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BASES FOR PROTECTION AGAINST RADIATION AND CONVENTIONAL HAZARDS

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Dedication:

I thank the Organising Committee members of the Society of Nuclear Medicine for inviting me to deliver this Homi Bhabha Memorial Oration. I feel deeply honoured. It is not for me to enumerate the many splendoured genius and accomplishments of this great son of the country. For those of us who came to work under his inspiration, it is almost impossible to make an objective assessment of the great losses suffered by the country at his untimely death under tragic circumstances and that too at the peak of his great constructive activities.

This talk delivered as an humble tribute to his memory, is only a sequel to one of the noble exhortations he made to those of us who were engaged in the

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work related to radiation protection and safety sciences. In one of his official memoranda in 1960, he desired that 'radioactive materials and sources of radiation should be handled in the Atomic Energy Establishment in a manner which not only ensures that no harm can come to the workers in the Establishment or any one else, but also in an exemplary manner, so as to set a standard which other organisations in the country may be asked to emulate'.

Introduction:

I have personal limitations in talking to this august gathering of medical men in your language and as such I shall be talking from the vantage point of a basic scientist, who wishfully thinks that all matters related to the preventive aspects of health and safety in human activities can be quantitated somehow in a rational manner, so that in the operative part of a safety programme the field man can deal with numbers and not with notions.

It is now generally realised that, in addition to ionising radiation (both natural and man-made) the human environment (both of his living and working environs) contains other important man-made agents which pose threats to his health and well-being. These are: non-ionising radiations such as microwaves, ultraviolet radiations, lasers and chemical compounds.

Non-ionising radiation hazards: I take only one example case of non-ionising radiation to make my point. With the advent of high power microwave generators and their application in radar, communication, broadcasting, medicine, industry and household appliances, the possibility has arisen of a large number of persons getting exposed to these radiations occupationally and non-occupationally.

At high levels of exposure, microwave radiations are known to interact with body tissues depositing their energy in the form of heat. These thermal effects are responsible for the tissue damage and lethality observed at high exposure levels (hundreds of milliwatts per cm^2). However, the effects of microwaves at low levels of exposure in the working and general environment are not well known. The Western scientists argue that at low levels, the heat generated by microwaves in body tissue is so small that no undue effects are discernible. On the other hand the scientists of the East European countries have reported a number of effects such as fatigue, headache, sleepiness, irritability, neurological effects, anxiety, behavioural changes and these are attributed to nonthermal effects of chronic exposure to microwaves at low levels. Because of the fundamental differences in understanding

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the effects at low levels, there are significant differences in the levels of maximum permissible exposure to microwave radiation recommended by the two groups. The Western group (U.S.A., U.K., Canada etc.) recommends a limit of 10 mW/cm^2 for continuous exposure, which can be raised to higher levels for shorter exposure periods. The East European group, on the other hand recommends a limit of 0.01 mW/cm^2 for continuous exposure. These two levels differ by a factor of 1000(1).

<u>Toxic chemical compounds</u>: Man is exposed to a number of chemical compounds, in various concentrations, in the form of pesticides, herbicides, cosmetics, food additives, drugs, industrial solvents and effluents, rubber, plastics, automobile exhausts, heavy metals etc. in air and water. There are about three million chemical compounds in use to-day and nearly 700 new ones are being introduced every year. Many of these compounds are produced in millions of tons per year and distributed throughout the world. Besides effluents generated in the manufacture are released in quantities to the ambient environment where man lives and works.

The effect of exposure to these chemicals may vary from skin irritation to malignancy. Epidemiological studies and laboratory experiments have established that many of these compounds are carcinogenic and mutagenic.

For example, it is known that exposure to asbestos results in lung cancer; Vinylchloride monomer in liver cancer, nickel in cancer of lung and nasal cavity, cadmium in prostrate and respiratory cancers[2]. The International Agency for Research on Cancer (IARC), has evaluated more than 270 chemicals for their carcinogenic risk to humans; of these 20 were found to be associated with the occurrence of cancer in humans. For the 15 of these 20 chemicals, exposure was solely or mainly occupational. Experimental evidence of carcinogenicity has been confirmed for 137 of the 270 chemicals considered. Evidence of human exposure exists for 131 of the 137[3].

