Radiation Safety for Laboratory Workers

Chapter 4: Current Standards and Dose Limits

Background Radiation

The radiation exposure that we receive in any given time period does not just come from manmade sources. Besides man-made radiation we are constantly bombarded by a low level of natural background radiation. In the United States the average radiation exposure of the population to both natural and man-made-sources is approximately 357 mrem per year. Of that total 294 mrem per year is attributed to natural sources and 63 mrem per year from man-made sources. The natural background sources of radiation are derived from four different sources. Table 10 provides a summary of the average U.S. population exposure to these sources.

Table 10. Average U.S. Population Radiation Exposure

Natural Background Sources	**Average Exposure**
Cosmic Rays	27 mrem/year
Terrestrial	28 mrem/year
Radon	200 mrem/year
Internal	39 mrem/year
Sub Total: 294 mrem/year	
Man-Made Sources	**Average Exposure**
Medical/Dental Radiation	53 mrem/year
Consumer Products	10 mrem/year
Other	< 1 mrem/year
Sub Total: 63 mrem/year	

- Cosmic radiation is high-energy particulate radiation produced in the stars and our own sun which bombards the earth and makes the atoms in the upper atmosphere radioactive. A persons exposure to cosmic radiation is dependent on how close they are to outer space.
- Terrestrial radiation is radiation resulting from the decay of naturally occurring radioactive materials, like uranium and thorium, in the earth's crust. The exposure is greater if one lives near large sources of naturally occurring materials as in granite-type mountainous areas as opposed to calcite type (limestone) areas.
- Radon is a gaseous element resulting from the decay of uranium, that escapes the earth's crust through fissures and other natural breaks. As the radon is inhaled, it is deposited in the lungs where the massive energy of the alpha particles can damage the exposed lung cells.
- Internal radiation results from naturally occurring radionuclides, like 14C, 3H, and 40K, that are ingested and treated by the body like their non-radioactive isotopes. They are stored in various organ systems and give a long-term, low-level radiation exposure.

History of Current Standards

Radiation safety regulations regarding the use and handling of radioactive materials have evolved significantly during the past century. Initially it was not well known what the effects of radiation were. Many early experimental procedures involved high radiation exposures and resulted in workers and patients suffering prompt, somatic effects such as skin burns and hair loss. As research continued, researchers found that exposure to radiation had the potential to cause long term genetic effects in addition to the somatic effects. Personnel exposed to high levels of radiation or radioactive materials seemed to have an increase in certain types of cancers over people not exposed to radiation. As further studies continued and more was learned about the potential effects of radiation exposure, federal regulators worked to determine what "acceptable risks" radiation workers could assume as they work with radioactive materials.

It must also be noted that society's perception of the risk from radiation is different from a scientist's perception of risk. While researchers were working with radiation and studying its effects, movie goers were watching "The Fly" and other science fiction films which portrayed radiation as universally harmful. Additionally, the generation from 1945 to 1975 saw the effects of radiation weapons on large, unprepared populations, experienced an increase in above ground nuclear testing, and lived with the threat these weapons posed to them. One effect of the above ground nuclear testing was the fear that all the nuclear fallout would have detrimental effects on the world's gene pool, potentially increasing the rate of birth defects and cancers. Thus, when determining radiation exposure levels the regulators needed to consider not just the effects on radiation workers, but society's fears and the potential effects to the entire population.

As the concept of ALARA (As Low As Reasonably Achievable) has been incorporated into federal exposure limits, the goal has been changed from only protecting workers from their radiation work to include reducing the risk of cancers and birth defects in a population which could result from our total radiation exposure.

Current Exposure Limits

Current federal exposure limits address exposure to several groups in the population. Their goal is to weigh the radiation risk to the groups involved with the benefits derived. There is no risk benefit question involved with exposing a person to 500 mrem that allows for a lifesaving medical diagnosis to be made. Nor is there undue concern with giving the population of the U.S. an average of 0.001 mrem/year from smoke detectors because of their early warning benefit. But, what about exposing laboratory workers to 10 mrem/year in the hope of finding the purpose of a specific DNA site?

Radiation workers do derive some benefit from their work, specifically their livelihood. However, while all jobs carry some risk (e.g., needle sticks in medical care, auto accidents in transportation, etc.) today's worker expects to survive work so they can retire. The permissible exposure limits for workers are thus set so there will be no somatic effects from their radiation exposure, even if the worker is exposed to the maximum allowed exposure year after year. Additionally, although statistics suggest that the worker population may be at an increased risk for cancer induction, at the permissible exposure level no increases in cancer have been detected in populations of "radiation workers". Table 11 outlines the permissible dose limits for workers.

Table 11. Maximum Permissible Dose Limits

Population	mrem/year
Radiation worker - whole body	5,000
Radiation worker - skin	50,000
Radiation worker - extremities, hands	50,000
Radiation worker - minor (under 18)	500
Unborn Child of Radiation Worker	500[1]
Individual Members of the General Public	100

[1]exposure over entire gestation period

Some workers (i.e., delivery people, clerical staff, physical plant personnel) are exposed to very small levels of radiation because of incidental exposure. Because these workers do not derive some benefit from this exposure, their allowable limits are less. Exposure to individual members of the general public who do not routinely access radionuclide labs as part of their assigned duties are limited to 100 mrem/year exposure. Unborn children may be exposed when their radiation worker mother is at work. To keep the unborn child's exposure below 500 mrem for the entire gestation period, the radiation exposure of a "declared" pregnant worker is below 500 mrem during her pregnancy.

