geotech

**Welcome to the Geotech XRF Safety and Operation Training.**

As a distributor of X-ray fluorescence (XRF) analyzers, we've developed this self-study presentation to ensure you, our customers, have the knowledge for safe handling and proper operation of your instrument. Upon completion, you will be directed to a quiz, and a Certificate of Completion will be issued upon passing with a score of 70% or better.

If you have any questions, please contact our main office at 800-833-7958.

# Geotech Environmental Equipment, Inc.

**800-833-7958 www.geotechenv.com**

Your complete source for performance-driven environmental equipment and supplies.

# Safety Training for Tube-Based XRF Instruments

Learning Objectives

- Radiation Exposure
- Measuring Dose Exposure
- Exposure Reduction (ALARA)
- XRF Basics
- Safety and Responsibility

# XRF Safety Training Definitions

| Dose Type | Definition | Traditional Unit | SI Unit |
|---|---|---|---|
| Absorbed Dose | The concentration of energy deposited in tissue because of exposure to radiation | RAD (Radiation Absorbed Dose) | Gray (Gy) |
| Dose Equivalent | The absorbed dose adjusted to account for the potential biological damage of the specific type of radiation (which is critical for setting safety limits | REM (Roentgen Equivalent Man) | Sievert (Sv) |

# 🔬 XRF Safety Training Glossary

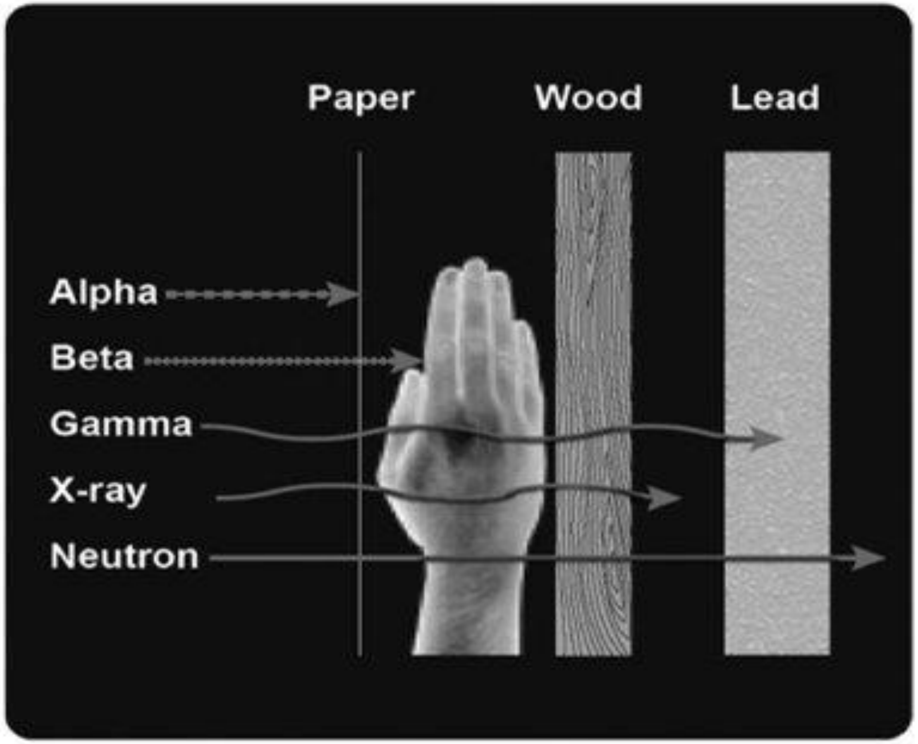
| Term | Definition for XRF Training |
|---|---|
| Radiation | The emission of energy (as invisible waves or moving subatomic particles) that is powerful enough to cause ionization—a key factor in biological risk. |
| Ionization | The process where an atom or molecule gains or loses an electron, giving it a negative or positive electrical charge. This change can damage or alter the chemical structure of living cells. |
| XRF (X-ray Fluorescence) | A process where a material, when bombarded with high-energy primary X-rays, emits its own characteristic "secondary" or fluorescent X-rays. |