Prevention of Carcinogenic & Mutagenic effects:

General legislation which limit the exposure to conventional toxic substances do not include carcinogenic and mutagenic effects. This is in contrast to the situation existing in the control of ionising radiation hazards. There are some estimates which suggest that the potential hazards of even the recommended values are much higher than those accepted for ionising radiation. Quantitative data on the induction of malignancy and genetic damage at low levels of chemical exposure are not readily available or existing data have not been evaluated against a specific safety standard to be attained. Hence legislation in the production, distribution and use of carcinogenic compounds is very scanty. In fact there are only 14 countries in the world which have some legislation in this regard[3]. Even in these countries the emphasis is more on providing monetary compensation than on primary prevention. Radiation protection discipline have not contributed so far to the concept of monetary compensation and save (or relax) on radiation hazards prevention.

Until now, the radiation safety scientists in radiological and nuclear industries were preoccupied with radiation hazards only and have not considered systematically the hazards of other agents even in their own operational areas. They accepted or took for granted the adequacy of safety standards that were in vogue in the conventional fields. We know now that the stipulations are not all valid for ensuring human safety in this area. It is realised now that the radiation hazards under the well disciplined controlled conditions as obtained today is only a very small fraction of the totality of hazards from other sources. Figure-1 indicates the spectrum of biological response to exposure to chemical pollutants and adverse health effects that are considered for air pollution control purposes. Our concern for setting up safety standards, however, should appropriately encompass the total gamut of hazards, including carcinogenic and

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mutagenic, to man from all sources in his environment and to bring about an uniformity in standards. It is all the more important when we consider the ubiquitous nature of chemical pollutants, and the possibilities of synergestic action amongst chemicals on the one hand and chemicals and radiation on the other. In the application of modern science and technology to human welfare, radiation safety scientists are placed in a situation of dichotomy in the nuclear industry where distinctly different standards are in force. One set of standards of long term objectives are applied to enforce radiation safety and another set of standards of short-term objectives are applied to conventional hazards. The great disparity in the performance because of conducting the safety programme with two different standards is exemplified in Table-1. Fortunately, some efforts are being made towards removal of this dichotomy by several workers in safety sciences[4].

Guidelines for developing common safety objectives:

The problem is how to evolve uniformity of approach to develop criteria for acceptable risk and detriment irrespective of the causative agents. A specific injury is an injury; a given hazardous situation is an hazardous situation, whether these are caused by radiation or otherwise. While the current practices in radiation health and safety take cognizance of the totality of radiation safety problems including its impact on environment, in the case of conventional hazards, the safety standards look mostly for safeguarding against somewhat immediate or acute health effects including fatalities (Fig. 1, Finklea[6]).

There are a number of lessons that have been learnt and a number of principles established in the process of setting up standards for radiation protection, which are worthy of emulation while setting up safety standards in the conventional fields.

Radiation safety has defined its objectives in the following terms: 'Radiation protection is concerned with the protection of individuals, their progeny and mankind as a whole, while still allowing necessary activities from which radiation exposure might result'. Permissible environmental radioactivity levels evolved in different countries are from these prime considerations of protection of man though without specific reference to the protection of other life forms or protection of environmental resources for economic exploitation, well-being and recreation of man. However, it is believed that the radiation protection of the other life forms in the environment have been indirectly accomplished through the efforts for safeguarding man and his interests. Experiences in the peaceful operations of atomic energy indicate that no significant deleterious

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effects have been discernible even in the immediate neighbourhood of the environment where radioactive wastes have been discharged for more than 3 decades in accordance with the prescribed limits, nor there were occasions when these practices have prejudiced harvesting the environmental products by man. This is stated notwithstanding the occasional clamour that are generated by the media. I do recognise that certain profound controversies still exist on this issue, but it should also be recognised that no such statements can be made in respect of disposal of conventional pollutants into the environment. The examples of damage to the ecosystem and environmental economic products and directly to man himself from effluent discharges are too numerous and obvious.

In the non-radiation field also it is recognised that 'the health of man is paramount'[5]. Primary air and water quality standards have been established to protect human health from adverse effects attributable to air and water pollutants arising from multiple sources[6].

