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S. D. Soman and K. S. V. Nambi

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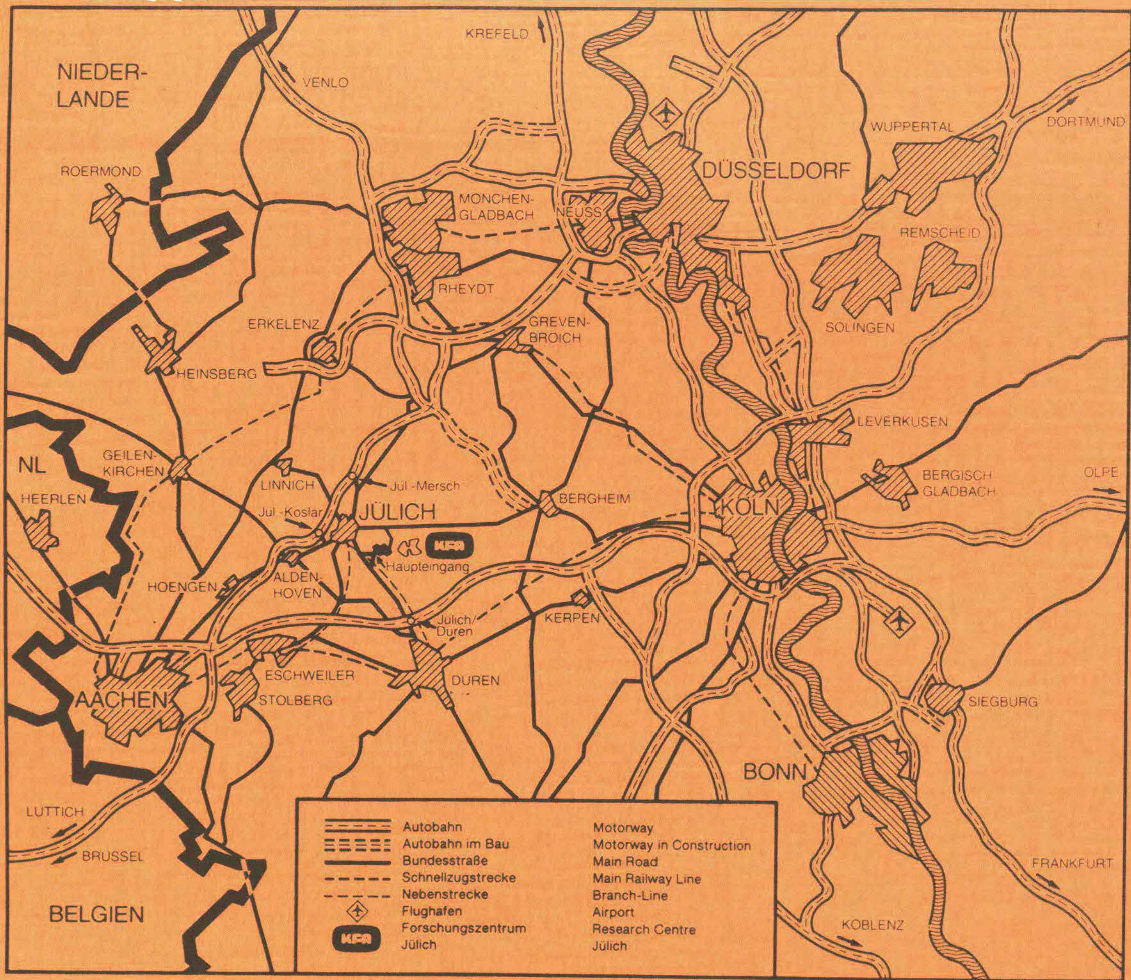

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Areas with Increased Natural Radioactivity

VII. Studies on the Environmental Radiation Distribution and Cancer Risk Prevalence in India[1)]

by

S. D. Soman and K. S. V. Nambi[2)]

[1)] Lecture at the Chemical Analysis Colloquium, KFA, on May 30, 1988

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Content

Tables

Figures

Preface

When studying possible health effects of environmental radioactivity to man, areas of high natural radiation background are especially valuable. Here, because of higher radio activities, the effects should be more pronounced and significant than under lower dose conditions. The classical and most investigated areas with this respect in the world are the monazite sand regions on the beaches of the States of Kerala and Tamil Nadu in South-India. Main centres of high natural radioactivity can be found there around the cities of Quilon and Manavalacurichi at the Malabar Coast, others are also e.g. at the Coromandel coast near Mahabalipuram.

In the region north of Quilon, for example, the areas of lowest background radiation have a mean dose rate of 18,0 µR/h (max.: 68,5 µR/h), corresponding to an average exposure of 158 ± 85 mR . y^{-1}, whereas areas of high exposure have a mean of 103 µR/h (max.: 411 µR/h), corresponding to an average exposure of 904 ± 489 mR .y^{-1}. The undersigned has measured at the beach north-east of Mahabalipuram in 1981 maximum dose rates above ground up to 320 µR/h. The highest values reported in literature around Manavalakurichi are up to 1200 µR/h. For comparison, the granite region of Fichtelgebirge with the highest natural radioactivity background in Federal Republic has a median of about 18 µR/h, within granite quarries a maximum of about 50 µR/h. The maximum values, therefore, are a factor of 20 - 25 higher in Kerala and Tamil Nadu, compared with Fichtelgebirge in West Germany. Therefore, possible negative health effects of gamma-rays, in general, should be more pronounced in the South-Indian monazite sand regions.