# Brief Examples and Common Sources for each Type of Ionizing Radiation

| Radiation Type | Description | Common Example/Source |
|---|---|---|
| **Alpha (alpha) Particles** | Heavy, positively charged particles (2 protons, 2 neutrons). They are the least penetrating. | **Smoke Detectors:** Americium-241 sources are used in common household smoke detectors. |
| **Beta (beta) Particles** | Small, fast-moving particles (electrons). They are more penetrating than alpha particles. | **Tritium Exit Signs:** Used in self-illuminating "EXIT" signs and glow-in-the-dark watch faces. |
| **Gamma (gamma) Rays** | High-energy electromagnetic photons originating from the atom's **nucleus** (pure energy, no mass or charge). They are very penetrating. | **Medical Sterilization:** Cobalt-60 sources are used to sterilize medical equipment and food. |
| **X-Rays** | High-energy electromagnetic photons originating from the atom's **electron shell** (pure energy, no mass or charge). They are very penetrating. | **Medical Imaging:** Used to take diagnostic images of bones (e.g., in a dental or hospital X-ray machine). |
| **Neutron Particles** | Uncharged (neutral) subatomic particles that are highly penetrating. | **Nuclear Reactors:** Released during nuclear fission (splitting of atoms) to sustain a chain reaction for power generation. |

# Brief Examples and Common Sources for each Type of Ionizing Radiation

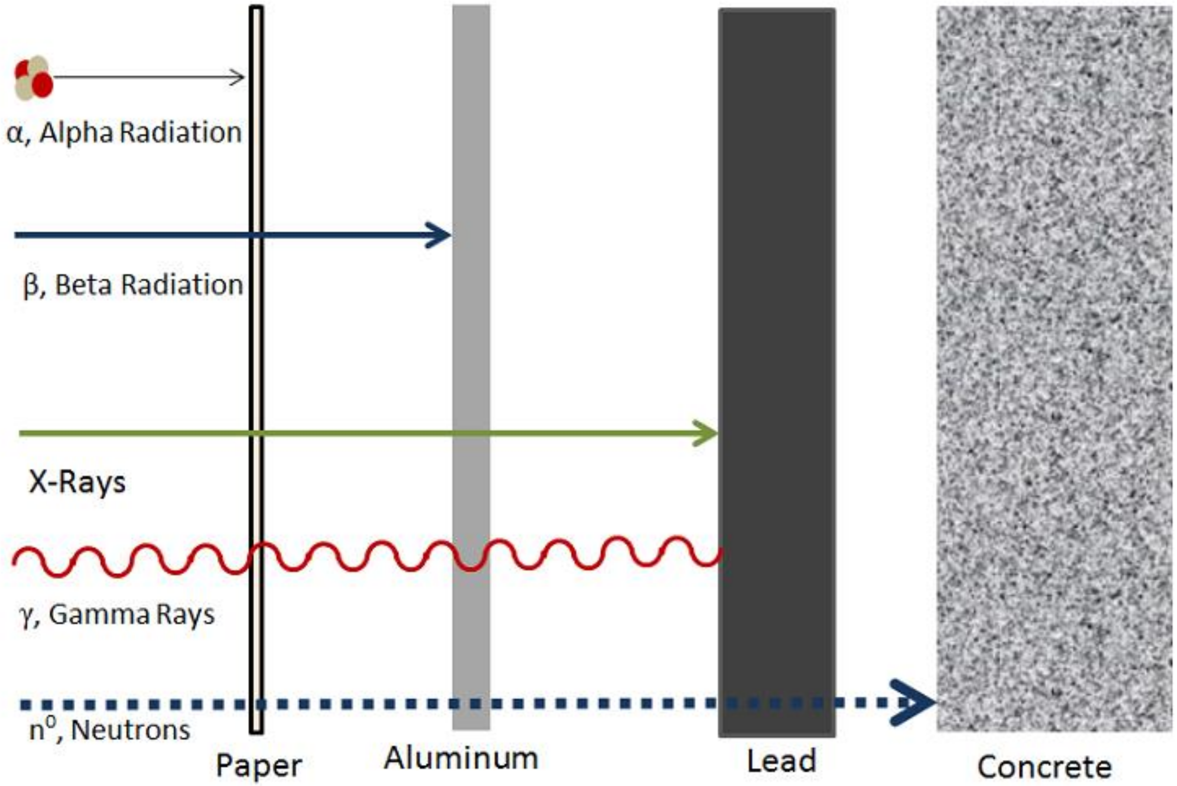
Note:
For this XRF training, both X-rays and Gamma rays are the most relevant types of XRF penetrating radiation.