The aim of radiation protection is to prevent detrimental non-stochastic effects (Fig. 2) even to individuals and to limit the probabilities of stochastic effects (Fig. 2) to acceptable levels. The prevention of non-stochastic effects is achieved by setting dose-equivalent limits at sufficiently low values so that no threshold dose (Fig. 2) would be reached even following exposure for life time or for total period of working life[7]. The additional requirement of limiting the stochastic effects is achieved by keeping all the justifiable exposures to as low as reasonably achievable (ALARA). In the conventional field, as indicated earlier, the injuries that are considered are of non-stochastic type, although some considerations are now emanating for stochastic injuries (genetic and somatic) but not practised. In a very recent attempt Vohra[9] considered the somatic stochastic effect like cancer induction by chemical toxins. From the statistics collected in different countries he correlated the radiation dose equivalents of two conventional polluting agents as given in figure-3.

Finklea et. al[6] of EPA, United States, made some elaborate efforts to identify the areas of ignorance on data base for understanding the risk equivalents of some conventional toxins like sulphur dioxide, carbon monoxide, oxides of nitrogen, dust particles etc. in air. In writing about 'what should a minimal adequate health-intelligence base assess?', Finklea et. al state that the 'base should ascertain the effects of long-term low level exposure and the effects of single or repeated short-term exposures. It should be remembered that the acute effects may be attributed to the cumulative effects of long-term low level exposures as well as to the effects of short-term peak exposures. This is essentially because the exposure response functions for the diverse efforts are not available'. It is further assumed in the estimation of risks that there exists a threshold for each type of detriment associated with different toxins (Fig. 2). The safety measures that are being talked about in setting up standards for conventional pollutants are invariably based on the information collected on exposure thresholds, which rely heavily on systemic recovery mechanisms in the exposed man. These effects do not indicate if a permanent or long lasting damage builds up when persons are continuously exposed below the exposure threshold although it is recognised as stated earlier that long-term low level exposures may lead to an acute effect of short-term exposures at a level below the prescribed exposure thresholds. The possible effects of different types of exposures can be understood through the following figures. During and after an acute exposure, the hazard parameter may build up sharply and then decrease exponentially. If the injury is completely reversible, the recovery is complete (Fig. 4). Otherwise some residual damage would remain (Fig. 4). In the case of chronic exposures (or repeated single exposures), the integral of the hazard parameter may tend to stay at

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a higher level than the sum of the residual hazards after separate exposures (Fig. 5). This is on the assumption that the systemic response to separate exposures are not distorted by previous exposure history.

Epidemiological data base and extrapolation:

The difficulty in translating these models into numbers is essentially because of the lack of experimental data base[6]. In formulating its earlier standards of radiation protection, the ICRP relied heavily on extrapolation from animal experiments to man. Primary standards were set initially on the basis of a few human exposure histories like those of the uranium mine workers, radium dial painters and experiences of early radiologists. The totality of human experiences on hazards from radiation exposure was extremely limited and I would consider that the totality of human experiences with conventional pollutants have been at any point of time much more elaborate than radiation exposure. The extrapolation methodology of the ICRP to arrive at numbers can be questioned at many points. However, that was the best that could be done within the framework of the then existing knowledge. This methodology may have to be adopted extensively in the conventional field. The present day epidemiological data on radiation effects are based on the studies of the ABCC in Hiroshima and Nagasaki and a number of published radiological

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surveys and radiation effects (cf. Ref. 9, 10, 11). In the conventional field there are extensive information available and it should be feasible to collate the published demographic data on the effects of many of the conventional pollutants and hazardous industries, e.g. Pochin studied the fatality data from the Chief Inspector of Factories in UK and arrived at the mean death rate for different industrial operations as given in Table-2.

One of the most significant contributions of the ICRP to the science of safety has been the stipulation of basic safety standards for the host of radio-isotopes that are generated in the atomic energy industry. It brought about an admirable international discipline in setting up safety standards in nuclear operations. Although the power reactor operations and irradiated fuel reprocessing facilities deal with concentrated radio-toxins in astronomical quantities, it is gratifying that there has not been a single death in the nuclear power industry in the last decade that is attributable to radiation exposure. Further, the radiation dose received by the population due to atomic energy operations is only in the range of a few percent (3% in UK) of the natural background radiation. This will result in an estimated cancer death rate of 0.0045 to 0.006 in a population of 10,000[8]. This

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can be compared with the cancer death rate in chemical industry which ranges from 10-30 per 10,000 workers[12]. Moreover, there is no international agreement in establishing permissible levels of exposure to chemical pollutants. For example, Table-3 compares the permissible limits for different chemicals adopted in different countries. The large differences amongst them perhaps indicate the non-uniformity of safety standards that have led these values. All these are cited as a plea to the radiation medicine scientists and radiation safety scientists: (i) for the evaluation of global information that is available, (ii) to develop cogent concepts of acceptable risks and detriments, (iii) to evaluate and extrapolate where necessary to evolve prescription for permissible levels for hazardous materials in the environment where man lives and/or works.