Base of this high natural radioactivity in South India are black monazite sands, deposited from the sea to the beaches as relatively thin black lenses of sand. The black sand constitutes about 4 to 5 % of monazite mineral, which is a mixed rare earth thorium phosphate. Other constituents are mainly ilmenite, rutile, zircon, sillimanite and garnet. The black colour is due to ilmenite and rutile, whereas monazite has a yellow earth colour. The monazites from Kerala contain about 60 % rare earth (as M_2O_3), 8 to 9 % thorium (as ThO_2), 27 to 29 % phosphate (as P_2O_5) and only a small percentage of uranium. Therefore, the natural radioactivity of the monazite sands at the beaches of Kerala and Tamil Nadu are mainly due to radionuclides of the Thorium-232- and only to a small fraction of the Uranium-238 series. At the Fichtelgebirge, carrier of natural radioactivities are mainly members of the Uranium-238 series within younger variskian granites.

Indian scientists from the Bhabha Atomic Research Center (BARC) have investigated possible health effects to man by the high natural background radiation in the Monazite sand areas in Kerala and Tamil Nadu since about thirty years. As a remarcable result of the epidemiological studies, no significant genetical radiation damage effects within a collective of about seventythousand investigated persons could be observed. The investigation included long term effects on vertility, abortions, still births, infant mortality, congenital abnormalities, embryonic mortality, skeletal and dental measurements.

The undersigned became familar with this studies, when he visited India in 1973 as a Consultant of the International Atomic Energy Agency Co-ordinated Research Project on Environmental Monitoring for Radiological Health in South East Asia, Far East and Pacific Region (1973 to 1976). Mr. S.D. Soman and the undersigned where participants of this project, S.D. Soman at that time was head of a section of the Health Physics Division of BARC under the late Prof. Dr. K.A. Ganguly. This visit was one of two starting points for the investigation of the natural radioactivity at the Fichtelgebirge, which is the scope of this publication series.

These monazite areas of Kerala and Tamil Nadu where the first carefully studied examples of regions with extremely high natural radioactivity. Other similar regions have been described later on in Brazil, China, Sweden, Finnland etc.. These areas are an excellent object for studying the influence of natural radioactivity to the radiation exposure of man and its possible healths risks. If one cannot find here any significant negative health effects, for example an increase in lung cancer mortality, than in regions whith much lower natural radiation exposure, as for example at Fichtelgebirge, no significant negative health effects are to be expected at all.

When studying lung cancer risk as a function of natural radiation exposure in the region of relatively low doses, the central problem is, how to extrapolate from the high doses of uranium miners to zero doses. Since the relative number of lung cancer is too small and does not exceed the statistical noise level, no significant experimental aproval could be made until today.

Therefore, one has to rely mainly on three different hypothesis, among which one cannot make an experimental decision at the moment. Hypothesis I (linear extrapolation) is the most pessimistic one, which denys the existence of repair mechanisms at all and extrapolates linear from the high dose of uranium miners to zero doses and wants to be always on the "safe" side. Hypothesis II (threshhold behaviour) is more realistic and considers repair mechanisms, which lead to threshhold dose values, below which no negative health effects can be observed. Hypothesis III (hormesis effect) assumes positive health effects at lower radiation doses because of the proved existence of repair mechanisms in the living human cell and their stimulation by irradiation. It is quite clear, that the first mentioned hypothesis, because of neglecting pepair mechanisms, must lead to much more pesimistic results than the two other ones.

In possible agreement with hypothesis III, within the last few years several authors in different areas of the world with higher natural radiation background have observed a significant decrease (!) of lung cancer risk with increasing natural radiation background, measured as gamma dose rate or equivalent dose per year, respectively. These results have been used to support the hypothesis of hormesis effect (3,4). This observations are contrary to the expectations of the hypothesis of linear extrapolation of the risk-dose-function to zero doses.

The authors of this report are demonstrating this behaviour for India with their sets of data. The report was presented by Mr. S.D. Soman on May, 30th 1988 as a lecture at the Chemical Analysis Seminar of the Kernforschungsanlage Jülich GmbH.

Mr. S.D. Soman is now Director of the Health Physics Group of the Bhabha Atomic Energy Research Centre (BARC) at Bombay and is responsible for Radiation Protection in India.

Jülich, December 1989 B. Sansoni

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Abstract

A national survey of the natural background gamma radiation levels has been concluded on 214 locations making use of mailed TLDs. Radiation monitoring has been done on a quarterly basis over one full year at each location and each measurement comprising of two evaluations. The salient results are:

1) While the air-kerma levels follow a log normal distribution, the population-weighted state averages are distributed normally.
2) After nationally taking into account the house shielding and house occupancy factors and body attenuations, the mean natural radiation per caput DE for the country works out to be 690 ± 200 μSv . y^{-1} (range 285 - 1065).

3) The application of the traditionally employed radiocarcinogenic risk factor would indicate that hardly 2 % of the total cancer fatalities occuring annually in India could be related to the environmental radiation.

4) An attempt to correlate the distribution patterns of the radiation levels and the cancer rates (as reported by the National Cancer Registry) resulted in an inverse correlation: where the radiation level is high, cancer risk in invariably low.

1. Introduction

With increased public concern for nuclear safety especially vis-a-vis the cancer risk, a programme was initiated to study the natural background radiation levels and their variation in different parts of India.

2. Environmental gamma radiation measurements (1,2)

The details of the CaF_2 - based thermoluminescence dosimeter (TLD) system employed and the methodology followed have been described in earlier publications (1). Suffice to recall here that,

1) the strong energy dependence of CaF_2-TLD was effectively reduced to measure satisfactorily typical environmental radiation fields by 1,5 mm brass encapsulation;
2) the self dose as well as the transit doses acquired by the TLDs were adequately taken care by the use of control TLDs.

The performance of the environmental TLDs to international standards have been verified by participating in the International Environmental Dosimeter Intercomparison Exercises being periodically organised by the Department of Energy, U.S.A.