U.S.NRC
As of July 2018

## Safety Training for XRF Instruments

Penetration: the power for each of the four basic radiations vary significantly, as shown here.



# Radiation Exposure (Dose) in Perspective

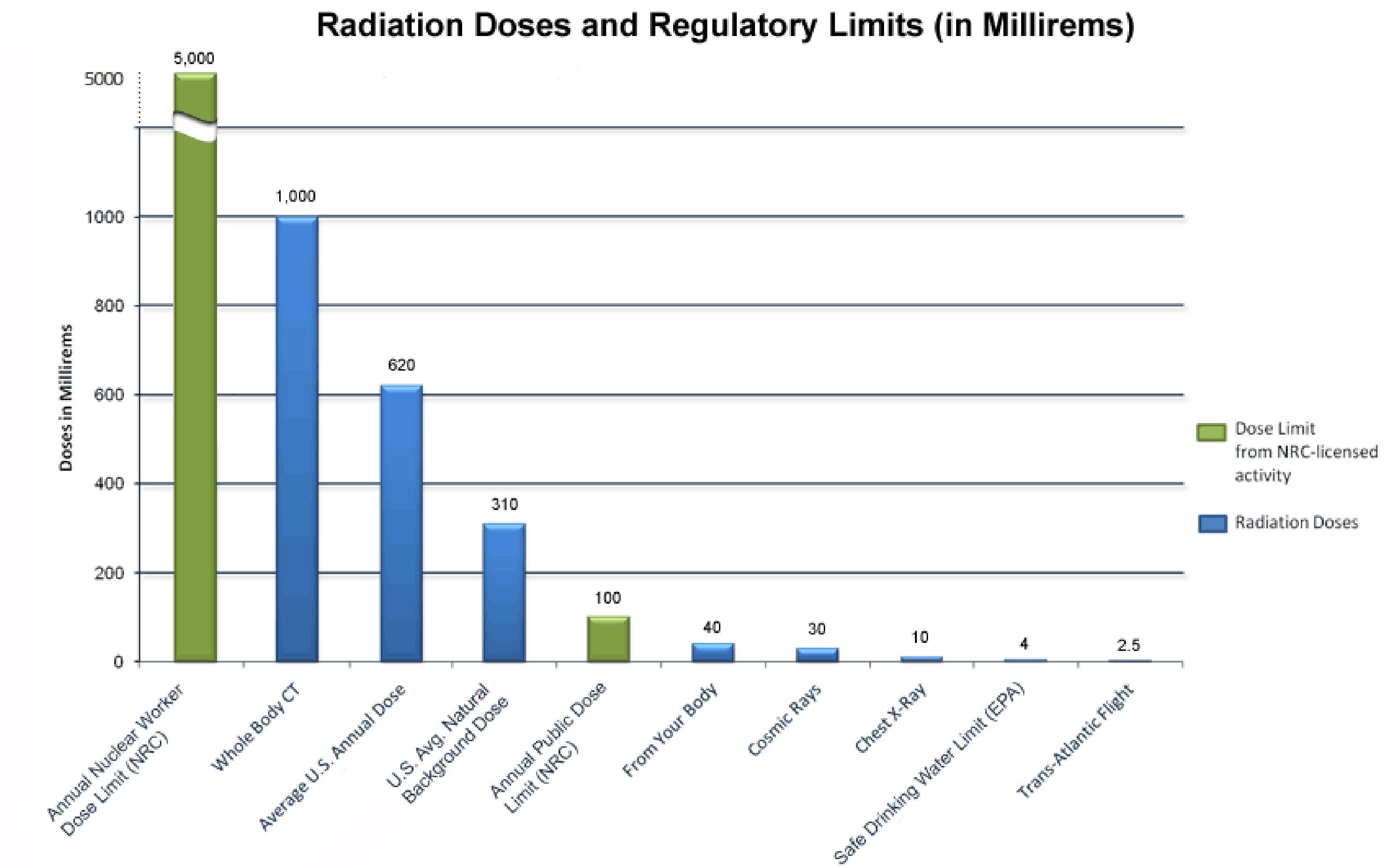
**Americans receive an average annual radiation dose of approximately 620 mrem (or 6.2 mSv) from all sources.**