Tissue at risk: As examples of assessment of relative radio-toxicity of glands and tissues, we may ponder the following and urge the toxicologists to make such assessments for conventional toxins and hazardous materials.

The earlier ICRP concept of critical organ did not permit the summation of detriment according to relative radio-sensitivities of the irradiated tissues. The commission now recommends (ICRP, 1977) a procedure which

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takes account of the total risk attributable to the exposure of all tissues irradiated. The following organs and tissues are considered because of their susceptibility to radiation damage.

1) Gonads: The most important effects are impaired fertility and hereditary effects. These effects are age-dependent in women. Reduction of fertility may be temporary in man at low doses.

2) Red bone marrow: Red bone marrow is taken to be the tissue mainly involved in the causation of radiation induced leukaemia. Radiation induced leukaemia reaches its peak value within a few years after irradiation, and returns to pre-irradiation levels after about 25 years.

3) Lung: Cancer of the lungs has been observed in miners exposed to high concentrations of radon and its decay products. There is evidence that external irradiation can also induce lung cancer in man. The present indication is that the risk of lung cancer is about the same as that for development of leukaemia.

4) Pulmonary lymphoid tissue: A particular case of importance concerns the retention of inhaled particles containing insoluble compounds in broncho-pulmonary lymph nodes, which comprise about 1% of all the lymphoid tissue

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in the body. Selective irradiation of lymph nodes can be considered as corresponding to extremely non-uniform irradiation of the lymphoid tissue and hence has a lower hazard factor. Since lung is regarded as of higher sensitivity than the lymphoid tissue, irradiation of lung is likely to be more limiting than that of lymphoid tissue.

5) Thyroid: The cells at risk in thyroid gland appear to be the epithelial cells of the thyroid follicles. The sensitivity of thyroid to the induction of cancer by radiation appears to be higher than that of the red bone marrow to the development of leukaemia. However, the mortality from these thyroid cancers is much lower than for leukaemia primarily because of the success in the treatment of cancer and the slow progress of this type of tumour.

6) Breast: Data on development of breast cancer following irradiation of women, suggest that, during reproductive life, the female breast may be one of the more-radio-sensitive tissues of the human body. The risk factor for breast cancer may be a few times higher than that for leukaemia.

7) Bone: The radio-sensitive cells in bone have been identified as the endosteal cells and epithelial cells on bone surfaces. Radio-sensitivity of bone in relation to

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the development of radiation induced cancer indicates that it is much less sensitive than breast, red bone marrow, lung and thyroid.

8) Children and foetuses: Exposure before birth or during child-hood may interfere with subsequent growth and development, depending on factors such as dose and age at irradiation. Susceptibility to the induction of certain malignancies also appears to be higher during the prenatal and child-hood periods than during adult life.

Is it not possible to promote and undertake a study of the published literature on toxicology of conventional toxins to develop similar assessment of their relative hazards to man and his environment?

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TABLE 1. UK FATAL ACCIDENT RATES (d/M/y, 12-YEAR MEANS), ACCORDING TO OCCUPATIONAL GROUP
(Data from the Chief Inspector of Factories, 1960-1972)

OCCUPATION OR MANUFACTURE	MEAN ± S.E.
CLOTHING AND FOOT-WEAR	3 ± 1
ENGINEERING AND ELECTRICAL GOODS	23 ± 1
TEXTILES	23 ± 2
VEHICLES	26 ± 2
PAPER, PRINTING AND PUBLISHING	28 ± 2
METAL GOODS NOT ELSEWHERE SPECIFIED	29 ± 2
FOOD, DRINK AND TOBACCO	34 ± 2
LEATHER, LEATHER GOODS AND FUR	37 ± 8
TIMBER, FURNITURE ETC.	64 ± 5
BRICKS, POTTERY, GLASS, CEMENT, ETC.	75 ± 5
CHEMICALS AND ALLIED INDUSTRIES	87 ± 5
METAL MANUFACTURE	136 ± 5
SHIPBUILDING AND MARINE ENGINEERING	162 ± 8

