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M. A. R. Iyengar

Radiation Environment at Kalpakkam

1989

Indian Society for Radiation Physics
Kalpakkam Chapter

About ISRP and this Series

Ionising radiation is a powerful tool finding increasing applications in almost all walks of life, be it agriculture, medicine, industry or basic research. By the very nature of its diverse applications, the study of ionising radiations and their interaction with matter has diffused into various other scientific disciplines. It is with the primary objective of providing a common forum for the scientists and engineers working on different basic as well as applied aspects of ionising radiation that the Indian Society for Radiation Physics (ISRP) was formed in 1976. Its membership consists of professionals from national laboratories, universities and institutions of higher education, industry etc. In line with its basic objective, ISRP has been organising periodic national and regional seminars, topical meetings etc.

It is recognised that for an optimum utilization of any technology, a comprehensive appreciation of its problems and potentials must prevail not only amongst the scientists and engineers associated with the technology but amongst the general public also. In the case of ionising radiations while its hazard aspects seem to have been overplayed for historical or other reasons, its full potential in the service of mankind does not seem to have drawn the deserved attention of the general public. It is to fill up this gap and to develop an overall perspective ISRP (Kalpakkam Chapter) has launched this series of semi-popular brochures on various facets of ionising radiation.

We feel that for any programme to be relevant and successful a strong user-feed back is essential. We earnestly solicit suggestions with regard to the content and level of these brochures, topics to be included etc. The suggestions may please be sent to.

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RADIATION ENVIRONMENT AT KALPAKKAM

M. A. R. IYENGAR

INDIAN SOCIETY FOR RADIATION PHYSICS

(Kalpakkam Chapter)

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FOREWORD

Thanks to the visionary and dynamic leadership provided by Dr. Homi Bhabha and the successive Chairmen of the Indian Atomic Energy Commission, there has been awareness and appreciation at the government level, in the scientific community and also in the minds of the general public, of the importance and potential of atomic energy development for the growth of the national economy. On the other hand, there has been till now no systematic effort on the part of the Department of Atomic Energy to publish books and monographs to project in detail the achievements in the field, and to disseminate information on all the various aspects of nuclear science and technology in a style that is scientifically objective and at the same time intelligible to the general public. The need for such an effort has become imperative in the present juncture when the nuclear power programme and the applications of ionising radiations are poised for substantial growth and when simultaneously anxieties about the safety of design and operation of nuclear power plants, management of radioactive waste, biological effects of radiation and the impact of the nuclear programme on the environment, have become accentuated following the Chernobyl nuclear plant accident in USSR in 1986.

It is in this context that the series publication of monographs on selected themes, by the Kalpakkam Chapter of the Indian Society for Radiation Physics (ISRP) is to be welcomed. The Chapter is fortunate to have dedicated and enlightened members who have taken a leading interest in the information dissemination and organising educational programmes for the benefit of the general public.

The monograph on Radiation Environment at Kalpakkam by Dr. M. A. R. Iyengar is based on his experience at the Environmental Survey Laboratory that has been in operation at the Kalpakkam site since 1974. It has been written in a very lucid style, to describe and explain —

1. how natural radiation has always been present in the earth's environment in the course of evolution of life, that radioactive equipment is quite commonly used in hospitals, and that the contribution of nuclear reactors to radiation exposure is very small ;

2. the detailed work of the Environmental Survey Laboratory to collect baseline data, well ahead of the commencement of operation of the power reactors ;

3. the programme of continuous environmental surveillence that is practised at Kalpakkam.

The monograph concludes on the reassuring note that the radiation levels in environment have stayed at the pre-operation levels in the last 5 years, as a clear demonstration of good and sound design, construction and operation of the power reactors.

I wish the Indian Society for Radiation Physics (Kalpakkam)'s Science Propagation Programme every success.

1/6/89

C. V. SUNDARAM
Director
Indira Gandhi Centre for Atomic Research
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RADIATION ENVIRONMENT AT KALPAKKAM

1. Introduction

In recent times there appears to be a growing apprehension in the public mind that nuclear radiation is the singlemost enemy of mankind and therefore that every effort should be made to eliminate this deadly danger from our midst - be it the nuclear power plant, nuclear warheads/missiles etc. While subscribing to the public anxiety related to nuclear warheads and other nuclear weapons of mass destruction, it would be naive to accept that we can do away with nuclear radiation, just by closing down all the existing nuclear power plants or abandoning plans for such future plants. While the public concern on nuclear radiation may be understandable, the basis on which their fears are based seems to be vague and unfounded. For example, it is an established fact of science that mankind has always lived in a radiation milieu and it could even be said that mankind evolved in an environment enveloped in nuclear radiation. Since millions of years and to this day, not only man but all forms of life inhabiting this planet earth, have continued to live in this natural radiation environment, without any danger to life or deleterious effects. In fact there seems to be very little public awareness about this natural radiation which contributes about four-fifths of the average annual radiation dose worldwide. But at the same time almost all public attention and apprehension appear to be focussed on nuclear power, which in the last four decades has only contributed a small increment of man-made radiation to an otherwise very large background natural radiation environment. To understand these aspects in more clear terms and appreciate the place of nuclear power vis-a-vis the environmental radiation impact, let us examine the actual components that go to make our radiation environment and with which we interact in our daily lives.

2. Sources of radiation

2.1. Natural radiation

By far the greatest part of the radiation received by the world's population comes from various natural sources, exposure to most of which is inescapable and hence involuntary. These natural radiation sources are of a) extra-terrestrial and b) terrestrial origin and together they cause external and internal exposures of the global population. Cosmic rays which are extra-terrestrial in nature are an important source of external exposure, while natural radiation from the earth's crust and in a number of materials or utilities of everyday human usage (building materials, food, air, water, air travel etc) could give rise to both external and internal exposures. Natural radiation levels generally remain relatively constant with time, but vary significantly with location. An estimate of annual exposures of man due to natural radiation in areas of normal background is given in Table 1. However, even in areas of

Table 1

Estimated annual exposures of man to natural sources of radiation in areas of normal background

Source	Annual Exposure (mR/y)		
	External	Internal	Total
Cosmic Rays :			
Ionizing component	28.0	—	28.0
Neutron component	2.0	—	2.0
Cosmogenic nuclides	—	1.5	1.5
Primordial nuclides in soils and rocks:			
Potassium-40	12.0	18.0	30.0
Rubidium-87	—	0.6	0.6
Uranium-238 series	9.0	95.0	104.0
Thorium-232 series	14.0	19.0	33.0
Total (rounded)	65.0	134.0	200.0

high background the exposure levels vary over an order of magnitude, depending upon the site specific terrestrial radioactivity, as may be seen in Table 2.

