# Radiation Exposure to the General Public

In light of persistent media coverage and public concern over nuclear power, radiation exposure and carcinogenesis, and with the proliferation of anti-nuclear organizations, it is surprising to note the vast number of individuals who believe that radiation was nonexistent prior to the development of the atomic bomb. Contrary to this fallacy, radiation has been present since the creation of the earth and mankind has evolved during continuous exposure to it.

The intent of this commentary is to review radiation exposure to the general public (excluding medical and occupational exposure) by briefly summarizing common sources and doses. It should be emphasized at this point that numbers have been rounded and no limitations or caveats are included. The range of dose equivalents covered in any average may be very great. Nonetheless, they can serve as a guideline to the relative importance of various sources of exposure. Furthermore, I have not attempted to estimate the risks associated with low-level radiation exposure. Such risk estimates can be found elsewhere (*1-6*).

A summary of estimates of average annual dose-rates in the U.S., excluding medical and occupational exposure, is shown in Table 1. As indicated, the vast majority of an individual's radiation dose is received from natural environmental sources. Global fallout and consumer products account for only a small percent, while nuclear power contributes only a trace of the yearly radiation dose. As a sidelight, it is interesting to note that radiation doses from airborne effluents of a coal-fired power plant may be greater than those from a nuclear power plant (*7-8*).

Table 2 summarizes estimates of average annual dose-rates in the U.S. from natural environmental sources. Cosmic rays constitute a significant, inescapable portion of an individual's radiation dose, with an average of 300 cosmic rays/sec passing through the body (*9*). Cosmic rays are attenuated by the atmosphere so dose-rate is related to altitude. For example, although the U.S. average dose from cosmic rays is 31 mrem/yr whole body, the doses range from 26 mrem/yr at sea level to 75 mrem/yr at 8,000 feet (*1*). As a rule of thumb, every 100-ft increase in altitude increases the dose by 0.7 mrem/yr (*10*). Air travel increases exposure to cosmic rays with consequent radiation doses estimated to be 0.2–2 mrem/flight on commercial jets and 1–10 mrem/flight on supersonic transports (*1,9-13*).

**TABLE 1. Summary of Estimates of Average Annual Dose-Rates in the U.S., Excluding Medical and Occupational Exposure**

| Source | mrem/yr whole body | References |
|---|---|---|
| Environmental | | |
| Natural background | 85 | 1 |
| Global fallout | 4-5 | 1,9 |
| Nuclear power | <1 | 1,10 |
| Consumer products | 4-5 | 1 |
| Total | 95 | |

**TABLE 2. Estimates of Average Annual Dose-Rates in the U.S. from Natural Environmental Sources**

| Source | Radionuclide | Dose-Rate* | Reference |
|---|---|---|---|
| Cosmic rays | — | 31 mrem/yr WB | 1 |
| Terrestrial, internal | C-14, K-40, H-3 | 28 mrem/yr GD | 1 |
| Terrestrial, external | K-40, U, Th | 26 mrem/yr GD | 1 |
| Housing, wood | K-40, U, Th, Ra | 50 mrad/yr in air | 15 |
| Housing, brick | K-40, U, Th, Ra | 60 mrad/yr in air | 15 |
| Housing, stone | K-40, U, Th, Ra | 90 mrad/yr in air | 15 |
| Housing, concrete | K-40, U, Th, Ra | 80 mrad/yr in air | 15 |

*WB = whole body and GD = gonadal dose.




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Radionuclides inside the body are another inescapable source of radiation exposure. They are in the air we breathe, the food we eat, and the water we drink. For example, the $1.9 \times 10^6$ Ci of H-3 and the $34 \times 10^6$ Ci of C-14 produced every year by cosmic ray interactions with the atmosphere have always exposed humans to about 0.001 mrem/yr and 0.7 mrem/yr, respectively (*1,14*). It is interesting to note that over 7,000 disintegrations/sec occur in each of us as the result of the decay of these internal radionuclides (*9*).

External radionuclides, predominantly in the the soil, are a third source of inescapable radiation exposure. The make-up of soil is quite varied throughout the country; resultant dose rates are also quite varied, ranging from 15–35 mrem/yr in Atlantic and Gulf Coast areas to 75–140 mrem/yr in the Colorado plateau (*1*). External radionuclides are also present in building materials, with stone or concrete housing giving somewhat greater whole body radiation doses than those of wood or brick (*15*). The benefits of shielding against cosmic rays afforded by housing are negated by higher doses from building materials. Resultant radiation doses average 57 mrem/yr indoors compared with 43 mrem/yr outdoors (*15,16*). The majority of indoor exposure, about 40 mrad/yr to the lungs, is due to the accumulation of radon gas (*15,17*). Further accumulation of radon gas—in houses that are insulated and sealed to improve energy efficiency—may double the radiation dose (*15*). In some cases, this may result in exposures that carry a health risk exceeding the 170 mrem/yr that the Federal Radiation Protection Guide gives for groups exposed to man-made radiation sources (*17*).