TABLE. 2. STATISTICS OF CONVENTIONAL INJURY AND RADIATION EXPOSURE IN B A R C DURING 1966 TO 1975

Year	No. of employees	No. of disabling injuries	No. of man-days lost	No. of radiation workers	No. of persons exceeding 5 rem /y
1966	9500	85	963	2951	16
1967	9800	53	903	3067	5
1968	10110	45	866	3082	6
1969	10540	58	844	3102	15
1970	10727	55	743	3295	5
1971	10968	41	603	3476	2
1972	11140	60	997	3456	3
1973	11290	68	988	3250	1
1974	11420	40	533	3083	1
1975	11740	49	999	3182	2

TABLE 3 PERMISSIBLE LIMITS OF EXPOSURE FOR CERTAIN CHEMICALS IN DIFFERENT COUNTRIES

CHEMICAL COMPOUND	MAC (RUSSIAN)	TLV (U.S.A.)
TRICHLORO ETHYLENE	10 mg/m^3	535 mg/m^3
VINYL CHLORIDE	30 mg/m^3	FDR-260 mg/m^3 USA-1300 mg/m^3 (UNTIL APRIL'74). 130 mg/m^3 (UNTIL MAY'74). 1 ppm (SINCE MAY'74).
MERCURY	0.3 mg/m^3	5 mg/m^3
LINDANE	0.05 mg/m^3	0.5 mg/m^3
HEPTACHLORE	0.01 mg/m^3	0.5 mg/m^3
MALATHION	0.5 mg/m^3	15 mg/m^3

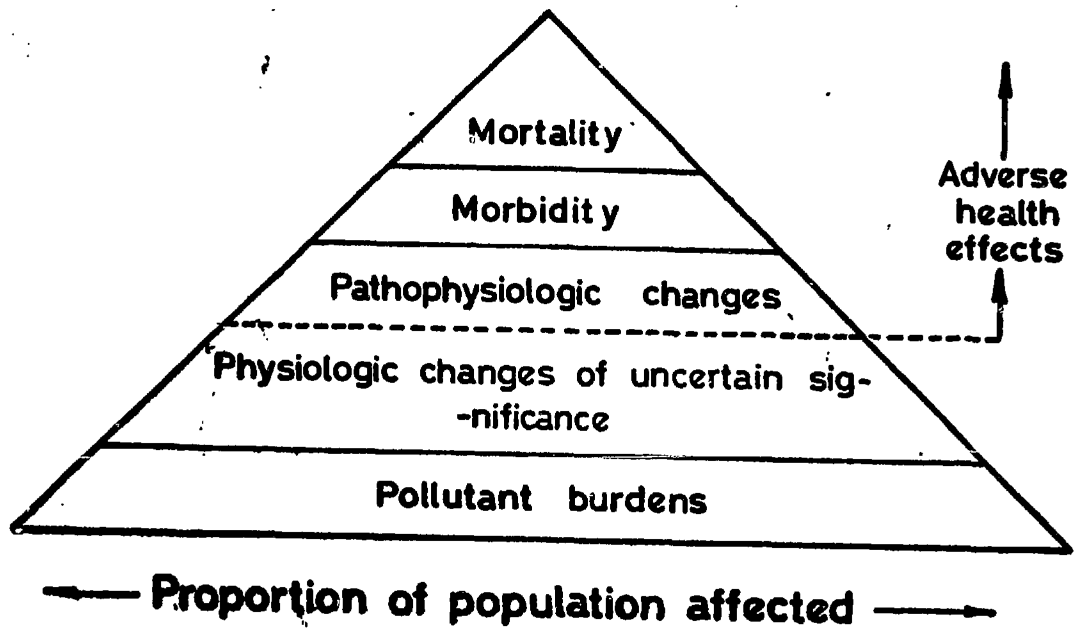

Fig. 1 Spectrum of Biological response to pollutant Exposures(6)

