

## RADIATION HORMESIS WITH INTERNAL AND EXTERNAL SOURCES

T. D. Luckey  
Loveland, Colorado 80538  
970-669 5853 FAX970 669 0186

### ABSTRACT

**Hormesis** is stimulation by low doses of any agent. Whole body exposures to low doses of ionizing radiation reduce total cancer mortality rates. Internal sources include plutonium, radium and radon. Information about the effects of low doses of external radiation is seven million person-years with contaminated and control nuclear workers. Both internal and external sources significantly reduce total cancer mortality rates. Human data confirm results previously obtained with experimental animals. Cancer mortality is of both personal and national concern. This country would have 200,000 fewer premature cancer deaths each year if the population received safe radiation supplementation equivalent to that of exposed nuclear workers. The thrust of international and national agencies must change from death, risk and protection to health and prolonged life. The \$trillion saved in waste management would provide a \$billion for safe radiation supplementation. Raising radiation limits would improve health for individuals and efficiency for the national economy.

### INTRODUCTION

High and low doses of ionizing radiation elicit opposite reactions. Stimulation by low doses is called "radiation hormesis". This is proven by statistically significant results with microorganisms, plants, invertebrates, experimental animals and humans (1, 2). Excess radiation is considered to be harmful; the opposite effect, induced by low dose irradiation, is beneficial. Major physiologic functions (Table 1) are benefitted.

TABLE 1  
RADIATION HORMESIS IN PHYSIOLOGIC FUNCTIONS

<u>INCREASED</u>	<u>DECREASED</u>
MEAN LIFE SPAN	TOTAL MORTALITY RATE
GROWTH RATE	CANCER MORTALITY RATE
DEVELOPMENT RATE	CARDIOVASCULAR DEATHS
NEUROLOGIC ACUITY	RESPIRATORY DEATHS
IMMUNE COMPETENCE	INFECTIONS
FECUNDITY	STERILITY

Total cancer mortality rates provide a definitive measure of the effects of low dose irradiation in humans. The rate of cancer deaths in the United States (Fig. 1) has increased during the past few decades (3). Since much of our medical resources are now directed to AIDS research, the war against cancer is lost. Results of chronic, whole body exposures to humans from internal and external radiation sources are reviewed. Statistically significant results show

that safe supplementation with low doses of ionizing radiation can lower the cancer mortality rate in adults. Overwhelming evidence shows health considerations eliminate the need for extravagant waste management.

