



Standard Operating Procedure for Handling Lead-Based Materials

All persons with the intention to use lead based materials inside KSC laboratory facilities must abide by the following KSC rules and procedures. If you have any questions or concerns, please contact Michael Salvador, KSC lab Manager, or Abdulrahman El Labban, Operations Engineer. This document is approved by the KSC leadership and it is complementary to all KAUST safety rules, regulations, and procedures.

A. PURPOSE

Lead(II) salts are toxic and suspected carcinogens. Lead(II) salts are precursors of lead-based perovskite semiconductors, an important research topic at the KAUST Solar Center (KSC). The intention of this Standard Operating Procedure (SOP) is to implement best practices for minimizing and controlling the risk of exposure to lead-based materials and devices within KSC.

B. SCOPE

This policy is applicable to all faculty, staff, students, researchers, and visiting scholars. The aforementioned have to adhere to the principles and code of conduct delineated in this policy prior to using KSC facilities.

C. GENERAL CONSIDERATIONS

- a) The principles and conduct described in this SOP do not replace other safety instructions that are in place in KSC as outlined in the GENERAL LABORATORY SAFETY RULES & PROCEDURES, but they have to be considered in addition to those.
- b) Principal investigators (PIs) shall provide a complete list of researchers working with lead-based materials to the Operations Team. In addition, to avoid uncontrolled use of the gloveboxes dedicated to perovskite research, a list of approved users is to be made publically available. Only listed personnel will be allowed to use such equipment and only after individual training has been conducted and documented by the Operations Team. It is the responsibility of the PI to provide an updated list to KSC upon new arrivals and departures of researchers and upon request.
- c) Prior to accessing KSC labs, researchers need to undergo a lead safety training. The training provides basic instructions related to safe behavior for handling lead-based materials in KSC and is in alignment with this SOP. The training is conducted by members of KSC Operations Team. A document summarizing KSC lead safety instructions will be handed out to the researcher.

D. HEALTH AND HAZARD INFORMATION

1. Introduction

Lead salts represent a potential health threat, if inhaled, ingested or absorbed through the skin. Health organizations advise 0.05 mg/m³ as the maximum permissible concentration of lead in the air and 5 µg/dL (five micrograms per deciliter) as the reference blood lead level for adults (according to the National Institute for Occupational Safety and Health, NIOSH). As with handling many other potentially harmful chemicals, it is possible to drastically reduce or even eliminate the implications of lead through containment and safe behavior.

2. Summary of toxicology

Reproduced from <https://www.cdc.gov/niosh/docs/81-123/pdfs/0368.pdf>

Effects on animals: In rats or mice, chronic oral administration or subcutaneous or intraperitoneal injection of lead subacetate, lead acetate, or lead phosphate produced cancer of the kidneys. Intravenous or intraperitoneal of lead nitrate, lead acetate, or lead chloride on pregnant mice, rats or hamsters caused increased fetal mortality and malformations of the posterior extremities and urogenital and intestinal tracts in the offspring.

Effects on humans: Inhalation or ingestion of inorganic lead has caused peripheral neuropathy with paralysis of the muscles of the wrists and ankles, encephalopathy, anemia (due to decreased red blood cell life and impaired heme synthesis), proximal kidney tubule damage, decreased kidney function, and chronic kidney disease. Lead can accumulate in the soft tissues and bones, with the highest accumulation in the liver and kidneys, and elimination is slow. Lead can penetrate the placental barrier, resulting in neurological disorder in infants. More recent evidence indicates that lead exposure at low doses can lead to adverse cardiovascular and kidney effects, cognitive dysfunction, and adverse reproductive outcomes. Current research has found decreased renal function associated with blood lead levels (BLLs) at 5 µg/dL and lower, and increased risk of hypertension and essential tremor at BLLs below 10 µg/dL.

3. Signs and symptoms of exposure

Short-term (acute): Exposure to inorganic lead can cause decreased appetite, insomnia, headache, muscle and joint pain, colic, and constipation.

Long-term (chronic): Exposure to inorganic lead can cause weakness, weight loss, nausea, vomiting, constipation, blue or blue-black dot-like pigmentation on the gums ("lead line"), severe headache and abdominal cramps, delirium, convulsions, and coma.

4. Common materials of concern

- **Lead (II) iodide, PbI₂**

Harmful if swallowed or if inhaled

May damage the unborn child. Suspected of damaging fertility.