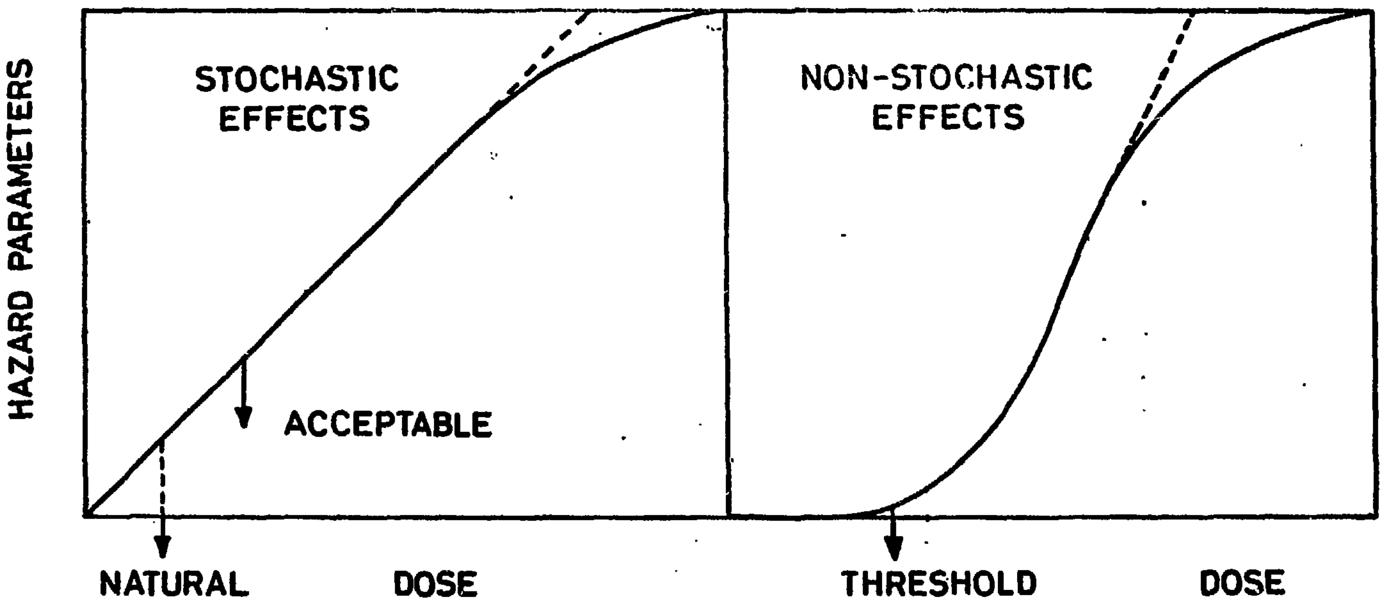

Fig. 2 VARIATION OF HAZARD PARAMETERS WITH DOSE FOR STOCHASTIC AND NON-STOCHASTIC EFFECTS.

