The Numbers Game

Occupational Health Hazards at Indian Rare Earths Plant

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The Department of Atomic Energy is currently pushing forward its ambitious plan involving a ten-fold expansion of nuclear power generation by the year 2000. This would involve the setting up of a number of nuclear establishments and would expose a number of people, workers and neighbouring communities to varying degrees of excess radiation. The Indian Rare Earths is the only DAE venture which has completed 30 years of operation, which incidentally is the average latency for cancer which is just one of the health hazards of exposure to radiation.

This paper (condensed from the Economic and Political Weekly, *March 8-15, 1986) reports a retrospective epidemiological study of workers at the Rare Earths Division of the Indian Rare Earths Limited, Alwaye in Kerala. The study examines the mortality profiles of workers for the last 15 years. Workers at the nearby Travancore Cochin Chemicals and those insured with the Employees State Insurance Corporation are taken as the control populations. The study demonstrates a significant difference in the incidence of cancer and mortality due to heart diseases and all causes between the IRE workers and the control populations. The incidence of sterility among the IRE workers and genetic disorders among their children also appear to be high. However, a study of this sort can only formulate a clinical hypothesis. There is an urgent need to institute a comprehensive, inter-disciplinary study of the plant and the workers. Such a study cannot unfortunately be conducted by independent workers or research centres because the Atomic Energy Act of 1962 prohibits any such inquiry into the affairs, including health and safety issues, of the DAE.*

AN Occupational Health (OH) study involves the use of multidisciplinary techniques of medicine, environmental science, social science and law. To be complete, the study should focus on the health status of workers, quantify the pollution load in the work environment and study the health and safety apparatus available including the internal safety organisation and compensation structure, etc.

In this paper, an attempt is made to study the health status of workers of Rare Earths (RE) Division of the Indian Rare Earths Limited (IRE) Udyogamandal, Ernakulam, Kerala. IRE, an undertaking of the Department of Atomic Energy (DAE), is engaged in the processing of monazite sand found in abundance in Kerala and Tamil Nadu coasts. The plant under study has a processing capacity of 4,000 tons of monazite a year. The main products of IRE are thorium, rare earths (RE) chloride and zirconium. Thorium is at present used in the production of gas mantles. The metal, which derives its name from Thor—the Scandinavian war god—would be used as fuel in breeder reactor which is still in research stage. Zirconium is used for cladding of uranium fuel pellets for atomic reactors. The other important product—RE chloride—is used in the chinaware industry. India commands a share of one third of the world market for this product.

The Health and Safety Division (HPD) of the Bhabha Atomic Research Centre (BARC) under DAE is entrusted with the sole responsibility of health and safety of workers in units under DAE. The Atomic Energy (AE) Act, 1962 prohibits an independent scholar or a research centre from making any inquiry into the affairs of the DAE, including the health status of its workers.[1] Even though the DAE units employ more than 20,000 people, no data regarding workers' health status is available, except, of course, occasional briefings to the press made by the official spokespersons.[2]

In this section, the production process at the plant under study is described briefly and an attempt is made to identify some of the more hazardous locations found on visits to the plant.

The main raw material used is monazite which is an orthophosphate of 15 rare earth elements and thorium. The sand is ground in the ball mill to 400 mesh size after which a suction pump pulls out fine dust through a filter and deposits it in a bin. Dust is then mixed with dilute caustic soda (lye). The solution is then pumped into the attack tank where caustic soda (flakes) is added. The solution is then moved to arelay tank and leached with water. The first product of the process—Trisodium Phosphate (TSP)—a general purpose detergent—is decanted here.