May cause damage to organs through prolonged or repeated exposure. Very toxic to aquatic life with long lasting effects.

Obtain special instructions before use.

Do not breathe dust/ fume/ gas/ mist/ vapours/ spray.

Wear protective gloves/ protective clothing/ eye protection/ face protection.

IF SWALLOWED: Call a POISON CENTER/doctor if you feel unwell. Rinse mouth.

IF exposed or concerned: Get medical advice/ attention.

Source: Sigma-Aldrich SDS dated 10/20/2017 CAS#: 10101-63-0

- **Lead (II) bromide, $PbBr_2$**

Harmful if swallowed or if inhaled

May damage the unborn child. Suspected of damaging fertility.

May cause damage to organs through prolonged or repeated exposure. Very toxic to aquatic life with long lasting effects.

Obtain special instructions before use.

Do not breathe dust/ fume/ gas/ mist/ vapours/ spray.

Wear protective gloves/ protective clothing/ eye protection/ face protection.

IF SWALLOWED: Call a POISON CENTER/doctor if you feel unwell. Rinse mouth.

IF exposed or concerned: Get medical advice/ attention.

Source: Sigma-Aldrich SDS dated 09/21/2017 CAS#: 10031-22-8

- **Lead (II) chloride, $PbCl_2$**

Harmful if swallowed or if inhaled

Suspected of causing cancer.

May damage the unborn child. Suspected of damaging fertility. Causes damage to organs through prolonged or repeated exposure. Very toxic to aquatic life with long lasting effects.

Obtain special instructions before use.

Do not breathe dust/ fume/ gas/ mist/ vapours/ spray.

Wear protective gloves/ protective clothing/ eye protection/ face protection.

IF SWALLOWED: Call a POISON CENTER/doctor if you feel unwell. Rinse mouth.

IF exposed or concerned: Get medical advice/ attention.

Source: Sigma-Aldrich SDS dated 09/21/2017 CAS#: 7758-95-4

- **Lead (II) acetate trihydrate, $Pb(CH_3COO)_2$**

May damage the unborn child. Suspected of damaging fertility.

May cause damage to organs through prolonged or repeated exposure. Very toxic to aquatic life with long lasting effects.

Obtain special instructions before use.

Do not breathe dust/ fume/ gas/ mist/ vapours/ spray.

Wear protective gloves/ protective clothing/ eye protection/ face protection.

IF exposed or concerned: Get medical advice/ attention.

Source: Sigma-Aldrich SDS dated 12/11/2017 CAS#: 6080-56-4

Note: Solvents such as dimethylformamide (DMF) and dimethylsulfoxide (DMSO) can significantly exacerbate the intoxication of lead and its compounds because it increases the risk of absorption via dermal contact.

Good sources for online safety data sheets, SDS:



<https://www.sigmaaldrich.com>

<http://www.sciencelab.com>

<http://msds.ehs.ucla.edu>.

MSDS are also accessible from the computer located at the entrance of the *Solution Processing and Device Fabrication Lab*.

E. BLOOD LEAD LEVEL TESTING

KSC has adopted guidelines and reference standards from other recognized institutions to monitor occupational exposure to lead including National Institute for Occupational Safety and Health, NIOSH, and the Association of Occupational and Environmental Clinics, AOEC, (see: <https://www.cdc.gov/niosh/topics/ables/>).

Every researcher working with lead-based materials is obliged to undergo medical surveillance. Medical surveillance includes blood testing to monitor the levels of lead in the blood system. Medical surveillance will follow international standards for monitoring exposure to lead and will be carried out by KAUST Health Clinic (KHC). Users of KAUST Solar Center shall adhere to the following procedure:

- a) Blood Lead Level (BLL) testing:
 - i. Shall be performed before the first assignment to an area that contains lead-based materials. This value shall be used as a future reference baseline for the individual.
 - ii. After 6 months of the first assignment.
 - iii. Once a year for students who had a Blood Lead Level (BLL) of less than 5 µg/dL in two consecutive tests or every 6 months for individuals with BLL > 5 µg/dL during the preceding 6 months.
 - iv. Students should be considered for removal from Lead-based work, if a BLL of more than 10 µg/dL is present during medical surveillance. Re-exposure to lead-based work should not begin again until the value has dropped to below 10 µg/dL.

The blood test analysis serves no other purpose than monitoring levels of lead but may include monitoring of vital factors that are intrinsically related to the presence of lead. The blood test will not screen for other substances than lead or other vital factors than those associated with lead-based exposure work.

