



Environmental Health and
Radiation Safety

Radiation Safety Guide

Analytical X-Ray Equipment

Table of Content		Page
1.	Radiation	2
	A. Radiation Quantities	2
	B. Background Radiation	2
	C. Biological Effect of Radiation	3
	D. Radiation Injury To The Hands	3
2.	Radiation Protection	4
	A. Occupational dose limit	4
	B. Dose to an embryo/fetus	4
	C. Registration of Radiation Workers	4
	D. Badging and Dosimetry	4
	E. Dosimeter Placement	5
	F. Exposure Reports and ALARA	5
	G. Training	5
	H. Written Operating Procedure	5
	I. Posting	6
	J. Notification	6
	K. Registration	6
	L. Radiation Survey	6
	M. Additional Requirement For X-Ray Diffraction Unit	7
	N. Additional Requirement For Cabinet X-ray system	7
Appendix A.	Radiation Worker Registration form	8
Appendix B.	Notice to Employees	9
Appendix C.	Accidental Radiation Injury To The Hand	10

1. RADIATION

Radiation is described as a bundle of energy in the form of electromagnetic waves. These bundles of energies are called photons. X-rays and visible light are both a form of electromagnetic radiation. However, X-rays used for imagining have significantly higher energy photons than visible light approximately 10,000 times higher. X-rays photons are energetic enough that they can disrupt the chemical bond and causes ionization. X-rays are one type of ionization radiation. Visible light does not have sufficient energy to cause ionization. Visible light is one example of non-ionizing radiation.

A. Radiation Quantities

Exposure is a measure of the ionization produced in air by x or gamma radiation. The conventional unit of exposure is the roentgen(R). The international unit (SI) of exposure is C/Kg. The effect that radiation has on any material is determined by the "dose" of radiation that the material receives. Radiation dose is simply the quantity of radiation energy deposited in a material. Absorbed dose is the amount of energy deposited in any material by ionizing radiation. The unit of absorbed dose, the rad, is a measure of energy absorbed per gram of material. The SI unit of absorbed dose is the gray. The dose equivalent is a measurement of the effectiveness of the absorbed dose. It expresses all radiations on a common scale for calculating the effective absorbed dose. The unit is rem. Rem is a multiplication of the absorbed dose by a quality factor that depends on the type of radiation. The quality factor is 1 for X-ray exposure. The SI unit of dose equivalent is the sievert. The conversions between conventional units and SI units are listed below:

Quantity	Conventional unit	(SI) unit	Conversion
Exposure	roentgen (R)	Coulomb/Kg of air (C/kg)	1 C/kg = 3876 R 1R = 2.58X10 ⁻⁴ C/kg
Dose	rad (100 ergs/g)	gray (Gy)	1 Gy = 100 rad 1cGy = 10 ⁻² Gy = 1 rad
Dose equivalent	rem (rad X quality factor(Q))	sievert (Sv) (Gy X Q)	1 Sv = 100 rem

The table below is the lists the smaller units that are commonly used in the academic environment.

Quantity	unit	conversion
Exposure	milliroentgen (mR)	0.001 R
Dose	millirad (mrad)	0.001 rad
Dose equivalent	millirem (mrem)	0.001 rem

B. Background Radiation

Radiation is all around us, occurring naturally in the environment. We are exposed to radiation from radon in the air all the time; uranium, radium and thorium in the earth; cosmic rays from outer space and the sun; radioactive potassium in our food and water; and radioactive material within our own bodies. This is commonly called naturally-occurring background radiation.

An individual in the United States is exposed to the average background radiation of about 300 mrem per year. Background radiation varies depending on the area where you live, the type of housing construction you live in, and what you eat. For instance, Colorado has higher radiation levels because, at its high altitude, there is more exposure to cosmic rays and with its naturally-occurring uranium enriched soil, there is more terrestrial radiation. Brick homes have higher natural radiation levels than homes made of other

materials such as wood; domestic water supplies naturally contain radon; and certain foods such as bananas and Brazil nuts naturally contain higher levels of radiation than other foods. In addition, consumer products such as tobacco, fertilizer product and coal have noticeable concentrations of naturally-occurring radionuclides including potassium-40.

C. Biological Effect of Radiation

Biological effects of radiation on living cells may result in three outcomes:

- cells repair themselves, resulting in no damage;
- cells die, much like millions of body cells do every day, being replaced through normal biological processes; or
- cells change their reproductive structure.

