY PLANNING AND PREPARATION FOR SAFE USE OF FORMALDEHYDE-CONTAINING MATERIALS

1. Develop a written laboratory-specific SOP for formaldehyde containing chemicals that will be used.
   a. It is recommended to start with the Formaldehyde, Formalin, and Paraformaldehyde SOP template provided by EH&S, to ensure the essential topics are covered.
   b. In many labs which use formaldehyde or paraformaldehyde under lower-risk conditions (e.g. use of small amounts of paraformaldehyde solution in a fume hood for fixing tissue samples), the EH&S SOP template may be sufficient as-is.
   c. If higher-risk formaldehyde/paraformaldehyde usage will occur (e.g. posing a high splash hazard, or large volumes are to be used), the SOP template should be modified to include lab-specific safety rules, safe work practices, and experimental procedures, as appropriate.

2. Contact EH&S Occupational Health & Safety at injuryprevention@usc.edu to request an Industrial Hygiene assessment for procedures not listed in the Table 2, or for procedures which are intended to be conducted outside of a fume hood or fume hood equivalent. The assessment may include quantitative formaldehyde air monitoring.
3. Provide and document annual formaldehyde training for personnel working with formaldehyde-containing materials. The training should preferably be given to all research group personnel, including those who do not directly work with formaldehyde. In a shared lab, it is recommended that personnel in all the research groups receive at least a basic training in formaldehyde hazard awareness and emergency response, even if one or more of the groups does use formaldehyde.
4. Ensure applicable chemical SDSs are accessible to staff at all times and that the chemicals are listed in the online chemical inventory (e.g. EHSA, Bruno, RSS).
   a. PIs are responsible for instructing their personnel:
      i. How to access SDSs, AND
      ii. To read and understand SDSs for the materials they work with, AND
      iii. To provide SDSs to medical staff and first responders in case of an incident
   b. PIs are responsible for ensuring their staff maintain an accurate chemical inventory.
5. Designate a laboratory, workspace and certified chemical fume hood, exhausted biological safety cabinet (BSC) or other approved containment for work with formaldehyde containing chemicals.
6. Designate an area for storage of formaldehyde containing materials which must be properly labeled, away from incompatible chemicals (such as oxidizers, strong acids and strong bases), adverse conditions (such as heat or ignition sources), and which has secondary containment.
7. Ensure that the 1-2-3 Serious Injury Reporting Flyer is posted in the laboratory.
8. Consider purchasing pre-made paraformaldehyde solution. If solution is to be made from solid paraformaldehyde, all steps (including weighing the paraformaldehyde) shall be conducted in a chemical fume hood. Use safe practices for making the solution, particularly if heating is employed (which obviously greatly increases evolution of formaldehyde vapor); see this reference for more information.
9. If large volume of formalin solution must be used (e.g. more than a liter), determine the best location, setup, and procedures to prevent exposure and spills. Evaluate all handling operations, training and procedures for use, change-out and refilling of containers. Consider using pump dispensing to obviate the need to lift large containers. Use spill containment trays of adequate volume. Record all safety procedures and safe working practices in an SOP.
10. Formaldehyde containing chemical waste shall be disposed in properly labeled chemical waste containers placed in secondary containment. A waste pick-up request shall be submitted within 9 months of the accumulation start date.
11. Ensure supplies are available for waste handling, disposal, and routine cleaning of surfaces.
12. Ensure appropriate supplies for spill cleanup are readily available in a clearly marked chemical spill kit.
13. Document and train staff on appropriate spill cleanup procedures and list required PPE. Specify when HazMat will need to clean up the spill (this should all be in the SOP).

14. Safety shower and emergency eyewash stations must be easily accessible and within the immediate work environment in areas where formaldehyde is used. (§5162 *Emergency Eyewash and Shower Equipment* and §5217 (i)(2) and (3); the latter Section requires eyewashes be provided whenever eye exposure to ≥0.1% formaldehyde solution is possible, and safety showers whenever skin splashes of ≥1% formaldehyde solution may occur.)

7.0 POTENTIALLY SENSITIZED INDIVIDUALS

Allergic-type symptoms which manifest during or after work with formaldehyde, or during or after presence in an area where formaldehyde is in use, may indicate that the affected individual has become sensitized to formaldehyde. Symptoms of a hypersensitivity reaction may include (but are not limited to) eye irritation, chest tightness, coughing, wheezing, and/or skin rash (dermatitis). An individual suspected of being sensitized to formaldehyde should cease working in locations where formaldehyde exposure is possible and should contact EH&S Occupational Health and Safety at injuryprevention@usc.edu.