- b) Medical examinations shall be available to all researchers at the moment where the researcher experiences symptoms of lead intoxication.
- c) Researchers are obliged to communicate positive tests that exceed the lead levels stated above to KSC so that the cause can be identified and reactive measures implemented. KSC and its PIs acknowledge that a positive test has by no means punitive repercussions on the researcher.
- d) Although a declaration of pregnancy is not mandatory, female researchers who are pregnant or planning to become pregnant, are encouraged to disclose that to their PI as an additional protective measure. In addition, we strongly encourage pregnant researchers to consult HSE's [Reproductive Hazard Guideline](#) and [Assessment](#).
- e) Researchers tested positive for lead will be assisted medically and professionally to reduce and normalize the levels of lead. This includes additional medical surveillance and professional assignments outside working areas with lead.



F. LAB PRACTICES AND PROTECTIVE MEASURES

The following describes measures that need to be adopted along with standard [KAUST Lab Safety Manual](#) policies and procedures while working with lead-based materials in KSC. **It must be stated that those who do not adhere to the policies, procedures and standards set forth in this SOP not only endanger the health & safety of themselves and their offspring but also that of their co-workers.**

1. Working with lead-based materials

- a) It is prohibited for researchers to conduct experiments using lead-based materials in areas other than those assigned as lead working areas. Lead working areas are clearly labeled with a red sign reading “WARNING—LEAD WORK AREA”.
- b) Glove boxes shall be considered as the primary location for handling lead-based materials in forms of powders and solutions.
- c) It is prohibited for researchers to handle lead-based powders in open bench spaces and fume hoods. The handling of perovskite powders, including weighing, is restricted to glove boxes. Deviations from this norm must be presented to the KSC Perovskite Safety Committee in the form of a request. The Committee will then decide about the request and make recommendations.
- d) Lead containing solutions can be handled in the fume hoods of the Perovskite Lab. It is necessary to prepare solutions inside the glove box first prior to executing chemical reactions or other manipulations in the fume hood.
- e) Scratching of devices is only allowed inside fume hoods.
- f) Recipients such as vials, containers or boxes that are used for preparing, storing or transporting lead based materials are to be labeled properly (type of material, solvent, user, date). In addition, a red sticker, following the reasoning “red is lead”, shall be applied to the recipient. Red stickers are available from the Operation Team.
- g) Users shall adopt good housekeeping practices by cleaning up surfaces immediately after an incident or upon concluding daily work to prevent surface contamination and to prevent exposure to lead. The user should follow the instructions for decontamination described in section H, point d.
- h) Users of KSC shall obey [KAUST Particularly Hazardous Substances Procedure](#) for safely handling lead-based materials in the labs.

2. Working with lead-based materials in glove boxes

- a) It is mandatory to use a pair of nitrile gloves on top of the black rubber gloves.
- b) It is mandatory to clean the antechamber after every usage. The antechamber is vented with nitrogen from the inside of the glove box, which may deposit lead particulates inside the antechamber during the venting process.
- c) Waste needs to be stored in zip-lock bags and shall be removed after work is concluded. Sharps shall be disposed of in dedicated red hard-plastic containers.

3. Personal protective equipment (PPE)

The use of gloves, lab coat, and safety goggles is mandatory and PPE is provided by KSC. It is not allowed to take used PPE outside the labs.

- a) **Respiratory protection**



The use of respirators is the least preferred method of controlling exposure and should not be used as the only means of preventing or minimizing exposure. Respirators should be used only under the following circumstances:

- As a last line of defense, i.e., after engineering controls and administrative controls have been exhausted (see section 8 “working with lead based materials”)
- When there is the possibility that the Permissible Exposure Limit will be exceeded
- Regulations require the use of a respirator
- A faculty/staff/student/researcher/visitor of KSC requires the use of a respirator
- As PPE in the event of a chemical spill clean-up process

As per KAUST policy, users of KSC intending to wear a respiratory mask must receive medical clearance, be trained and fit tested by the HSE department (Health Safety & Environment). KAUST procedure and the process for how to arrange a fit test is available under [Respiratory Protection Program](#). Only KSC approved respirators shall be used. Please contact KSC Operation Team for assistance.