The remaining slurry containng hydroxides of rare earths, thorium, uranium, mesothorium and lead is pumped into a set of 'More Filters' where it undergoes filtration and washing. Traces of phosphate are removed and slurry is pumped into four extraction tanks where concentrated hydrochloric acid is added. At this stage, the RE fraction of the compound becomes RE chloride which is drained out and pumped into a deactivation tank in which barium chloride and sodium sulphate are added. Deactivation involves separation of radioactive elements like uranium, thorium and their 'daughters'. These as well as lead are then allowed to precipitate in the tank. The precipitate is mechanically separated through press filters. The clear solution which is pure RE chloride, is decanted and the precipitate is scrapped off the press filters manually. Thorium hydroxide is also sent to another set of press filters to remove traces of RE chloride. Thorium hydroxide is scraped manually and pumped into a silo.

While no spot in the IRE compound seems to be free of radioactivity, there are a few processes which involves considerable threats to the workers. Let us consider a few examples:

(a) *Ball Mill*: The mill where monazite is ground is not air tight. There are numerous holes through which dust can escape. Moreover, mill vents have to be opened frequently for sample collection. This is done manually by the operator/helper. Though respirators are given, the workers do not wear them because: (i) it is uncomfortable; (ii) since a worker has to attend three spots, it is inconvenient; and (iii) since the volume of air breathed is reduced considerably, the worker is not able to cope with the work-load.

(b) *Filter Press ('Cancer Ward')*: At filters where thorium and mesothorium are pressed into cakes, materials handled are richest in radioactivity. Here work is done in pairs, each worker standing on either side of a 10′×2′ rectangular press, with a series of wooden frames. The top of the press is at chest level. The sticky concentrate has to be scraped from the frames using a metal sheet as big as a kitchen knife.

Workers on this job are given gum boots and rubber gloves. On the day of our visit, one of the two workers was not wearing gloves. He said that with gloves, the speed of work is reduced considerably. The plant superintendent who accompanied us did not ask him to use the 'protection gear' either. Mesothorium has gamma activity. Rubber, in any case is not a shield against this.

(c) *Lead sulphide disposal*: Lead sulphide (which contains lead, mesothorium, etc,) collected in the RCC barrels remains unsealed for a week. The barrel is located by the side of a road leading to the canteen/dispensary. They are sealed once in a week. After a year or so the barrels are buried in the factory compound itself by a disposal team consisting of a crane operator from the Fertilisers and Chemicals Travancore Ltd (FACT) and contract workers. The latter have to remain close to the barrel for securing its hooks.

According to the International Labour Organisation (ILO) guidelines, this class of radioactie waste can only be handled in "sealed-in operations, with people working in plastic suit with controlled ventilation".[3] In IRE, workers wear only cotton khakhi uniforms.

(d) *Thorium Silo*: Wet thorium hydroxide, kept in silos is removed occasionally for transportation to the Trombay facility. (This is a Government of India-owned company which is under the management of the IRE. Here, thorium hydroxide is converted into thorium nitrate for gas mantles and thorium oxide for research purposes.) Since silos contain many hundred tons of thorium stored for over three decades, there is the possibility of a high concentration of thoron, a thorium 'daughter' in gaseous form. According to ILO, air in the silo has to be evacuated once in every 17 minutes.[4] There is no facility for this in IRE. With radionuclides and thoron gas, work in the silo can be equated to both a radiation bath as well as a radiation dust bath.

(e) *Open Vessels*: Almost all chemical treatment is carried out in open vessels. Spillover of considerable vintage has accumulated all over the vessels. Because of the openness, radionuclides and thoron gas float freely in the workplace. In almost all processes, the external skin contamination is totally unavoidable because of the bad housekeeping. According to the plant superintendent the vessels as well as the floor, which appeared no different from a paddy field during transplantation had not been cleaned for over a decade. While the above hazards are of a day-to-day nature, there are riskier operations which have to be performed periodically. Some examples are given below:

(a) *Digging the Pond*: After extraction of TSP, the remaining slurry is washed in three tanks. The slurry is moved from tank to tank with an electrically-operated crane with a maximum capacity of five tons. At times, when the slurry is beyond the carrying capacity of the crane, or due to some other faults, it has to be removed manually. Workers, usually new recruits, enter the tank with a shovel. They can wear their gum boots and rubber gloves, if they wish to. The slurry is removed with the shovel and this job is known as 'kulam vettal" which, in Malayalam, means digging the pond. The approximate frequency of this event is one a month. The tank contains hydroxides of rare earths, thorium, mesothorium and uranium which have alpha, beta and gamma activity.