Estimates of annual dose-rates in the U.S. from consumer products are shown in Table 3. Obviously, this list is not intended to be comprehensive but rather indicates some common products and their relative contribution to total dose. In many cases, the doses are estimates derived from detailed calculations based on underlying assumptions and may not reflect actual population exposure.

Fertilizers, akin to soil, are sources of radiation exposure to both agricultural workers and the general public (*18*). Nonmedical x-rays are received from televisions and airport inspection systems (*1,10,19*). Ionization smoke detectors typically contain about 1.0 $\mu$Ci Am-241 and, while saving many lives a year, contribute a very small radiation dose (*19,20*).

Radionuclides present in tobacco leaves are inhaled during cigarette smoking and irradiate the lungs. The bronchial epithelium uniformly receives about 0.05 rem/yr (*21*), although small areas of segmental bifurcations may receive up to an average of 8 rem/yr (*1,19*). The amount of radiation exposure, however, is estimated to contribute less than 10% of the risk of developing lung cancer, even in those smokers receiving the highest doses (*22*).

Radioactivity is found in some ophthalmic glass as a natural consequence of glass manufacturing processes and can locally irradiate the eyes. Establishment of ophthalmic glass standards in 1975 has significantly reduced the corneal dose from the previous 2–4 rem/yr (*19,23*) to less than 0.5 rem/yr (*23*). In spite of the widespread use of eyeglasses, corneal tumors remain very rare, and degenerative changes associated with wearing spectacles have not been reported (*23*).

Incandescent mantles used in camping lanterns are another source of radiation exposure. Ingestion of thorium that adheres to the fingers when removing a broken mantle and inhalation of airborne thorium during mantle changes and initial burns account for approximately 80% of this dose (*24*).

Radium has long been used in the production of radioluminous clocks and watches. In recent years, it has been almost entirely replaced with tritium and prometheum, both of which give significantly lower radiation exposure (*1,10,19,25–28*).

Uranium contaminants in scrap iron may become incorporated into consumer products, such as frying pans, and contribute a very small portion to the annual dose

**TABLE 3. Estimates of Annual Dose-Rates in the U.S. from Consumer Products**

| Product | Radionuclide | Dose-Rate* | References |
|---|---|---|---|
| Fertilizers | K-40, U, Th, Ra | General population: 1.7 mrad/yr GD | 18 |
| | | Agricultural worker: 2 mrad/yr GD | 18 |
| Televisions | X-rays | Consumer: 0.5-1.5 mrem/yr WB | 1,10,19 |
| Airport x-ray inspection system | X-rays | Traveler: 0.001 mrem/air trip GD | 19 |
| Ionization smoke detectors | Am-241 | Consumer: 0.007 mrem/yr WB | 20 |
| Tobacco smokers | Po-210 | Smokers: 50 mrad/yr bronchial epithelium | 21 |
| | | Nonsmokers: 10 mrad/yr bronchial epithelium | 21 |
| Eyeglasses | Th, U, Po | Consumer: less than 500 mrem/yr cornea | 23 |
| Incandescent mantles | Th | Camper: less than 0.4 mrem/yr WB | 24 |
| Luminous alarm clocks | Ra-226 | Consumer: 0.6 mrem/yr WB (1 μCi) | 26,27 |
| | H-3 | Consumer: 0.05 mrem/yr WB (1.6 mCi) | 28 |
| Luminous wrist watch | Ra-226 | Consumer: 35 mrem/yr GD (0.5 μCi) | 19,26,27 |
| | H-3 | Consumer: 0.03 mrem/yr WB (1 mCi) | 26-28 |
| | Pm-146 | Consumer: 0.20 mrem/yr GD (41 μCi) | 19,26 |
| Luminous pocket watch | Ra-226 | Consumer: 60-80 mrem/yr GD (1 μCi) | 19,25-27 |
| Frying pans | U | Consumer: less than 0.0004 mrem/yr WB | 24 |
| Ceramic tableware, glazed | U | Consumer: 500-2400 mrad/yr hands | 19,29 |
| Porcelain dentures | U, K-40 | Consumer: 700 mrem/yr gums | 31 |
| Natural gas, cooking | Rn-222 | Consumer: 9 mrem/yr bronchial epithelium | 1,10,19 |
| Natural gas, heating | Rn-222 | Consumer: 22 mrem/yr bronchial epithelium | 1,10,19 |

*WB = whole body and GD = gonadal dose.