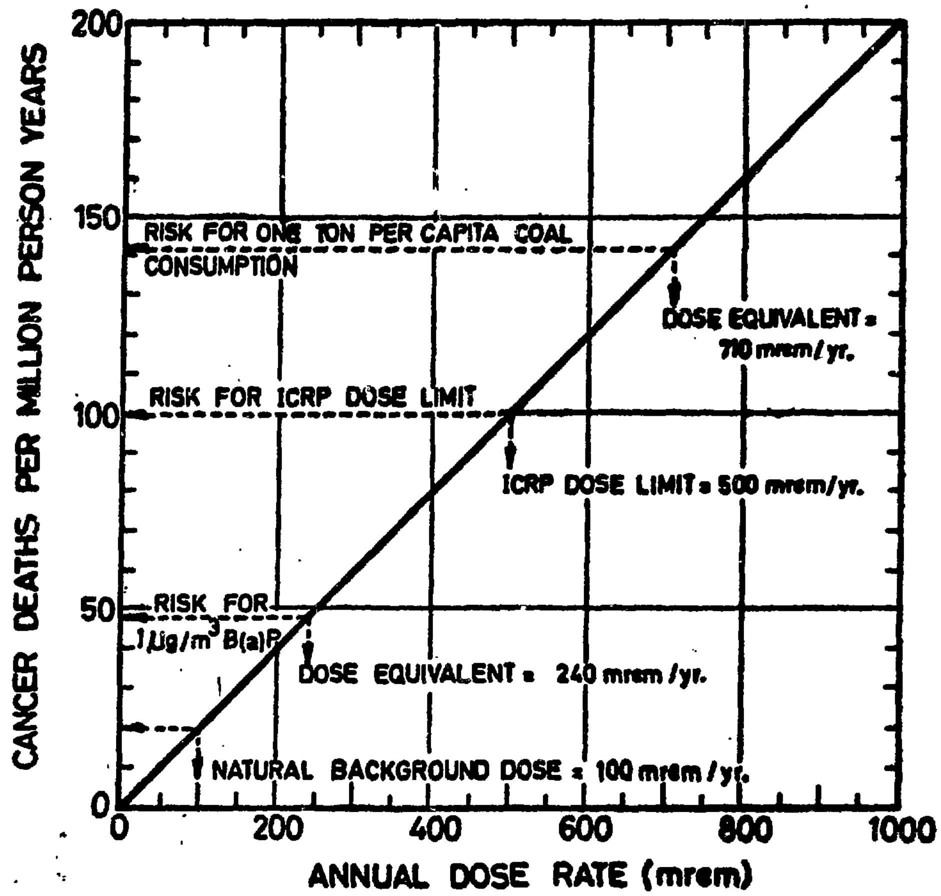

FIG. 3. GRAPHICAL REPRESENTATION OF THE CANCER RISK OF RADIATION EXPOSURE, BASED ON BEIR COMMITTEE REPORT. DOSE EQUIVALENTS FOR LUNG CANCER RISK OF POWER FROM COAL BURNING AND RISK OF BENZO (a) PYRENE ARE ALSO SHOWN.