Table 2

Natural exposure levels in high background areas

Kerala, India	:	1600	mR/y
Black Forest, Germany	:	1800	,,
Central City, Colorado	:	2200	,,
Guarapari, Brazil	:	17000	,,

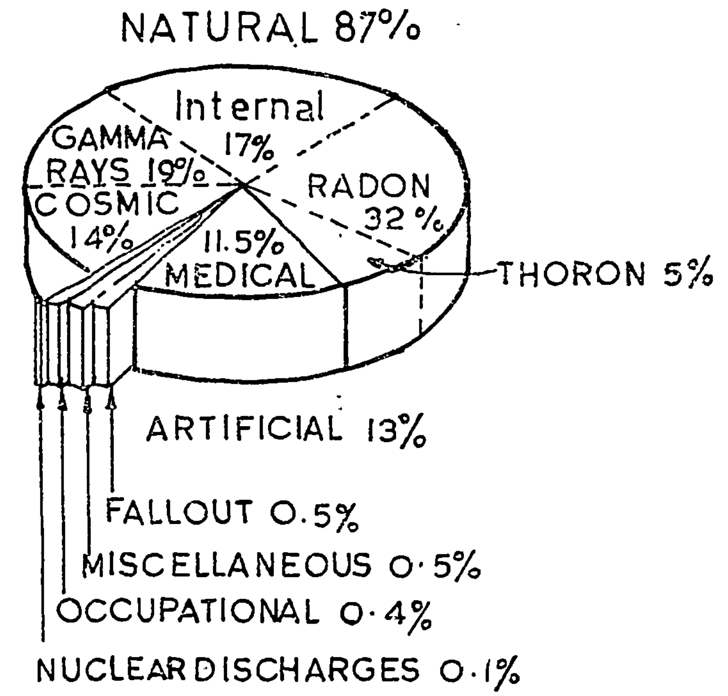
2.2. Man made sources

In addition to natural background radiation, man is also exposed since recent times to other artificial sources of radiation, created by himself: for example X-rays and other types of radiation used in medicine, nuclear weapon testing fall-out, occupational exposure from nuclear and other industries dealing with ionising radiation.

Fig. 1 shows the composition of the total radiation exposure of the United Kingdom population in which natural sources account for nearly 87% while the remaining 13% comes from artificial sources. Even among the artificial or man-made sources, the bulk of the exposure is accounted for by medical sources, both in diagnosis and therapy, while the exposure contribution due to nuclear discharges is only to the extent of 0.1% which compared to all other sources is far too less, to be considered significant.

3. Biological effects of radiation

The basic process that takes place when ionising radiation interacts with matter is the transfer of energy. When such an interaction takes place in a biological system, three stages of reactions may be said to occur, which are :



THE COMPOSITION OF THE TOTAL RADIATION EXPOSURE OF THE POPULATION OF THE UNITED KINGDOM NATURAL SOURCES ACCOUNT FOR 87% (Fig.1)
(REF: RADIATION: A FACT OF LIFE, IAEA, MAY 1985)

(a) Elementary reactions: The absorption of energy from ionising radiation results in excitation and ionisation of molecules in the path of radiation. This reaction lasting about 10^{-17} to 10^{-15} seconds is physical in nature. Excited and ionised molecules are highly reactive and hence unstable.

(b) Primary reactions: Free radicals and excited molecules, formed as a result of elementary reactions, tend to either react among themselves or with other molecules. These reactions are essentially chemical in nature and generally last from a few seconds to a few hours.

(c) Secondary reactions : Rearrangement of molecules following the primary reactions cause interaction among macromolecules of biological significance. These reactions may lead to alterations and impairment of biological systems at cellular and sub-cellular levels.

Although the basic processes causing the radiation effects for all components of biological systems are similar, the actual effects may be different for somatic and genetic cells. This distinction has certain significance because while somatic effects affect only the individual exposed, the genetic effects may be transferred to future generations.

While discussing the biological effects of radiation, yet another classification is adopted, which describes in terms of 'stochastic' and 'non-stochastic' effects. Stochastic effects are those for which the probability of an effect occuring rather than its severity is regarded as a function of dose without threshold. Non-stochastic effects are those for which the severity of the effect varies with the dose for which a threshold may occur.

The main objective of radiation protection is to prevent the detrimental non-stochastic effects and to limit the probability of stochastic effects, to as low as reasonably achievable. At the dose range encountered in the environment, during the normal operation of a nuclear power plant generally stochastic effects only need to be considered. In this context, the annual Dose Equivalent limit for a member of public is 1 milli Sievert (mSv) as compared to 50 milli Sievert for an occupational worker. Such limits are based upon review and recommendations of the International Commission on Radiological Protection (ICRP) — a widely respected non-profit and non-governmental body of experts drawn from different parts of the world.

4. Environmental impact of nuclear power

Like any other power generating source, an atomic power plant also produces wastes, the difference being that the effluents from the latter contain radioactive nuclides, due to fission and activation products produced in the course of the reactor operation. If these active wastes are let out to the environment in an uncontrolled manner, some of the radioactive elements present therein could be taken up by the environmental flora and fauna, passed on to man, eventually causing considerable radiation exposures to the population. The active wastes produced in a nuclear reactor, contain a number of radionuclides varying in half-lives, types of radiation emitted and energies. Some of the key radioelements which have a direct or indirect exposure significance to the public are strontium-90, caesium-137, iodine-131, zirconium-95, argon-41, tritium, cobalt-60, zinc-65, manganese-54 etc.

4.1. Pathways

Because of the considerable radioactivities involved and their inherent hazard potential, these active wastes could be either concentrated and contained before storing in a safe site or diluted and dispersed in the environment during effluent release. In the context of environmental impact surveillance in the reactor neighbourhood and possible exposure of the population it would be important to know what pathways the released radioactivity takes. A schematic diagram showing the environmental pathways for the stack discharges (air route) and aquatic discharges (water route) of radioactivity are shown in Figs. 2 and 3.

From the figures one could visualise the importance of monitoring selected environmental matrices which would be of considerable value in the assessment of environmental and human exposures. Some of the matrices employed in the Kalpakkam study are :

Marine : Seawater, silt, seaweed, fishes & shell fishes, salt etc.

Terrestrial : Air, fallout, soil, grass, milk, cereals, vegetables, goat thyroid, drinking water, rainwater etc.

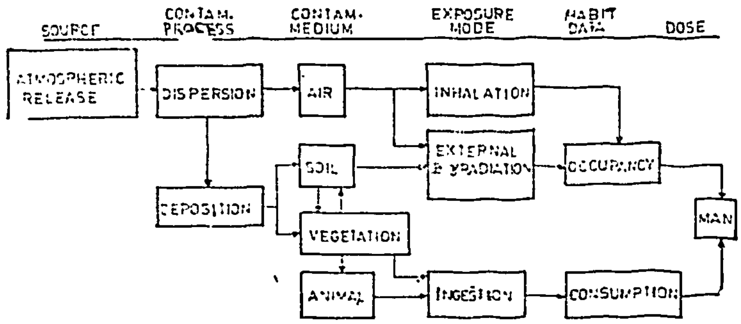


Fig 2 ENVIRONMENTAL PATHWAY-AIR ROUTE

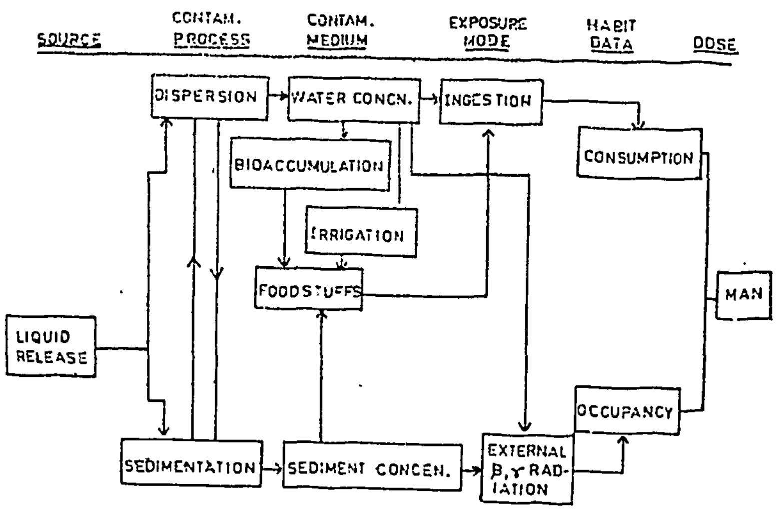


Fig 3 ENVIRONMENTAL PATHWAY - WATER ROUTE

5. Nuclear facilities at Kalpakkam

Kalpakkam lies on the east coast of India, adjacent to the bay of Bengal, about 60 km south of Madras city (Fig. 4). The main activities at Kalpakkam are centered around the Madras