Formaldehyde sensitization is uncommon when formaldehyde exposure is properly controlled by safety precautions such as appropriate use of chemical fume hoods. However, certain individuals have an exceptionally high propensity towards formaldehyde sensitization due to unpredictable factors like genetics and may develop a formaldehyde hypersensitivity even with appropriate safety practices.

Responses to formaldehyde hypersensitivity have to be formulated on a case-by-case basis, taking into account medical and industrial hygiene assessments. Typical responses may include respiratory protection, reassigning job duties to avoid direct work with formaldehyde, or in the most extreme cases it may be necessary to change work location to an area where formaldehyde is not present.

8.0 PERSONAL PROTECTIVE EQUIPMENT (PPE)

Please refer to Appendix 2 for information on PPE and Cal/OSHA regulations.

Basic minimum PPE guidelines are given in Table 2. Please consult the EH&S formaldehyde SOP template for more complete information on appropriate choice of PPE. In particular, glove selection and the limitations in protection afforded by certain types of glove (e.g. disposable nitrile gloves) are covered in the SOP.

Disposable gloves contaminated with formaldehyde or paraformaldehyde shall be disposed as solid hazardous waste, appropriately labelled, and appropriately packaged to prevent the escape of formaldehyde vapor (i.e., before removing from a fume hood, the waste should be in a closed airtight plastic container, or double-bagged in sealed polyethylene bags (e.g. Ziplock™-style)). Reusable gloves shall be decontaminated and washed on the exterior surface before removal.

If a lab coat is splashed with formaldehyde or paraformaldehyde, it should immediately be removed. If the splash is a small one, the user should thoroughly rinse the splash at a sink to remove the hazard before allowing the lab coat to dry in a well-ventilated area. The coat may then be placed in a laundry locker. If a lab coat or personal clothing is contaminated by a significant splash of formaldehyde or paraformaldehyde, the coat/clothing should immediately be removed and placed in a fume hood, and ultimately disposed as hazardous waste.

If the individual's skin is also splashed, the immediate priority is for them to get under a safety shower. It is not safe for lab personnel to attempt decontamination of clothing or lab coats which are significantly contaminated; furthermore, items which are contaminated with any amount of formaldehyde/paraformaldehyde shall not be taken home or placed in a laundry locker.

In general, formaldehyde should be handled in a way that ensures respiratory exposure is minimal and far below levels requiring the use of a respirator (see Table 1 above). For all normal lab operations, appropriate use of fume hoods and other safe working practices should reliably reduce exposure to negligible levels. Any formaldehyde work requiring the use of a respirator is only allowed if approved on a case-by-case basis by EH&S Occupational Health (injuryprevention@usc.edu). Strict stipulations will apply, including that all respirator users are enrolled in the respiratory protection program, medically cleared, fit tested, and trained. Furthermore, provisions of the Cal-OSHA formaldehyde regulation have to be met, including exposure monitoring, medical surveillance, and establishment of signed regulated areas from which unauthorized persons are excluded. Additionally, as per §5203, USC will be required to report to the State any formaldehyde work which requires establishment of a regulated area.

Individuals who are not exposed to levels of formaldehyde which mandate respiratory protection (Table 1) may nonetheless on occasion desire respiratory protection, for example on medical advice due to formaldehyde sensitization, or pregnancy. Provision of respiratory protection under the "voluntary" provisions of Cal/OSHA respiratory protection regulations may be possible on a case-by-case basis; please email injuryprevention@usc.edu for guidance. If respiratory protection is issued under the "voluntary" provisions, this does not reduce the requirement to use fume hoods and appropriate work practices to keep formaldehyde exposure well below the levels which activate regulatory provisions such as exposure monitoring, medical surveillance, or mandatory respiratory protection.

9.0 OTHER CONSIDERATIONS

Please refer to the EH&S formaldehyde SOP template for information on storage, waste disposal, and emergency response for formaldehyde/paraformaldehyde-containing materials.