(b) *Digging the Grave*: Lead sulphide, the main solid waste, which contains mesothorium and other radioactive materials, is stored inside an RCC barrel which can accommodate 200 kg, the approximate output is more than normal, excess quantity bulges out of the polythene bag kept inside the barrel and is removed manually with a shovel. This has to be done approximately once every month. The materials have beta and gamma activity.

(c) *Occasional Activities*: Apart from these, occasional activities like shifting of godowns are done by contract workers. During 1983, dock workers of Cochin were employed to remove thorium concentrate stored in IRE godown near the port. According to an eyewitness, many of the MS drums in which the concentrate was stored were corroded and broken. During January/February 1985, casual workers were employed to shift thorium produced during he early fifties to the present silo. No protection was given in the above cases.

Among the permanent employees, the exposure rate is not uniform for all categories of workers. While helpers remain in close proximity of the production process, operators and supervisors who do not have to do much of a manual handling, remain a little away from it. However, the management has made it a point to evenly distribute hazards among all the workers. This has been achieved in two ways: (i) In IRE, there is only one entry point for workers, they are recruited as helpers. The posts of operators and supervisors are time-scale-promotion based; (ii) After a complete monitoring of the plant by HPD in 1966, permanent posting of workers to separate sections within the production line was discontinued. A rotation system was introduced under which every worker moves out of one section after a fixed interval.

The production technology was imported from France where it was developed in the forties and is outdated by nearly half a century. During those days, the awareness of radiation hazards was at a very low ebb, restricted as it was to a few radiologists. Between then and now, developments of a far-reaching nature have taken place. In IRE, however, the increased awareness of radiation hazards has not lead to any innovation to prevent it at source. Instead, cheap and totally inefficient measures like gloves and gum boots have been resorted to.

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In a latter addressed to the Prime Minister April 15, 1985 Professor K V Thomas, member of the Lok Sabha from Ernakulam, alleged that 14 workers of IRE died of cancer between 1970 and 1984. The prime minister in his reply (April 23, 1985) promised that he would have the issue examined. Earlier, in a memorandum addressed to prime minister, all the recognised trade unions of IRE had pointed out that the high incidence of cancer among workers can be attributed to radioactivity.

In our review of literature, we saw that the cause-effect relationship between radiation and diseases like cancer, genetic disorders, etc, has been well established. However, these diseases can also be caused by agents other than radiation. There is no way to ascertain the initiating factor in carcinogenesis at present.

Since occupational diseases do not carry a label indicating their origin, indirect methods have to be resorted to understand their aetology. Causative relationship between an agent and a disease is established through epidemiological studies, in which the incidence of disease in the exposed population is compared with that of a non-exposed population. An epidemiological study can be either retrospective or prospective. In the former, disease/deaths which have already occurred in the past are studied. In contrast, a prospective study is futuristic, the student waits for the event to occur. If a clearly identifiable trend is discernible, it is ethically sound to study the past, so that speedy remedial action can be initiated.

In this section, the incidence of cancer and mortality due to heart disease and all causes during 1970-1984 among IRE workers is examined. In an epidemiological study, the two population compared (the exposed and the control groups) should belong to similar socio-economic, age-sex groups.

Given the weakness of available estimates/data, use of a sample of industrial workers sharing a common socio-economic background would yield mroe reliable results. Adjacent to IRE, there are three more industries which form a cluster. There are the Hindustan Insecticides Limited (HIL), producing organochlorine pesticides like DDT and BHC, the Fertilisers and Chemicals Travancore Limited (FACT), manufacturing nitrogenous and phosphatic fertilisers and the Travancore Cochin Chemicals Limited (TCC) producing caustic soda, chlorine, etc. HIL and FACT have carcinogens in the work-places, like BHC and DDT in the former and rock phosphate which contains uranium in the latter.[5] None of the chemicals handled in TCC is known to be cancer causing. Moreover, since both IRE and TCC went on stream during the same year, the age composition of workers is more or less similar.

