1. Introduction

For the purposes of this document, the term "nanomaterial" includes nanoparticles and other materials having at least one dimension between approximately 1 and 100 nanometers that may exhibit unique physical, chemical, and biological properties compared to their bulk counterparts. Due to their size and increased surface reactivity, exposure to nanomaterials may present health and safety risks that are not yet fully understood. Research involving engineered nanomaterials may present potential exposure risks through inhalation, skin contact, or accidental ingestion. Given the uncertainties surrounding the long-term health effects of these materials, appropriate controls and precautionary measures must be implemented to minimize exposure.

2. Purpose

The purpose of this guidelines document is to minimize the potential for exposure to nanomaterials and associated hazardous chemicals by implementing appropriate engineering controls, administrative controls, safe work practices, personal protective equipment (PPE), spill response procedures, and waste management practices. Researchers are required to perform all nanomaterial work in accordance with these guidelines, the KSU Chemical Hygiene Plan, applicable laboratory-specific procedures, and all federal, state, and university safety requirements.

3. Scope

This guidelines document applies to all personnel engaged in research, teaching, testing, storage, handling, transportation, characterization, disposal, or use of nanomaterials on KSU-owned, leased, or operated facilities. An example list of activities these guidelines cover is included below:

- Nanomaterial synthesis using chemical, physical, or biological methods.
- Metal and metal oxide nanomaterial synthesis.
- Polymeric nanomaterial and liposome preparation.
- Nanomaterial purification and concentration.
- Surface modification and coating.
- Functionalization with antibodies, proteins, peptides, nucleic acids, or other biomolecules.
- Nanomaterial incorporation into diagnostic devices, including lateral flow assays.
- Drug loading, binding, and release studies.
- Cellular uptake, toxicity, and biological interaction studies.
- Characterization and analytical preparation of nanomaterials.
- Handling, weighing, packaging, drying, milling, or transferring dry nanomaterials.

4. Responsibilities

A. Department Administration

- Set performance expectations, manage laboratory safety risks, and ensure the department adheres to these guidelines and other environmental and occupational safety laws, regulations, and policies.
- Ensure that the affected department's personnel and students have received the appropriate safety training on the safe use of nanomaterials.
- Ensure prompt reporting and appropriate investigations of incidents involving nanomaterials.

B. Faculty, Staff, and Students

- Understand and comply with the requirements of these guidelines.
- Complete all required safety training as assigned.

C. Environmental Health and Safety (EHS)

- Develop safety guidelines for nanomaterial work and revise them as needed.
- Conduct hazard assessments of the existing and the proposed processes and advise colleges and departments on the appropriate safety control measures.
- Develop and provide training on the safe use of nanomaterials.
- Conduct routine inspections to ensure the proper use of nanomaterials.

5. Requirements

A. Hazard Identification and Risk Assessment

When determining the appropriate controls for any work using nanomaterials, the hazards of the material and the procedure must be evaluated and taken into consideration. Examples of hazards which must be evaluated are described below.

- **Nanomaterial Hazards**

  Engineered nanomaterials may exhibit unique physical, chemical, and biological properties that differ from their bulk counterparts due to their small size, increased surface area, and enhanced reactivity. This guidelines document applies to a broad range of nanomaterials including, but not limited to:

  - Metal nanomaterials (e.g., gold, silver)
  - Metal oxide nanomaterials (e.g., iron oxide, titanium dioxide)
  - Core-shell nanomaterials
  - Polymeric nanomaterials
  - Liposomes and lipid-based nanomaterials
  - Functionalized nanomaterials and nanomaterial-bioconjugates

  Nanomaterials may be encountered as suspensions, gels, powders, coatings, or materials incorporated into diagnostic devices and research substrates. In addition, certain nanomaterials may exhibit increased combustibility, explosivity, catalytic activity, or chemical reactivity compared to larger-particle forms of the same material. Dry nanopowders should receive additional hazard evaluation before use.