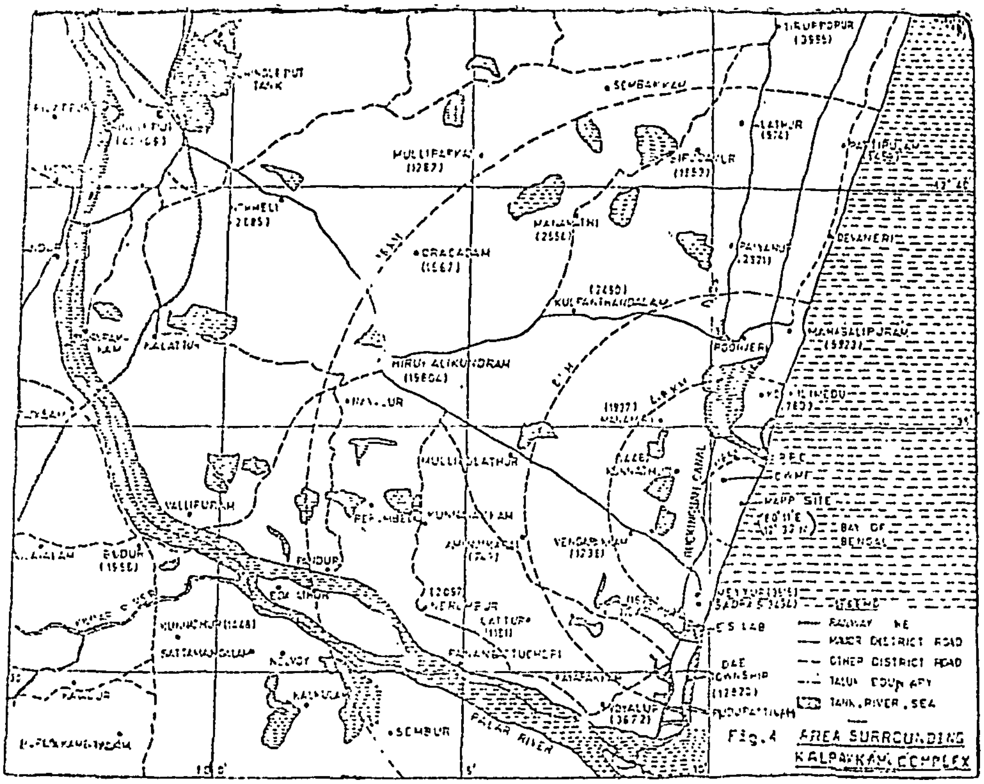


Fig. 4 AREA SURROUNDING KALPAKKAM COMPLEX

Atomic Power Station (MAPS) and the Indira Gandhi Centre for Atomic Research (IGCAR), with a host of Service and R & D units supporting both the programmes. The MAPS has twin reactor units of 235 MWe each, which are of the Pressurised Heavy Water Reactor (PHWR) type using natural uranium as fuel and heavy water as both moderator and coolant. The Fast Breeder Test Reactor (FBTR) at Kalpakkam, is a sodium cooled, plutonium-uranium carbide fuelled, loop type fast reactor, with a capacity to produce 40 MW of thermal power and 13 MW electricity.

The Centralised Waste Management Facility (CWMF) at Kalpakkam is a specialised agency responsible for the collection, treatment and safe disposal of all active wastes generated during the nuclear operations at site. At CWMF the long lived activities present in the liquid and solid wastes are concentrated using advanced technology and stored in the safest possible manner in high integrity underground RCC trenches and tile holes. Any residual radioactivity in extremely small quantities but present in bulk volumes in the liquid effluents, are carried through pipelines and discharged into the sea well within the regulatory limits. Reactor off-gases are also similarly led through an efficient filter system and discharged through a 100 m stack to the atmosphere.

Interaction of the radioactive liquid effluents with seawater results in an enormous dilution, but in course of time some activity could concentrate to a degree in the marine flora and fauna. Seaweed, fish, oyster, clam and crab are a few examples, known to accumulate radioactivity - natural and manmade - and they all form part of man's food chain. If some of these dietary materials happen to carry any radioactive contamination due to low-level reactor effluent discharges, consumption of such items by the public could result in additional exposures to population over that of natural radiation exposure levels.

5.1. Environmental survey laboratory, Kalpakkam

With the aim of ensuring environmental safety and protection of public from the normal day-to-day operations of the reactors and other nuclear facilities at site, an Environmental Survey Laboratory (ESL) was set up at Kalpakkam in 1974. The main work programme of ESL is to carry out the following:

a) radiation surveillance measurements in the environment in both pre-operational and operational phases,

b) evaluation of the radiological impact on the environment and public during site operations and

c) assessment of the radiation exposures of the population, and comparison with those existing before and ensuring that the regulatory limits are complied with.

This involves,

(i) establishing the baseline data for natural and fallout radionuclides in the environment,

(ii) studies on dietary intake pattern of local population, for use in identification and evaluation of critical pathways, critical population groups and critical radionuclides,

(iii) environmental measurements following routine radioactive discharges into the environment during operations,

(iv) computation of population exposure levels and

(v) R & D programmes in support of the above objectives.

5.2. Micro-meteorological laboratory, Kalpakkam

Micro-meteorological observations, such as wind speed, wind direction, temperature, humidity etc., are also of vital importance in predicting the dispersal of stack discharged radioactivity in the environment. For this purpose a 30 m micromet tower which is part of the micro-met laboratory has been in operation since 1967 and the data gathered so far have yielded valuable information on site meteorology, which is highly useful in environmental impact studies, both during normal and emergency situations.

6. Dietary survey of population

An essential input in computing population exposures is the per capita consumption of different items of human diet for which information has to be obtained for each site. A survey involving about 300 families residing within 8 km from Kalpakkam site demonstrated that there were two major groups of population i.e. fishermen and farmers and a small group of miscellaneous trades. The data on per capita consumption of food stuffs in the area by different groups of population was collected through a questionnaire and field survey (Table 3). Fish consumption by fishermen at 120 g/day and sizeable cereals consumption (Av : 604 g/day) by all groups of population are significant from the point of view of marine and terrestrial pathways of exposure.

7. Natural background

During the early stages of pre-operational background radiation surveys, a slightly enhanced ambient radiation level

Table 3

Dietary pattern in Kalpakkam area

Dietary item	Fishermen	Farmers	Others	Average
	Intake in g/day/capita			
CEREALS				
Rice	617.9	627.5	565.3	603.6
Wheat	0.3	5.4	9.4	5.0
Ragi (Millet)	81.6	99.1	50.9	77.2
Total	699.8	732.0	625.6	685.8
PULSES				
Turdhal	8.4	11.3	12.7	10.8
Green Gram	1.3	3.5	4.8	3.2
Black Gram	5.5	8.9	10.3	8.2
Bengal Gram	3.6	6.3	6.0	5.3
Dry Beans	—	1.0	1.3	0.8
Total	18.8	31.0	35.1	28.3
VEGETABLES				
Potato	10.2	15 7	14.1	13.3
Onion	10.7	16.7	15.6	14.3
Others	28.5	46.8	44.9	40.1
Total	49.4	79.2	74.6	67.7
MEAT & FISH				
Meat	9.9	11.4	9.3	10.2
Fish	120.7	53.2	34.8	69.5
Total	130.6	64.6	44.1	79.7

Continued...