The effects of radiation, like those of most chemical substances, can be seen clearly only at doses much higher than are allowed by Federal and State regulations.

Biological effects of radiation may be classified as prompt or delayed. Prompt effects can appear in a matter of minutes to as long as a few weeks after exposure to very high doses of radiation. The higher the dose, the sooner the effects will appear, and the higher the probability of death. For example, in 1986, firefighters battling the fire at the Chernobyl nuclear power plant in the Ukraine died from very large doses approximately 1,100,000 millirad of radiation.

Because radiation affects different people in different ways, it is not possible to indicate what dose is needed to be fatal. However, it is believed that 50% of a population would die within thirty days after receiving a dose over a period of a few minutes to hours of between 250,000 to 450,000 mrem. This would vary depending on the health of the individuals before the exposure and the medical care received after the exposure. These are acute whole body doses, meaning that the whole body is exposed to the radiation in a very short period of time (minutes to hours). Exposure of only parts of the body will likely lead to more localized effects, such as skin burns or tissue damage in the exposed area.

Delayed effects of radiation are effects that appear many years (usually between 5-20 years) after exposure. The period before cancer appears is known as the latent period. Genetic effects and the development of cancer are the primary health concerns. The cancers that may develop as a result of radiation exposure are indistinguishable from those that develop spontaneously or as a result of exposure to other carcinogens. Radiation exposure may be only the initiating step that may or may not eventually lead to cancer. Genetic effects may appear in the exposed person's direct offspring, or may appear several generations later, depending on whether the altered genes are dominant or recessive.

D. Radiation Injury To The Hands

There are documented radiation induced injuries to dermal cells by individuals repairing or manipulating analytical X-ray devices when safety interlocks are bypassed. (Appendix C)

2. RADIATION PROTECTION

Minimizing radiation exposure to the public and persons whose work involves exposure requires trained and experienced workers using good safety practices and equipment with proper safety features, in appropriately shielded facilities.

A. Occupational dose limit

The annual dose limit for occupational radiation workers is 5,000 mrem for whole body, 15,000 mrem for the lens of the eye and 50,000 mrem for organs (e.g. breast, lung), skin and extremities.

B. Dose to an embryo/fetus

The National Council on Radiation Protection and Measurements (NCRP) has recommended limits for radiation exposure to an embryo/fetus. The Nuclear Regulatory Commission (NRC) and the Department of Environmental Protection of the State of Pennsylvania (PA) have set limits for radiation exposure to the embryo/fetus of a declared pregnant woman. The NRC and PA require that the dose to an embryo/fetus during the entire pregnancy, from occupational exposure of a declared pregnant woman, must not exceed 500 mrem. Efforts must be made to assure that this dose is distributed uniformly over the entire period of pregnancy.

A pregnant employee is highly encouraged to voluntarily inform her employer, in writing, of her pregnancy and the estimated date of conception. Further, such an employee is encouraged to visit the Radiation Safety Department and receive information regarding concerns she may have about radiation exposure during pregnancy. Such an employee may discuss her concerns with the Health Physicist.

Upon submission of a completed "Declaration of Pregnancy" form (available at the Radiation Safety Department, 3307 N. Broad Street, # B 49), the Radiation Safety Department will:

- Evaluate the exposure history of the individual and her coworkers;
- Provide information concerning risk and precautions;
- Evaluate the working environment with respect to radiation exposure;
- Make recommendations for reducing radiation exposure;
- Monitor monthly radiation exposure with respect to the NRC and PA limits.

C. Registration of Radiation Workers

The Department of Environmental Protection of the State of Pennsylvania regulations require that those who work with analytical X-ray equipment are provided training, and are monitored for potential radiation exposure. In order to assure that the requirements of these regulations are met, a Radiation Worker Registry is maintained by the Radiation Safety Department (RSD). This registry includes, but is not limited to, those who are addressed by the Radiation Dosimetry Program. Appendix A is a copy of the Radiation Worker Registration form.

D. Badging and Dosimetry

The Radiation Safety Department uses personnel monitoring to identify inadequate or improper radiation safety practices and potentially serious radiation exposure situations. Ring Dosimeter are used to monitor

extremity exposure. Radiation exposure (individual radiation exposure as well as collective dose equivalent) must be kept as low as reasonably achievable. This so called "ALARA" principle has been introduced into the regulations of the U.S. Nuclear Regulatory Commission and the Pennsylvania Department of Environmental Protection, and has been adopted by our institution. The RSD will issue dosimeters when evaluation of equipment or workload reveal that the radiation dose to personnel could potentially be larger ALARA limits.

