Chapter I

Introduction

1.1 Introduction


However, most developing countries have pursued economic development without taking into consideration the environmental concerns. This has led to many environmental problems such as water and air pollution, and pesticides in food supply (World Bank, 2000). In the developing countries, environmental pollution has been one of the most important causes of environment degradation. Environmental pollution is a negative externality, which is considered as a public 'bad' that results from waste discharges associated with the production of private goods (Cropper and Oates, 1992). But the health effects of environmental pollution have not been given as much priority as is needed. Environmental health still remains at the periphery of sustainable development because it is inadequately defined and rarely quantified, and institutionally fragmented (Listorti and Doumani, 2001). The environment in which people live greatly influences their health. A
degraded environment leads to poor quality of life, loss of productivity and higher health care costs. According to World Health Organization (1997, p.4), 'Environmental Quality is an important direct and indirect determinant of human health; deteriorating environmental conditions are a major contributory factor to poor health and quality of life and hinder sustainable development; poor environment quality is responsible for around 25 per cent of all ill health in the world today.'

A great deal of the underlying causes of disease, injury and death in developing countries lie beyond the purview of health care system, but are caused by environment factors. The ambient environment, which includes the outdoor environment to which the general public is exposed, includes air and water pollution, and radiation exposure that causes the most damage to human health in developing countries in recent times (World Bank. 2000).

1.2 The Problem of Radiation

Radiation induced Pollution has also become a major source of pollution affecting human health in the world¹. Radiation is a form of energy and exposure to radiation derives primarily from the natural background ionized radiation, the radiation used in medical and dental diagnosis and treatment, mining of radioactive minerals, and the radiation exposure in factories and industries. Accidents and other occupational risks to workers in the factories and industries that extract chemicals from the radioactive minerals like ilmenite, monazite and titanium are high. The world population became aware about the

¹ For a detailed description on the dose effects and risks of radiation refer UNEP (1985). Radiation not only affects human health but also has impacts on drinking water, fisheries and vegetation. However this does not come within the purview of the current study.
health effects of radiation especially after the nuclear bombings at Hiroshima and Nagasaki in Japan that resulted in the end of II World War (1945). The accident at Chernobyl in Ukraine in 1986 recently brought into the focus the dangerous implications of radiation on health\textsuperscript{2}. The World Health Organization (1959) had already identified the regions of the world, which had high background radiation. Preceding these dreadful incidents the concern for quality of health and serious effects of radiation have become major universal issues to be discussed and debated.

1.3 Review of Studies on the Effect of Radiation on Human Health in the Global Perspective

Various medical studies were conducted in the developed countries probing the effect of radiation on the health of population since the atom bomb explosions in Hiroshima and Nagasaki of Japan. But surprisingly, the results were contradictory in nature with most studies showing a negative influence while a few showed positive results. This could mainly be due to the methodological weaknesses in the epidemiological survey techniques used in these studies. The effects of low-level radiation as a factor responsible for human carcinogen\textsuperscript{3} as well as genetic effects were mostly studied. The investigation was primarily to find out the ecological association of radiation and illnesses in various geographical and occupational environments.

\textsuperscript{2} The Chernobyl accident in Ukraine in 1986 was the result of a flawed reactor design that was operated with inadequately trained personnel and without proper regard for safety and had affected human health.

\textsuperscript{3} Carcinogen is a substance which causes cancer (or is believed to cause cancer)
The enquiry into finding out a relationship between radiation and human health started right from the early 20th century. However, it was only after the Second World War that there was a persistent need to understand the relationship emerged. The World Health Organization (1962) identified the major diseases that could be caused due to radiation. This included different types of cancer, genetic illnesses, stomach skin and respiratory ailments. Court-Brown et al (1960) reported a significantly higher occurrence of leukaemia in a high radiation exposure area in Italy than a low exposure area. Another study, which looked into the association between ionised radiation and health, was Lindell and Dobson (1961). This report citing examples from all over the world proves that radiation mainly caused leukaemia, a major type of cancer, and genetic effects to the humans. The study undertaken by Plewa et al (1962) in Poland showed positive associations between leukaemia and radiation. The Third Expert Committee on Radiation by the World Health Organisation (1959) highlighted the potential adverse health effects of radiation. It identified leukaemia liver cancer, stomach cancer, and bone cancer apart from skin problems, eye problems and genetic diseases especially downs syndrome, as the major causes of high radiation on humans. Archer (1980) concluded from his review-based study that the association between cancer and radiation was not observed because of the confounding factors. He suggested that epidemiological methods have to be applied to find the effects of low-level radiation on man. The reports from the high background radiation area of China studied by Luxin (1980) showed that there was no