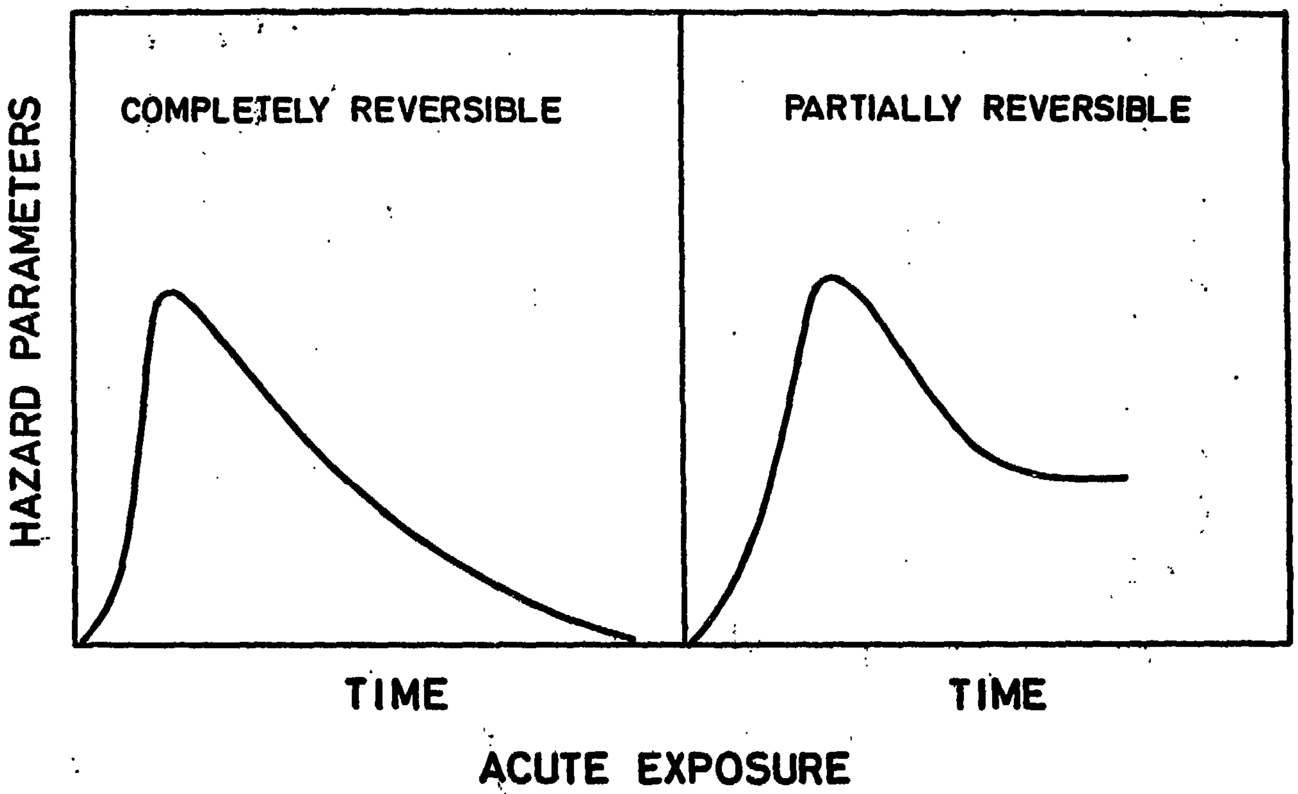

Fig. 4 VARIATION OF HAZARD PARAMETERS WITH TIME (SINGLE EXPOSURE)

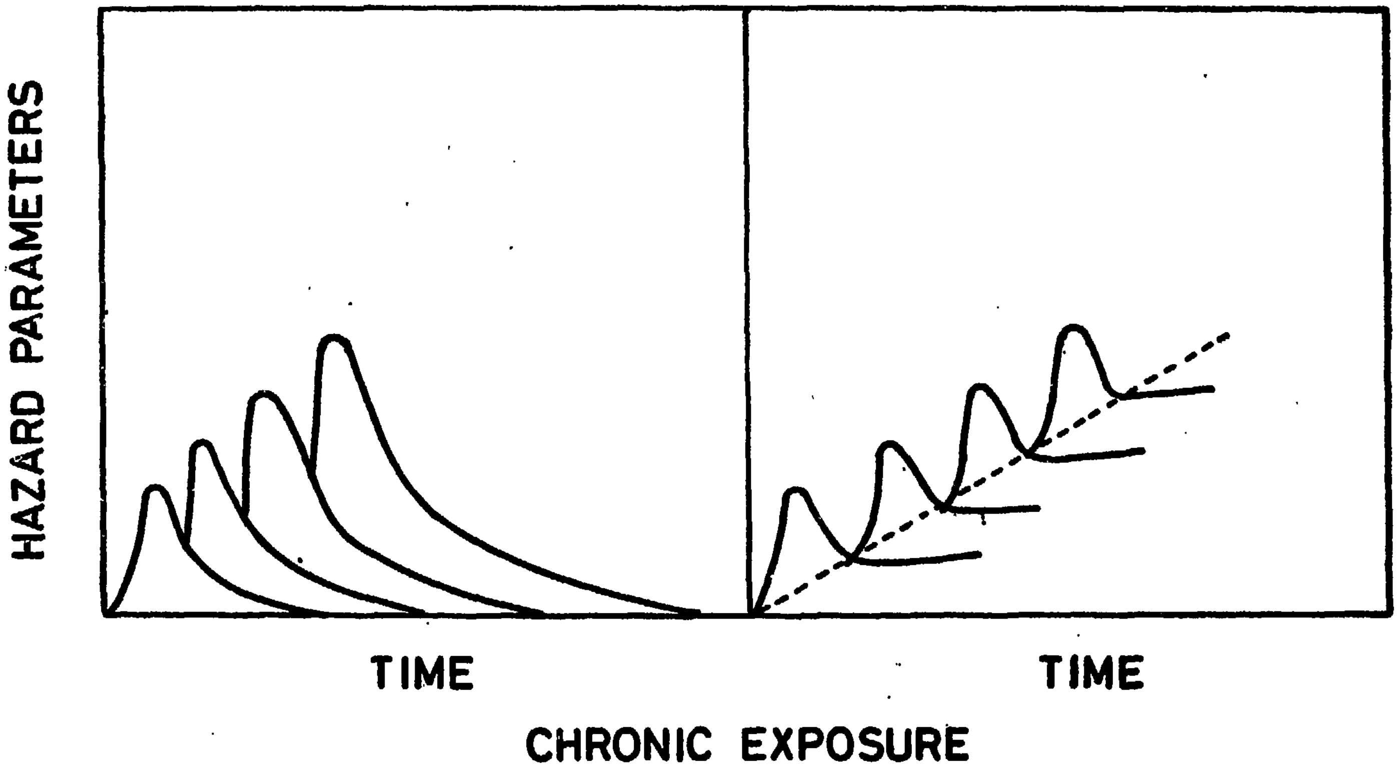

Fig. 5 VARIATION OF HAZARD PARAMETERS WITH TIME (CHRONIC EXPOSURE)