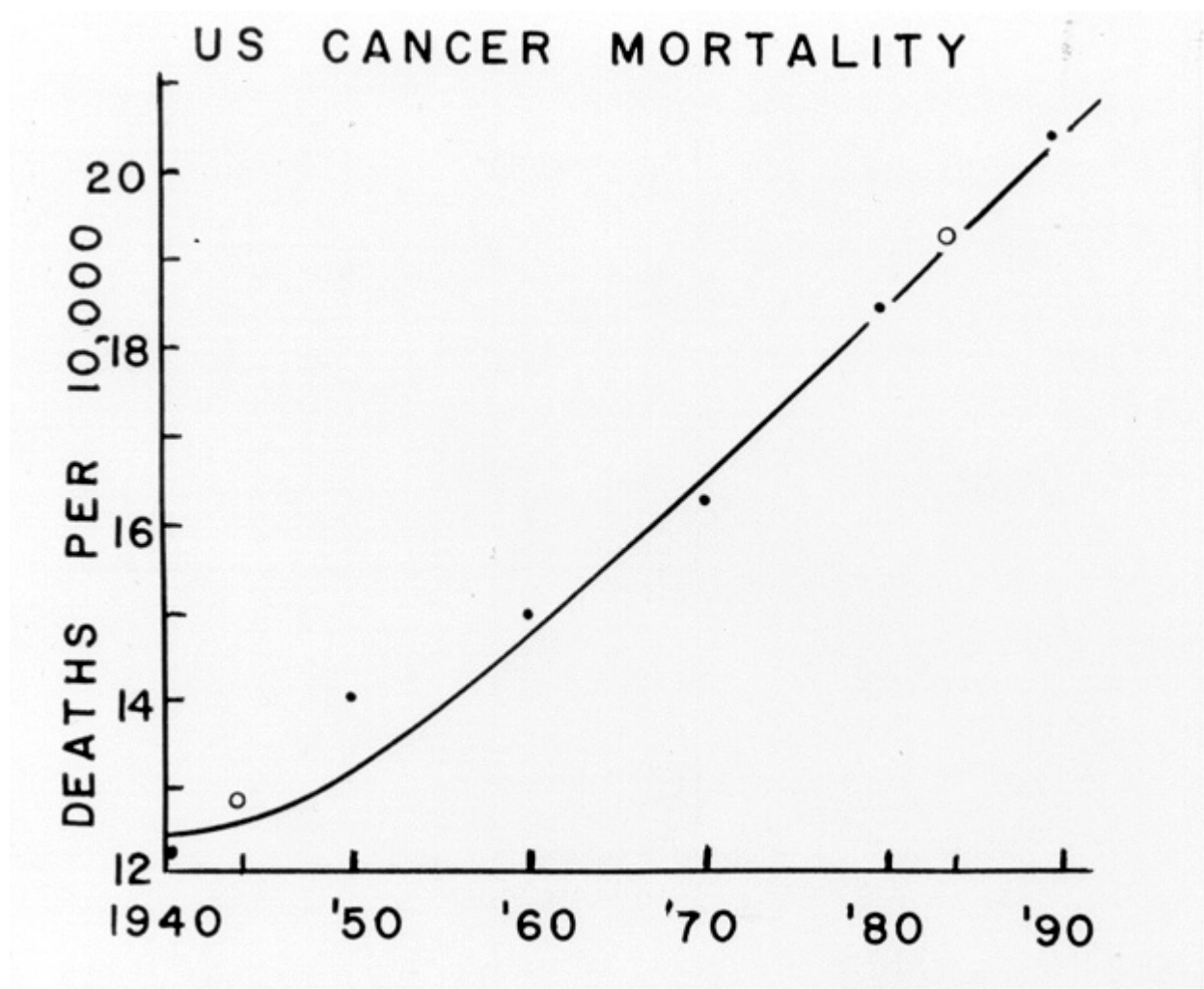


Figure 1. Cancer mortality rates in the United States (3).