APPENDIX 1 – CAL/OSHA REGULATIONS AND FORMALDEHYDE IN RESEARCH LABS

Applicability of §5191 to Research Laboratories

Within the Cal/OSHA General Industry Safety Orders, the primary regulation covering chemical safety in USC research labs is *§5191 Occupational Exposure to Hazardous Chemicals in Laboratories*. This regulation is limited in scope and application to "...*employers engaged in the laboratory use of hazardous chemicals...*", and provides further clarification in subsection (b) *Definitions*, as follows:

> *"Laboratory. A facility where the "laboratory use of hazardous chemicals" occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis.*
>
> *Laboratory scale. Work with substances in which the containers used for reactions, transfers, and other handling of substances are designed to be easily and safely manipulated by one person. "Laboratory scale" excludes those workplaces whose function is to produce commercial quantities of materials."*

Furthermore, subsection (a) states:

> *"(3) This regulation shall not apply to:*
>
> *(A) Uses of hazardous chemicals which do not meet the definition of laboratory use, and in such cases, the employer shall comply with the relevant regulations in Title 8, California Code of Regulations, even is such use occurs in a laboratory."*

Essentially all of the research labs at USC which use hazardous chemicals fall unambiguously within the scope of §5191.

Relationship Between §5191 and Article 110, Specifically §5217

Cal/OSHA General Industry Safety Orders *Article 110 Regulated Carcinogens* contains a number of sections regulating various aspects of workplace carcinogen use and exposure, including *§5217 Formaldehyde*.

There are significant differences between chemical usage in industry and in research laboratories. In industry, processes often use a relatively small number of individual chemicals in large quantities (kilograms to tons), with processes staying much the same from day-to-day. Industrial workers are mostly not scientists or chemistry experts; rather, they are usually non-specialists who are trained to follow a particular procedure which is laid out for them. In contrast, research lab activities may use very large numbers of individual chemicals in small quantities and processes may change at any time depending on the progress of the research. Research workers are highly trained experts, are expected to develop a high-level understanding of the materials they use, and have the knowledge and expertise to design new procedures rather than merely following instructions. Cal/OSHA regulations appear to have been developed in a manner mindful of these differences between research labs and industry, and thus, presumably to avoid impracticably onerous regulatory burdens on research labs, *§5191 Occupational Exposure to Hazardous Chemicals in Laboratories* explicitly preempts some of the other, more industry-focused, regulations. To quote, in part, §5191 (a) *Scope and application*:

> *"(2) Where this section applies, it shall supersede, for laboratories, the requirements of Title 8 of the California Code of Regulations Section 5190 and Article 110, Regulated Carcinogens of the General Industry Safety Orders, except as follows:*
>
> *(A) The requirement to limit employee exposure to the specific exposure limit.*
> *(B) When that particular regulation states otherwise, as in the case of Section 5209(c)(6).*
> *(C) Prohibition or prevention of eye and skin contact where specified by any health regulation shall be observed.*
> *(D) Where the action level (or in the absence of an action level, the exposure limit) is exceeded for a regulated substance with exposure monitoring and medical surveillance requirements.*
> *(E) The "report of use" requirements of Article 110, (Section 5200 et. seq.) Regulated Carcinogens regulations.*
> *(F) Section 5217 shall apply to anatomy, histology and pathology laboratories."*

Section 5190 refers to control of cotton dust and is not important in the current context.

By combining the scope of Section 5191 with the formaldehyde regulation (§5217), the following rules result:

i. Anatomy, histology, and pathology labs which use formaldehyde are fully subject to Section 5217; therefore, such labs should be assessed and guided on a case-by-case basis by EH&S Occupational Health under the Formaldehyde Program. Please email injuryprevention@usc.edu for more details.