- **Biological and Functionalization Hazards**
  The hazards associated with both the nanomaterial and the functionalization reagents must be evaluated prior to initiating work. Additional approvals and biosafety review may be required when nanomaterials are used in cellular, toxicological, or biological studies. Many nanomaterial research activities involve:
    - Antibodies
    - Proteins
    - Peptides
    - Crosslinking agents
    - Surface modifiers
    - Polyethylene glycol (PEG) derivatives
    - Polymer coatings

- **Exposure Routes**
  When working with nanomaterials, opportunities for exposure are numerous, and each procedure performed must be evaluated for the potential exposure routes listed below.
    - Inhalation of airborne nanomaterials or aerosols
    - Skin contact with nanomaterial-containing suspensions or powders
    - Eye contact with nanomaterial solutions or reagents
    - Accidental ingestion from contaminated hands or surfaces

  As inhalation is a primary exposure route for nanomaterials, procedures which may potentially generate airborne particles or aerosols, including centrifugation and sonication must be evaluated with special care.

- **Procedural Hazards**
  Activities with elevated exposure potential include:
    - Nanomaterial synthesis
    - Sonication
    - Centrifugation
    - Transfer of nanomaterial suspensions
    - Surface coating and functionalization
    - Filtration and purification
    - Drying or concentration of nanomaterials
    - Spill response and waste handling
    - Lyophilization
    - TEM or SEM sample preparation

- **Risk Assessment**
  Risk assessments for work with nanomaterials must be performed to identify the likelihood of the exposure and the potential severity of the outcome to determine the risk level. Table 1 shows general examples to assist with performing lab-specific risk assessments. Actual risks shall be determined through task-specific risk assessments. Once the risk of a procedure is determined, appropriate controls must be selected to mitigate the risk.

Table 1. Example Hazard Assessment Matrix.

Hazard	Likelihood	Severity	Risk Level
Aerosol generation during sonication	Possible	Major	High
Aerosol release during centrifugation	Possible	Moderate	Medium
Inhalation exposure to suspended nanomaterials	Possible	Major	High
Chemical exposure from precursor reagents	Possible	Major	High
Exposure during nanomaterial coating or functionalization	Possible	Moderate	Medium
Exposure during cellular uptake or biological studies	Possible	Moderate	Medium
Environmental release	Unlikely	Major	Medium
Improper waste disposal	Possible	Moderate	Medium

B. Personnel Training and Competencies

- **Training**:
  The Principal Investigator (PI) is responsible for providing laboratory-specific training and ensuring personnel are competent to perform assigned tasks. Training shall be documented and refreshed annually, whenever procedures or materials change, or following an incident or identified safety concern. Only trained and authorized personnel may independently work with nanomaterials. Training shall include:
  - Laboratory Safety Training
  - Review of applicable Safety Data Sheets and laboratory-specific SOPs.
  - Nanomaterial hazards, exposure routes, and control measures.
  - Proper use of engineering controls and PPE.
  - Spill response, waste management, and emergency procedures.

- **Competencies**:
  Only trained laboratory personnel may handle engineered nanomaterials. Required competencies include:
  - Understanding nanomaterial hazards and exposure routes.
  - Knowledge of equipment used in nanomaterial synthesis and processing.
  - Emergency response procedures for spills, and exposure incidents.
  - Documented proficiency with laboratory-specific SOPs and protocols.
  - Personnel must complete hazard-specific training, including annual refresher sessions.