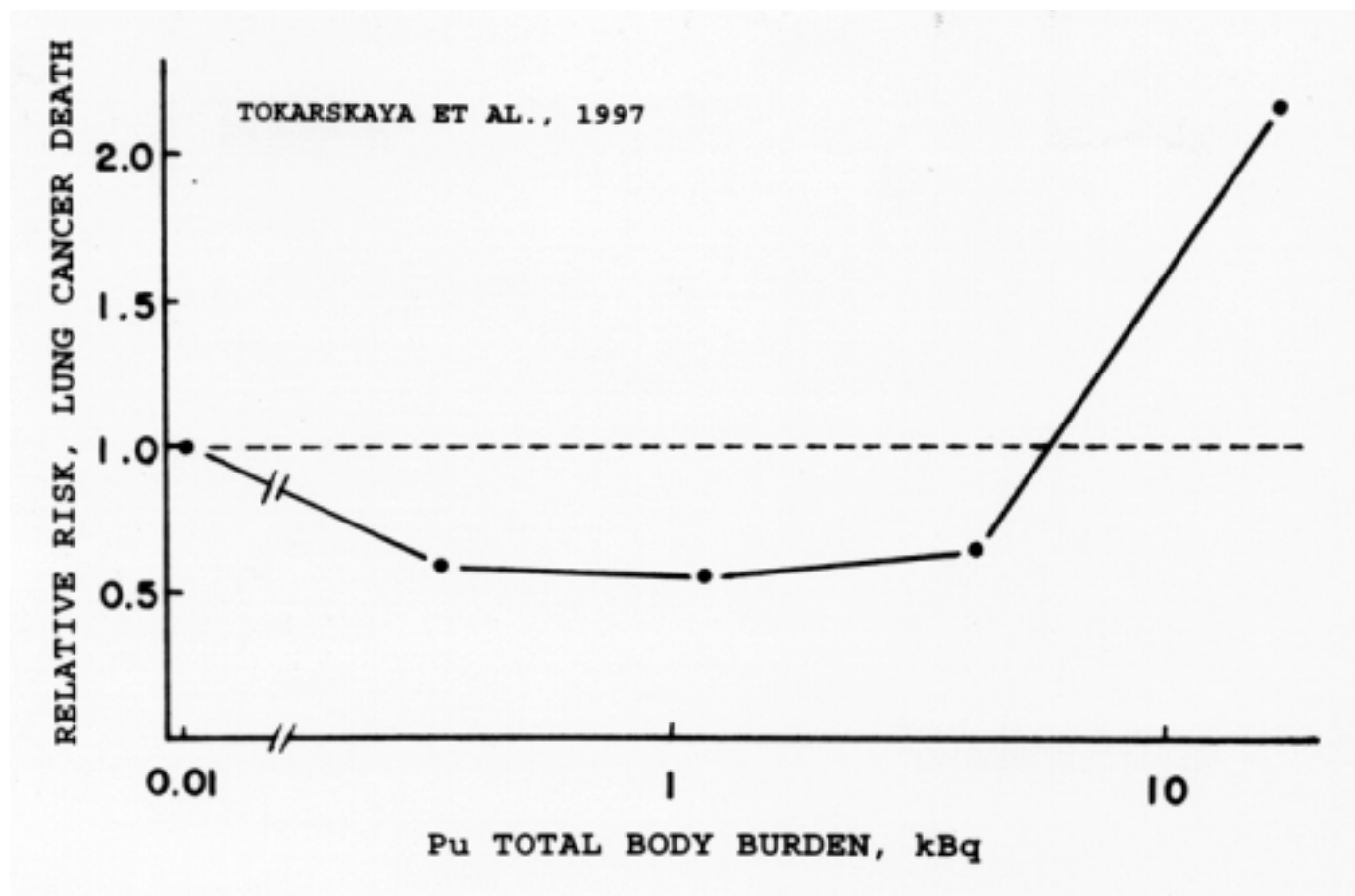
### INTERNAL EXPOSURES PLUTONIUM

In order to provide a standard for persons who might be exposed to plutonium in the manufacture of atomic bombs, 17 "terminally ill" patients were intravenously injected with 95 to 400 nCi of  $^{239}\text{Pu}$  between April 1945 and July 1947 (4). None who lived longer than nine months died with cancer. Their individual lifetime dose was 155-1000 cSv. Four lived with their plutonium 30-44 years. Another received 3.5  $\mu\text{Ci}$  of  $^{238}\text{Pu}$ ; his lifetime dose was 6.4 Sv. He lived with plutonium 21 years before dying with a heart disease. This is evidence that low doses of plutonium are not carcinogenic.

Voelz and associates followed the medical history of 26 workers accidentally exposed to plutonium in 1944-45 at Los Alamos National Laboratory (5). The standard mortality ratio (SMR) for all deaths was 0.41, for cardiovascular deaths it was 0.21, and for all cancer deaths it was 0.45. Although the small

number of subjects allows no statistical significance, the data suggest plutonium exposures are beneficial. Beral and associates found no leukemia deaths in over 22,000 British nuclear workers exposed to plutonium, actinium or tritium (6).