In TCC, caustic soda is produced by electrolysing sodium chloride (common slat) using mercury as cathode. Mercury is highly toxic; chronic exposure can cause neurological and skeletal disorders. Workers are also exposed to heavy concentration of chlorine which is a by-product. Over and above the pollutants released by their respective industries, the workers of both IRE and TCC have to live with invading pollutants from neighbouring factories—sulphur dioxide, ammonia and fertiliser dust from FACT and DDT from HIL.

In terms of wages and perks, both the population groups are on a more or less equal footing—the only difference being a higher rate of bonus and a liberal housing loan in IRE. On the health care front, workers receiving less than Rs 1,000 a month are insured under ESIC. Those earning above Rs 1,000 have a company medical scheme under which expenses incurred on treatment of workers and their families in private hospitals recognised by the management are reimbursed.

TCC has a residential colony in Udyogamandal itself, which is high pollution zone.[6] In contrast, workers of IRE have their residence scattered in the entire district. Hence, the pollution load in the living environment (beyond the factory) of TCC workers is higher than that of IRE.

In this study, we have used the workers of TCC as well as those insured under the ESIC as our control populations.

In the case of cancer, there is a time lag between the crucial exposure to carcinogen and the manifestation of the disease. Known as the latency period, this ranges from six to 30 years. In this study, we are examining cancer cases between 1970 and 1984. While the exact time of the crucial exposure cannot be known, we can be reasonably sure that the first worker diagnosed as a cancer patient in 1970 must have had his exposure at least six years before, i e, in 1964. As such, we would have to consider the worker strength of 1964 as the base line population.

In an industry, exposure to pollutants is not uniform among all categories of workers. An estimated 20 per cent of employees who are on non-production jobs (like clerks, peons) can be classified as the marginally exposed group. The remaining 80 per cent of employees, whom we classify as the seriously exposed group are taken as the base-line exposed population.

These manipulations are not possible in the case of ESIC data because we have no way to ascertain the year of enrolment or the nature of the job of the workers who have been diagnosed as cancer. As such, we would take the entire insured workers of the respective years as the base-line population.

Since ours is a retrospective study, we are examining the mortality profile of the past 15 years. Here, we are confronted with the problem of assessing the exact cause of death. What are the sources of information from which we can obtain reliable data? Firstly, the hospitals. While some hospitals informed us that the old documents are not preserved, two major hospitals refused to co-operate for reasons known only to themselves.[7] Then we looked into the register of births and deaths maintained by the local self-governments. In many cases the cause of death has not been recorded properly. This is an all-India phenomenon. It is only recently that the Indian Council of Medical Research (ICMR) has initiated a programme for maintaining the mortality data in India according to the World Health Organisation (WHO) norms.[8] Another source could be the personal dossiers of workers maintained by the management. Even this source is not free of errors as can be seen in the ensuing discussion.

Insted of depending on a single source, various soruces as given below have been consulted so as to arrive at a near accurate conclusion. Lists of workers who died along with the cause of death were obtained from the trade unions of IRE and TCC. The cause of death was cross-checked from dossiers. Cases in which the union data did not tally with the dossier, detailed interviews of co-workers, trade unions activists, family members and neighbours were conducted.[9]

To enable comparison of the data of all the three population groups (IRE, TCC and ESIC), it has been converted into rate per 10,000. After conversion, the relative risk in IRE was estimated.[10] Statistical test (chi square) was used to see if the difference between the study and control populations is significant.

Cancer

According to the unions, 14 workers of IRE and four workers of TCC died of cancer between 1970 and 1984. As per the IRE dossiers, only eight workers died of cancer.