In the recently concluded national enviromental radiation survey programme, 214 locations in India were monitored for one full year each on a quarterly basis and a total of 2800 TLD values were computer processed and statistically analysed. Some of the important findings are:
1) Temporal variations in the environmental radiation levels follow a log normal distribution and could be generally ascribed to seasonal varations in the ambient radon and thoron levels <u>(Figs. 1 and 2)</u>.

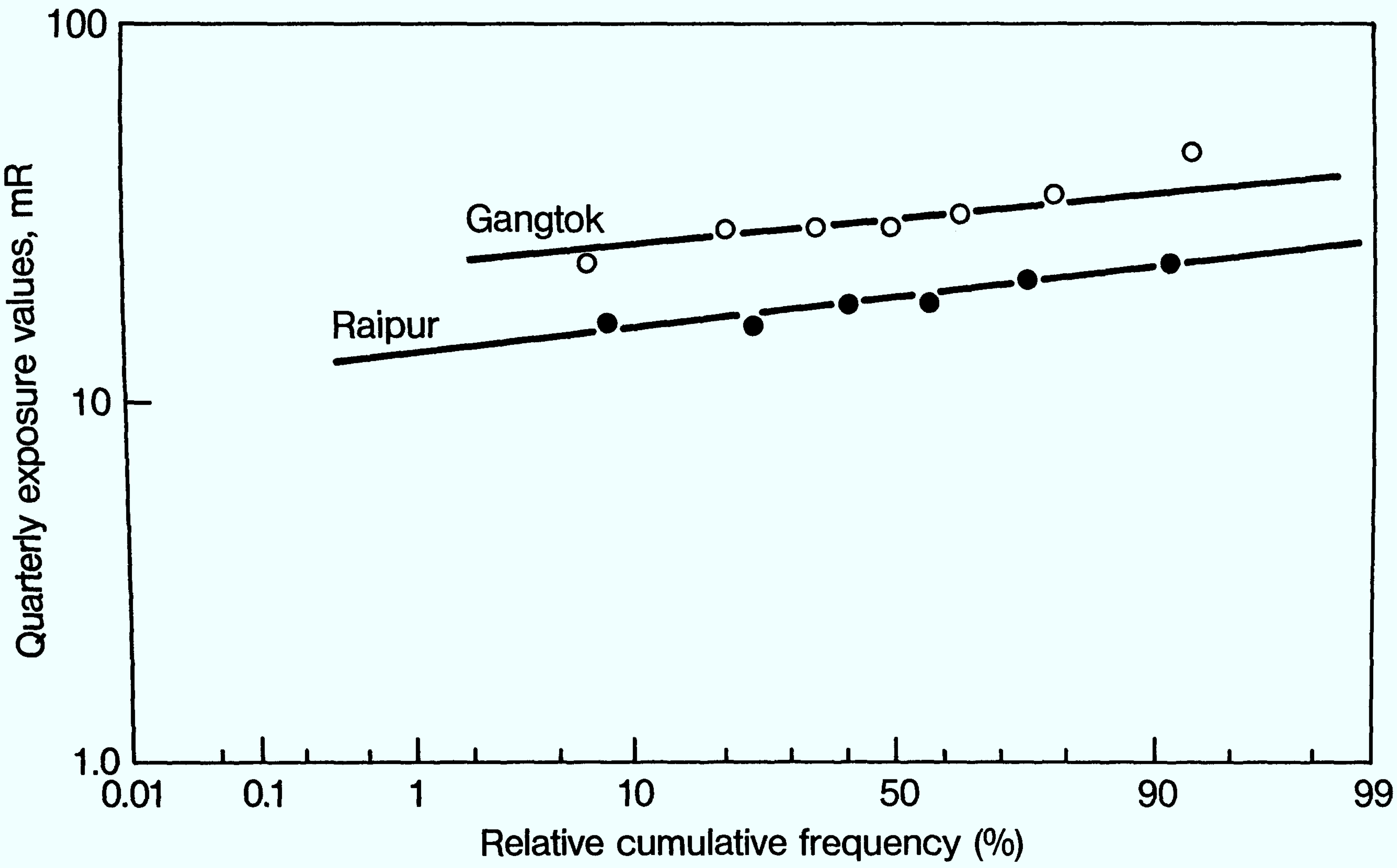

Figure 1: Log probability plots of quarterly background radiation levels at Raipur and Gangtok (Period of monitoring: 6 & 7 consecutive quarters respectively)