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4 Epidemiology is defined as the study of the distribution and determinants of disease prevalence in man. The agent factor, host factor and environmental factor for the occurrence of disease are studied in the descriptive Epidemiology. Moreover Time, place and person are also studied. It means that what is causing the disease, in whom the disease is usually occurring and what environment this condition is seen is looked into regarding the Epidemiology of each disease condition. When this disease is occurring (Time), what is the geographical area where this disease is occurring (place), how many people are affected and what type of people are affected (Person) all these factors are studied in epidemiological studies.
significant difference in the cancer rate between the high and low exposure areas. The author suggested that the sample size of the study was too small to detect a significant association between these factors. The study also showed that continuous exposure to low-level radiation throughout life is unlikely to increase the risk of thyroid cancer significantly, but may cause chromosomal damage\(^5\). Later, a study by Wang and Luxin (1990) tried to find out the relationship between thyroid cancer and radiation among women in China. They concluded that there were not enough reasons to believe that radiation caused thyroid cancer. However, they reported that there was high level of Chromosomal aberrations. Neel (1991) updated the genetic effects due to radiation among bomb survivors in Nagasaki and Hiroshima. A case control study was conducted on the fathers and their children to look into the presence of genetic diseases and cancer. It was found that while the children in both groups did not show any statistical significant results in terms of the diseases present, the fathers in the affected area showed a significant prevalence of leukaemia as compared to the control group. The study pointed out the need for more in-depth analysis to get relevant results. The study reports of Walter et al (1986) showed that the relationship of terrestrial radiation on the cancer incidence in Connecticut, USA was not significant. They suggested that the power of epidemiological studies involving only few thousand people over a small period of years would be small to detect the effect of radiation. They pointed out that if the confounders affecting the cancer incidence were measurable, ecologic analysis would become more sensitive to the radiation effect. Hall (1989) linked the health effects with radiation in the population affected all over the world. He pointed out that the bomb survivors of

\(^5\) Here Chromosomal damage refers to the physical interference caused by the breaking and rejoining of chromatids, potentially leading to genetic diseases to the offsprings.
Hiroshima and Nagasaki were affected by thyroid cancer, breast cancer and lung and liver cancer. There was also prevalence of leukaemia, skin cancer, stomach cancer and bone cancer. The study also highlighted the link between the genetic effects like downs syndrome and radiation among children. The severity of the diseases differed with the amount and time of exposure. A study by Fry and Fry (1990) supported the argument that radiation could lead to genetic diseases and specific types of cancer. Clarke and Southwood (1989) also had identified the link between lung cancer and radiation among the population in both United States and United Kingdom. National Geographic (1994) reported that around 10,000 Ukrainians had died from various ailments connected with radiation caused by the Chernobyl Accident and one of the most tragic consequences was the large increase in thyroid cancer in children. It was also found that the number of cancer cases due to Chernobyl accident ranged from 5000 to 1,000,000 and chromosomes of the affected people were mangled and damaged indicating a risk of leukaemia and other cancers. The Chabad Medical Report (2001) point out that the children who survived the Chernobyl accident suffered from thyroid problems, which was 8 times more than the number from a control group of non-contaminated areas. The morbidity rate was high which accounted for two times more than that of the control group. About the same percentage of cases were reported with eye problems and a four-fold increase in digestive and respiratory problems were there.

There are extensive studies conducted by the Radiation Effects Research Foundation (RERF) among the atomic bomb survivors in Hiroshima and Nagasaki that looked into the mortality and morbidity patterns due to radiation. The Fifth Biological Effects of Ionising Radiation Report (BEIR V 1999) also highlight the relationship between
radiation and health effects on the human population. The above review showed the
presence of radiation problem in different parts of the world. While some studies hinted at
the prevalence of radiation induced illnesses among such population, a lot of studies citing
methodological lacunae and sample size problems were not able to conclude in certainty
that radiation has specific human health effects. The studies on radiation in the
international context are enumerated in Table 1.1

Table 1.1

Studies on Radiation and Health in the Global Context

<table>
<thead>
<tr>
<th>Name of Author</th>
<th>Year</th>
<th>Place of Study</th>
<th>Major Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Court Brown et al</td>
<td>1960</td>
<td>Italy</td>
<td>Occurrence of Leukemia in high radiation exposure area as compared to low exposure area</td>
</tr>
<tr>
<td>Lindell and Dobson</td>
<td>1961</td>
<td>All parts of the world</td>
<td>Positive relation between leukemia, a type of cancer and radiation.</td>
</tr>
<tr>
<td>Plewa et al</td>
<td>1962</td>
<td>Poland</td>
<td>Positive relation between radiation and leukemia</td>
</tr>
<tr>
<td>Archer</td>
<td>1980</td>
<td>Review of earlier studies</td>
<td>Cancer not caused by radiation, but result not based on any epidemiological survey.</td>
</tr>
<tr>
<td>Luxin</td>
<td>1980</td>
<td>China</td>
<td>No significant association between radiation and cancer and genetic illnesses.</td>
</tr>
<tr>
<td>Wang and Luxin</td>
<td>1990</td>
<td>China</td>
<td>No significant relationship between Thyroid cancer and Radiation.</td>
</tr>
<tr>
<td>Neel</td>
<td>1991</td>
<td>Japan</td>
<td>Positive relationship between leukaemia and radiation among bomb survivors in Nagasaki</td>
</tr>
<tr>
<td>Walter et al</td>
<td>1986</td>
<td>USA</td>
<td>Critical review of earlier studies and provided reasons for finding no relationship between radiation and cancer in other studies.</td>
</tr>
<tr>
<td>Hall</td>
<td>1989</td>
<td>Japan</td>
<td>Prevalence of Lung Liver Stomach Thyroid Skin and Bone cancer among bomb survivors in Hiroshima and Nagasaki affected by radiation.</td>
</tr>
<tr>
<td>Fry &amp; Fry</td>
<td>1990</td>
<td>USA</td>
<td>Radiation can cause short term illnesses like respiratory illnesses and gastro intestinal problems and long term illnesses like cancer</td>
</tr>
<tr>
<td>Clarke &amp; Southwood</td>
<td>1989</td>
<td>United States and United Kingdom</td>
<td>Positive relationship between liver and lung cancer and radiation</td>
</tr>
</tbody>
</table>
1.4 Review of Studies on Radiation and Health in Coastal Kerala