**Where does this average dose come from?**

- Natural Background (About 310 mrems per year): Radiation from the environment, including cosmic rays (from space), terrestrial radiation (from the earth/soil), and radon gas.
- Man-Made Sources (About 310 rems per year): Primarily medical procedures, such as CT scans and nuclear medicine treatments.

Goal of XRF Safety: Your occupational dose from operating the XRF analyzer is managed to be **As Low As Reasonably Achievable (ALARA)** and is a small fraction of the total limit for radiation workers.

# Radiation Exposure (Dose) in Perspective



# 🚧 Occupational Dose and Exposure Limits

## 1. Defining "Occupational Dose"

**Occupational Dose** is the amount of radiation exposure an individual receives specifically because of their assigned job duties. It does not include doses from background sources (like the earth or medical procedures).

- **Effective Dose (Whole Body Dose):** The dose limit used to manage the long-term risk of cancer (called stochastic effects). It accounts for the varying sensitivity of different organs and tissues.
- **Equivalent Dose (Organ/Tissue Dose):** The dose limit used to prevent immediate tissue injury or organ damage (called deterministic effects). It applies to specific sensitive areas.

Bruker S1 Titan Broad Metals XRF Analyzer

# 🚧 Occupational Dose and Exposure Limits

## 2. Key Dose Limits for Adult Radiation Workers

Regulatory agencies set strict annual limits (U.S. Nuclear Regulatory Commission standards shown below) to ensure worker safety.

The following slide is a summary of the current major annual occupational dose limits for adults in the United States, as established by the Nuclear Regulatory Commission (NRC) in **10 CFR Part 20**.

# 🚧 Occupational Dose and Exposure Limits

## 2. Key Dose Limits for Adult Radiation Workers

| Organ or Tissue | Dose Equivalent Limit (Annual) | Notes on Measurement |
|---|---|---|
| **Whole Body** (Total Effective Dose Equivalent - TEDE) | **5 rems** | Sum of external and internal whole-body doses. This is the overriding limit. |
| **Skin of the Whole Body** (Shallow-Dose Equivalent) | **50 rems** | Dose averaged over the contiguous 10 cm2 of skin receiving the highest exposure. |
| **Hands, Forearms, Feet, and Ankles (Extremities)** (Shallow-Dose Equivalent) | **50 rems** | This limit applies to the skin and tissues of the extremities, which include the hands and forearms. |
| **Lens of the Eye** (Lens Dose Equivalent) | **15 rems** | Dose equivalent at a tissue depth of .3 cm. |
| **Any Individual Organ or Tissue** (Total Organ Dose Equivalent - TODE) | **50 rems** | Sum of deep-dose equivalent and committed dose equivalent to the organ/tissue. |

# Understanding Radiation Risk and Dose Limits

The Low-Dose Challenge (Stochastic Effects)

When humans are exposed to low levels of ionizing radiation (doses typically below 100 mSv or 10 rem, the health effects—primarily an increased risk of cancer—are classified as stochastic effects.

- Risk vs. Observation: The risk of an individual contracting cancer from a low dose is extremely small. The effect is often considered non-existent or too small to be reliably observed in epidemiological or medical studies.

Regulatory Protection: Preventing Harm

Regulatory authorities establish occupational dose limits to ensure that workers are not exposed to radiation levels known to be hazardous. The core principle of radiation protection is to keep doses As Low As Reasonably Achievable (ALARA), and always below these mandated limits.