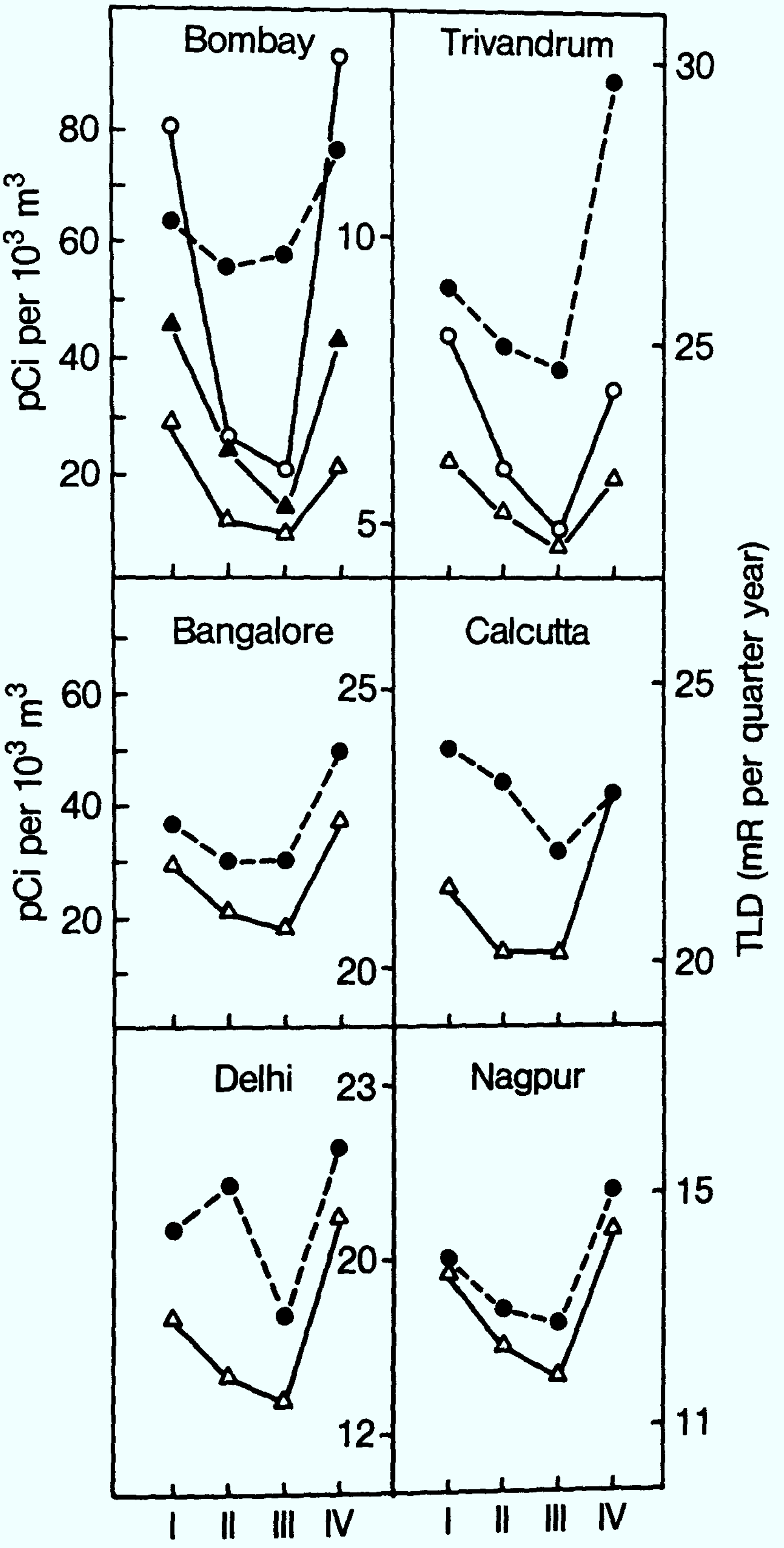

Figure 2: Quarterly variations in radon daughter air concentrations and natural background gamma radiation levels (TLD values) at six locations in India.

O - - - O - - - O TLD values
O —— O —— O Ra-B (^{214}Pb)
△ —— △ —— △ Th-B (^{212}Pb)
X —— X —— X Ra-D (^{210}Pb)

(The radon concentration scales shown on the left side of each row is applicable to both the figures in the row; the TLD scale applicable to each figure appears on its right.)

2) The environmental radiation levels (air kerma values) of the 214 locations monitored in this survey, are also log normally distributed (Fig. 3).

3) While the "field" TLDs yielded a national (monazite regions excepted) mean value of 765 ± 300 μGy/y, the "mail control" TLDs gave a mean value of 785 ± 225 μGy/y.

An important realisation in the present study is that the "mail control" TLD readings besides serving to account for the self and transit doses, can be effectively used to arrive at a truly national average value for the environmental radiation level. Most of the TLDs follow rail/road routes through the length and breadth of the country; the slightly higher value obtained from the mail control TLDs can be attributed to the air travel exposure received by some of the TLDs. Thus the additional of a nearly 1400 control readings have boosted up statistically the significance of the national mean obtained in this study viz. 770 ± 370 μGy/y.

To arrive at a meaningful value for the population dose due to the environmental gamma radiation, three important factors have been given due considerations (Table 1). The population-weighted state averages (using 1981 census data) of the percaput dose equivalent values have been found to be normally distributed (Fig. 4) and the national mean is found to be 690 ± 200 μSv/y.

A very important finding regarding the population dose distributions in India is the extreme variations seen in the regional values; some typical results are shown in Table 2. It is important to realise that the variations are mainly due to the differences in the geological formations characterised by inherent differences in the primordial radioactivity viz. the U, Th and K concentrations. A detailed study (3) was undertaken to calculate the expected terrestrial gamma radiation levels at various geological units of the country based on catalogued values of U, Th and K characteristic of the each geological formation and compu-