Dietary item	Fisherman	Farmers	Others	Average
	Intake in g/day/capita			
MILK & MILK PRODUCTS	21.0	53.8	79.0	51.3
OTHERS				
Sugar	6.4	13.8	20.1	13.4
Jaggery	5.4	6.3	6 5	6.1
Oils & Fats	8.6	13.3	14 5	12.1
Salt	17.0	16.1	14.7	15 9
Chillies	12.8	9.4	7 6	9.9
Tamarind	14.1	13.0	11.5	12.9
GRAND TOTAL	983.9	1032.5	933.3	983.1

Area of urvesy	:	8 km radius around MAPS
No. of villages surveyed	:	18
No. of families surveyed	:	312
No. of adults	:	1148 } Ratio = 1.3 : 1.0
No. of children	:	846 }
Population density	:	0-8 km radius: 200 persons/km^2

was noticed on a beach location near Sadras East Township. The beach sand samples taken from the area on subjecting to gamma spectrometry, showed the presence of monazite -a radioactive mineral of thorium - with characteristic gamma peaks, as in the case of Kerala monazite (Fig. 5). However quantitative measurements showed the monazite content in Kalpakkam beach sands to be of a low order (0.4-0.6%) compared to the richer monazite sands of Kerala (5-9%).

Further surveys of the Kalpakkam beach extending from Mahabalipuram to Pudupattinam revealed a highly shifting radiation profile with the ambient radiation levels ranging from

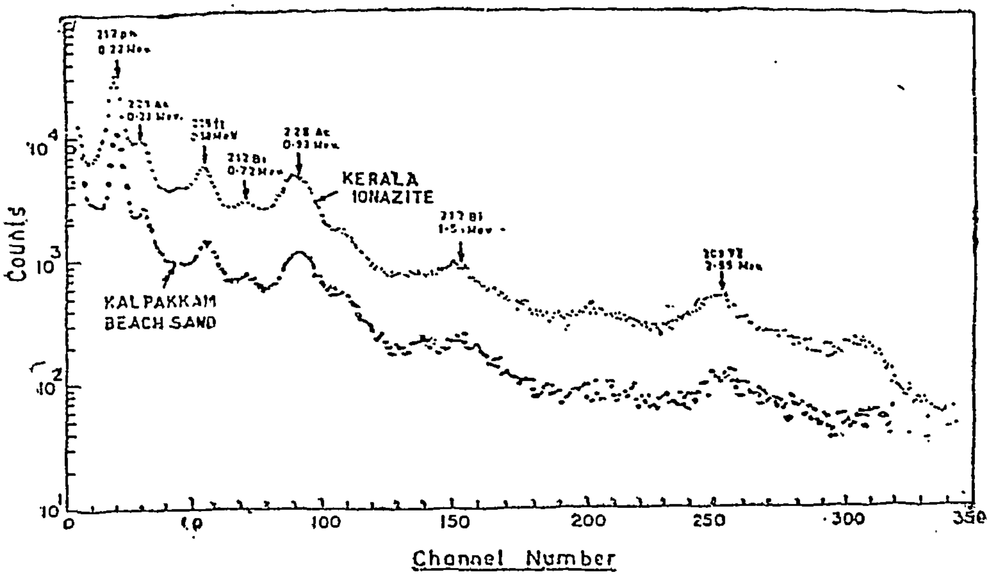


Fig.5 GAMMA SPECTRA OF KALPAKKAM BEACH SAND AND KERALA MONAZITE

10 to 400 μR/h, which demonstrated that monazite was occuring in pockets in the beach. Depth samples from areas of relatively higher background radiation also showed that monazite was occuring mostly as a surface deposit.

The radiation surveys in villages located away from beach showed fairly uniform ambient radiation levels ranging from 8 to 38 μR/h. The increased radiation background was thus found confined to the beach regions only. In contrast with the pre-operational radiation background at Tarapur and Rajasthan, the local population was thus receiving relatively enhanced exposure at the pre-operational stage from natural radioactivity. Hence greater emphasis has been given to the study of distribution of daughter species of uranium and thorium i.e. Ra-226, Ra-228, Po-210 etc., in the pre-operational measurements. Among the population groups, fishermen residing in hutments on the beaches are subjected to radiation exposures of a relatively higher level than inland people.

7.1. Air monitoring

Atmospheric radioactivity is being monitored at ESL by collection of air particulate samples and counting of the gross long lived activities. In Fig. 6 is illustrated the gross beta activity of air samples at Kalpakkam for the pre-operational

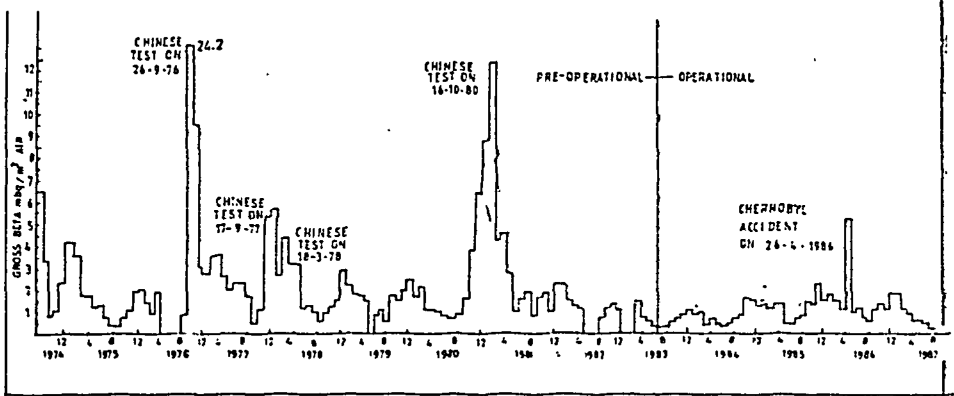


Fig.6 BETA ACTIVITY IN AIR PARTICULATES AT KALPAKKAM

period 1974 - 1983 and operational period 1983 - 1988. Four occasions of enhanced activity levels are evident in October-November 1976, December - January 1977 - 78, March - April 1978 and November-December 1980 in the pre-operational period. These instances of relatively higher activities are found to correlate with the atmospheric nuclear weapon tests conducted by China during the period. Simple but sensitive techniques such as these employed by the laboratory are found to be highly useful in detecting radioactive contamination of the ambient environment, originating from either nuclear tests or accidents, occuring even in far-off places.