Inhalation exposures to plutonium show radiation hormesis for lung cancer (7). When compared with the general population, the SMR for lung cancer mortality rate was 0.14, 0.20 and 0.29 in exposed plutonium workers at Rocky Flats Nuclear Weapons Plant, Los Alamos National Laboratory and the Hanford Site, respectively. Lung cancer mortality rates showed no correlation with either smoking or external exposures in a study which involved 500 Russian nuclear plutonium workers for 40 years (8). When the exposure was less than 0.8 Sv (6 kBq), the lung cancer mortality of exposed workers was significantly less than that of controls (Fig. 2).



**Figure 2. Dose-response curve of lung cancer mortality rates in Russian plutonium workers (used with permission, Radiation Protection Management) (8).**

## RADIUM

Radium elixirs awakened an "anti-nuke" movement about 1932 (9). Early investigators knew radium erythema and burns became cancers. However, they also knew low doses were therapeutic and physicians used radium extensively in medicine. Widespread use of radium elixirs came to a sudden halt when an overenthusiastic sportsman named E. Byers took about 3000 doses of Radithor (1 uCi of Ra-228 and 1 uCi of Ra-226 in 15 gm water) in a short period of time. His celebrated disfigurement and death from cancer aroused public opinion and brought radiation under control of the Food and Drug Administration (FDA). Although a half million vials were sold, one death was enough. The FDA did not bother to evaluate

the thousands of persons who took reasonable doses of this elixer with no discernable ill health.

The Federal limit for radium-226 in drinking water is 5 pCi/1 or about 5 pCi/day. One vial of Radithor contains almost one million times more radium than the allowance. Muckerheide noted that no health problems have been found in the United States or other countries for exposures less than 50 uCi. It would take 140,000 years for one to drink enough water with 5 pCi/1 to absorb 50 uCi radium. Since Homo sapiens originated on the shores of South Africa 140,000 years ago, it is not surprising that the scientific community considers the FDA limit to be ridiculous.

Evans' studies of dial painters showed the threshold for bone cancer was about 5 Gy for whole body burden of radium (10). This threshold has been raised by the Center for Human Radiobiology at Argonne National Laboratory (11). Excepting cancer in bone, paranasal and mastoid air cells of the most heavily exposed workers, Rowland states: "However, the great majority of exposed individuals went through life with no recognizable consequences of their exposures. They lived as long as, and apparently in as good health as, their unexposed neighbors. This fact seems to have been little appreciated and seldom mentioned, but it may be the most important finding of the entire study."