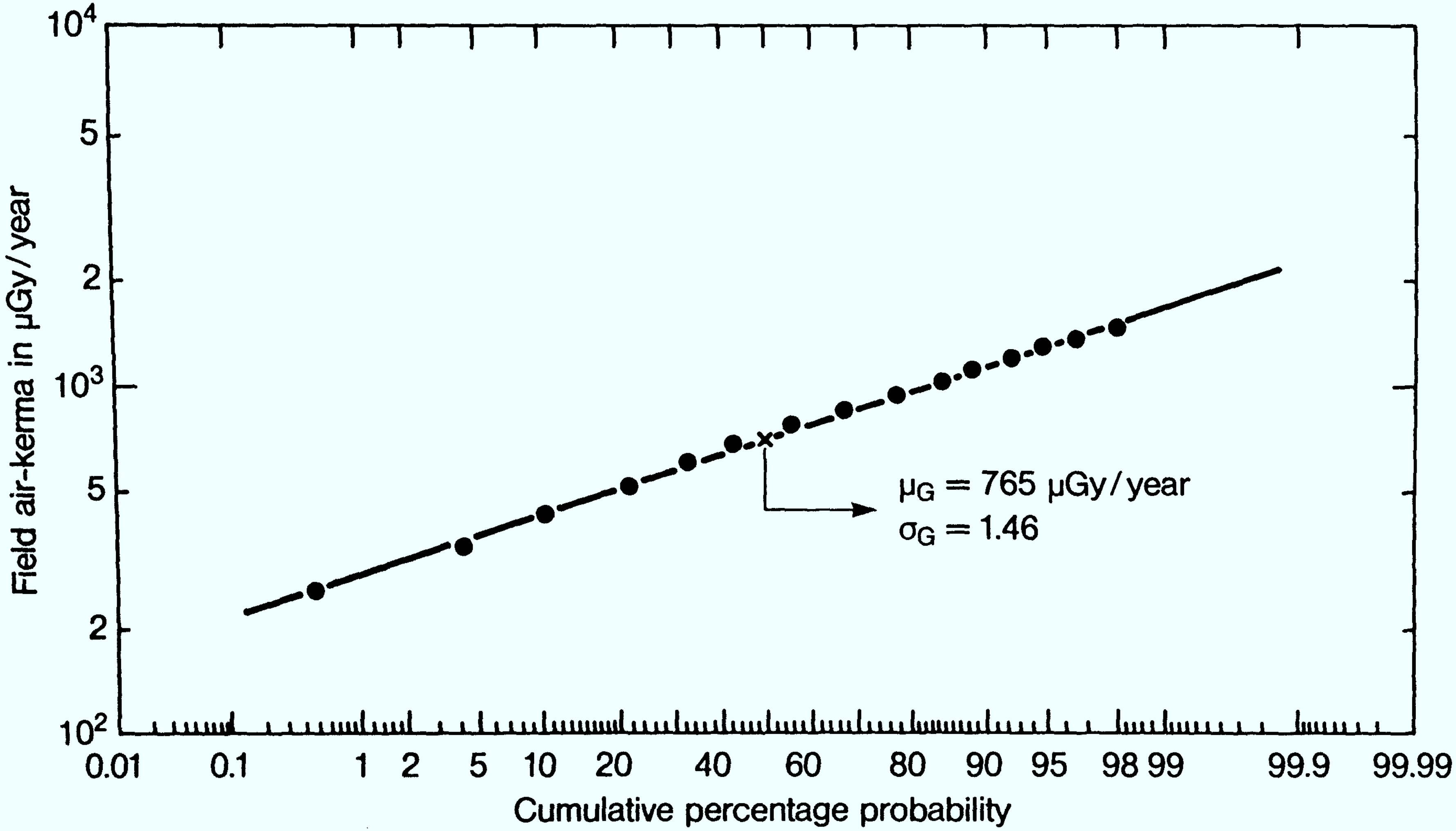

Figure 3: All India natural background radiation levels: Relative cumulative frequency vs. annual air-kerma values

Table 1: Factors considered to evaluate the population dose from exposure values

1. Indoor/outdoor exposure ratio[1]	= 1.195
2. House occupancy factor[2]	= 0.85
3. Effective dose equivalent/exposure ratio[3]	= 6.69 mSvR^{-1}

(1) House types considered: clay huts, concrete dwellings, granite constructions and brick houses (see ref. 1)

(2) Weighted for population categories of women, children < 5 years, old people > 60 years, agricultural labourers and the rest (see ref. 1)

(3) Weighted for a 7-group exposure – energy spectrum of typical natural background radiation (see ref. 2)

Table 2: Population dose distribution in selected parts of India due to environmental external radiation

State/territory	Environmental radiation DE per caput µSv/y
Laccadiv	285
Maharashtra	370
Andaman	450
Kerala *	595
Delhi	665
Tamil Nadu *	705
Assam	820
Uttar Pradesh	910
Andhra Pradesh	1065