ii. For research labs which meet the §5191 criteria for a laboratory and which use formaldehyde:
   a. Mandatory exposure limits still apply (0.75 ppm PEL; 2 ppm STEL; §5217 and Table AC-1).
   b. If exposure levels never exceed both the action level (0.5 ppm 8 h TWA) and the STEL (2 ppm 15 min TWA) then exposure monitoring and medical surveillance requirements of §5217 do not apply.
   c. By following this document, and by following and enforcing safe working practices (e.g. consistent use of chemical fume hoods) as laid out in a satisfactory SOP (e.g. the EH&S formaldehyde SOP customized as needed to be lab-specific), labs conducting typical formaldehyde works should be able to keep exposures to a minimal level, well below the action level. In this way, employee/student safety is maximized and the substantial burden in time, money, and administrative complexity of activating the exposure monitoring, medical surveillance, and other aspects of §5217 will be avoided.
   d. Labs intending to conduct formaldehyde/paraformaldehyde work lying outside the guidelines of this document and the EH&S formaldehyde SOP may have potential for non-trivial exposure. Such labs should contact injuryprevention@usc.edu for an assessment before starting work.
   e. It is not completely clear whether §5191 preempts the §5217 training requirements, which are required for formaldehyde workers unless they are demonstrably exposed to less than 0.1 ppm formaldehyde (§5217 (n)(1)). However:
      i. For typical research work with formaldehyde, proper safe working practices and use of engineering safety controls should reliably keep exposures below this level.
      ii. Notwithstanding the previous point, everyone using formaldehyde in labs shall be trained by the PI or other appropriately experience person designated by the PI on safe formaldehyde working practices. At a minimum, this training shall cover the contents of the EH&S formaldehyde SOP, but should preferably also have a hands-on component for new researchers, until the PI is satisfied they can work in a safe and competent manner.
         1. SOP shall be reviewed annually by lab personnel.
         2. PI shall keep internal training records, of which SOP signed acknowledgements can meet the minimum requirements.
      iii. All persons who may be exposed to 0.1 ppm or higher shall additionally complete the EH&S Occupational Health formaldehyde training, which shall be repeated annually.
         1. This training is recommended but optional for all formaldehyde users who are not exposed to 0.1 ppm or above.

APPENDIX 2 – PPE AND FORMALDEHYDE REGULATIONS

Appropriate PPE shall be provided to prevent skin and eye contact, and the supervisor/manager/PI shall ensure researchers use the PPE.

i. §5217 (h) "*… When protective equipment or clothing is provided..., the employer shall... assure that the employee wears them.*"
ii. §5217 (h) also states that employers shall comply with §3380 (general standard for personal protective equipment and protective devices), §3382 (eye and face protection), §3383 (body protection), and §3384 (hand protection).
iii. §5217 (h)(1) "*Selection. The employer shall select protective clothing and equipment based upon the form of formaldehyde to be encountered, the conditions of use, and the hazard to be prevented.*"
    a. §5217 (h)(1)(A) "*All contact of the eyes and skin with liquids containing 1 percent or more formaldehyde shall be prevented by the use of chemical protective clothing made of material impervious to formaldehyde and the use of other personal protective equipment, such as goggles and face shields, as appropriate to the operation.*"
    b. §5217 (h)(1)(B) "*Contact with irritating or sensitizing materials shall be prevented to the extent necessary to eliminate the hazard.*"
    c. §5217 (h)(1)(C) "*Where a face shield is worn, chemical safety goggles are also required if there is a danger of formaldehyde reaching the area of the eye.*"
iv. §5217 (h)(2) contains additional requirements for handling, storing, and labelling PPE which is contaminated with formaldehyde.
    a. In USC research labs, the only PPE which will routinely (i.e. in a non-emergency situation) become contaminated with formaldehyde is gloves, which should be dealt with either by disposal as solid hazardous waste, or in the case of reusable gloves, they should be washed and decontaminated before removal.
    b. Minor splashes on lab coats can be immediately washed off by the user. In case of significant contamination, an unacceptable hazard (plus stringent regulatory requirements §5217 (h)(2)(B), (C), (D), and (F)) would arise from placing the coat into laundry, or from the user attempting themselves to decontaminate the coat. In such cases, the coat should be disposed as hazardous waste, thus ensuring safety and avoiding regulatory complications.
    c. Formaldehyde contaminated PPE or clothing shall not be taken home (§5217 (h)(2)(D)).

APPENDIX 3 – REPORTING REQUIREMENTS

EH&S is responsible for fulfilling Cal/OSHA carcinogen reporting requirements (§5203). In part, this states (subsection (c)(1)), "*... For all regulated carcinogens that specify a requirement for the employer to establish a regulated area, use of a regulated carcinogen within such a regulated area shall be reported.*" The formaldehyde standard (§5217) requires the establishment of "*...regulated areas where the concentration of airborne formaldehyde exceeds either the TWA* [8 h PEL] *or the STEL...*". No lab at USC shall use formaldehyde in such a way as to trigger the regulated area and other requirements of §5217 unless the lab is enrolled in the Formaldehyde Program under the auspices of EH&S Occupational Health (injuryprevention@usc.edu). If a lab is in the formaldehyde program and a regulated area is established under the guidance of the Occupational Health Industrial Hygienist, then Occupational Health will also fulfil the reporting requirements.