# 🎯 The Critical Difference: Dose Rate

It is fundamentally true that all radiation, if received in sufficient quantity and concentration, can damage living tissue. The key factor is not just the total dose, but how much and how quickly a dose is received, which defines the dose rate.
Doses of radiation fall into two main categories based on the time frame of exposure: Acute & Cronic

**1. Acute Exposure (High Dose, Short Time)**

- An acute dose is a large dose of radiation received over a short period (minutes to hours).
- Health Effect: Acute exposure is associated with deterministic effects, where cell death leads to observable, non-random injuries, such as skin burns or Acute Radiation Syndrome (ARS). These effects have a threshold dose—a dose below which the effect does not occur.

Example: Receiving a whole-body dose of 100 rads in a matter of minutes.

# 🎯 The Critical Difference: Dose Rate

Doses of radiation fall into two main categories based on the time frame of exposure: Acute & Chronic

**2. Chronic Exposure (Low Dose, Long Time)**

- A chronic dose is a small dose of radiation received repeatedly over a long period (months or years).
- Health Effect: Chronic exposure generally only leads to stochastic effects. Because the dose is spread out, the body's natural repair mechanisms have time to fix much of the cellular damage, preventing acute injury.

**Example:** A nuclear power plant worker receiving 0.5 rem per year over a 20-year career.
The difference in dose rate is why receiving a single, large dose of 500 rems is deadly, but receiving that same total dose spread out over 50 years would likely cause no acute effects.

## ALARA (As Low As Reasonably Achievable)

The ALARA principle is the fundamental philosophy of radiation safety, stating that even though occupational dose limits are legally established and ensure minimal risk, all radiation doses must be kept as far below those limits as possible. This involves a continuous effort to reduce exposure.

The ALARA program exists in addition to legally mandated dose limits (e.g., 5 rems annual whole-body dose) and internal administrative control levels (ACLs), which are internal benchmarks set by an organization, usually at 10% of the regulatory limit, to trigger investigation and dose reduction efforts.

# The Three Pillars of ALARA

1. **Time**

   **Principle: Minimize the time spent** near a radiation source.

   Application: Since the dose received is directly proportional to the exposure time, reducing the time you are exposed proportionally reduces your total dose. This means planning work carefully, practicing complex tasks beforehand, and ensuring the source is off or shielded whenever possible.

2. **Distance**

   **Principle: Maximize the distance** between yourself and the radiation source.

   Application: Radiation intensity decreases rapidly with distance according to the Inverse Square Law. Doubling the distance from a point source reduces the dose rate by a factor of four. Using long-handled tools or remote manipulation is highly effective.