* except monazite areas

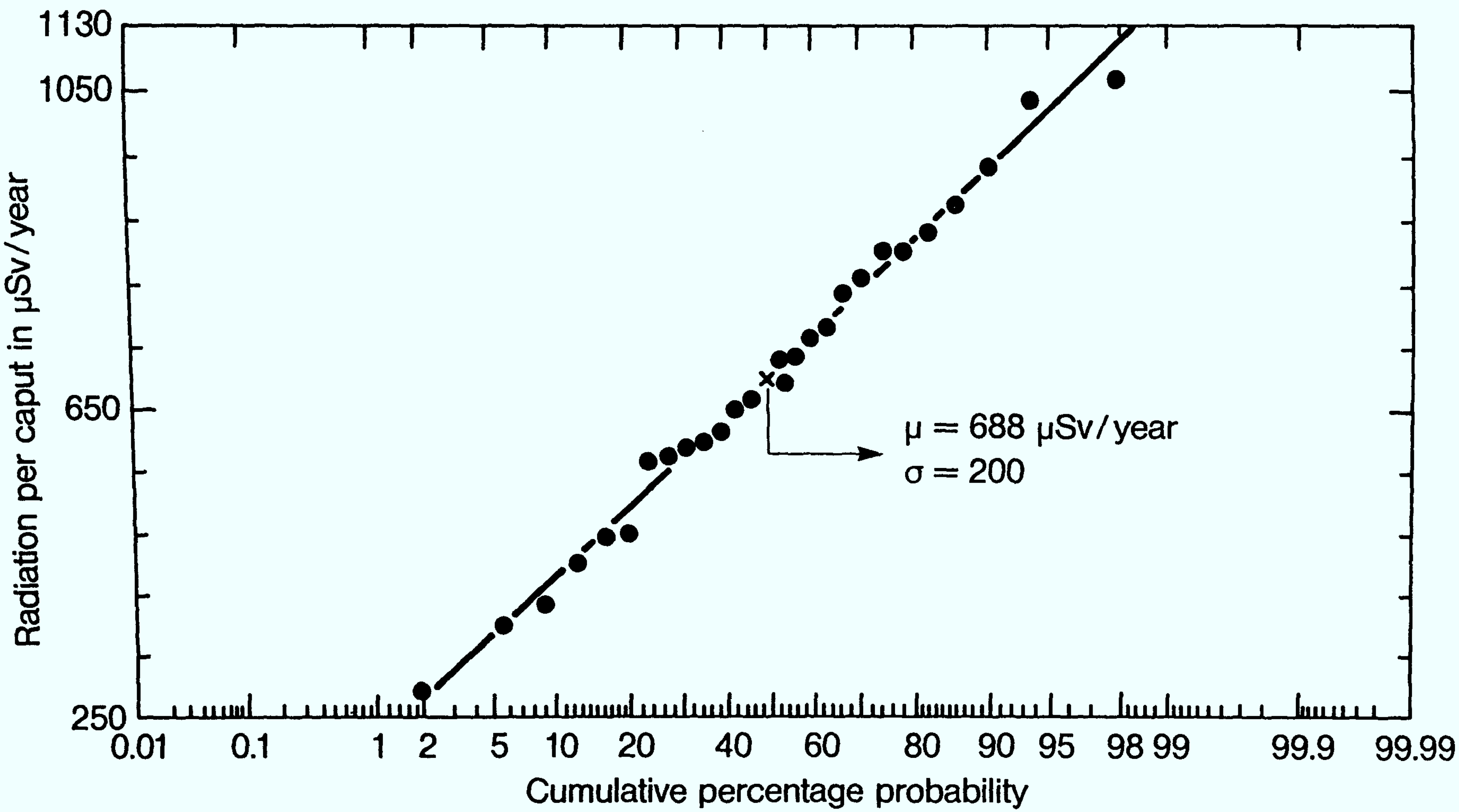

Figure 4: The normal distribution of population weighted state average radiation per caput values

terprocessed to generate 3-D radiation profiles. The values inferred for the 214 TLD stations were also individually calculated and compared with the TLD measurements (Fig.5). Remembering that the TLD values include the cosmic background which is mostly around 280 µGy/y but could be significantly more for high altitude stations, it is remarkable that the inferred and measured values have yielded a correlation coefficient of 0.64 and indicated a national mean cosmic ray background level of 281 µGy/y. The scatter in the figure is mainly due to the fact that the inferred values are not from actual radioactive analysis of soils and rocks but based on catalogued values for the respective "geological formation type". On the other hand, the TLD values represent the factual levels averaged over seasonal variations in a year.

Thus, although the actual measurements have been made only in 214 locations, there is reasonable prospect of being able to predict background radiation levels anywhere in India from the data base and computer software already generated.

3. Cancer prevalence in India (4,5,6)

Two types of cancer data are available: population-based and hospital based. Cancer rates, age-adjusted to the world standard population of 100,000 - AAR values - are readily available for the former and for a few cities only. The hospital data are compounded for each state/union territory separately and weighted for the respective populations to yield a crude, hospital reporting rate for the cancer incidence, CR_H.

While the population-based data from the cancer registries are more complete and reliable, the hospital data can be relied upon only to confirm whatever trends are indicated by the analysis of the former.