Exposure of a personnel monitoring device to deceptively indicate a dose delivered to an individual is prohibited and is a violation of Pennsylvania Department of Environmental Protection regulation. (PA 221.11.j)

E. Dosimeter Placement

Finger or wrist personnel monitoring devices must be worn by individuals who work with open beam analytical x-ray equipment without safety device or perform the maintenance procedures and the procedure require the presence of primary x-ray beam when safety devices are bypassed.

- Ring dosimeters are to be worn on the hand that receives the maximum exposure.
- Dosimeters must be return to RSD promptly at the end of the time period specified by the RSD.
- Individuals who are late in returning their dosimeters will be referred to the RADIATION SAFETY COMMITTEE (RSC) for proper disciplinary actions.

F. Exposure Reports and ALARA:

The Radiation Safety Department sends dose summary reports to the department on quarterly and an annual basis. These reports must be posted in a conspicuous location in the department. The Radiation Safety Department reviews exposure reports periodically. Subsequently, high or unusual exposures are reported to the Radiation Safety Committee. Written investigations by the RSD are performed when an individual's extremities dose exceeds 1800 mrem per quarter.

G. Training

Individuals who use analytical X-ray equipment must receive radiation safety training. In addition the primary researcher must provide training in

- Sample insertion and manipulation
- Equipment alignment
- Routine maintenance
- Data recording procedures

The individuals must demonstrate competence in these areas.

H. Written Operating Procedure

Written operating procedures must be available at each area that analytical x-ray equipment is used.

I. Posting

A warning label should be posted on each analytical X-ray equipment which states, "Caution Radiation - This Equipment Produces Radiation When Energized", or words containing a similar warning.

The Commonwealth of Pennsylvania Department of Environmental Protection " Notice to Employees" form must be posted in conspicuous locations in all clinical areas in which X-ray equipment is used. Appendix B is a copy of this notification.

J. Notification:

Report all conspicuous problems with X-ray equipment as well as any other safety problems observed by personnel to the Radiation Safety Department at 215-707-2520 immediately. The primary researcher shall inform the EHS whenever:

- Acquiring a new equipment
- Any new personnel working with the equipment
- Any modification performed in the initial arrangement of the equipment
- Any possibility of an accidental exposure.

K. Registration

All X-ray producing equipment must be registered with the Pennsylvania Department of Environmental Protection. The RSD will register all the units on an annual basis. RSD must be notified if you are going to acquire, dispose or transfer any analytical X-ray equipment.

L. Radiation Survey

Each analytical device must be tested upon installation and, thereafter, annually by the Radiation Safety Department and whenever:

- There is a change in the initial arrangement, number or type of local components in the analytical unit system.
- Following maintenance requiring the disassembly or removal of a local component.
- During the performance of maintenance and alignment procedures if the procedures require the presence of a primary x-ray beam when a local component in the system is disassembled or removed.
- When a visual inspection of the local component in the system reveals an abnormal condition.
- When the machine is operated in a manner other than the routine specified procedure written in the operating manual.

M. Additional Requirement For X-Ray Diffraction Unit

- Equipment with an open beam configuration manufactured and installed after December 19, 1987, each port on the radiation source housing shall be equipped with a shutter that cannot be opened unless a collimator or coupling has been connected to the port.

(An open beam configuration system is an analytical x-ray system in which the beam is not enclosed or shielded so any portion of an individual's body could accidentally be placed in the beam path during normal operation.)

- Unused ports on radiation housings shall be secured in the closed position in a manner, which will prevent accidental opening.
- An open-beam configuration unit must have a device, which either prevents the entry of any portion of body into primary beam path, or causes the beam to be terminated.
- An easily visible warning light illuminated when the X-ray tube is energized and labeled with the words "X-Ray ON". For Open beam configuration warning light must be illuminated in each port on radiation source housing when the shutter is open.

N. Additional Requirement For Cabinet X-ray system

Cabinet x-ray system may not operate unless all openings are securely closed. Each access door to the cabinet shall have interlock, which terminates the exposure, whenever that door is opened