3. **Shielding**

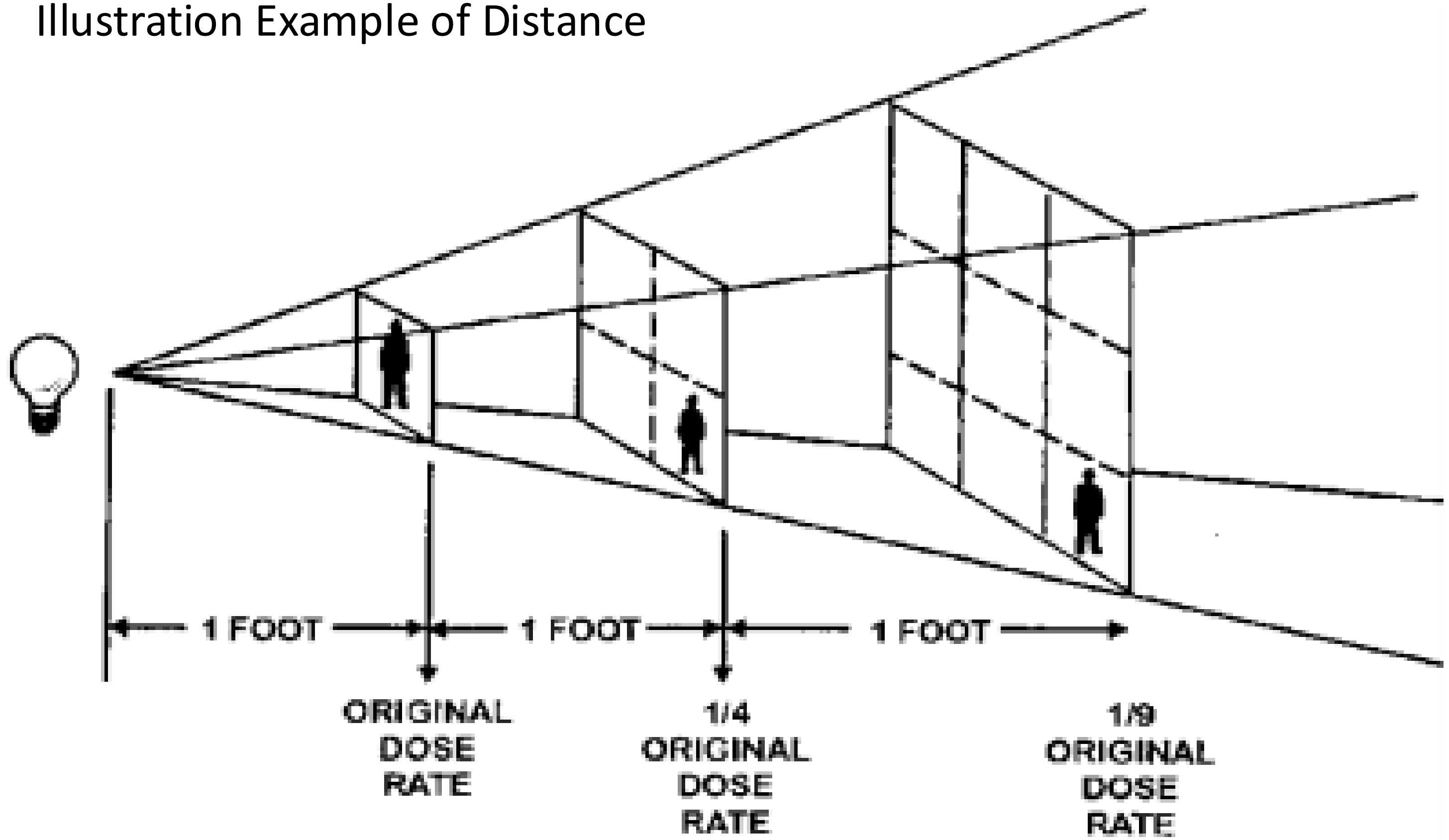
   **Principle: Place a physical barrier** between yourself and the radiation source.

   Application: Shielding materials absorb radiation, reducing the dose that reaches the worker. The material used depends on the type of radiation:

   - High-Z materials (like lead, tungsten, or concrete) are used to shield gamma rays and X-rays.
   - Low-Z materials (like plastic or water) followed by heavier materials are often used to shield beta and neutron radiation.

# ALARA (As Low As Reasonably Achievable)

Illustration Example of Distance



# Dosimeters: Measuring Radiation Exposure

Image By: The XRF Company

- Dosimeters are essential monitoring tools because humans cannot sense radiation. They measure the dose received but do not provide protection.

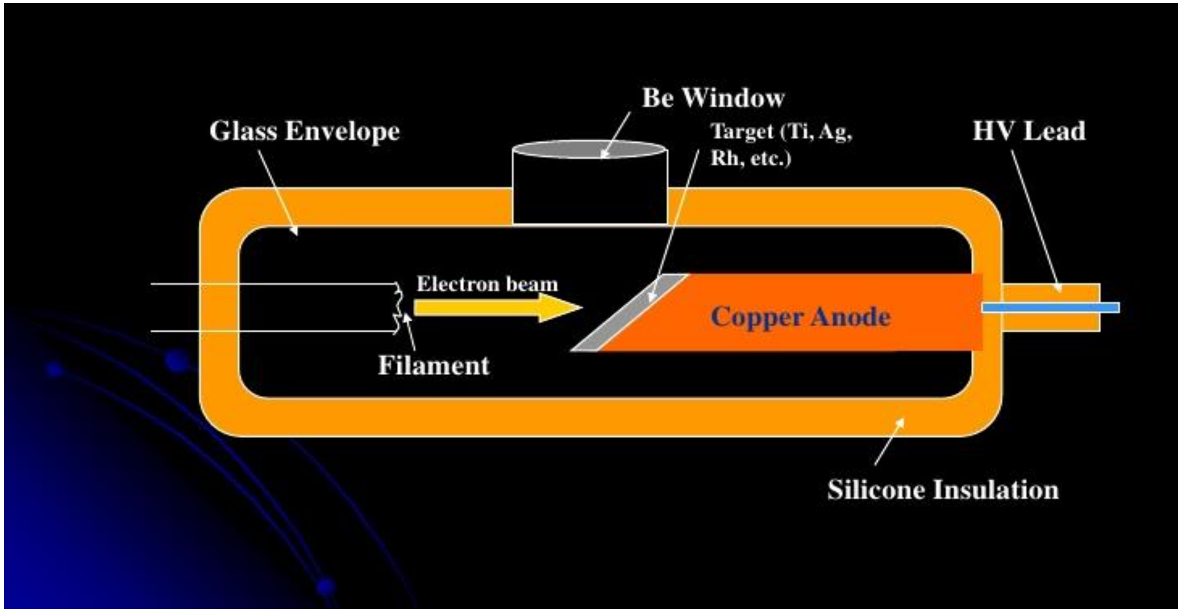
# Dosimeters: Measuring Radiation Exposure