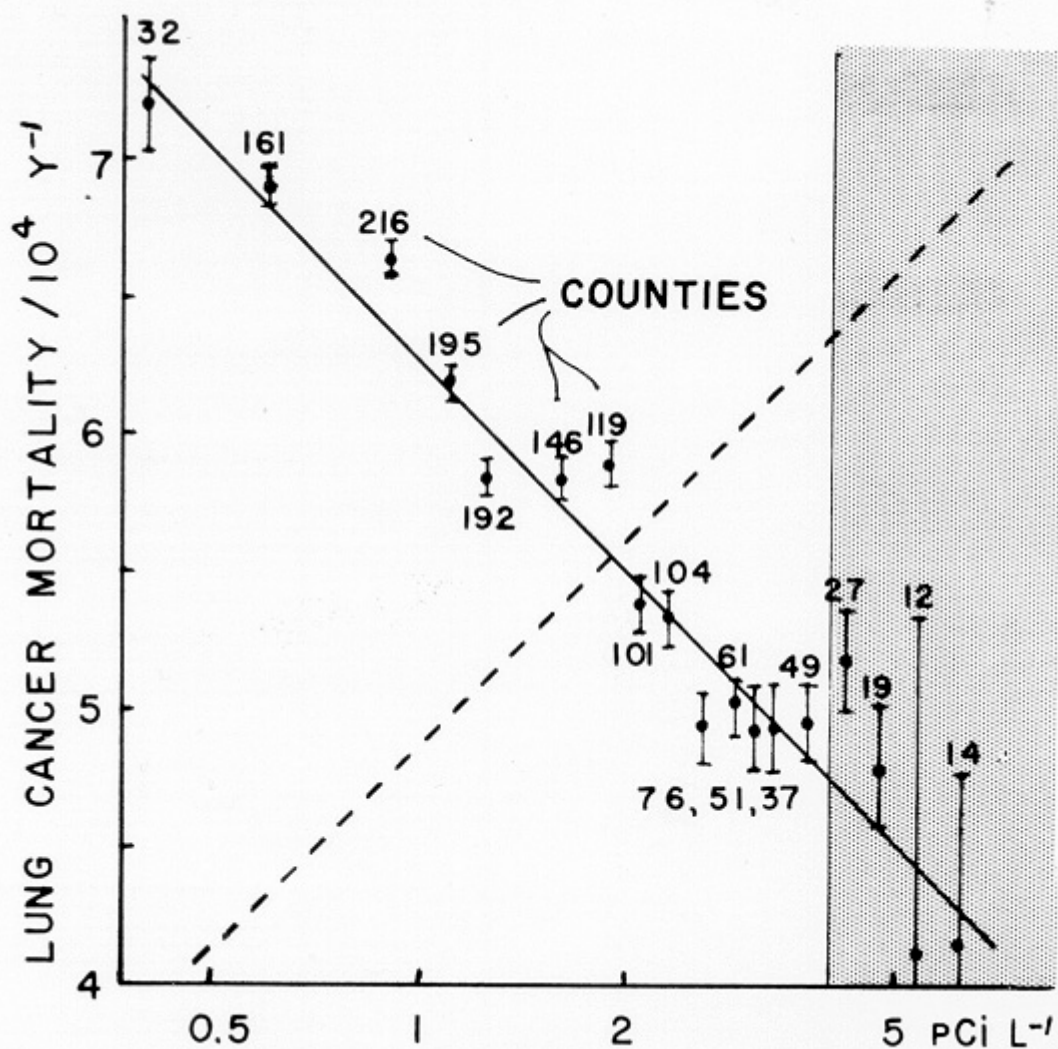
Except for breast cancer, other cancer mortality rates in radium exposed workers show no change from the general population; and there was no dose dependent increase in breast cancer mortality rates (11). Leukemia deaths in female radium dial painters were much lower than expected; the SMR for 1,285 workers was 0.22 (12). The gamma ray environment of these workers was estimated to be 4 cGy/y, the average bone marrow dose was about 8 cGy/y. No leukemias were found in female British dial painters (13).

The average lifespan of radium exposed persons may exceed that of the general population. In U.S. white female dial painters the SMR for all causes of death, all circulatory system disease, and cerebrovascular disease were, respectively, 0.88,  $p < 0.05$ ; 0.75,  $p < 0.01$  and 0.48,  $p < 0.01$  (11). In British female dial painters an increased lifespan was apparent, the SMR was 0.90; this was not statistically significant (14). Excepting cancer, the British female dial painters had an increased average lifespan, the SMR was 0.81,  $p < 0.01$ . For women who worked longer than two years, the non-cancer lifespan increased significantly; when grouped by years at work, the SMR for 0-10 years was 0.31,  $p = 0.008$ ; for 10-20 years it was 0.47,  $p = 0.066$ ; and for all, 0-50 years the SMR was 0.72,  $p = 0.001$ . Clearly, radium dial painting was advantageous for 20 years. These studies should continue to be funded.

## **RADON**

Radon and lung cancer have usurped public fear previously held for ionizing radiation and genetic monsters. The monsters did not appear; serious chromosomal aberrations were not found in atom bomb survivors exposed to low dose irradiation. There is good evidence for radiation hormesis in reproduction (2). Now we find radon reduces lung cancer deaths.