Out of the six controversial cases, it is impossible to accept the unions' claim of cancer as cause of death in the first three cases. In the case of one, it is difficult to arrive at a definite conclusion. The last two workers, we are reasonably sure, died of stomach cancer. This brings the total number of cancer deaths in IRE to ten. One worker is now under treatment for lung cancer. In all, there have been 11 cancer cases in IRE since 1970.

Our data have the following serious limitations:

(a) Workers who left service since 1964 have not been followed up. Table 2 provides the service particulars of the existing workforce in IRE. Out of 471 employees, 67 started working before 1960 and another 30 joined between 1961-66. Average annual enrolment during 1961-66 being 5, there were 87 employees on April 20, 1985, who belong to the pre-1964 stock. Thirty-two workers of the pre-1964 stock are now in the managerial cadre, another 22 died while in service during 1970-1984. In other words, out of 328 base-year worker population of IRE, 187 have either resigned or retired. Of these, 140 (80 per cent) belong to the seriously exposed populaton. Since we do not know what happened to them, our result is likely to be a gross underestimation of the exact risk in IRE.

(b) The level of accuracy with which cause of death is recorded in the dossier is questionable. For instance, in one case, of death has been mentioned as "failure of heart." which is a layman's term for cardiac arrest. More revealing is the entry showing costochondritis as cause of death.

In IRE, there were four cases of stomach cancer. The remaining cases are of different sites. While radiation injury can produce malignacy of any organ, there is a strong association between certain types of cancer and occupational exposure, like lung cancer among uranium dial painters. Let us see if we can offer any explanatory hypothesis for the randomness of 'site of cancer' in IRE.

IRE has all kinds of radiation hazards, *viz*, external from beta and gamma rays, internal from ingested nuclides and inhaled radioactive gases like thoron and radon. The most serious threat in IRE seems to be from the internal emitters which are either ingested or inhaled. Now let us see the behaviour of internally deposited radioactive elements:

(a) Thoron is a noble gas (it does not react at all). It has alpha activity and a half life of 54.5 seconds. Polonium, the thoron daughter is a slid with alpha activity and a half life of 0.16 seconds. Next in the series is Thorium B with beta and alpha activities and a half life of 10.6 hours. While thoron does not react, her daughters get attached to the tissues nearby, in this case lungs. And keep on damaging the cells.

(b) We have earlier observed that all heavy metals (including the radioactive ones) follows the course of calcium. In other words, as the ageing process sets in, ingested radioactive metals settle down at soft tissues all over the body.

(c) The ITRC study quoted above reveals that thorium also settles down in testicles. Albert R E reports that workers in plants refining thorium have shown chronic deposition of the metal in lungs, lever, kidneys, spleen and bones.[11]

All this evidence proves tht once thorium enters the body, it behaves very randomly. So does tumour. Clumps of cancerous cells, often break away from the parent tumour, migrates to new organs seed out and start growing as secondary cancers, which are known as metastases (literally, "standing in an abnormal place"). Sometimes, the primary cancers remain undetected. We have therefore taken all types of cancer (including leukemia) into a single group for the purpose of analysis.

Heart Diseases

Let us now examine the incidence of heart diseases in IRE and TCC. The method of data collection for this has been the same as that for cancer.

A word of caution—as mentioned earlier, workers of both the factories are exposed to invading pollutants from neighbouring factories. Among such pollutants, sulphur dioxide released by FACT is of more significance in terms of concentration as well as the associated health hazards. Chronic exposure to this gas leads to thickening of alveoli walls of lungs, causing respiratory diseases like bronchitis, which at a later stage can graduate to heart diseases. This disease cycle is kwnon as Chronic Obstructive Pulmonary Diseases (COPD). The incidence of respiratory and heart diseases is very high in the entire area.

All the cases of heart diseases in IRE therefore cannot be attributed to the pollution caused by the manufacturing process in the plant. Likewise, the frequency observed in TCC may not be the expected frequency in an average factory. Assuming that the pollution load by FACT is equal in both IRE and TCC, the difference in frequency between the two population groups can be attributed to the presence or absence of causative agents in their respective work environments.