(*24*). Uranium-glazed ceramic tableware is another source of radiation exposure. Mass-produced in the 1920s and 30s, uranium glaze gave California Fiestaware its bright yellow, orange, and red colors (*19,29–30*). Although sizable skin doses to the hands can result from daily handling of such tableware, internal body doses remain negligible because of the poor penetrating ability of the beta particles. Uranium glazes are currently used in low concentrations and only for fine patterns on dishware rather than the heavier coating on Fiestaware. Uranium is also used in porcelain teeth, where small amounts of it are largely responsible for the cosmetic quality of the dentures. Radiation exposure to the gums is common since approximately half of all artificial teeth today are of the porcelain type (*19,31*). Although the superficial layers of tissue in direct contact with the teeth may receive an alpha dose of 60 rem/yr (*19*), the basal tissue cells receive only about 0.7 rem/yr (*31*). In spite of the large number of denture wearers, the incidence of oral cancers is low and no causal relationship has ever been reported for oral cancer and dental porcelain (*31*).

Lastly, radon gas is present in natural gas and serves as a source of irradiation to the lungs (*1,10,19*).

In conclusion, I wish to re-emphasize the purpose of this commentary. It is not intended to alarm or frighten; it is intended to educate. Radiation exposure is present from inescapable environmental sources and consumer products. Although I have rounded numbers to give averages, excluded limitations, and covered great ranges, I hope to have given a rough picture of the relative importance of various sources of exposure.

James A. Ponto
College of Pharmacy and
University of Iowa Hospitals and Clinics, Iowa City, Iowa

## References

*1.* National Research Council, Advisory Committee on the Biological Effects of Ionizing Radiations. *The Effects on Populations of Exposure to Low Levels of Ionizing Radiation* (BEIR III). Washington, DC, National Academy of Science, 1980.

*2.* United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 1977). Report A/32/40. General Assembly Official Records. 32nd Sess. Suppl. No. 40. New York, United Nations, 1977.

*3.* Jablon S, Bailar JC. The contribution of ionizing radiation to cancer mortality in the United States. *Prev Med* 1980; 9:219-26.

*4.* Linos A, Gray JE, Orvis AL, et al. Low-dose radiation and leukemia. *N Engl J. Med* 1980; 302:1101-05.

*5.* High Background Radiation Research Group, China: Health survey in background radiation areas in China. *Science* 1980; 209:877-80.

*6.* Baverstock KF, Papworth D, Vennart J. Risks of radiation at low dose rates. *Lancet* 1981; 1:430-33.

*7.* Eisenbud M, Petrow HG. Radioactivity in the atmospheric effluents of power plants that use fossil fuels. *Science* 1964; 144:288-89.

*8.* McBride JP, Moore RE, Witherspoon JP, et al. Radiological impact of airborne effluents of coal and nuclear plants. *Science* 1978; 202:1045-50.

*9.* Chase GD, Rabinowitz JL. *Principles of Radioisotope Methodology*, 3rd Edition. Minneapolis, Burgess, 1967:491-92.

*10.* Taylor LS. The NCRP study of radiation exposure from consumer products. In *Radioactivity in Consumer Products*, Moghissi AA, Paras P, Carter MW, et al, eds, NUREG/CP-0003, Washington, DC, U.S. Nuclear Regulatory Commission, 1978:4-10.

*11.* Upton AC. Radiobiological aspects of the supersonic transport. *Health Phys* 1966; 12:209.

*12.* Hepburn AN. Cosmic radition and the Concorde. *Ann Occup Hyg* 1968; 11:341-46.

*13.* Bennett G. Medical aspects of supersonic transport aircraft. In *Human Problems of Supersonic and Hypersonic Flight*, Barbour AB, Whittingham HE, eds, New York, Pergamon, 1962:369-76.

*14.* Eisenbud M. Radioactive wastes from biomedical institutions. *Science* 1980; 207:1299.

*15.* Harley JH. Radioactivity in building materials. In *Radioactivity in Consumer Products*, Moghissi AA, Paras P, Carter MW, et al, eds, NUREG CP-0003, Washington, DC, U.S. Nuclear Regulatory Commission, 1978:332-43.

