Health Survey in High Background Radiation Areas in China

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Since 1972 we have studied the health status of a large number of people living in some parts of Yangjiang County, Guangdong Province, China, where the radiation level is about three times that in the neighboring areas. We hope that this investigation of a large population whose families have been continuously exposed to a low dose rate of ionizing radiation for many generations may provide some information for evaluating whether any detrimental effect of such exposure exists.

High-Background and Control Areas

The high-background areas in Yangjiang County are two regions separated by a short distance, which cover a total area of about 540 square kilometers. The source of background radiation in the first region (Dong-anling) is a hill whose surface rocks are granites, from which fine particles of monazite are washed down continually by rain and deposited in the surrounding basin region. A similar mechanism operates in the second region (Tongyou); monazites washed down from a mountain near Tongyou are deposited in another basin region and elevate its background radiation level.

More than 80,000 people live in these two regions. For the purpose of this investigation, those who live at the borders of the high-background areas were not examined; therefore, only about 73,000 people were investigated.

Two control regions were selected not far from the high-background areas (the closest points are about 10 km apart). Both types of regions are at comparable altitudes, less than 50 meters, and there are 77,000 inhabitants in the control regions (Fig. 1).

Nationality, occupation and history of inhabitation. From the general records of these counties, the family trees of the inhabitants, and interviews with aged people, we learned that the overwhelming majority of the inhabitants of the regions studied are of the Han nationality and most of them are peasants and their families. They have lived there for many generations. The inhabitants whose families have lived in the high-background areas for six or more generations comprise 90.6 percent of the total (see Table 1).

Medical exposure. During the investigation, inhabitants who had been occupationally exposed to ionizing radiation were not examined. A survey of medical exposure was carried out (Table 2).

Results of the investigation carried out from 1972 to 1975. In the period 1972 to 1975 we investigated only some of the inhabitants and their environments. In the Dong-anling (high-background) region, 20,154 people were studied; in the Sanhe (control) region, 21,235 people. The investigation included radiation level and dosimetry, chromosomal aberrations of peripheral lymphocytes, frequencies of hereditary diseases and deformities, frequencies of malignancies, growth and development of children, status of spontaneous abortions, and some nonstochastic effects.

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Table 1. Distribution of inhabitants whose families lived in investigated areas for various numbers of generations.

Generations	High-background areas		Control areas	
	Persons	Percent	Persons	Percent
2 to 5	6,912	9.4	25,126	32.6
6 to 10	25,737	35.0	39,230	50.9
11 to 15	17,501	23.8	9,172	11.9
16 or more	23,384	31.8	3,545	4.6
Total	73,534	100.0	77,073	100.0

Table 2. Status of medical exposure (person-times per 10^3 persons per year).

Areas	Fluoroscopic examination		
	Chest	Gastrointestinal	Pelvic
High-background	36.2	1.0	27.7
Control	28.7	2.5	19.7

Table 3. Contents of natural radionuclides in surface soil.

Areas	Uranium (10^{-3} g/kg)	Thorium (10^{-3} g/kg)	^{226}Ra (10^{-9} Ci/kg)	^{40}K (mg/kg)
High-background	5.8 to 9.2	35.0 to 49.7	1.7 to 2.0	1.3 to 2.5
Control	1.5 to 3.3	4.3 to 10.7	0.3 to 0.9	0.2 to 0.5

Table 4. Cumulative exposures measured by $CaSO_4$ and fluoroglass dosimeters. Values are means ± standard deviation (S.D.).

Areas	Exposure (mR/month)		
	Field	Indoor	Individual
	$CaSO_4$ dosimeters		
High-background	14.5 ± 2.5	28.7 ± 3.6	25.0 ± 4.0
Control	5.9 ± 1.2	9.4 ± 2.2	9.3 ± 2.3
	Fluoroglass dosimeters		
High-background	19.5 ± 2.4	28.5 ± 3.9	25.0 ± 2.7
Control	7.5 ± 1.8	10.5 ± 2.2	9.2 ± 1.9

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Radiation Level and Dosimetry

Contents of natural radionuclides in the surface soil were examined by radiochemical analyses. The results are shown in Table 3.