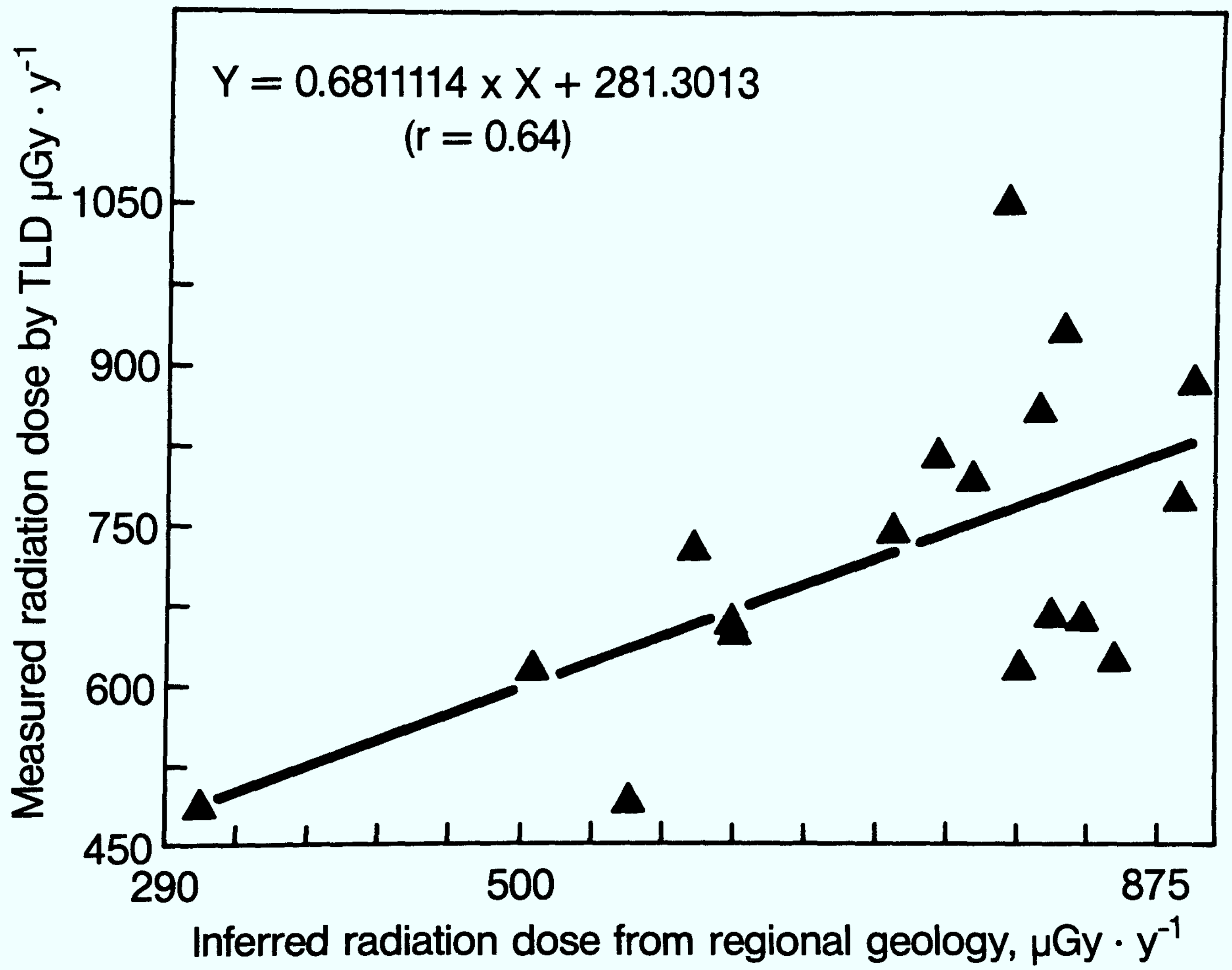

Figure 5: Correlation between inferred and measured values of environmental radiation doses in various states of India

If one considers all types of cancers specified by WHO - ICD nos. 140 to 208, the crude as well as the age adjusted cancer incidence rates work out to be in the neighbourhoods of 73 and 145 per year per 100,000 population respectively; these are significantly lower than what are observed in most of the western countries which are in the neighbourhood of 300 and 200 respectively (7).

4. Correlation between environmental radiation and cancer (8)

The data have been analysed for a linear regression fit, and the statistical significance of the correlations have been tested using a null hypothesis of zero correlation and t-statistics. The results for the population and the hospital-based cancer data are presented in Figs. 6 and 7.

It is emphasised here that similar correlation graphs were published earlier (8) based on cancer data available prior to 1982 and the present results including more recent data have yielded better correlation coefficients.

It is recognised that there are many confounding factors in any epidemiological studies on cancer as it is influenced by widely different factors including socio-economic ones. In a developing country like India, the factors which come upper-most in mind are the effects of population density, and literacy levels (9). We do see a plausible direct correlation of cancer reporting rates in various states and the respective percentage literacy levels but such correlation vanishes with the population based city data where literacy levels are more or less the same. Similarly no correlation could be found between cancer and population density.