Ever since the World Health Organization (1959) identified the presence of high radiation in Karunagapally panchayat in coastal Kerala and Kanyakumari district in Tamil Nadu, attempts were made in various studies, primarily to measure the radiation level and to link it with health effects. The Bhopal Gas tragedy\(^6\) showed the ill effects of radiation in India. Serious radioactivity problem in India also exists in places like Jadugoda in Bihar and Domiasiat in Meghalaya (Ramana and Reddy, 2003). The Atomic Energy Commission, which is functioning under the Department of Atomic Energy of the Government of India, conducted a number of studies in coastal Kerala. Kartha (1968) reported that radiation exposure was prevalent in the coastal areas of Kerala. This study was conducted under the auspices of the Trivandrum Medical College, in which the radiation in the sands of the seashore was measured using radiation survey meters and lithium fluoride dosimeters. The initial study was aimed at the estimation of radiation exposure within different types of residential houses, and in the latter the radiation exposure to personnel living in that area was measured. The study revealed that the average radiation exposure in houses was higher than normal. The radiation problem was mainly found in the coastal villages of Kollam district in Kerala. Ahuja et al. (1973) tried to find out some of the genetic traits, which are present among the inhabitants of the monazite belt in Kerala. It was a study comparing two groups who are exposed to high levels of radiation and normal levels of radiation. The results of this study showed that there were considerable differences between these two groups and the inhabitants who

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\(^6\)The Bhopal Gas tragedy in 1984 was due to the leakage of methyl isocyanate a poisonous vapour that was emitted from the Union Carbide Factory. Around 2000 people died immediately and 3,00,000 lakh people were prone to radiation effects over a period of years.
were exposed to the higher background radiation were affected more with genetic
defects.

The study conducted by Kochupillai et al (1976) tried to examine the problems related to
radiation exposure in the coastal areas of Kerala, especially in the areas of Chavara and
Neendakara villages in Kollam district. They measured the radiation levels in the area as
1500-3000 micro radon per year due to the presence of thorium containing monazite
sands in the soil on the seashore. It was a case control epidemiological household survey
and it revealed that there was an apparently high prevalence of Down’s syndrome\(^7\) and
other forms of mental retardation among the people in the radiation exposed area. The
frequency of the chromosome aberrations in a sample of radiation exposed population
and the normal population was looked into. The observations supported the view that the
prevalence of radiation induced genetic anomalies was significantly high among the
population living in the area with high background radiation. Kochupillai et al (1976a)
also looked into the nodular lesions of the thyroid in an area of high background radiation
in coastal Kerala. The study was conducted in Neendakara village in Kollam district and
the control area was Punnapra in Alleppey district. The study showed that thyroid nodular
lesions were high for both the study and control group and the differences were not
statistically significant. However, this result became contradictory as per the recent
reports made regarding the high radiation levels existing at the control area of Punnapra
in Alleppey district in Coastal Kerala (Jacob, 2003). This may be the reason for getting
the result of no significant difference in the prevalence of nodular lesions between study

\(^7\) Down’s syndrome is a complex symptom of disease caused by chromosome abnormality leading to
mental retardation and other abnormalities
and control area. Nambi and Soman (1987) studied the relationship between environment radiation and cancer in different parts of India, including coastal Kerala. They found that there was a negative correlation between annual levels of environmental external radiation and cancer rates in India in year 1980. As the study was done using limited secondary data, the results are likely to be biased and cannot be generalized. A more detailed study done by the same authors in 1990 came to the conclusion that there is a relationship between environmental radiation and certain types of cancer, and respiratory diseases. Lung cancer and leukemia were the most significant prevalent diseases. Nambi (1994) measured the level of radon and thoron levels in this taluk and found that the levels were very high as compared to other radiation areas.

Nair et al. (1999) did an epidemiological survey that gave a comprehensive analysis of the population exposed to radiation and tried to assess the health effects of radiation in the Karunagapally Taluk. The study revealed that Karunagapally taluk had the highest radiation levels in the coastal areas of Kerala and it also varied across the villages in the taluk. Due to the presence of the Indian Rare Earth Factory in the coastal area, and the extensive mining over the coastal belt of this area, the study attached lot of importance in finding out the health effects of radiation, especially cancer. This study concluded that there was not much evidence to prove that there is a relationship between radiation and cancer.

The study conducted by Centre for Earth Science Studies, Trivandrum (2001) identified that the radiation level in the Alappad grama panchayat in Karunagapally taluk is high.