Cumulative exposure to radiation. Both calcium sulfate and fluoroglass dosimeters were used to determine the cumulative exposure of the inhabitants to their environments. According to the exposure distribution in the investigated regions, which was measured with radiation detectors, 14 villages in the high-background area and 16 villages in the control area were selected; their inhabitants comprised approximately one-fourth of the total number investigated. By a random process, 408 people in the high-background area and 417 in the control area were selected to wear the dosimeters; 56 in the high-background area and 64 in the control area wore both types of dosimeters, the others wore calcium sulfate dosimeters only. They wore the dosimeters around their waists in the daytime and put them on their beds at night for a period of 2 months. Meanwhile, dosimeters were also placed on stakes at approximately 1 m above ground level in the rooms and fields of these villages; 1019 calcium sulfate dosimeters and 314 fluoroglass dosimeters were issued for this purpose, and 940 and 312 dosimeters, respectively, were returned to us in readable condition. The results are shown in Table 4.

The results obtained with the two kinds of dosimeters are almost identical. Doses absorbed by the gonads, whole body, red bone marrow, and endosteal cells were calculated. The average dose absorbed per year from external radiation was 196 millirads for those in the high-background area and 72 millirads for those in the control area.

Internal radiation. To ascertain the daily intake of natural radionuclides, a dietary investigation was carried out. Samples of local foodstuffs, vegetables, and drinking water were collected and analyzed by radiochemical procedures. Body burdens of natural uranium, natural thorium, ^{226}Ra, ^{228}Ra, and ^{40}K were calculated and the doses they contribute annually to the endosteum, bone marrow, and gonads were estimated. In addition, the concentrations of ^{222}Rn, ^{220}Rn, and their daughter products in the air indoors and outdoors at various times of day were measured and the annual doses to the lungs were estimated; these are shown in Table 5.

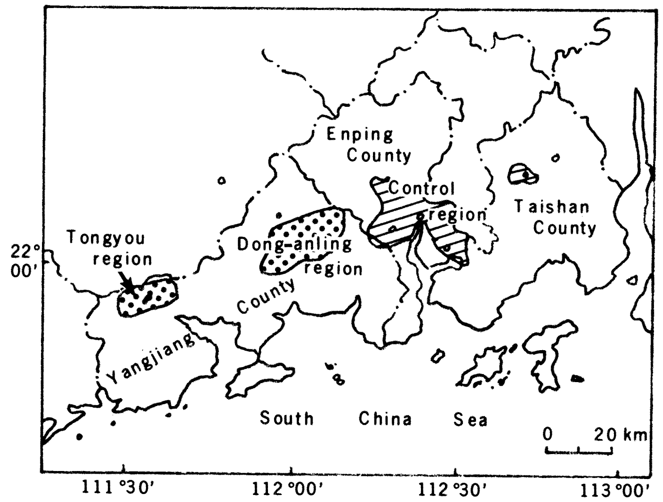

Fig. 1. Locations of the high-background and control regions.

Table 5. Annual dose equivalents (millirems per year).

Exposure	High-background areas				Control areas			
	Whole body	Gonads	Endosteum	Bone marrow	Whole Body	Gonads	Endosteum	Bone marrow
External radiation	196	196	196	196	72	72	72	72
Internal radiation								
^{226}Ra	4.0	4.0	58.8	10.7	1.3	1.3	19.1	3.5
^{228}Ra	10.5	10.5	156.5	28.5	2.7	2.7	40.9	7.4
^{40}K	19	19	15	15	19	19	15	15
Daughter products of ^{222}Rn	1.3	1.3	1.5	1.5	0.7	0.7	0.9	0.9
Daughter products of ^{220}Rn	0.5	0.5	8.9	8.9	0.3	0.3	4.7	4.7
Total	231	231	437	261	96	96	153	104

Table 6. Incidence of rings and dicentrics.

Areas	Cases	Cells scored	Rings + dicentrics per 100 cells	P
		1973		
High-background	95	9,642	0.031	> .20
Control	95	12,757	0.024	
		1975		
High-background	106	21,144	0.019	> .10
Control	104	20,778	0.005	

Table 7. Incidence of chromatid and chromosomal aberrations of peripheral lymphocytes (1975).

Areas	Cases	Cells scored	Number of		
			Cells with chromatid or chromosomal aberrations	Chromatid aberrations	Chromosomal aberrations
High-background	106	21,144	232 (1.097)*	190 (0.899)	57 (0.269)
Control	104	20,778	205 (0.987)	154 (0.741)	57 (0.274)

*Figures in parentheses are changes per 100 cells.