7.2. Radioactivity in goat thyroids

Animal thyroids are excellent indicator materials for detection and measurement of I - 131 levels in the environment, appearing either from fallout or from reactor stack discharges. This is because of the fact that thyroids concentrate I - 131 in their tissues (Concn. Factor : $\sim 10^4$). Routine monitoring of goat thyroids has been in vogue at ESL, which has enabled detection of I - 131 fallout in the Kalpakkam environs, following the Chinese nuclear tests between 1976 - 1978 (Fig. 7). These distinct peaks of I - 131 in goats thyroids were observed to correlate well with the periods of high air activities mentioned earlier. Occasionally higher I - 131 levels in milk (0.9 Bq/l) and grass (1.4 Bq/kg) were also recorded

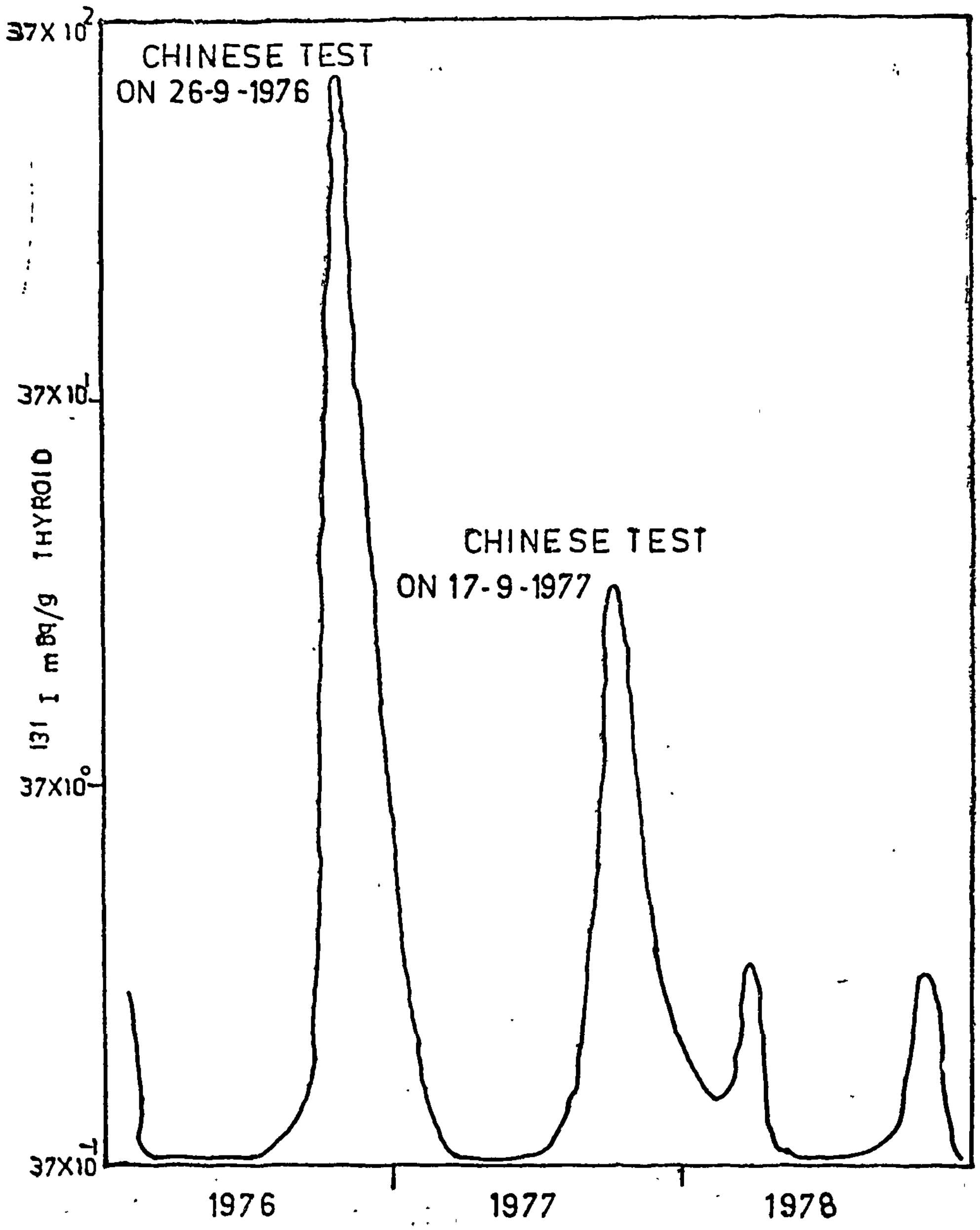


Fig. 7 IODINE - 131 IN GOAT THYROIDS IN KALPAKKAM (PRE - OPRATIONAL)

at Kalpakkam during times of intense Chinese fallout. Even recently the radioactive debris from Chernobyl accident was detected at Kalpakkam during May - July 1986, with the peak I-131 activity around 2.4 Bq/g of thyroid.

7.3. Terrestrial monitoring

The presence of monazite in patches is reflected in some of the terrestrial samples. Fig. 8 shows the presence of monazite

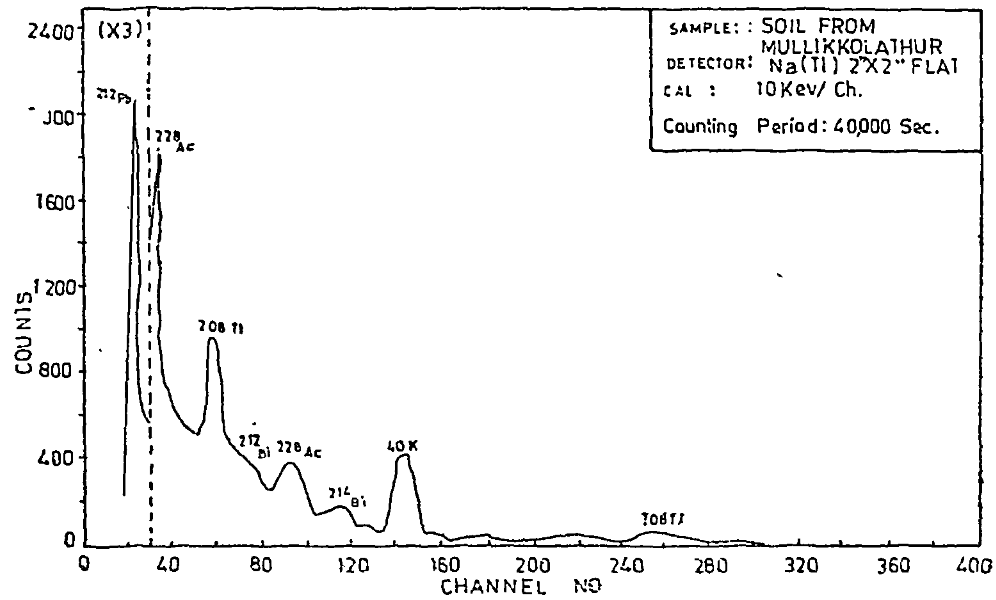


Fig 8 GAMMA SPECTRUM OF SOIL

in a soil sample from a nearby agricultural area. The radium content of such soils is higher by roughly an order of magnitude compared to normal background. Soil is an important reservoir for fallout and natural activity, which could ultimately result in human exposure through terrestrial food chains. As a result of monazite presence at Kalpakkam, an occasional value of increased natural activity in some terrestrial matrices like vegetables, rice etc., may be expected.

7.4 Marine monitoring

The effluent management system at Kalpakkam envisages collection and treatment of effluent from MAPS and IGCAR facilities at CWMF and controlled release of low level effluents to the coastal waters at a carefully chosen nearshore location at MAPS through a special discharge line. The location of the effluent discharge point itself has been arrived on the basis of a number of field experiments at sea using Rhodamine dye dispersal, drift bottle studies etc., which gave a clear insight into the coastal water circulation and dilution parameters. Following release, the effluent radioactivity undergoes dilution manyfold, as a result of which the ambient radioactivity levels existing already are not appreciably altered. However, side by side with dilution a process of activity concentration also would be taking place among some marine species like seaweed, plankton, oysters, crabs, fish etc., and silt. In view of this and the consequent radiation exposure potential to the public by way of consumption of marine food items, surveillance of marine environment would be constantly needed to determine concentrations of radioactivity in marine organisms and possibly identify specific organisms as pollution monitors. Amongst a number of marine samples examined surface sediments, seaweed. barnacle etc., have shown evidence of monazite based activity (Figs. 9, 10 and 11).