Cohen's outstanding study of radon in homes of 1700 counties which embrace 90% of the U.S. population (Fig. 3) is ample proof of a strong inverse relationship between radon inhalation and lung cancer death (14). The curve was comparable for either sex with or without smoking. Other epidemiologic factors were found to be without effect.



**Figure 3. Dose-response curve for the effect of radon on lung cancer mortality rate in the United States (14). The numbers of counties and one standard deviation are shown. The dashed line**

shows agency interpretation. The stippled area is agency recommended for remedial action.

Data from case-control studies of 1,973 lung cancer cases in Finland would fit the Cohen curve very well (15). However, the lung cancer mortality rate of people living with very high radon levels (11-34 pCi/13 ) was higher than that of the general population. Comparable results were obtained from Britain (16). The radon levels in Cornwall and Devon were 3.0 and 2.0 pCi/1, respectively. The SMR for lung cancer deaths for males and females in Cornwall were 0.96 and 0.91, respectively; for Devon these values were 1.02 and 1.13, respectively.

Radon hospitals in Russia treat 1000 individuals daily for asthma, rheumatism, immune deficiency and hormone disorders (17). About 75% of the people respond (Fig.4). In this study with air given to the placebo group, the optimum therapeutic dose was 2 mSv during a two week period. These data support testimonials of people who frequent radon mines for health in Austria and Montana (18, 19).