The figures for IRE and TCC are fatal heart diseases. The ESIC data, which also is presented below represents the incidence only—not all of them might be fatal.

Mortality Profile

So far, we have examined the frequency of two radiation caused diseases—cancer and heart diseases. There is another group of diseases which is broadly classified as radiation-aided. We saw that radiation can also cause cell death. An absorbed bone marrow dose destroys white blood cells, which are essential for fighting infection. If cell death is massive, the organism would be rendred incapable of fighting even a very common infection.

Cell death can also lead to premature ageing. Measurement of the ageing process involves high technology gadgets which we have not been able to use. However, since the end result of ageining is death, consideration of the total mortality profile might reveal certain basic trends. Let us compare the total mortality (due to all causes other than suicide and accident) in IRE and TCC. (Mortality data pertaining to workers insured under ESIC is not available.)

In order to facilitate comparison between units, data presented earlier has been converted into rates per 10,000. Relative risk between IRE and TCC for cancer and heart diseases is 4.62 and 2.24 respectively. Coming to total mortality, IRE workers had 2.72 times greater risk of dying of all causes. More pronounced is the relative risk between IRE and ESIC which is 6.77 and 2.72 for cancer and heart diseases respectively.

How significant are these differences? In the case of cancer, difference between IRE and TCC/ESIC is statistically significant at 0.01 level. For heart diseases, while the difference between IRE and TCC is significant at 0.2 level, the difference between IRE and ESIC is significant at 0.01 level. Difference in mortlity due to all causes between IRE and TCC is significant at 0.01 level. In short, we can conveniently reject the null hypothesis.

Genetic Disordes and Infertility

During the course of the study, we also stumbled upon a few cases of sterility among workers and genetic disorders among their offsprings. The data is not comprehensive. Major reasons for limitation in data ae as follows:

(a) Most diseases of autosomal dominant variety manifest themselves at a later age. The parents do not perceive such cases as genetic.

(b) A welfare measure in IRE has not made any survey (with limited resources) of families virtually impossible. IRE is one of the few industries in India which has a unique housing scheme. An employee can build a house with a liberal loan from the company at a place of his choice. Since every worker with a minimum of ten years of service can own a house under this scheme, the unions did not press for a housing colony. Some workers in IRE feel that the liberal scheme was introduced for concealing the increased incidence of genetic disorders among the employees' offsprings. Incidentally, the scheme was introduced a couple of years after the health physicists' team took position in IRE.

Among the affected workers, one in three alone presented the children before a medical board, consisting of three doctors of Lissie Hospital, Ernakulam. The board ruled that the cases can be attributed to inbreeding.

There are two types of inheritance of genetic disorders—autosomal dominant and autosomal recessive. In autosomal dominant inheritance, only one of the parents supply a defective gene, while in the recessive inheritance, both the parents supply the defective gene at the same genetic locus. The 'book' has the following to say on the nature of inheritance:

> In as much as recessive diseases require the inheritane of a mutation at the same genetic locus from each parent, when the genes are rare, the likelihood of any two parents being the carriers for the same defect becomes small. However, if the parents have a common ancestor, and if that ancestor was a carrier of the recessive gene, then the likelihood that two of the descendants have inherited the gene becomes relatively great.[12]

A person who has inherited a defective gene which lies dormant would not be affected by the disease. He or she is called a carrier. When two carriers of the defective gene at the same locus mate, the statistical probability of inheritance is:

> twenty-five per cent of the children will be normal, 50 per cent would be heterozygous carriers and 25 per cent would be homozygous and affected with the disease . . . Since with recessive inheritance, only one of the four children in a sibship is expected to be affected, multiple cases in a family might not occur.[13]

In the case another worker, all the four children have been affected. Moreover, according to the worker, he and his wife are sixth in a chain of consanguinity. This introduces an increased possibility of some other relatives also being affected. No one has been, so far. Secondly, as the provisional diagnosis shows, all the children do not share the same symptom complex or clinical history. This suggests the possibility of damages at different genetic loci. Hence, the probability of both the husband and wife carrying several damaged genes seems to be extremely remote.