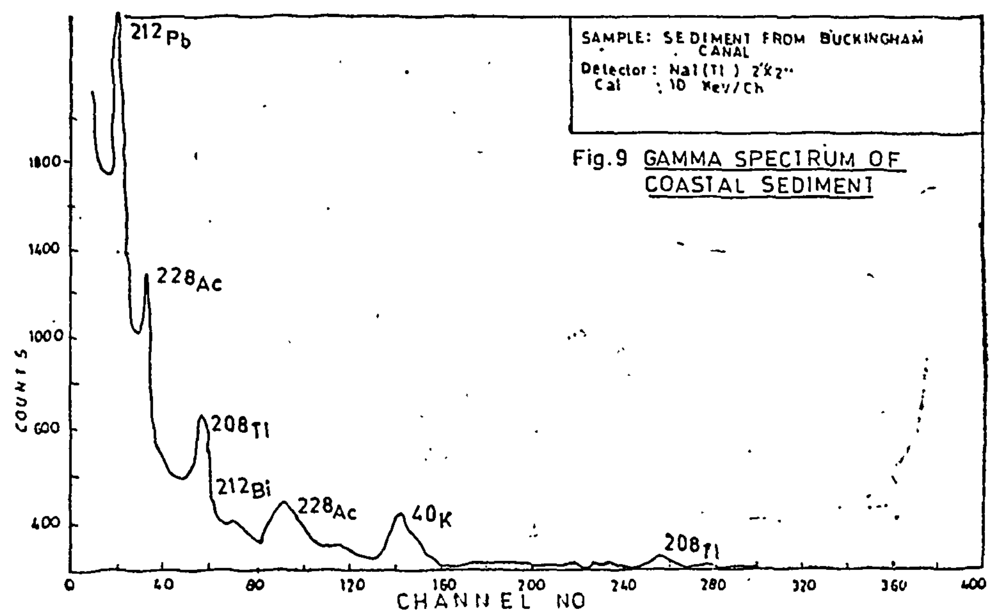
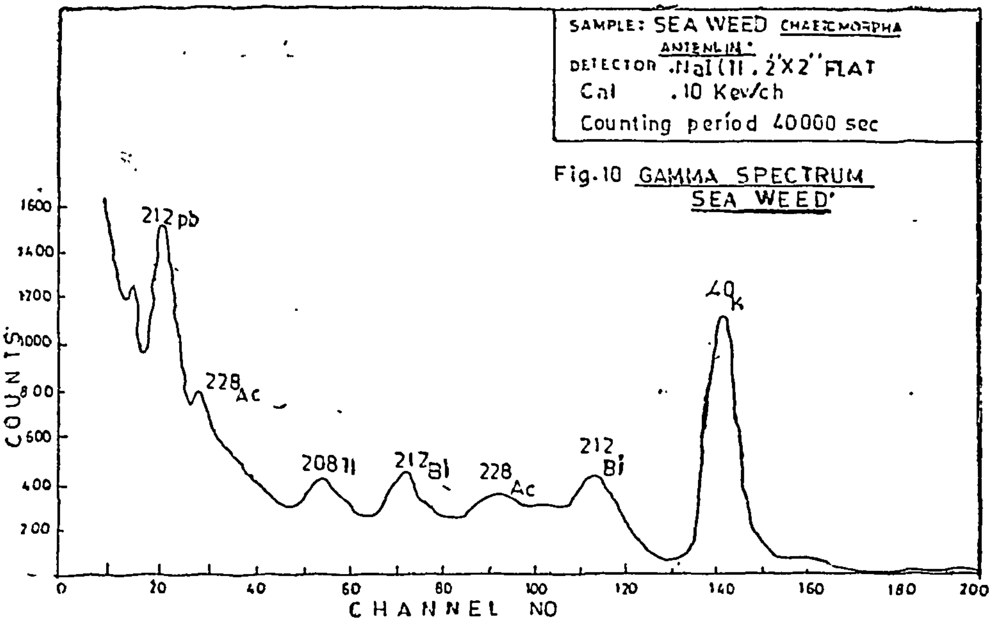


Fig.9 GAMMA SPECTRUM OF COASTAL SEDIMENT

The marine flora and fauna concentrate many elements present in the enviromental media in traces, either by active



metabolic uptake or by passive physical adsorption. ESL has undertaken a study of the concentration factors (CF) and the concentration mechanisms for some natural radioelements like Ra-226, Ra-228, Pb-210, Po-210 etc., in marine organisms. Among these, Po-210 was found to accumulate to a high degree in crustacea, mollusca and fishes with CF's in the range of 10^2-10^4. In the tissues of the same organisms the CF's observed are:

Fish : Liver ($\sim 10^4$) ; Bone ($\sim 10^3$); Muscle ($\sim 10^2$)

Crustacea : Shell ($\sim 10^4$) ; Soft parts ($\sim 10^3$)

Many marine organisms generally appear to accumulate Po-210 in preference to its Pb-210 precursor from the environment either directly or through their food chain, thus leading to substantial exposure from Po-210 source.

8. Environmental surveillance during operation

The data collected during the pre-operational phase act as a very valuable reference parameters with which the results of survey during operations of various nuclear facilities at site can be compared and an assessment of environmental impact can be

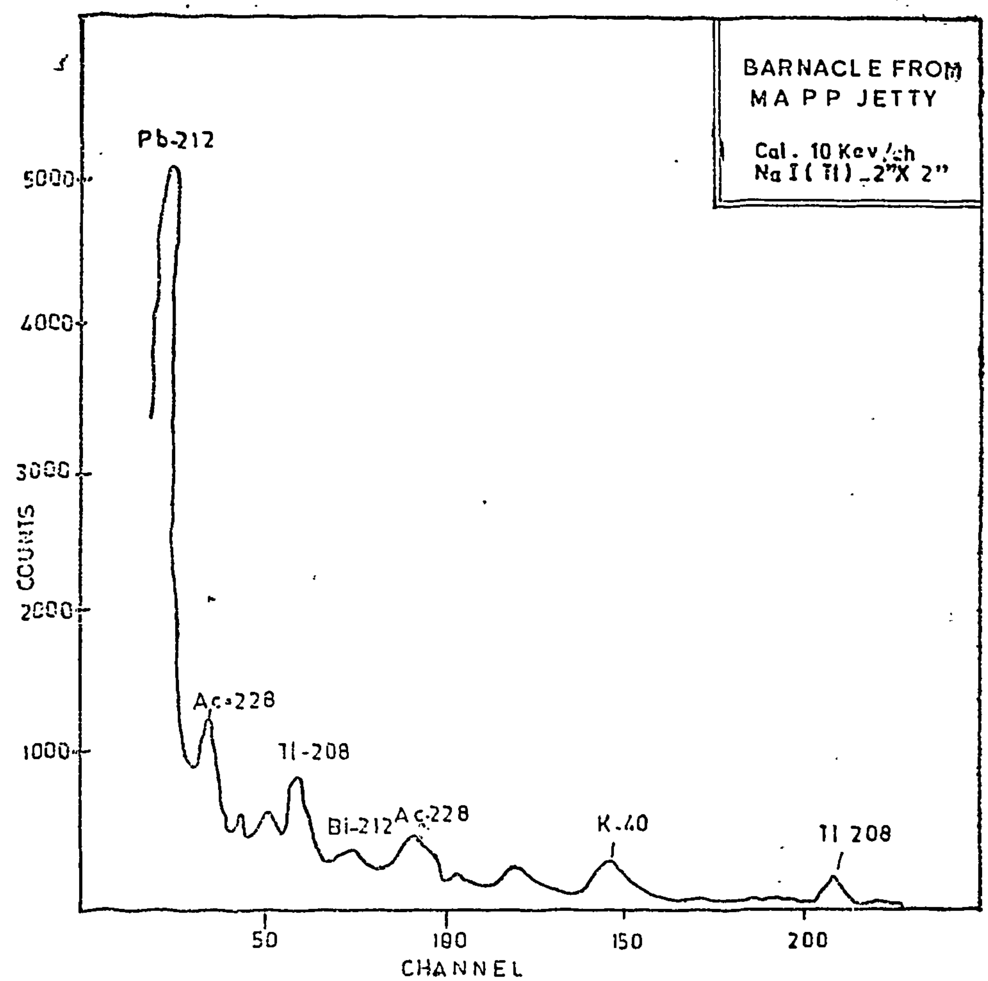


Fig. 11 GAMMA SPECTRUM OF BARNACLE, BALANUS Sp.

made. Unit-I of MAPS has been generating power since July 1983, while Unit-II is operating since August 1985. Besides, FBTR at IGCAR has gone critical in October 1985 and a number of site facilities have since become operational. It would be appropriate to compare some of the environmental data following operation with those of the earlier period.