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8 The contradictions in the studies on radiation in the study area are dealt in detail in chapter 3.
where mining is done and people in the area are affected by cancer and other genetic traits. A Comprehensive Epidemiological Survey was conducted in 1990 at the Karunagapally taluk with the collaboration of Bhabha Atomic Research Centre and Regional Cancer Centre, Trivandrum. This study looked into the health effects of radiation in that area. However, emphasis was given only to the incidence of Cancer in that area due to radiation. The Regional Cancer Centre (2000) has published the Cancer Morbidity and Mortality Statistics of Karunagapally taluk for the period 1993 to 1997. The study tried to identify the different areas with high radiation, the areas with high incidence of cancer and specified how the cancer is causing/related to radiation. This study, a house-to-house survey by enumerating and interviewing every individual living in the coastal belt recorded the basic socio-demographic features and life style characteristics of the people. Complete Radiation level measurements were taken (both internal and external) in the houses, and finally, the complete Cancer Registry covered the whole population in the taluk. The study in the Karunagapally taluk started in 1990 and the complete enumeration and radiation survey completed in 1998. Although, the report states that the high cancer incidence is not due to the radiation, it was found that the prevalence of liver cancer, and thyroid cancer among females, and lung cancer among males were the highest when compared to metropolitan cities like Delhi and Mumbai. This report fails to give any answer to the causative factors behind the high incidence of these specific radiation induced cancers. Moreover, the prevalence of non-radiation induced cancers was found to be very low in this taluk.

Forster et al (2002) conducted a study in Karunagapally taluk to look into the health effects of radiation. They mainly tried to see whether the population in the taluk had
DNA mutations, which could result in other serious illnesses like Cancer and genetic traits. They sampled 248 pedigrees (988 individuals) and sequenced their mtDNA, and found that the pedigrees living in the high-radiation area have significantly increased germ-line point mutations between mothers and their offspring. Strikingly, it was found that the radioactive conditions accelerate mutations at nucleotide positions that have been evolutionary hotspots for at least 60,000 years. They found that the people living near the mining site in the high radiation area could be affected.

All the studies mentioned above looked mainly into the health hazards faced by the people due to the high radiation exposure in the coastal areas of Kerala. It was quite evident from these studies that the levels of radiation are high here and the local community are affected with specific types of cancer and other genetic illnesses. Padmanabhan (1988 b) observed that the epidemiological studies were undertaken without proper seriousness in the coastal areas due to political reasons. Two factories, the Indian Rare Earths Limited and Kerala Minerals and Metals Limited are located in this taluk, which do the mining and process the radioactive minerals in the factories. An enquiry into the health condition of workers of these factories was conducted in 1980. Padmanabhan (1986) studied the occupational health hazards at the Indian Rare Earths Plant (IRE) situated in coastal Kerala. The Indian Rare Earths Plant was a unit of Department of Atomic Energy, which processed the highly radioactive monazite sands found in Coastal Kerala. The products in this factory are Thorium, Uranium and Rare Earths Chloride. The workers belonging to all categories of work in the factory were

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9 A detailed analysis on the health effects of radiation-induced pollution in Coastal Kerala will be dealt in chapter 3.
studied, especially in the more hazardous jobs. The study was conducted as a retrospective epidemiological survey. The control group was the workers in a nearby factory. The study found that 15 workers in the Indian Rare Earth factory had died of cancer while working in the factory, few of them died due to cancer immediately after their retirement. The study also observed that the incidence of heart diseases was also high among the workers of IRE.

A number of studies have shown that factories in the coastal area of Kerala, which produce nuclear compounds, are affecting not only their workers but also the local fishermen community living in the vicinity. This is basically due to the radiation exposure through the waste disposal from these factories to the areas where local people live. Padmanabhan (1987, 1988 a) who studied the waste disposal pattern of the Indian Rare Earths Plant found that the radioactive wastes have been buried in the factory compound while some are allowed to flow into the nearby river. Of the wastes, mesothorium is a highly toxic nuclear compound, not to ignore uranium and thorium. The disposal of both liquid and solid wastes produced harmful effects on the health of the ignorant local fishermen community staying there.

Paul (1994) assessed the thoron and their decay products in the Indian Rare Earths Factory at Chavara. The study dealt with the assessment of internal exposure to the workers in the factory due to radon and thoron exposure. They found that the radiation level of exposure were not high among the workers. However, it was not clear from the study whether the temporary workers\(^\text{10}\) were also considered for analysis. The sample

\(^{10}\) It's the temporary workers who do work in factories relating to more radiation exposure.
selected for the study was not clearly mentioned in the study\textsuperscript{11}. Sreekumar (1996) argued that the extensive mining near the Indian Rare Earth Factory has led to severe problems to the local community and to the environment in which they live. It also led to the loss of land for the people owing to the advancement of the sea swallowing of the coastal land. Prakash (2000) who studied the health impact as well as the environmental impacts of industrial pollution in the coastal area of Eloor in Kerala noted that the waste generated from the factories to the Periyar River consisted of 111 types of poisonous materials. The prevalence of cancer, respiratory diseases, and other water-contaminated diseases were found to be high among the inhabitants of this area. The results of the studies on radiation and health in the Kerala context are given in Table 1.2.