Infertility

It is not possible to assess at this stage whether all these cases are radiation-related. If they are, then the situation in IRE would have historical significance. IRE, in that case would be the first reported nuclear facility in the world to cause radiation-induced sterility among workers.

Cases of sterility deserve a closer examination. In the survey of literature, we saw that unlike cancer and genetic disorders, sterility is a non-stochastic effect which has a safe threshold. Since there is no history of radiation-induced sterility among males, the exact sterilising dose is not known. Sterilising dose for females is 700 rems, administered during a short span of time. Since overies are more protected than testicles, male sterilising dose should be lesser than that of females. One estimate places the dose at 60 rems. Assuming that the workers became sterile during the first twelve years of their service, the annual average exposure works out to 50 rems, which incidentally is ten times higher than the maximum permissible limit.

Health and Safety Apparatus

HPD of BARC is responsible for monitoring the health of workers in all DAE undertakings. Health physicists were posted in IRE, Alwaye, in 1962, ten years after the factory went into stream. In 1966, the team recommended a few safety steps, like rotating workers from spot to spot after a fixed interval, provision of gumboots and rubber gloves, etc. HPD is supposed to monitor the dose absorbed by workers and take remedial action in critical cases. Monitoring is done by analysing the film badges worn by workers. Film badge analysis alone is not adequate in an industry like IRE where the major hazard comes from radionuclides and radioactive gases like redon and thoron. A near accurate account of the dose absorbed can only be made through analysis of biological samples which is not being done in IRE. Even the results of film badge analysis is not communicated to the workers. Similarly, HPD had conducted a chromosome analysis of Alwaye workers during the late seventies, the result of which has also not been communicated so far.

In the past, three workers were transferred to less hazardous jobs because of adverse medical findings. In these cases, the workers who had got medical advice from private practioners had to fight their way out for transfer. HPD, rather than assisting in such cases, strongly opposed the transfers. Even though all workers suffering from occupational diseses are entitled for compensation under the Workmen's Compensation Act 1923, no one in IRE has got it so far. In short, there is nothing much to comment on the health and safety apparatus in IRE.

Chromosome aberration, chemical change of DNA and cell death are the immediate cellular responses to an absorbed dose of radiation. The end result could be any of the stochastic or non-stochastic diseases mentioned earlier. In this paper, we have been able to demonstrate statistically significant differences in incidence of cancer and mortality due to heart diseases and all causes between IRE workers and control populations. The incidence of sterility among workers and genetic disorders among their off-springs reported above is seemingly higher than their spontaneous occurrence in general population.

A retrospective epidemiological study of this nature, can only formulate clinical hypothesis. At best, one can state that the study population was exposed to the agent under consideration during the reference period—in this case till 1964. Incidentally, two years after this, the so-called control measures were introduced in IRE an HPD. How effective are these measures? To obtain an answer through an epidemiological study, one would have to wait a few more years. Fortunately, we have a little more concrete evidence. In 1978, BARC conducted a chromosome study of IRE, Alwaye, workers. Though the results of this sutdy are yet to be published, there is a reference to this one of the DAE annual reports:

> In continuationof the efforts to evaluate the biological effects of high background radiation on human population residing in the monazite belt (Chavara, Neendakara in Quilon district, Kerala), chromosome analysis was carried out on 179 samples.
>
> Under our chromosome analysis programme, broad sample in the normal background areas were analysed. Data on newborn and their mothers did not indicate any differences in the chromosome aberration frequency between samples from normal background radiation areas and those from high background radiation areas.
>
> In the samples taken from the IRE workers at Alwaye, a high aberration frequency was indicated than that observed in the high background radiation, Chavara and Manavalankurichi samples.[14]

In short, workers' health was, and still is in jeopardy.

During the course of our study, we also found that there are gross irregularities in the fields of radioactive waste management, as well as storage and transportation of radioactive materials—issues which are beyond the scope of this paper and hence being reported separately.