b) Hand protection

Gloves must be worn at all times. It is advised to wear two pairs of gloves simultaneously and to change the outer gloves frequently, particularly, when noticing contact with chemicals. Gloves with extended cuff for preventing exposure between wrist and forearm are available and should be used. Contact with areas of general use, e.g., door handles, antechambers, etc., while wearing potentially contaminated gloves is strictly prohibited. The user should practice and adopt proper glove removal technique as to avoid any skin contact. KSC provides nitrile gloves that offer protection against lead salts and solutions.

c) Eye protection

Safety or chemical splash goggles must be worn at all times. KAUST provides safety goggles with prescription glasses, if needed. Face shields are recommended and available when certain procedures (i.e. splash hazards) are being performed.

d) Skin and body protection

Flame resistant, appropriately sized lab coats must be worn and buttoned to their full length. Laboratory coat sleeves must be of sufficient length to prevent skin exposure while wearing gloves. Gloves with long sleeves are available and can be worn over the lab coat. As outlined in KSC’s general safety policy, full length pants and close-toed shoes must be worn at all times by all individuals that are occupying the laboratory area. The area of skin between the shoe and ankle should not be exposed. Used lab coats, for laundry purposes, need to be separated from lab coats belonging to users that do not handle lead components.

e) Hygiene measures

Wash hands and skin thoroughly with soap and water after removing gloves. Wash hands again with soap and water before eating, smoking, or using toilet facilities. Dedicated hand washing stations are available inside the laboratory areas. Refrain

from using common rest rooms for the purpose of washing hands and skin immediately after handling laboratory materials. Remove any contaminated lab coat(s) and clothing before leaving the laboratory and wash before reusing.

4. Storage requirements

As received lead salts are to be stored in a dedicated, nitrogen ventilated cabinet. The cabinet is located in the so-called *Perovskite Lab*. Do not overstock lead-based powders. Containers with lead-based powders can only be opened and handled inside a glove box. Once opened containers can only be stored inside a glove box. Containers with lead-based materials need to be labeled with a red sticker.

5. Transportation requirements

Transportation of lead-based materials and devices across KSC is only allowed in the presence of dedicated secondary containers. KSC provides secondary containers for transporting glass vials and chip holders for devices and glass substrates. For transferring glass vials and devices into and/or between glove boxes using antechambers, secondary containers need to be used in all instances.

G. EMERGENCY RESPONSE

1. Spill and accident procedure

Dial 911 immediately in case of an emergency (012-808-0911 from cell phone)

Assess the extent of danger. Help contaminated or injured persons as long as it does not endanger yourself. Evacuate the spill area, if you cannot safely manage the spill. Avoid breathing vapors. If possible, confine the spill to a small area using a spill kit or absorbent material. Prevent others from entering contaminated area (e.g., use caution tape, barriers, etc.).

- a) **Spill (<1 L, outside glove box)** – If you received KAUST's chemical *spill training*, which is mandatory for KSC users, assist in the clean-up effort by following the instructions provided in the training. Use appropriate personal protective equipment. Use clean-up material and tools (scraper and pans) provided in the chemical spill kit (green boxes). Treat the spilled, lead containing material using the appropriate treatment agents (Spill-X-A → for mineral and organic acid spills; Spill-X-C → for caustic and organic base spills; Spill-X-S → for common hydrocarbon solvents and fuel spills). Double bag spill waste in plastic bags, label and take to the chemical waste pick-up at the exit of area 3. Provide clear information about the spill to the Operation Team. Note: it might be required to decontaminate surface areas using special products for lead treatment (cf. section *Decontamination Procedure*).
- b) **Spill (<1 L, inside glove box)** – use absorbent material and appropriate solvent to treat the spill. Use double zip lock bags to collect and dispose of the absorbent material. Inform the Operation Team.
- c) **Spill (large, >>1 L)** – Dial 911 (012-808-0911 from cell phone) and contact the Operation Team for immediate assistance.
- d) **Chemical Spill on Body or Clothes** – Remove clothing and rinse body thoroughly in emergency shower for at least 15 minutes. Contact the Operation Team for immediate



assistance and notify supervisor. Seek medical attention and dial 911 (012-808-0911 from cell phone).

- e) **Chemical splash into eyes** – Immediately rinse eyeball and inner surface of eyelid with water from the emergency eyewash station for 15 minutes by forcibly holding the eye open. Contact the Operation Team for immediate assistance and notify supervisor. Seek medical attention and Dial 911 (012-808-0911 from cell phone).
- f) **Report all incidents to [Reportit](#)** at least 24 hours after the occurrence of the incident.