Table 1.2

<table>
<thead>
<tr>
<th>Name of Author</th>
<th>Year</th>
<th>Place of Study</th>
<th>Major Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kartha</td>
<td>1968</td>
<td>Coastal Kerala</td>
<td>Presence of high radiation in coastal Kerala. The measurements through dosimeter showed 15 times more exposure in the area than other normal areas.</td>
</tr>
<tr>
<td>Ahuja \textit{et al}</td>
<td>1973</td>
<td>Coastal Kerala</td>
<td>No evidence of genetic illnesses in the radiation area</td>
</tr>
<tr>
<td>Kochupillai \textit{et al}</td>
<td>1976</td>
<td>Chavara and Neendakara Village</td>
<td>Presence of high radiation in the area and prevalence of Down's syndrome was high.</td>
</tr>
<tr>
<td>Kochupillai \textit{et al}</td>
<td>1976 a</td>
<td>Neendakara Village</td>
<td>The prevalence of nodular thyroid lesions were high but had no statistically significant difference in the control group of Punnapra in Alleppey.</td>
</tr>
<tr>
<td>Nambi and Soman</td>
<td>1987</td>
<td>Coastal Kerala</td>
<td>The prevalence of Cancer in the coastal area not correlated with radiation levels</td>
</tr>
<tr>
<td>Nambi and Soman</td>
<td>1990</td>
<td>Coastal Kerala</td>
<td>There is correlation between radiation levels and specific types of cancer and respiratory illnesses.</td>
</tr>
</tbody>
</table>

\textsuperscript{11} An earlier study by Paul \textit{et al} (1987) looked into the occupational exposure due to solid waste disposal from the IRE factory.
The above-mentioned studies clearly shows that certain parts of Kerala Coast are abundant in radioactive materials. The extensive mining over the coastal area, and the existence of mineral factories there affect human health due to radiation exposure. The population living in the coastal belt of Kerala is more exposed to radiation due to the extensive mining there. The workers in the factories producing radioactive compounds are the vulnerable group who are susceptible to various health hazards. The Department of Atomic Commission owns these factories and the studies on health effects are also conducted under their guidance. This could be one of the reasons why the negative health effects of radiation-induced pollution have not been emphasised in most of the above studies. The studies by independent researchers have shown a positive relation between health effects and radiation induced pollution.

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12 The discrepancies of the data generated by Bhabha Atomic Research Centre and Regional Cancer Centre is explained in detail in Chapter 3.
1.5 Economic Analysis of Pollution

The major concern of the environmental economists from the late 21st century was to find out the economic implications of pollution. According to Kolstad (2000) the major concerns of environmental economists were what is the right amount of pollution, how the pollution can be controlled and what are the damages from pollution? Different methods\(^\text{13}\) have been used to value the environment in order to address the above issues. In this section a brief review of the studies, which have looked into the economic aspects of pollution viz. air and water pollution, indoor air pollution and radiation induced pollution in the International and Indian context.

1.6 Studies in the International Context

The studies in the international context have mainly concentrated on the health effects of air and water pollution on human health. They used methods like Cost of Illness approach, Willingness to Pay/Accept based on Contingent Valuation Surveys, Human Capital Approach and Disability Adjusted Years to value health effects of pollution\(^\text{14}\). Gerking and Stanley (1992) looked into the morbidity health effects of air pollution on 824 adult workers of St Louis in USA. They analyzed the costs incurred by the people to prevent the adverse health effects of pollution and used the Willingness to Pay (WTP) approach to find out whether the population affected by chronic illness and years of having the disease influenced the result. They found that the WTP figures were low basically because the area was not yet severely affected by the ill effects of air pollution.

Berger et al (1987) reported data on medical expenditure net of insurance payments plus

\(^{\text{13}}\) The need for valuation and different valuation methods are dealt in detail in Chapter 2.

\(^{\text{14}}\) The different methods to value health effects due to pollution are also explained in the next chapter 2.
lost earnings for some of the respiratory symptoms due to pollution. The study found that
the cost of illness for drowsiness as $1.80 per day and $14.56 (based on 1984 dollars) for
itchy eyes.

Maddison and Gaarden (2002) have looked into how effectively the results that link the
impact on health effects due to air pollution in developed countries can be applied to
developing countries. Ostro (1994) estimated the health impact of air pollution for the
city of Jakarta (Indonesia). He first identified a health impact function taking dose
response functions from the data based on US. Then the cost of illness approach was
used to measure the impact of morbidity. The restrictive activity days, which includes
days spent in bed, days missed from work, and other days when normal activities are
restricted due to illness even if medical attention is not needed. The emergency room
visits and the respiratory hospital admissions were also considered for the study.
Mortality due to air pollution was not measured by the study. Dixon et al (1994) relying
on the study by Ostro (1994) also looked into the health effects of air pollution in
Jakarta, Indonesia. Based on dose response functions from USA the study tries to look
into the factors affecting premature mortality and morbidity. He used the cost of illness
approach to value the costs involved in days lost due to the disease and costs incurred in
hospitals for illness like respiratory ailments like bronchitis and asthma.

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15 Ostro (1987) had looked into the relationship with air pollution and morbidity in US by analyzing the
workdays lost.