The situation is alarming. This calls for immediate action. The management of IRE has agreed to palliative measures like scanning of all workers for tumour by the Cancer Detection Centre, Cochin, which is not enough in a hot spot like IRE. The need of the hour is a comprehensive, interdisciplinary study of the plant and the workers. In order to take effective remedial action, there should be a health survey of the workers which should include analysis of urine, blood, chromosome and tissues of critical organs like gonads. The workers who have absorbed dose above the permissible levels should be removed to safety. In the case of work environment, activity status of each spot would have to be measured and engineering measures adopted.

Such a study should have representation from the workers as well as the people because what at stake is not only the health of over 500 employees, but also the national gene pool which the present decision-makers have no right to tamper with. We do not own the gene pool.

A clear understanding of the exact magnitude of hazards posed by IRE assumes national importance at this juncture of our history. IRE is the only DAE venture which has completed 30 years of operation, which incidentally is the average latency for cancer. Today, DAE is pushing forward its ambitious plan which involves a tenfold expansionof nuclear electricity generation by 2000 AD. Before allocating a massive Rs 22,177 crore from the public exchequer for the planned expansion, people have a legitimate right to look into the track record of DAE during the past three decades of its existence.

[This report is part of a book which is now at the design stage. This study is a joint venture by the trade union activists of IRE and TCC, Forum for Occupational Health and Environmental Studies, Alwaye, E P Mohanan and a group of students of Medical College, Calicut, and Krishnamohan, a scholar of environmental science at Jawaharlal Nehru University (JNU), New Delhi. The team acknowledge guidance and help by Gyanesh Khudaisya, D Banerji and Imrana Quadeer of JNU. Fraternal assistance from Nikolai Izmerow, Director, Institute of Industrial Hygiene and Occupational Diseases of the Academy of Medical Sciences of the USSR, Moscow, Ralph Nader and Joan Claybrook of the Critical Mass Nergy Project, Washington, and Anthony Mazzocchi, Director of Health and Safety, Oil, Chemical and Atomic Workers International Union is gratefully acknowledged.]

Notes

1 **R V R Krishna Iyer, (1985): 'Nuclear Nationalism and the Law',** *Philosophy and Social Action*, Vol XI, No 2, pp 9-19.

2 For the first time in the history, DAE released the annual average radiation exposure to workers of Tarapur Atomic Power Station (TAPS) on May 10, 1983 (See *Times of India*, Bombay, May 11, 1983). This release was in response to a detailed report by Praful Bidwai in *Times of India* dated May 9, 1983.

3 ILO (1983): *Encyclopaedia of Occupational Health and Safety*, Vol II, p 1882.

4 Ibid, p 1883.

5 ILO, (1983) ibid, Vol.II, p 1679.

6 Concentration of sulphur dioxide and particulates in the area, measured by the National Environmental Engineering Research Institute (NEERI) is given in Table A.

7 Lissy Hospital and Medical Trust Hospital, Cochin are the Major hospitals which refused to co-operate without assigning any reason.

8 Gandharan P, ibid.

9 E P Mohanan a tutor in Trichur Medical College was present in many of these interviews. Statements involving medical judgments are his.

10 "Relative risk is the ratio between the incidence among exposed and incidence among non-exposed". See J E Park and K Park (1981), *Text-book of Preventive and Social Medicine*", Jabalpur, pp 279-280.

11 Albert, R E (1966): *'Thorium: Its Industrial Hygiene Aspects"*, Academic Press, New York/London, pp 58-64, quoted in Tandon, S K *et al*, (1977): 'Effects of Monazite on Body Organs of Rats' *Environmental Research*, Vol 13, pp 347-357.

12 Robert G Petersdorf, *et al*, (ed) (1983): *Harison's Principles of Internal Medicine* 10th edition, McGraw-Hill, p 319.

13 Ibid, p 318.

14 Government of India, Department of Atomic Energy (DAE) Annual Report 1978-79, p 38.

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