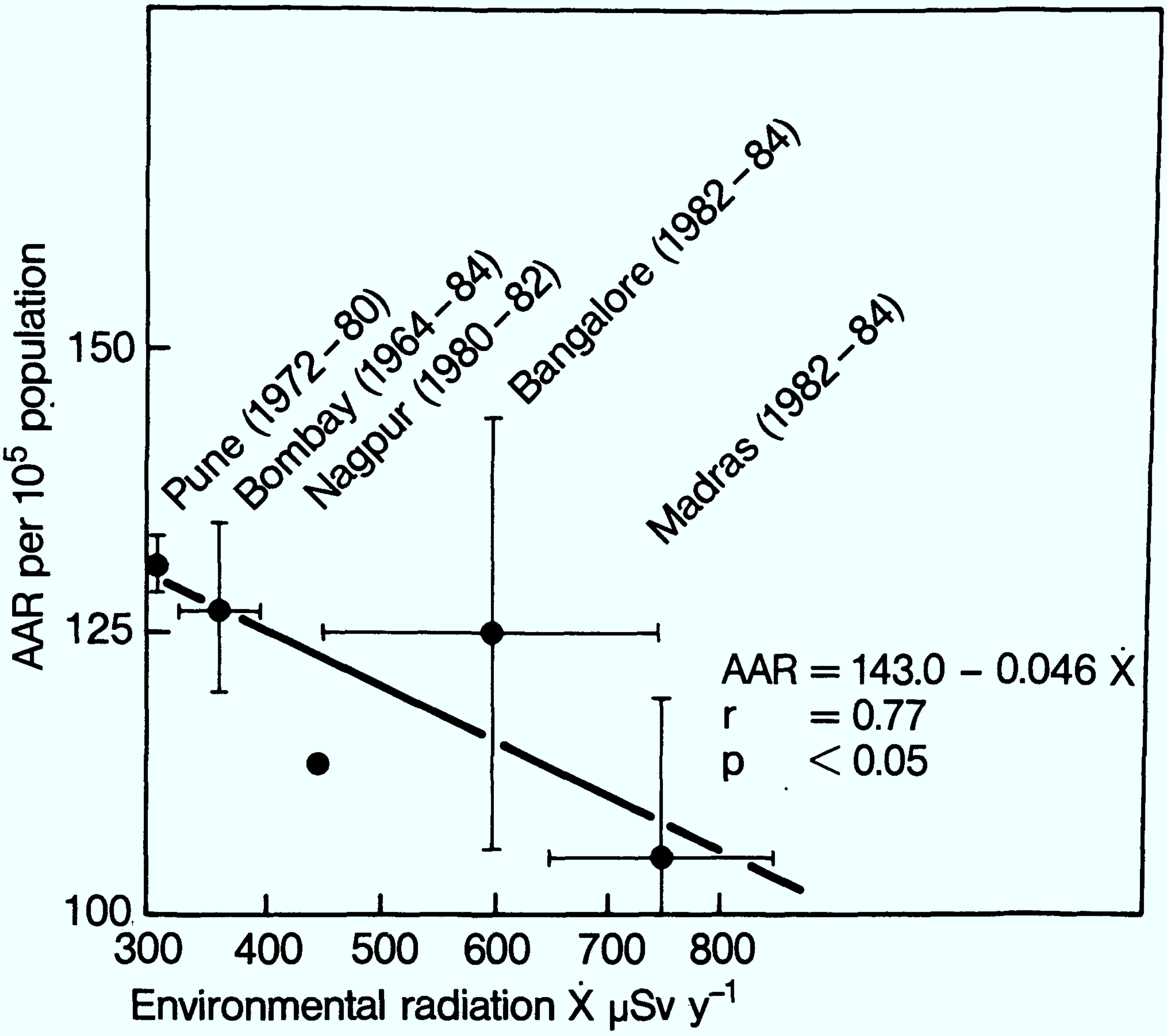

Figure 6: Environmental radiation vs. age adjusted cancer incidence in five indian cities

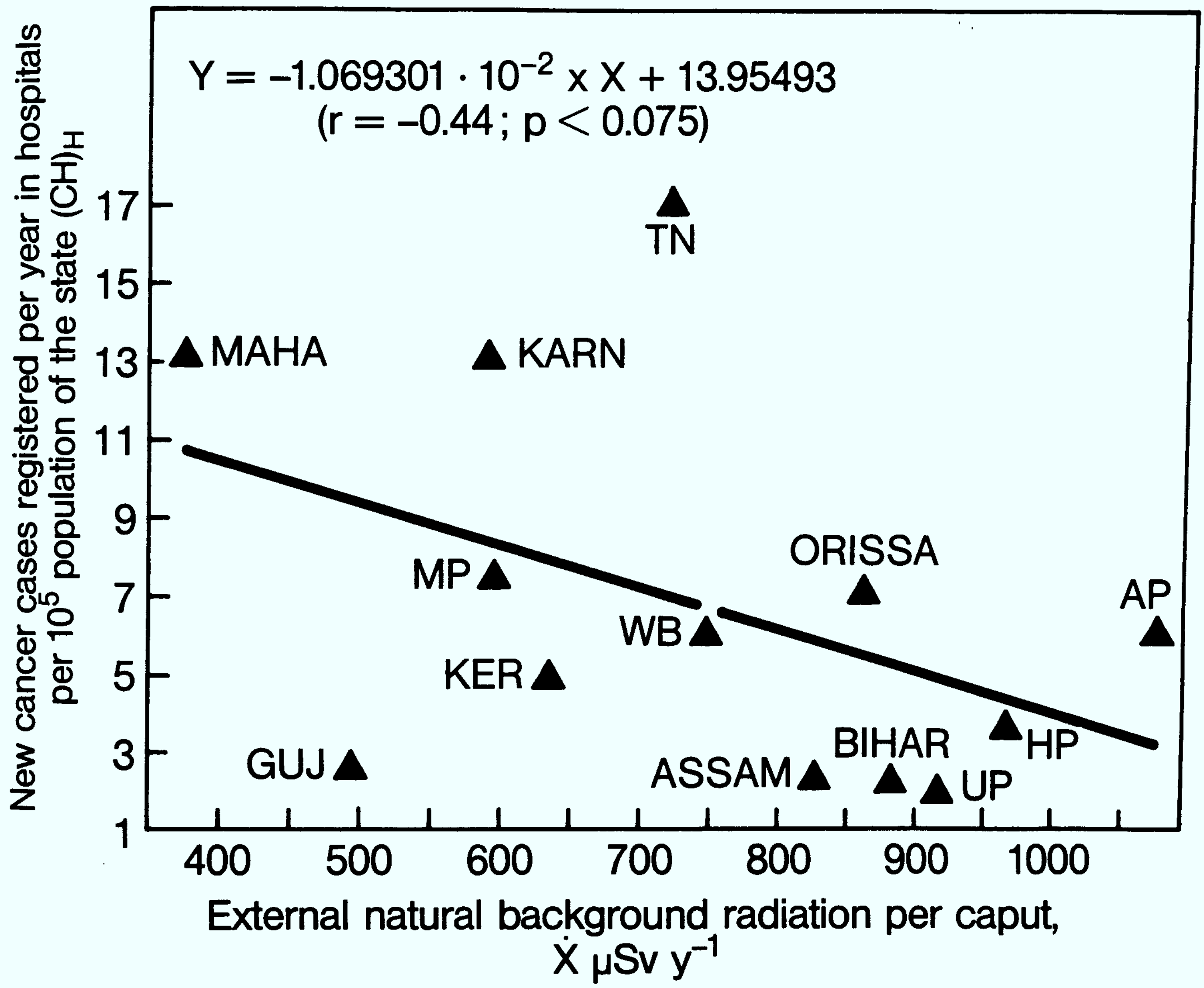

Figure 7: Cancer reporting rate in hospitals during 1981-83 versus natural background radiation per caput: statewise distribution in India.

For further confirmation of the inverse trend seen, attempts were also made to correlate individually some of the well known radiation - prone cancer types like leukamia, cancer of respiratory organs, cancer of digestive organs etc. and these also yielded statistically significant inverse correlations (8).

5. Concluding remarks

While an inverse correlation between cancer and radiation might sound incongruous, it is certainly neither a new nor an isolated observation. Similar results on USA already exists in literature (10) and new ones have been reported from China (11) and Czechoslovakia (12) recently.

It is important to realize that the internal dose component should also be taken into account to make the correlation more meaningful. Indications (8) are that the inverse correlation will still be valid and only the correlation quotient values will change. Nevertheless it is considered necessary to substantiate further these observations with more complete dosimetry data as well as cancer data on more number of cities.

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