16 Dose- response function establishes a relationship between environmental damage (response) and some
cause of the damage such as pollution (dose) such that a given level of pollution is associated with a change
in output that is then valued at market.
Larson *et al* (1999) undertook a combined health risk assessment, cost-effectiveness analysis and benefit-cost analysis for direct particulate emissions from 29 stationary source polluters in the city of Volgograd, Russia. Annual particulate-related mortality risk from these stationary sources is estimated to be substantial, with an estimate in the range of 960-2,667 additional deaths per year in this city of one million. For several emission reduction projects, the cost-per-life saved was estimated to be quite low. The total net benefits to the city of implementing five of the six identified projects, leading to roughly a 25% reduction in mortality risk, are estimated to be at least $40 million in present value terms.

Aunan *et al* (1998) tried to assess the cost and benefit of the implementation of a specific energy saving program in Hungary. They considered the possible reduced damage to public health that may be obtained from reducing emissions of important air pollutants and also how the program contributes to reduced emissions of greenhouse gases. The measures are described in the National Energy Efficiency Improvement and Energy Conservation Programs (NEEIECP), elaborated by the Hungarian Ministry of Industry and Trade and accepted by the Government in 1994. The energy saving expected from the program is approximately 64 PJ/year. The benefits were estimated using monitoring data and population/recipient data from urban and rural areas in Hungary together with exposure-response functions and valuation estimates mainly from western studies. Their analysis indicated that the main benefit from reducing the concentrations of pollutants relates to public health and that reduced prevalence of chronic respiratory diseases is an important effect. Reduced premature mortality is also important and the estimated attributable risk of air pollution to excess mortality at present is approximately
6%. The estimated annual benefit of improved health conditions alone was likely to exceed the investments needed to implement the program. Alberini and Krupnick (2000) compared cost-of-illness and willingness-to-pay estimates of the damages from minor respiratory symptoms associated with air pollution using data from a study in Taiwan in 1991-92. A contingent valuation survey was conducted to estimate WTP to avoid minor respiratory illnesses. Health diaries were analyzed to predict the likelihood and cost of seeking relief from symptoms and of missing work. The ratios of Cost of Illness to WTP were similar to those for the United States, despite the differences between the two countries.

Chestnut et al (1997) looked into the benefits to human health through reductions in particulate matter air pollution, a common pollutant in the urban environment. The authors summarize the results of a set of health effects and economic valuation studies conducted in Bangkok, Thailand, concerning particulate matter air pollution and highlight what these results imply regarding how transferable results from other countries are for assessing health benefits of particulate matter reductions in Bangkok. Comparing the willingness-to-pay (WTP) values from Bangkok to U.S. estimates, this study finds that Bangkok residents are willing to pay a higher share of their income to protect their health. A plausible explanation provided for this result is that health may be seen as a basic necessity like food and shelter. Alberini and Krupnick (1997) explored the appropriateness of concentration-response function transfers by comparing two health studies conducted following a similar format; but years apart— in Los Angeles and Taiwan. Daily records from a diary-type epidemiological study were used to fit logit equations predicting the probability of experiencing minor acute respiratory symptoms as
a function of pollution and weather variables, individual characteristics, and health background and proxies for reporting effects.

Pearce (1996) argued that studies of air pollution epidemiology have resulted in the use of transferable dose-response coefficients whereby the statistical relationship between air pollution and human health is applied outside the countries of the original studies. The aim was to predict changes in premature mortality and morbidity. Some studies then apply economic valuations in order to see if health damage from air pollution should be treated as a priority concern in the countries to which the coefficients are applied. Preliminary work suggested that some forms of air pollution, notably inhalable particulate matter and ambient lead, are serious matters for concern in the developing world.

Two studies by Baulista et al (1996) and Furst et al (1996) looked into the health effects of air pollution for the city of Santiago, Chile and three cities of Taiwan respectively. Here the dose-response function showing the cause effect relationship of the effect of air pollution on health was borrowed from the data sets of USA. The study by Baulista used willingness to pay approach to value morbidity due to pollution. It was found that health conditions of the respondent significantly affected the willingness to pay for reduction in pollution measures. The study by Furst et al found that the health effects were mainly due to PM-10 SO2 and NO2 emissions and used cost benefit analysis to find out the benefits of pollution control. T Yongguan et.al. (2001) studied the environmental cost of water pollution in Chingqing, a highly polluted city in China. All approaches to value health effects, namely the cost of illness approach, the willingness to pay approach and the
human capital approach are used in the study. They used simple calibrated dose-response functions\textsuperscript{17} to identify the cause-effect relation between water pollution and health effects. Since these dose response functions had inherent problems, they used a modified dose response function. The study also depended on a lot of epidemiological studies\textsuperscript{1} in the study area to find out the causes of water pollution and its impact on health. The cost of illness approach was used to calculate the costs of medical treatment and costs due to days off from work to the affected people. The human capital approach and the willingness to pay approach were used to assess the costs of premature death of the affected people.

Day and Mourato (2002) tried to estimate the value of improving water quality in rivers in Beijing in China. Based on Contingent Valuation Survey and Willingness to Pay approach they elicited responses from the residents of Beijing. They found that the average WTP for improvement in water quality for two rivers was about $15 and $12 respectively. Tiwari (2002) looked into the factors affecting the Willingness to Pay for improved water quality in Kathmandu, Nepal. The Cost of illness approach was used to study the costs of water pollution. It was also found that the averting expenditure to prevent water pollution was very high. The users were willing to pay for better water quality.