| Topic | Key Information |
|---|---|
| **Function** | A dosimeter is a passive device containing a material (e.g., crystal or film) that absorbs and records ionizing radiation exposure. It is processed by a specialized, accredited company (e.g., NVLAP accredited) to determine the measured dose. |
| **Requirements** | Dosimetry may be required for personnel operating XRF Analyzers, subject to local regulations. Monitoring is typically required for a three-month period. |
| **Placement** | * Whole Body Dosimeter: Worn on the upper body (chest or torso).<br><br>* Extremity Dosimeters: Worn on the fingers or wrist (often required for handheld XRF operators due to proximity to the primary beam). |
| **Handling Rules** | * **DO NOT** expose the dosimeter to the XRF primary beam. |
| | * **DO NOT** expose it to non-work related radiation sources (e.g., medical procedures). |
| | * **DO NOT** pack the dosimeter in checked or carry-on luggage (ship separately). |
| | * **NOTIFY** your supervisor or RSO immediately if the dosi**meter is damaged or lost.** |

# 💡 Miniature X-Ray Tube Components and Function

A modern miniature industrial X-ray tube operates on the same principle as large X-ray sources, but within a compact, sealed ceramic container maintained under a high vacuum.

The tube relies on three primary components: the cathode, anode, and vacuum chamber.



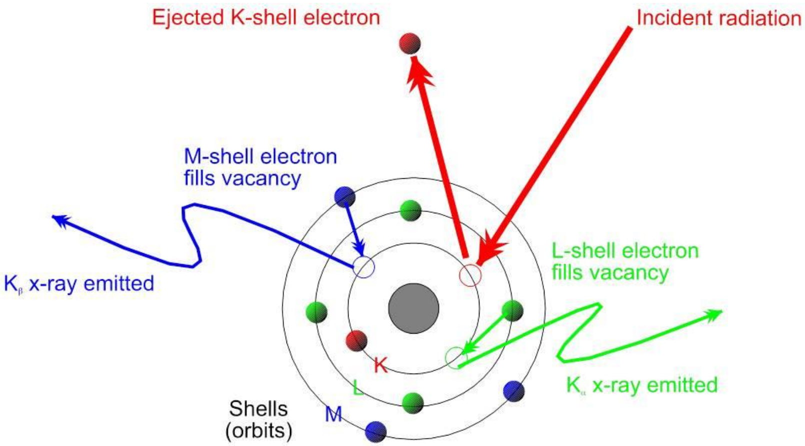
# Miniature X-Ray Tube Components and Function

The X-ray generation process involves three steps:

- Electron Emission (Cathode): A high-voltage bias is applied between the anode and cathode. The tungsten filament (part of the cathode, or negative terminal) is heated, causing it to emit electrons (thermionic emission).

- Acceleration: These electrons are attracted to the highly positive charge of the anode and are accelerated across the vacuum gap. The high voltage potential, typically between 40 to 50 keV (kiloelectron volts), imparts a large amount of kinetic energy to the electrons.