*16.* Kolb W, Schmier H. Building material induced radiation exposure of the population. In *Radioactivity in Consumer Products*, Moghissi AA, Paras P, Carter MW, et al, eds, NUREG/CP-0003, Washington, DC, U.S. Nuclear Regulatory Commission, 1978:344-50.

*17.* U.S. Radiation Policy Council. *Report of the Task Force on Radon in Structures*. Washington, DC, RPC-80-002, 1980.

*18.* Guimond RJ. The radiological aspects of fertilizer utilization. In *Radioactivity in Consumer Products*, Moghissi AA, Paras P, Carter MW, et al, eds, NUREG/CP-003, Washington, DC, U.S. Nuclear Regulatory Commission, 1978:380-93.

*19.* National Council on Radiation Protection and Measurements. *Radiation Exposure from Consumer Products and Miscellaneous Sources*. NCRP Report No. 56, Washington, DC, 1977.

*20.* Johnson JE. Smoke detectors containing radioactive materials. In *Radioactivity in Consumer Products*, Moghissi AA, Paras P, Carter MW, et al, eds, NUREG CP-003, Washington, DC, U.S. Nuclear Regulatory Commission, 1978:434-40.

*21.* Harley NH, Cohen BS. Polonium-210 in tobacco. In *Radioactivity in Consumer Products*, Moghissi AA, Paras P, Carter MW, et al, eds, NUREG/CP-0003, Washington, DC, U.S. Nuclear Regulatory Commission, 1978:199-216.

*22.* Walsh PJ. Radiation dose to the respiratory tract due to inhalation of cigarette tobacco smoke. In *Radioactivity in Consumer Products*, Moghissi AA, Paras P, Carter MW, et al, eds, NUREG/CP-0003, Washington, DC, U.S. Nuclear Regulatory Commission, 1978:217-26.

*23.* Goodman M, Yaniv SS. Naturally occurring radioactivity in ophthalmic glass. In *Radioactivity in Consumer Products*, Moghissi AA, Paras P, Carter MW, et al, eds, NUREG/CP-0003, Washington, DC, U.S. Nuclear Regulatory Commission, 1978:227-40.

*24.* O'Donnell FR. Assessment of radiation doses from radioactive materials in consumer products—methods, problems, and results. In *Radioactivity in Consumer Products*, Moghissi AA, Paras P, Carter MW, et al, eds, NUREG/CP-0003, Washington, DC, U.S. Nuclear Regulatory Commission, 1978:241-52.

*25.* Klein HF, Robinson EW, Gragg RL, et al. Evaluation of emissions from radium dial watches. *Radiol Health Data Rep* 1970;11:7-9.

*26.* Moghissi AA, Carter MW. *Public Health Implications of Radioluminous Materials*. DHEW Publication (FDA) 76-8001. Rockville, MD, Bureau of Radiological Health, 1975.

*27.* Moghissi AA, Carter MW, Simpson RE, et al. Evaluation of public health implications of radioluminous materials. In *Radioactivity in Consumer Products*, Moghissi AA, Paras P, Carter MW, et al, eds, NUREG/CP-0003, Washington, DC, U.S. Nuclear Regulatory Commission, 1978:256-76.

*28.* Krejci K, Zeller A. Public health aspects of production and application of radioluminous materials activated with tritium and carbon-14. In *Radioactivity in Consumer Products*, Moghissi AA, Paras P, Carter MW, et al, eds, NUREG/CP-0003, Washington, DC, U.S. Nuclear Regulatory Commission, 1978: 285-93.

*29.* Simpson RE, Shuman FGD. The use of uranium in ceramic tableware. In *Radioactivity in Consumer Products*, Moghissi AA, Paras P, Carter MW, et al, eds, NUREG/CP-0003, Washington, DC, U.S. Nuclear Regulatory Commission, 1978:470-74.

*30.* Holm WM. Radium in consumer products: A historical perspective. In *Radioactivity in Consumer Products*, Moghissi AA, Paras P, Carter MW, et al, eds, NUREG/CP-0003, Washington, DC, U.S. Nuclear Regulatory Commission, 1978:118-21.

*31.* Thompson DL. Recommendations on the use of uranium in porcelain teeth. In *Radioactivity in Consumer Products*, Moghissi AA, Paras P, Carter MW, et al, eds, NUREG/CP-0003, Washington, DC, U.S. Nuclear Regulatory Commission, 1978:475-78.