8.1. Air activity and thyroid monitoring

During the operational phase since 1983, air activity levels continue to be monitored as before and no appreciable change in the beta activity in air samples could be observed when compared with the pre-operational baseline values (Fig. 6). A small spurt in the air activity is noticed however during May-June 86, which is attributed to the Chernobyl accident in USSR on April 26, 1986, following which atmospheric activity levels went up in many parts of the world. However, the higher activity levels persisted only for a period of 3 months at Kalpakkam and returned to normal levels subsequently. It is significant that efficient monitoring techniques employed in the surveillance programme could not only keep track of the local operational releases, but also successfully detect the impact of accidental contamination of the local environment due to nuclear mishaps elsewhere in the world.

As already said, I-131 levels in the terrestrial environment could be conveniently monitored using indicator materials like thyroid glands of goats. This is a continuing programme and the I-131 levels in the goat thyroids of Kalpakkam in the operational phase are given in Fig. 12. From the figure the only rise in the thyroid I-131 activity during operational phase appears during May-June '86 coinciding with the increased air activity levels at Kalpakkam following the Chernobyl accident.

8.2. Ambient gamma monitoring by thermoluminescence dosimetry

A continuous watch on environmental radiation levels is being maintained in the environment by placing TLDs in 40 locations in the spread out area in the 32 km zone of Kalpakkam. The cumulative data, covering the pre-operational and operational phases are given in Table 4. A comparison of the operational values with the pre-operational data brings out very clearly that the nuclear operations at site has not significantly altered the radiation status of the environment. Small differences observed at some points are insignificant as they are due to statistical factors.

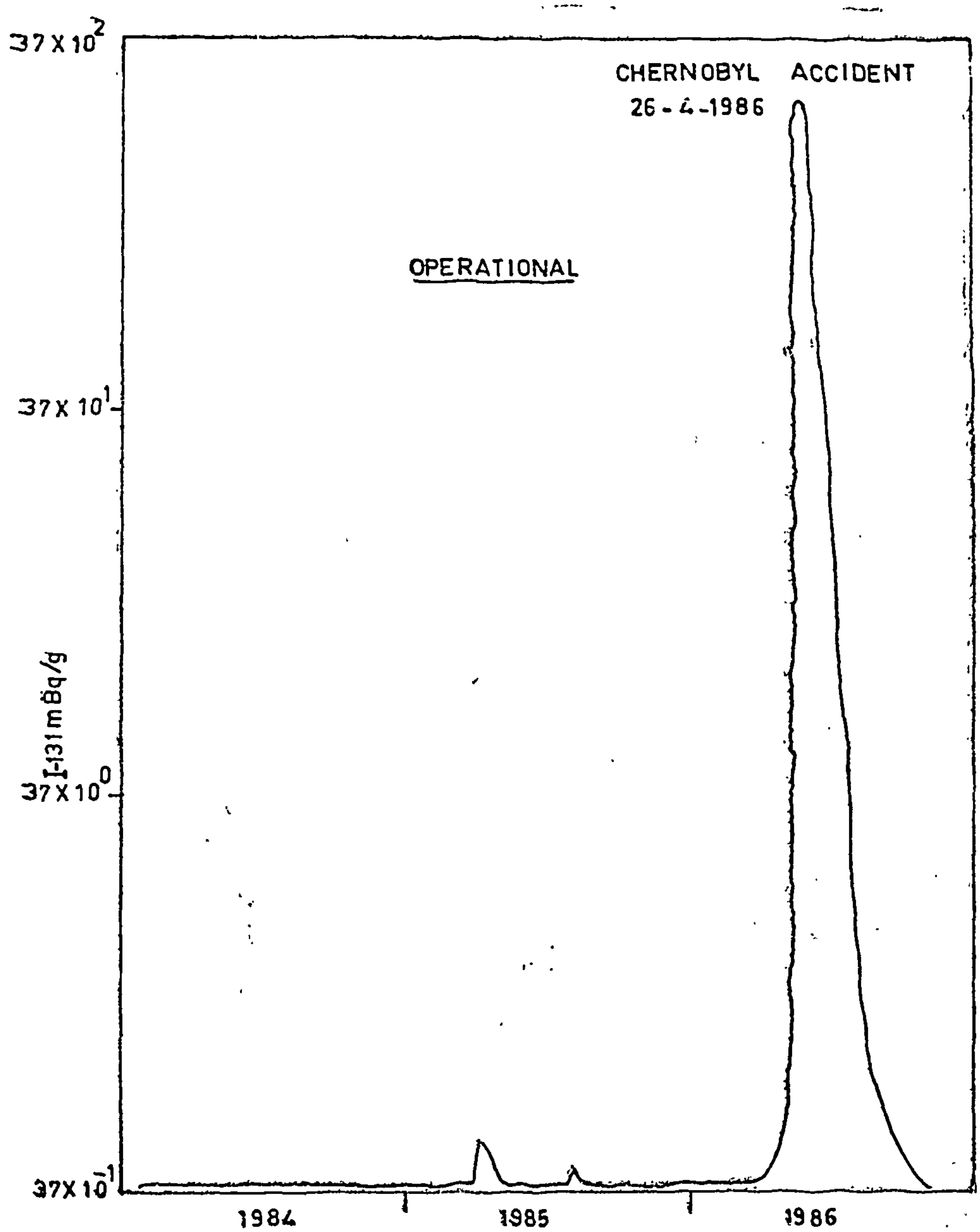


FIG.12 IODINE-131 IN GOAT THYROIDS AT KALPAKKAM (OPERATIONAL)

8.3. Terrestrial and marine activity

Sr-90 and Cs-137 concentrations in several matrices of terrestrial and marine environment, both for the pre-operational and operational periods are presented in Figs. 13 and 14.

Table 4

Environmental does estimates by thermoluminescence dosimetry

Zone/Location	Exposure Rate (mR y)	
	Pre-operational	Operational
a) **1.6 - 8 km zone**		
Sadras Kuppam	279 — 320	249 — 299
Vittilapuram	121 — 148	108 — 126
Vengampakkam	119 — 136	95 — 132
Mahabalipuram	149 — 156	126 — 140
b) **8 - 16 km zone**		
Devaneri	238 — 282	223 — 288
Paiyanur	93 — 106	87 — 112
Tirukkalukundram	160 — 204	142 — 222
c) **>16 km zone**		
Kovalam	89 — 98	86 — 100
Chingleput	111 — 134	88 — 120
Madhurantakam	83 — 124	68 — 92
Madras	111 — 112	99 — 132

In the seawater medium (Fig. 13), very slight increase in both Cs-137 and Sr-90 levels over the pre-operational background levels have been recorded. However, it should be noted that the data reported here are for the effluent discharge point, and since these values are only marginally higher than the pre-operational levels, the activity concentrations farther from here in the open environment are bound to be less. This is indeed found to be the case as demonstrated by environmental measurements carried out and the activity spread as a result of low level effluent discharge has not been detected in sea water at other locations.