Results of Health Survey

Cytogenetic study. Before blood sampling, clinical examinations of a large number of inhabitants of both areas were performed to rule out those who suffered from diseases associated with chromosomal aberrations and those who had been exposed to medical x-rays and agricultural insecticides not long before the examination. Thus, in the first period (1973 and 1974) 95 inhabitants each from the high-background and control areas, and in the second period (1975) 106 inhabitants from the high-background area and 104 from the control area were selected for analysis of lymphocyte chromosomal aberrations. Since the durations of blood culture in the two periods were different (72 hours in 1973–1974 and 54 to 56 hours in 1975), the results are listed separately (Tables 6 and 7).

The results showed that the frequencies of chromatid and chromosomal aberrations among inhabitants of the high-background and control areas are almost identical, within the normal ranges. The incidence of chromatid and chromosomal aberrations in 1975 is shown in Table 7.

Hereditary diseases and congenital deformities. Infants and children below 12 years of age in both types of areas were examined clinically by experienced physicians, pediatricians, dermatologists, and gynecologists for 31 kinds of diseases and defects. Diagnoses were checked once or twice whenever necessary. The chromosome number of some patients who suffered from Down's syndrome was determined to confirm the diagnoses.

The results of these examinations are shown in Table 8. The frequency of hereditary diseases and congenital deformities in the high-background area is somewhat lower than that in the control area, but the difference is not statistically significant. The incidence of Down's syndrome in the high-background area (1.71 per thousand) is significantly higher than that in the control area (zero). However, the size of population investigated is quite small to show this difference. It will be necessary to examine more children in further investigations.

Spontaneous abortion rate. A retrospective survey of the incidence of spontaneous abortions was carried out in both areas. In the high-background and control areas, respectively, 1551 and 1716 married women were interviewed about the courses of their pregnancies from 1963 to 1975. Spontaneous abortion was defined as termination of any pregnancy within 28 weeks after conception, excluding artificial abortion. Results obtained from both areas were almost identical (Table 9).

Frequency of malignancies. Both general clinical examinations and 5-year (1970 through 1974) retrospective surveys were carried out to determine the frequency of malignancies in the high-background and control areas. Materials and information were collected from demographic survey and hospital records. Death rates were standardized according to the distributions of age and sex of the inhabitants in both areas. Results are shown in Tables 10 to 12.

Neither the morbidity rates from general clinical examinations nor the mortality rates from retrospective surveys showed significant differences between inhabitants living in the high-background and control areas. It was reported that the average annual mortality rate from malignancies between 1970 and 1972 in the whole Guangdong Province was 50.90 per 10^5 persons; in the Hupei Province between 1971 and 1973 it was 68.34 per 10^5 persons. The mortality rates in both investigated areas were comparable with that in Guangdong Province, but lower than that in Hupei Province.

Table 8. Frequencies of 31 kinds of hereditary diseases and congenital deformities of children in high-background and control areas.

Areas	Persons examined	Persons diseased	Frequency (per 1000)	*P*
High-background	3504	48	13.70	> .05
Control	3170	46	14.51	

Table 9. Spontaneous abortion rate from 1963 to 1975.

Areas	Pregnancies	Abortions	Abortion rate (per 1000)	*P*
High-background	3896	288	73.9	> .05
Control	3062	222	72.5	

Table 10. Frequencies of malignancies observed in 1975.

Type of malignancy	High-background area (N = 20,154)		Control area (N = 21,235)	
	Cases	Frequency (10^{-5})	Cases	Frequency (10^{-5})
Cancer of nasopharynx	0	0	3	14.13
Cancer of esophagus	0	0	1	4.71
Cancer of liver	3	14.85	2	9.42
Cancer of intestine	2	9.92	1	4.71
Cancer of breast	0	0	1	4.71
Cancer of cervix	0	0	3	14.13
Other cancers	2	9.92	3	14.13
Total	7	34.69	14	65.94

Table 11. Mortality rates from malignancies in high-background and control areas (1970 through 1974, retrospective survey).