Frischknecht \textit{et al} (2000) have estimated the health damages to humans due to man-made routine releases of radioactive material to the environment. The study was conducted in

\textsuperscript{17} The dose response functions were modified/calibrated and made simple, as the original dose response functions had uncertainties in measuring the relationship between exposure and health effects.
France on the local community near the nuclear plants. The study also brought out newer methodological approaches on the valuation of health damages due to radiation. The study used the Disability Adjusted Life Years (DALY) approach to calculate the damages caused by radiation. It was found that the assessment of the human health damages showed that low dose ionising radiation contributed to 80-90% of total human damages associated with nuclear production.

The following table 1.3 gives the summary of some of the studies conducted in the global context, which looks into the economic analysis of different types of pollution.

**Table 1.3**

<table>
<thead>
<tr>
<th>Name of author</th>
<th>Year</th>
<th>Country/Region</th>
<th>Type of Pollution</th>
<th>Methodology</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gerking and Stanley</td>
<td>1986</td>
<td>St Louis, USA</td>
<td>Air Pollution</td>
<td>Willingness to Pay Approach using Contingent Valuation</td>
<td>The WTP figures were low because the area was not yet severely affected by the ill effects of air pollution.</td>
</tr>
<tr>
<td>Berger <em>et al</em></td>
<td>1987</td>
<td>USA</td>
<td>Air Pollution</td>
<td>Cost of Illness</td>
<td>The study calculated the cost of illness due to air pollution causing respiratory ailments.</td>
</tr>
<tr>
<td>Baulista <em>et al</em></td>
<td>1996</td>
<td>Santiago, Chile</td>
<td>Air Pollution</td>
<td>Willingness to Pay approach based on Contingent Valuation survey in three cities.</td>
<td>The WTP increased with illness episodes for the people affected by air pollution.</td>
</tr>
<tr>
<td>Furst <em>et al</em></td>
<td>1996</td>
<td>Taiwan</td>
<td>Air Pollution</td>
<td>Cost benefit and Cost effectiveness analysis from US data</td>
<td>The health effects were mainly due to PM-10 SO₂ and NO₃ emissions.</td>
</tr>
<tr>
<td>Ostro</td>
<td>1994</td>
<td>Jakarta, Indonesia</td>
<td>Air Pollution</td>
<td>Cost of illness approach using dose response from US data</td>
<td>Calculated the health costs due to air pollution and was significantly high.</td>
</tr>
<tr>
<td>Alberini and Krupnick</td>
<td>2000</td>
<td>Taiwan</td>
<td>Air Pollution</td>
<td>Contingent Valuation Method (CVM) approach and Willingness to Pay approach</td>
<td>CVM estimates exceeded the Cost of Illness estimates.</td>
</tr>
<tr>
<td>Study</td>
<td>Year</td>
<td>Location</td>
<td>Issue</td>
<td>Methodology</td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>------</td>
<td>----------------------</td>
<td>------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Aunan et al</td>
<td>1998</td>
<td>Hungary</td>
<td>Air Pollution</td>
<td>Damage Cost approach based on Western Countries exposure response functions. Initially looked into the health effects of air pollution and then tried to find out the impact of human health due to air pollution by implementing energy saving mechanisms in Hungary. Health conditions improved if such energy saving measures are implemented.</td>
<td></td>
</tr>
<tr>
<td>Chestnut et al</td>
<td>1997</td>
<td>Bangkok, Thailand</td>
<td>Air pollution</td>
<td>Willingness to pay approach. Dose response function of US data used in analysis. Bangkok residents are willing to pay a higher share of their income to protect their health from air pollution</td>
<td></td>
</tr>
<tr>
<td>Larson et al</td>
<td>1999</td>
<td>Volgograd, Russia</td>
<td>Air pollution</td>
<td>Health Risk Assessment Cost effectiveness analysis. The study calculated the mortality due to air pollution and found that around 960-2667 people died in the city. The study concluded that the cost of life saved from pollution averting projects were low.</td>
<td></td>
</tr>
<tr>
<td>Yongguan et al</td>
<td>2001</td>
<td>China</td>
<td>Water Pollution</td>
<td>Human Capital approach, Cost of Illness approach and Contingent Valuation approach. Used all valuation techniques and concluded that water pollution affected morbidity of the people affected significantly.</td>
<td></td>
</tr>
<tr>
<td>Day and Mourato</td>
<td>2002</td>
<td>Beijing, China</td>
<td>Water Pollution</td>
<td>WTP approach based on Contingent Valuation Survey. The people interviewed were willing to pay for better water quality.</td>
<td></td>
</tr>
<tr>
<td>Tiwari</td>
<td>2002</td>
<td>Kathmandu, Nepal</td>
<td>Water Pollution</td>
<td>WTP approach based on Contingent Valuation Survey and Averting behaviour approach. The cost of illness results showed that the averting expenditure to prevent water pollution was high; The users were willing to pay for better water quality measures.</td>
<td></td>
</tr>
<tr>
<td>Frischknecht et al</td>
<td>2000</td>
<td>France</td>
<td>Radiation Induced Pollut</td>
<td>Disability Adjusted Life Year Approach (DALY) Damage analysis based on DALY revealed 80-90% of the human health damages caused due to nuclear power production.</td>
<td></td>
</tr>
</tbody>
</table>
1.7 Studies on Economic Aspects of Pollution in the Indian Context

There are studies in the Indian context, which looked into the health effects of pollution. Parikh *et al* (1997) studied the health effects of air pollution in Mumbai using the cost of illness approach. They derived the cause-effect relationship based on data from the Mumbai pollution control board and hence this can be considered an accurate measure. However, they did not measure the costs due to loss of leisure as well as pain to the family and individuals. Using a logit model they measured the relationship between air pollution and morbidity. The study provided estimates of health damages due to air pollution and argued that it could be a component of the system of National Accounts.