C. Control Measures

- **Engineering Controls**:
    - Conduct nanomaterial synthesis, purification, coating, and functionalization activities inside a chemical fume hood whenever practical.
    - Sonication of nanomaterial suspensions shall be conducted in a manner that minimizes the potential for aerosol generation and exposure. When using sealed or capped containers in a bath sonicator, benchtop operation is generally acceptable. Activities with a greater potential for aerosol release, such as probe sonication or sonication of open containers, shall be performed in a chemical fume hood or other approved containment device.
    - Dry nanopowder handling shall be performed in a chemical fume hood, glove box, or other containment system approved by EHS.
    - Use sealed centrifuge tubes and inspect tubes for leakage or damage before opening. When aerosol generation is suspected, open tubes within a chemical fume hood or other appropriate containment device. Additional precautions may be required based on nanomaterial, process, and risk assessment.
    - Utilize secondary containment for nanomaterial transport and storage.
    - Use local exhaust ventilation, enclosed HEPA-filtered containment systems, or glove boxes for operations with increased aerosol generation potential. Biological safety cabinets may be used when biological containment is required and when compatible with the hazards of the nanomaterials and chemicals involved.
    - Recirculating clean benches and laminar flow hoods shall not be used for operations that may generate airborne nanomaterial contamination.
    - Consult EHS prior to performing any work involving dry nanomaterial powders, large-scale synthesis, spray applications, or engineered nanomaterials with elevated toxicity concerns.

- **Administrative Controls**:
    - Complete a task-specific risk assessment before beginning nanomaterial work.
    - Maintain laboratory-specific SOPs for synthesis, coating, functionalization, characterization, and biological applications.
    - Review applicable SOPs and Safety Data Sheets before beginning work.
    - Minimize the quantities of nanomaterials synthesized or stored.
    - Label all nanomaterial primary and secondary containers with the material identity, hazards, and the descriptor "Nano."
    - Verify engineering controls are functioning properly.
    - Inspect personal protective equipment (PPE) and equipment prior to use.
    - Keep nanomaterial suspensions in sealed, properly labeled containers when not actively in use.
    - Designate and clearly identify nanomaterial work areas. Limit access to personnel involved in the activity and minimize unnecessary traffic or unrelated work in the immediate area during active nanomaterial operations.
    - Use secondary containment when transporting nanomaterials.
    - Use good housekeeping practices and decontaminate work surfaces at the completion of work and anytime contamination or small spills occur.
    - Avoid generating dry powders whenever possible by maintaining nanomaterials in suspension or immobilized formats.

- Conduct work in a manner that minimizes the generation of nanomaterial aerosols or dust.
- Dispose of nanomaterial-containing waste through approved hazardous waste procedures.
- Wash hands thoroughly after handling nanomaterial-containing materials and before leaving the laboratory.
- Report incidents, exposures, spills, or unsafe conditions to the Principal Investigator or area supervisor immediately and follow University Incident Reporting Procedures.
- Never eat, drink, chew gum, apply cosmetics, or handle contact lenses in spaces where nanomaterials are used.

- **Personal Protective Equipment (PPE)**:

  The following PPE are required when working with engineered nanomaterials, as a minimum. Additional PPE may be required based on specific materials, processes, and exposure potential.
  - Eye protection: safety glasses with side shields; chemical splash goggles when splash hazard exists.
  - Body protection: lab coat, long pants, closed-toe shoes.
  - Hand protection: Appropriate glove selection shall be based on compatibility with both nanomaterials and associated chemical hazards. Double-gloving may be required during certain operations.
  - Respiratory protection: respirators shall only be used in accordance with the KSU Respiratory Protection Program and after consultation with EHS.

D. Waste Management

Nanomaterial waste shall be managed as hazardous waste unless otherwise approved by EHS.

- Collect nanomaterial suspensions, contaminated PPE, wipes, filters, and cleanup materials in sealed, compatible containers.
- Label all waste containers with the material name, hazards, and the term **"Nano"**.
- Keep waste containers closed when not in use and store in appropriate secondary containment.
- Clean nanomaterial contamination using wet wiping methods or HEPA-filtered vacuum systems. Do not dry sweep or use compressed air.
- Do not dispose of nanomaterials or nanomaterial-containing waste in sinks, drains, regular trash, or recycling containers. Nanomaterial-containing liquid waste shall not be discharged to sinks, drains, or sanitary sewer systems.
- Contact EHS for collection and disposal in accordance with KSU hazardous waste procedures.

E. Emergency Response and Incident Reporting

- **Emergency Equipment and emergency preparedness:**

- Personnel shall be familiar with the location and proper use of emergency equipment, including eyewash stations, safety showers, fire extinguishers, spill kits, and emergency exits.
- Personnel shall report damaged, missing, or inaccessible emergency equipment to the PI or area supervisor immediately.
- In the event of any emergency, including spills, exposure, or fires, call public safety (470-578-6666) immediately. This will activate the necessary emergency response and alert EHS and other first responders as appropriate for the incident.