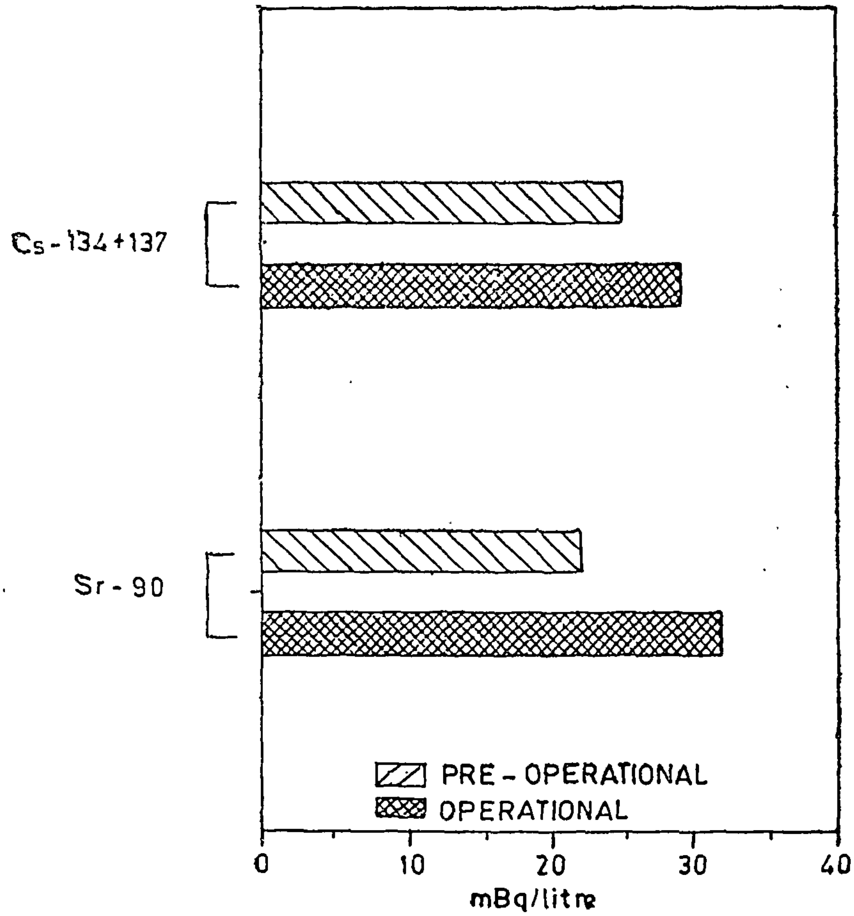


Fig.13 RANGE OF Cs 134+137 AND Sr-90 ACTIVITIES IN SEAWATER FOR PRE-OPERATIONAL AND OPERATIONAL PERIODS

In most of the matrices of terrestrial and marine origin (Fig-14) the radioactivity levels of Sr-90 and Cs-137 have virtually remained close to pre-operational values, as reflected in the observed concentrations. In the case of seaweed some slight increase in Sr-90 and Cs-137 activity levels are seen. However seaweed is not an edible item of human diet, but it could serve as a good indicator of environmental radioactive pollution. In the case of cereals also which is an important

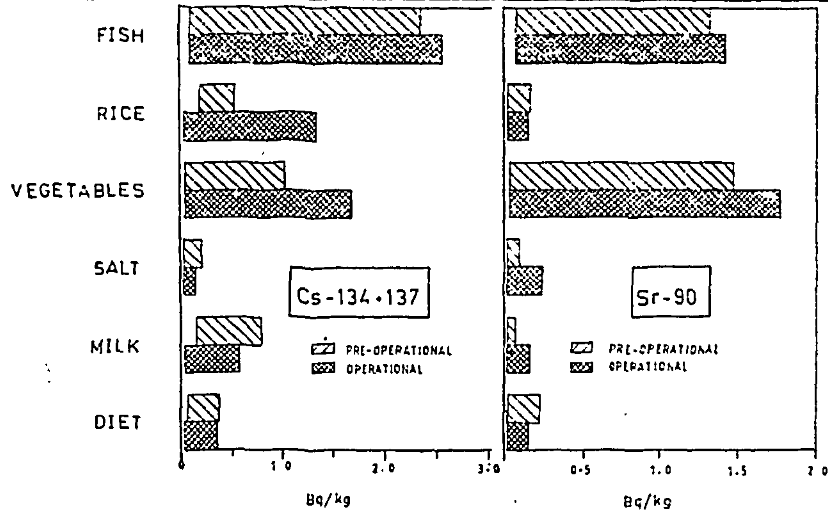


Fig 14 RANGE OF Cs 134+137 AND Sr-90 ACTIVITIES IN ENVIRONMENTAL MATERIALS FOR THE PRE-OPERATIONAL AND OPERATIONAL PERIODS.

diet component, a small increase in the operational Cs-137 value (maximum) over that of the pre-operational value is noticed. But no corresponding rise due to Sr-90 activity (maximum) is noticed in the very same cereals matrix as both the pre-operational and operational Sr-90 values are virtually identical. This situation is somewhat at variance with Sr-90 and Cs-137 levels in most other matrices where the concentration trend of both the radionuclides, appear to be similar. Further surveillance data would therefore be needed in the coming years to confirm the observed Cs 137 activity trend in cereals. Despite this, the increment of radiation exposure is low and far below the permissible exposure limits. Constant monitoring of the diverse matrices of human exposure significance has clearly demonstrated that the various site units- MAPS, FBTR, CWMF etc., - have been operating within the accepted safety criteria, thus resulting in a good environmental safety record.

8.4 Tritium monitoring

Tritium (H-3) levels are also monitored in air and water in the operational phase, since H-3 is an important activation product produced in the operation of PHWR reactors using heavy water, as at MAPS. Continuous surveillance over the years in the public domain has demonstrated negligible increase of H-3 over pre-operational levels. For example, in air, H-3 was in the range, from <2.5 - 17 Bq/m^3, while in well waters it ranged from <0.1 - 0.2 Bq/ml, which are of a very low order from considerations of public exposures.

9. Conclusion

In conclusion it may be said that radioactivity and radiation levels in the environment have virtually stayed at the pre-operational levels in spite of nearly five years of operation of MAPS and other site units. This has been possible due to the integrated efforts in evolving and applying a conscious and purposeful safety philosophy devoted to the maximum well being of man and his environment. The surveillance results presented here demonstrate in good measure, the confidence placed on nuclear energy as source of safe power in meeting the growing energy demand in the nation's development.

About the author

M. A. R. Iyengar holds a doctorate degree in chemistry from Bombay University. As a professional environmentalist, he has worked at the Health Physics Division, BARC Trombay, Bombay, and in the uranium mining and milling complex and its environs at Bihar. Since 1973, he has been heading the Environmental Survey Programme at Kalpakkam. During 1981-82, he has worked at KFA, Julich. West Germany under Indo-German exchange programme. He has studied extensively the complex behaviour of radionuclides in the marine ecosystem around Kalpakkam. Dr. Iyengar has to his credit the development of several sensitive and accurate analytical techniques essential for estimating ultra trace levels of radionuclides in sea water.