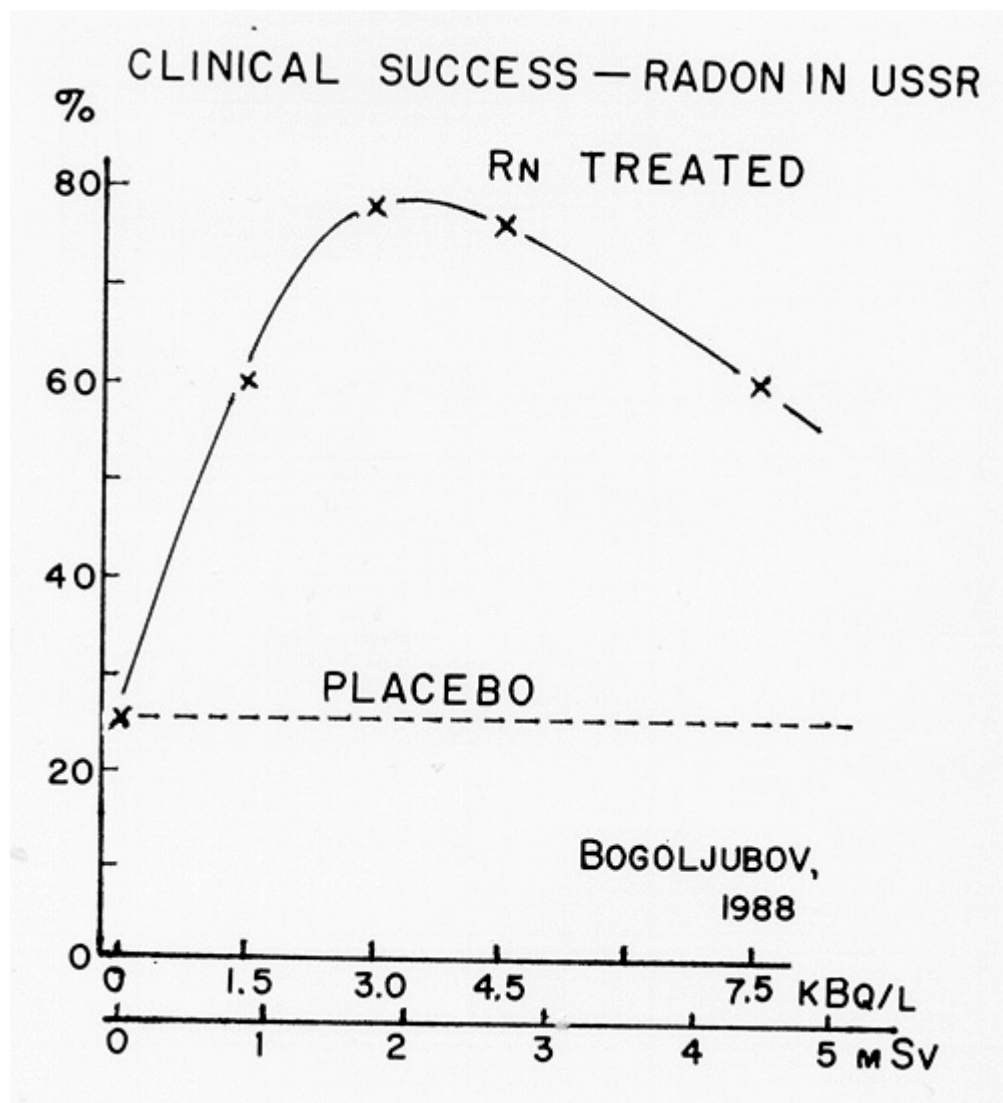


Figure 4. Dose-response curve for radon therapy from 20 years experience in Russian clinics (Used with permission of CRC Press) (17).

### EXTERNAL EXPOSURES

Seven studies involving seven million person-years experience with nuclear workers provided consistent and convincing evidence that low doses of external ionizing radiation decrease total cancer mortality rates (Table 2) (20). The estimated lifetime dose (most is gone in one year) of 152,000 exposed workers averaged 5.5 cSv above background. They were carefully matched (age, sex, sociologic factors) with over 149,000 unexposed persons working in the same plants. Since all workers had comparable entrance examinations, environment, management, and medical care, there was no "healthy worker effect". Cancer and leukemia deaths within the first ten and two years, respectively, were not counted in order to eliminate persons who had these prior to employment. When weighted according to the numbers involved, the total cancer mortality rate of exposed workers was only 52% that of the controls. These carefully controlled studies suggest that almost half of all cancer deaths are premature. Low doses of ionizing radiation can prevent these. Since our country has about 600,000 cancer deaths annually, low dose irradiation would prevent almost 300,000 premature cancer deaths each year.

TABLE 2  
NUCLEAR WORKERS IN CANCER MORTALLITY STUDIES

<u>COHORT</u>	<u>NUMBER</u>	<u>PERSON-YEARS</u>	<u>DEATHS/1000</u>		<u>%</u>
			<u>EXP</u>	<u>CON</u>	
SHIPYARDS	72,356	1,591,832	9.8	13.4	73
HANFORD	44,100	1,675,800*			
OAK RIDGE	8,318	291,130*	20.8	34.8	60
ROCKY FLATS	5,897	165,116*			
LOS ALAMOS	14,280	457,000	17.7	20.5	86
CANADA	8,944	268,320	20.3	23.7	86
BRITAIN	95,217	3,237,378	2.8	9.9	28
TOTALS/AVE	249,112	7,686,576			52

NOTES:

EXP = exposed nuclear workers; CON = unexposed nuclear workers. \* Hanford, Oak Ridge and Rocky Flats were reported as one unit. AVE - The average is weighted by the person-years for each cohort.

Japanese atomic bomb victims are considered to provide the most reliable index for the effect of external radiation in humans. Those exposed to low doses of radiation in Hiroshima and Nagasaki had fewer cancer deaths than controls. For every thousand persons there were 3 fewer leukemia deaths and 49 fewer solid cancer deaths among those exposed to 1-1.9 cSv than in controls (21). Fallout from a hydrogen bomb at Bikini Island covered 23 Japanese fishermen on March 1954. Whole body exposures from gamma rays were estimated to be 200-670 cGy (22). All had radiation sickness. One died within eight months. One died 21 years later with liver cirrhosis. None died with cancer within 25 years of their exposure.