- **Spill response:**
  - Small spills are spills of liquid nanoparticles that can be managed by trained personnel, do not involve significant airborne release, and do not present an immediate threat to personnel, property, or the environment. In the case of a small spill:
    - Stop work and notify nearby personnel.
    - Restrict access to the affected area.
    - Call Public Safety (470-578-6666) to give a notification of the incident.
    - Allow airborne particles or aerosols to settle before beginning cleanup.
    - Don appropriate PPE.
    - Clean liquid spills using absorbent materials or wet wiping methods. Do not attempt to dry sweep or use compressed air to treat nanomaterial spills.
    - Collect cleanup materials in a compatible waste container labeled with the material name and the designation "**Nano".**
    - Decontaminate affected surfaces using appropriate cleaning methods.
    - Dispose of all contaminated materials through approved hazardous waste procedures.
    - Report the incident following incident reporting procedures.

  - Large spills include releases involving dry nanopowders, significant aerosol generation, unknown exposure conditions, or any spills involving highly hazardous chemicals used with the nanoparticles. Only trained personnel using appropriate controls and PPE may respond to large nanomaterial releases. In the case of a large spill:
    - Stop work and notify nearby personnel.
    - Evacuate and isolate the area.
    - Call Public Safety (470-578-6666) to give a notification of the incident and notify the PI or area supervisor.
    - Await further instructions from emergency responders or EHS personnel.
    - Submit an incident report following incident reporting procedures.

- **Exposure response:**
  - Skin contact:
    - Remove contaminated gloves, clothing, or PPE immediately.
    - Wash affected skin thoroughly with soap and water.

        - Continue washing for a minimum of 15 minutes.
        - Call Public Safety (470-578-6666) to give a notification of the incident and notify the PI or area supervisor.
        - Seek medical evaluation if irritation, injury, or symptoms occur.

    - Eye exposure:
        - Immediately flush eyes using an eyewash station, holding eyelids open while flushing.
        - Continue flushing for a minimum of 15 minutes.
        - Obtain prompt medical evaluation.
        - Call Public Safety (470-578-6666) to give a notification of the incident, and notify the PI or area supervisor.

    - Inhalation:
        - Stop work immediately.
        - Move to fresh air.
        - Seek medical evaluation if symptoms develop or if significant exposure is suspected.
        - Contact emergency medical services if difficulty breathing occurs.
        - Call Public Safety (470-578-6666) to give a notification of the incident and notify the PI or area supervisor.

    - Ingestion:
        - Rinse mouth thoroughly with water.
        - Do not induce vomiting unless directed by medical personnel.
        - Seek immediate medical evaluation.
        - Provide information regarding the nanomaterial and associated chemicals involved.
        - Call Public Safety (470-578-6666) to give a notification of the incident and notify the PI or area supervisor.

- **Fire response:**
  Certain nanomaterials, particularly dry nanopowders, may exhibit increased combustibility, dust explosion potential, or enhanced chemical reactivity compared to bulk materials. If a fire occurs:
    - Activate the building fire alarm if required.
    - Call Public Safety (470-578-6666) to give a notification of the incident and notify the PI or area supervisor.
    - Evacuate the area according to building evacuation procedures.
    - Close doors to the affected area if it can be done safely.
    - Proceed to the designated assembly location.
    - Do not re-enter the building until authorized.

- **Incident Reporting:**
  All safety incidents must be documented and reported immediately through the university's incident reporting process.

- Report fires, spills, equipment failures, and near-misses to the Lab Manager and EHS.
- Complete an incident report within 24 hours.
- EHS will investigate the incident to identify the root cause and make recommendations for appropriate corrective actions.

F. Document Control

- This guideline will be reviewed annually by Environmental Health & Safety (EHS) and updated to reflect new hazards, equipment changes, or regulatory requirements.