- X-ray Production (Anode/Target): The high-kinetic-energy electrons violently impact the X-ray producing target (part of the anode, or positive terminal). When the electrons rapidly decelerate upon impact, their energy is converted into X-rays (Bremsstrahlung) and characteristic X-rays.



# Handheld XRF Safety: Your Responsibility

As the operator, you are the primary safety control. You are responsible for your own safety and the safety of everyone around you.

1. Immediate Pre-Use Checks (Before Pulling the Trigger)

These actions prevent direct exposure to the X-ray beam:

- Directional Awareness: Be aware of the direction the X-rays travel and the beam's hot spot.
- Keep Clear: Move all body parts (hands, fingers, legs, eyes) away from the examination area and out of the primary beam path.
- Secure Samples: NEVER hold a sample being analyzed by hand. Use a benchtop stand, tripod, or a flat, secure surface.
- Area Control: Be aware of others near the examining area and restrict access.
- Safety Features: NEVER attempt to defeat or bypass the proximity sensor or any other safety interlock circuit.
- Shielding: Use the optional safety shield or benchtop stand whenever possible.

# Handheld XRF Safety: Your Responsibility

2. Operational & Security Responsibilities

These actions ensure continuous regulatory compliance and instrument integrity:

- Training & Authorization: Ensure you are trained and certified to operate the analyzer.
- Dosimetry: Be aware of and comply with local dosimeter regulations. Wear your assigned dosimeter correctly.
- Pregnancy Risk: If pregnant, be aware of the specific risks and contact your Radiation Safety Officer (RSO) regarding required fetal dose limits.
- Inspection: Inspect the analyzer for damage before each use.
- Security: You are responsible for the security of the analyzer at all times. Always store the instrument in a secure, designated location when not in use.

3. Action for Damage

- If you suspect the analyzer is damaged:
  - Remove the battery pack and disconnect all power sources.
  - Contact Geotech immediately (or the designated company/RSO).

# ⚠️ Hazard Awareness: Low-Density Samples

Analyzing samples of low density (such as plastics, wood, soil, and ceramics) presents two distinct radiation hazards to the operator: Backscatter and Transmission.

1. **Backscatter Hazard** 💡

Backscatter is radiation that reflects off the sample surface back toward the operator.

- **Low-Density Effect**: When analyzing low-density (LD) materials, the amount of X-ray backscatter is higher than when analyzing dense materials like metal.
- **Sample Geometry**: Flat sample surfaces tend to reflect more backscatter toward the analyzer nosepiece than curved or irregular surfaces.

# ⚠️ Hazard Awareness: Low-Density Samples

Analyzing samples of low density (such as plastics, wood, soil, and ceramics) presents two distinct radiation hazards to the operator: Backscatter and Transmission.

## 2. Transmission Hazard ➡️

Transmission is the X-ray beam passing directly through the sample.

- **Low-Density Effect**: LD materials do not attenuate (absorb) high-energy X-rays efficiently. A significant amount of the beam can transmit through the sample, potentially causing a high dose rate to the operator or others on the far side of the sample.

## 3. Mitigation and Safe Practice 🛡️

- Mandatory: **NEVER** place hands, fingers, or eyes near the analyzer nosepiece or in the path of the beam.
- Best Practice for LD Samples: If low-density samples are measured frequently:
  - Use a Bench-Top Stand (highly recommended to maximize distance and shield the operator).
  - If samples are small, utilize the Small Sample Safety Shield.
  - Remember: Always consult the instrument's User Guide and your organization's Radiation Safety Plan before use.

# Radioactive Materials Licensing Authorities

## Nuclear Regulatory Commission (NRC) Agreement State”
## (Authorized by Agreement with the NRC)

The Occupational Safety and Health Administration (OSHA) has regulations limiting ionizing radiation dose to occupational workers that are consistent in magnitude to the NRC limits. OSHA does not license radioactive material. It has agreed to allow the NRC to regulate “OSHA workers’” exposure to radioactive materials.

# Geotech Environmental Equipment, Inc.

## 800-833-7958

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Open the XRF Safety Training Test using the link below.

- XRF Safety Quiz