A remarkable example of radiation hormesis in cancer mortality involves people in 1360 Taiwan homes built in 1982-3; in 1992-98 these were found to have  $^{60}\text{Co}$  contaminated steel beams (23). Assuming occupancy of eight hours per day the average exposures were estimated to be 0.5 cSv/y with 10% receiving  $>5$  cSv/y. The yearly cancer death rate in Taiwan was 10.5 per 10,000 people, 157 in 15 years. Only four persons died with cancer in the 10,000 people living 15 years in contaminated buildings. The SMR for total cancer mortality in this exposed population was 0.025, an extraordinarily low value. More study is needed.

The Chernobyl nuclear reactor explosion revealed the depth of misguided beliefs about low dose irradiation. Fear of radiation caused over 100,000 deaths by abortions and suicide; however, only 31 workers died from radiation within the first four months (24). No one exposed to  $<2$  Gy died with cancer (25).

## DISCUSSION

Both animal experiments and human experiences show most physiologic functions (Table 1) are benefitted by low doses of ionizing radiation. The cumulative evidence clearly indicates we live with a subclinical deficiency of ionizing radiation (26). The focus here is on cancer mortality. Human experiences reported during the past decade confirm the conclusions from animal experiments and provide overwhelming evidence that whole body exposures to low doses of ionizing radiation decrease cancer mortality rates.

Why are these consistent results opposite from those usually reported? Epidemiologists usually err by one or more of the following: a) assume that all radiation is harmful and thus, b) utilize a linear no threshold dose-response curve, c) interpolate between high doses and zero to obtain fancied results to produce and support unreasonable regulations, d) ignore data that does not fit the concept expressed in a), e) use a one dimensional formula or statistic which does not allow expression of beneficial effects, f) do not utilize dose-response evaluations, g) do not give enough raw data to construct a dose-response curve, h) include data from low dose participants in their control cohort, or i) distort results by the use of median in place of mean or average value. Largely ignored by modern radiobiologists is the mass of data showing radiation hormesis in invertebrates and vertebrates, including humans, reported in over 2000 references (1, 2).

Most government agencies are oriented toward protection and restriction. Federal agency penchant for protection at any cost leads to intellectual dishonesty and disaster for health considerations. Politically directed spin from regulatory agencies dominates rational interpretation of scientific data. Without realistic concepts of health involved, risk/benefit analyses are useless. People would be better served if these agencies were oriented toward health and safety. If one death in 1932 could affect FDA regulations, where is consideration for over 200,000 premature cancer deaths each year? For example, the Environmental Protection Agency should be subsumed into the National Institutes of Health (NIH). If NIH allowed it, safe radiation supplementation would prevent 800 premature cancer deaths every day.

Safe supplementation of ionizing radiation could come from internal, external or combined sources (26). For example, nutritional supplementation might include increased  $^{40}\text{KCl}$  in salt. The plutonium, radium, radon and other radionuclides in our bodies could be increased (Table 3). No research was found on benefits from the addition of other major radionuclides in our body. External sources should include utilization of nuclear waste and facilities. Safe radiation supplementation would include raising limits for environmental and industrial exposures.

TABLE 3  
RADIONUCLIDES IN HUMAN ADULTS (27)

NUCLIDE	BIOLOGIC HALFLIFE	DOSE uSv/y
H-3	10 d	1
C-14	40 d	13
K-40	30 d	180
Rb-87	30 d	10
Sr-90	60 d	4
Pb-210	25 y	50
Po-210	50 d	40
Rn-222	AIR	10
Ra-226	---	5
Ra-228	---	6
Th-230	22 y	7
Th-232	22 y	100
U-238	14 y	11
Pu-239	50 y	10



The concept that improved health requires radiation supplementation reverses waste management paradigms. Waste management practices should be reoriented to provide waste utilization for health. The \$ trillions for nuclear waste management can be reduced to \$ billions to provide safe, low dose irradiation to improve our health. The direction is obvious; the first step remains to be taken.

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