2. Medical Emergency

Dial 911 immediately in case of an emergency (012-808-0911 from cell phone)

- a) **Life Threatening Emergency, After Hours, Weekends and Holidays** – Dial 911 (or 012-808-0911 from cell phone).
- b) **Non-Life Threatening Emergency** – Go to the KAUST Health Facility, **(0)12-808-0940**.
- c) **Needle stick/puncture exposure** – Wash the affected area with antiseptic soap and warm water for 15 minutes. For mucous membrane exposure, flush the affected area for 15 minutes using an eyewash station.
- d) Report all of the above medical incidents to [Reportit](#) at least 24 hours after the occurrence of the incident.

H. WASTE DISPOSAL AND DECONTAMINATION

Use adequate personal protective equipment to properly dispose chemical waste (cf. section F). Lead-containing waste should be treated as hazardous waste. Waste containers for hazardous solids (yellow bags), sharps (red boxes) and liquids (glass bottles in fume hoods) are available across KSC. Follow [KAUST Hazardous Waste Manual](#).

a) Labeling Waste

Waste containers should be readily available inside fume hoods, glove boxes and in open laboratory areas. Ensure the container is marked with a correct hazardous waste tag prior to using it. The tag should clearly state the type of hazardous waste that the container is used for (“lead iodide, lead salts, etc.”). Ask Operation Team for assistance, if needed. A clearly visible rack with safety and waste management items is located in the service area of the *Solution Processing and Device Fabrication Laboratory*.

b) Storing Waste

- i. Store hazardous waste in closed containers, in secondary containment and in a designated location (ask KSC Operation Team for assistance)
- ii. Use red containers with yellow bags to dispose of solid waste; use dark red containers to dispose of sharps; use labeled glass bottles to dispose of liquid waste; glass substrates and devices should be disposed of using the containers for sharps
- iii. Double-bag dry waste using waste bags (stored in the service corridor; ask KSC Operation Team for assistance)
- iv. Waste must be under the control of the person generating & disposing of it



c) **Disposing of Waste Containers**

Waste container disposal is of the responsibility of the KSC Operation Team and is performed on a regular basis. For questions or assistance contact KSC Operation Team.

d) **Decontamination**

Work areas must be kept free of lead residues. KSC provides special lead cleaning products (detergent and surface wipes) to decontaminate minor spills. These are located in all labs and in a clearly visible rack in the service corridor of the Solution Processing and Device Fabrication Laboratory. Use wet surface wipes to remove powder and solution residues. Do not attempt to clean up dry powders and residues using dry wipes or a brush as this may create hazardous airborne particles. Test the surface for lead using lead testing equipment provided by KSC. Repeat cleaning procedure until test is negative. KSC users should seek the KSC Operation Team for assistance with monitoring the presence of lead.

e) **Monitoring of Lead**

The KSC Operation Team will perform qualitative surface swipe tests on a regular basis and as needed as a means to identify and control the origin of lead contamination. In addition, KSC will perform random, quantitative lead tests of surface areas using ICP (inductively coupled plasma) analysis with a sensitivity of 0.02 ppm. If thought meaningful, KSC will request quantitative swipe and air sampling tests from external contractors. For questions or assistance contact KSC Operation Team.

I. REQUIRED TRAINING AND DOCUMENTATION OF TRAINING

- Prior to conducting any work with lead salts, KSC users must attend training by KSC's Operation Team acknowledging the hazards involved in working with these substances, handling requirements specific to KSC, work area decontamination, and emergency procedures.
- Users working with lead based materials need to complete Particularly Hazardous Substances (HSE122) training in addition to other trainings required by KSC.
- KSC through its Operation Team will enforce that KSC users have attended appropriate laboratory safety training or refresher training within the last year.
- Users and PIs must acknowledge the *Standard Operating Procedure for Handling Lead Based Materials* by signing this document.

J. REFERENCES

Reference blood lead level for adults, in Adult Blood Lead Epidemiology and Surveillance (ABLES) from The National Institute for Occupational Safety and Health (NIOSH), and references therein: <https://www.cdc.gov/niosh/topics/ables/>

Data into Action. NIOSH blood lead surveillance program contributes to a decline in national prevalence rates, and references therein: <https://www.cdc.gov/niosh/docs/2012-164/pdfs/2012-164.pdf>