Areas	Person-years	Deaths (No.)	Mortalities averaged (10^{-5})	Mortalities standardized (10^{-5})
High-background	96,533	45	46.61	45.69
Control	122,554	55	44.87	44.83

Table 12. Mortality rates from various malignancies in high-background and control areas (1970 through 1974, retrospective survey). Data were standardized according to age and sex.

Type of malignancy	High-background areas		Control areas	
	Deaths (No.)	Mortality (10^{-5})	Deaths (No.)	Mortality (10^{-5})
Cancer of liver	12	12.10	21	16.83
Cancer of nasopharynx	11	11.37	12	9.34
Cancer of stomach	6	6.39	1	0.77
Cancer of cervix	3	3.19	1	0.69
Cancer of esophagus	2	1.60	3	2.07
Cancer of lung	1	0.23	4	2.94
Cancer of intestine	0	0	3	4.20
Cancer of breast	0	0	1	2.57
Leukemia	5	5.31	5	4.14
Other cancer	5	4.71	4	3.09

The mortality rates from leukemia, about which we were more concerned, were not significantly different between both areas. Nevertheless, the size of the population investigated in this period was relatively small, and further study is necessary.

Growth and development of children. Measurements of head circumference, body weight, and height of the children below 12 years of age in the high-background area (3239 persons) and the control area (2991 persons) showed that differences in growth and development of children between these two areas were not statistically significant.

Conclusions

The radiation level in some regions of Yangjiang County, Guangdong Province, is about three times that in the neighboring control areas, but lower than that in some parts of high background radiation areas in India and Brazil. However, the distribution of exposure rates in the investigated regions is relatively even, and there is a high density of people whose families have lived there for many generations. Results of the health survey carried out between 1972 and 1975, which did not demonstrate any significant difference between inhabitants living in the high-background and control areas, suggest that the size of the population investigated may be not large enough to reveal minor increments of detrimental effects at such a low dose range of ionizing radiation. Or there might be a practical threshold dose; that is, the possibility that the dose-effect curve had a zero slope at these doses cannot be ruled out. For the reasons given above, further investigation of a larger population is necessary.

Additional Readings

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Innovation and Scientific Funding

Richard A. Muller

It is difficult to judge the performance of scientific funding agencies, for, like physicians, they often bury their mistakes. Rejected proposals usually mean doomed projects. If the projects survive rejection and succeed, it is rare that they achieve recognition soon enough to alert the funding agencies that mistakes are being made. In 1978 I was given the Alan T. Waterman Award of the National Science Foundation and the Texas Instruments Foundation Founders' Prize for research that initially had been rejected for funding by the National Science Foundation (NSF), the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA), and the Department of Defense. I felt an obligation to make my experience known, not because I thought it unique, but because of my unique position as the recipient of the awards. A discussion with Dr. Frank Press of the White House Office of Science and Technology Policy led to meetings with agency heads and testimony before the Committee on Science and Technology of the U.S. House of Representatives. This article is an adaptation of that testimony.

I was able to proceed with the rejected projects by "circumventing the system." I had been advised by my mentor, Luis Alvarez, to spend money designated for other projects on the unfunded work. He said that if the projects were successful, nobody would question the propriety of having done this. I was helped by our NASA funding monitor, who allowed us to designate a fraction of one of our grants as "seed money" for new projects, as long as the amount was small and remained "low profile." In addition, I was able to obtain some seed money from the Lawrence Berkeley Laboratory, although those involved felt that they were taking a risk, since the projects were not immediately relevant to the DOE's mission.

It is well known in the research community that one cannot expect a proposal to be funded until a considerable amount of work has been done on the project. When I began research in 1965, our research group often received more than the minimum support necessary for our projects, and the excess money was used to seed new ideas. Only a small fraction of these ideas led to a formal proposal. If the proposal was funded, it could provide seed money for the next idea.

This situation gradually changed. By 1972 our proposals were scrutinized to ensure that we received no more than the necessary minimum. Rarely did we receive the total requested. By 1976 few of our proposals received enough money even to sustain a project, and we had to obtain support from more than one agency. Much of the time we had devoted to thinking about new projects was now spent writing and polishing proposals. Tight funding, increasing overhead, and additional constraints on spending have made it more and more difficult to begin new projects. Fortunately, the Lawrence Berkeley Laboratory has continued to provide seed money, making it possible for our research program to continue to evolve.

Innovation

I have originated several projects termed innovative by the award committees and others. The periods when I

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