Radiation Exposure Risks

One common way to assess radiation risk is to compare it to other risks. Several studies have been done comparing the projected average loss of life expectancy from radiation exposure to other health risks. Using these studies, an individual who gets cancer loses an average of 15 years of life expectancy while his/her coworkers suffer no loss. The average US radiation worker exposure in 1992 was 0.3 rem and the University's radiation worker average annual exposure is below 0.02 rem. Using this data we can compare the average number of days of life expectancy lost per rem exposure to other health risks. Thus, we assume 0.3 rem radiation exposure per year from 18 to 65 results in a projected estimate of life expectancy loss of 15 days. Radiation risks are compared with other risks in Tables 12 and 13.

Table 12. Health Risks vs Life Expectancy

Health Risk	Expected Life Expectancy Loss
Smoking 20 cigarettes a day	6 years
Overweight (by 15%)	2 years
Alcohol consumption (US average)	1 year
Motor Vehicle Accidents	207 days
Home disasters	74 days
Natural disasters (earthquake, flood)	7 days
0.3 rem/year from age 18 to 65	15 days
1 rem/year from age 18 to 65	51 days

Table 13. Industrial Accidents VS Life Expectancy

Industry Type	Estimated Life Expectancy Loss
All Industries	60 days
Agriculture	320 days
Construction	227 days
Mining / Quarrying	167 days
Transportation / Public Utilities	160 days
Government	60 days
Manufacturing	40 days
Trade /Services	27 days

ALARA Program

As a safe-sided estimate, it is believed that exposure to radiation may carry some risk. Therefore, it is the goal of Radiation Safety to keep radiation exposures **ALARA** (**A**s **L**ow **A**s **R**easonably **A**chievable). Additionally, Radiation Safety works to protect radiation workers from predicted cancers and reduce the predicted risk of cancers and birth defects in the population as a whole from radiation exposure. The University has implemented an ALARA program aimed to keep radiation exposure to workers and members of the general public ALARA by focusing on the following areas:

- Control the use of radioactive materials. Radioactive material use is strictly controlled. All orders for radioactive material must be approved by the Radiation Safety Officer. Each authorized user is allowed sufficient material to perform research, however there are limits established to insure new receipts of radioactive material are balanced by disposals of on-hand radioactive material.
- Prevent the spread of contamination. All lab workers must be sufficiently trained in both radiation safety and general laboratory procedures to work competently and insure that accidents with radioactive material are kept to a minimum. Additionally, lab personnel need to be trained in emergency response so that if an accident occurred proper actions would be taken to prevent the spread of contamination off site.
- Audits of Authorized Users. Radiation Safety inspects each authorized user of radioactive materials to insure that the labs record keeping system meets the conditions of our NRC license. These inspections review both the ability of the lab to document their use of radioactive materials and that the adequacy of required surveys. Radiation Safety Program Staff also perform radiation and contamination surveys both in the laboratory and in areas outside the laboratory to insure that radiation exposure of non-radiation workers is kept as low as reasonably achievable.
- Review of dosimetry records. As part of the ALARA program established at UWM, the Radiation Safety Program is required to monitor and investigate, as necessary, worker radiation exposure. Normally, when a worker's monthly exposure (as reported by our dosimetry service) is more than 100 mrem, a member of the Radiation Safety Program staff will investigate the situation to determine why the worker received such a dose and what potential actions can be taken to reduce future doses for similar work.

Internal Doses

Radiation exposure from internal doses to radioactive materials is restricted by defined Annual Limits of Intake (ALI's). The ALI is a derived limit for the amount of radioactive material that, if taken into the body of an adult worker by inhalation or ingestion in one year, would expose an individual to the occupational limits. Table 14 lists the **Annual Limits of Intake** (ALI'S) of some commonly used radionuclides.

Table 14. Annual Limits of Intake for Various Radionuclides

Radionuclide	ALI in mCi
Tritium	80.0
Carbon-14	2.0
Sodium-22	0.4
Phosphorus-32	0.6
Phosphorus-33	6.0
Sulfur-35	10.0
Calcium-45	2.0
Chromium-51	40.0
Magnesium-54	2.0
Iron-59	0.9
Nickel-63	9.0
Iodine-125	0.1
Cesium-137	0.1

The NRC requires that any individual who may receive, in a year, an intake in excess of 10% of the applicable ALI must be monitored for internal exposure. To ensure regulatory limits are not exceeded, urine samples or other bioassay methods to monitor an individual's intake of beta or gamma emitters will be required when working with unsealed sources of radionuclides that exceed certain quantities. Additionally, other random bioassays may be required of individuals working with radioactive materials to ensure that the occupational limits are not being exceeded.