Abubacker (1994) studied the impact of industrial pollution on human health due to cement industries in Tiruchirapalli district in Tamil Nadu. The study found that the workers reported respiratory and skin diseases more frequently. The study based on primary survey asked the workers about the disease they had in the past one-month.

Brandon and Homman (1995) tried to estimate the cost of inaction by valuing the economy-wide cost of environmental degradation in India. Here the cost of air and water pollution was calculated in terms of the public health impacts and productivity impacts. The study considered the direct links between environmental degradation and public health, which included the link between 1. air pollution and respiratory diseases and 2. water pollution and water related diseases like dysentery, cholera and typhoid. Both mortality and morbidity estimates were calculated in the study. The value of human life based on human capital approach was used to measure mortality, while the morbidity costs included the medical expenses and lost wages. The study used only the indirect
measures of valuing morbidity due to the lack of adequate data. The dose response function used in the study was based on the developed countries and, as mentioned earlier, this could make the results biased. The individual disutility (discomfort, suffering and opportunity cost of time) was not considered in this study. Nevertheless this is one of the few attempts in India, which tried to value the costs of pollution in terms of health. Cropper et al (1997) reported the results of a study relating levels of particulate matter to daily deaths in Delhi, India, between 1991 and 1994. Delhi was chosen for the study because it is one of the world’s most polluted cities. This study concludes: (a) The impact of particulate matter on total non-trauma deaths in Delhi was smaller than effects found in the United States. (b) The impacts of air pollution on deaths by age-group may be very different in developing countries than in the United States, where peak effects occurred among people aged sixty-five and older. In Delhi, peak effects occurred between the ages of fifteen and forty-four, implying that a death associated with air pollution causes more life-years to be lost.

Smith (2000) studied the health effects of indoor air pollution by evaluating the existing epidemiological studies and applied to the resulting risks to more than three-quarters of all Indian households dependent on fuels that cause such pollution. Attributable risks were calculated in reference to the demographic conditions and patterns of each disease in India. Sufficient evidence was available to estimate risks most confidently for acute respiratory infections (ARI), chronic obstructive pulmonary disease (COPD), and lung cancer. The resulting conservative estimates indicated that 400-550 thousand premature deaths could be attributed annually to use of biomass fuels in these population groups. Using a disability-adjusted lost life-year approach, indoor air pollution contributed to 4-
6% of the Indian national burden of disease, placing it as a major risk factor in the country.

Markandaya and Murthy (2000) studied the health impacts of Ganga Action Plan. The study used both costs of illness and willingness to pay approach to measure the health costs. The study did not use any dose-response functions but instead relied on the epidemiological studies conducted in the study area by the World Bank. Sankar (2001a) studied the health impact of tannery effluents on water quality. The study probed into the problems of tanneries and textile bleaching units in specific areas of Tamil Nadu. Based on the epidemiological studies conducted before, the cause-effect relation between the pollution and health effects is identified. The cost of illness approach was used to analyze the health costs of the people affected. The health costs were calculated based on the responses given by the people affected in the past one year. The diseases they suffered, the cost of medicines, the days lost due to illness were all calculated. The willingness to pay approach was used to evaluate the preferences of the people on better water quality to reduce health impacts. The study found that respiratory and other allergic illnesses were caused due to water pollution. Most of the people were willing to pay more than Rs.50 for better water quality. Dasgupta (2001) tried to value health damages from water pollution in urban Delhi using a health production approach. The engineering and infrastructural variables along with individual behaviour were used in empirically estimating the damages due to water pollution. The study also calculated the total cost of illness to the people affected by diarrhoeal diseases. The following table 1.4 gives the summary of the Indian studies, which have looked into the health effects of pollution from an economic perspective.
## Table 1.4

**Studies on the Economic Analysis of Pollution in India**

<table>
<thead>
<tr>
<th>Name of author</th>
<th>Year</th>
<th>Region</th>
<th>Type of Pollution</th>
<th>Methodology</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sankar</td>
<td>2001a</td>
<td>Tamil Nadu</td>
<td>Pollution in Tanneries</td>
<td>Both Cost of Illness and Contingent valuation. The cost of illness based on epidemiological studies.</td>
<td>The study found that respiratory and other allergic illnesses were cause due to water pollution. Most of the people were willing to pay more than Rs.50 for better water quality</td>
</tr>
<tr>
<td>Brandon and Homman</td>
<td>1995</td>
<td>All India</td>
<td>Water and Air Pollution</td>
<td>Cost of Illness approach using dose response from western Countries and Human capital approach.</td>
<td>The study found out the cost of inaction due to environment degradation. The health costs and productivity loss were high due to the two types of pollution in India.</td>
</tr>
<tr>
<td>Markandaya and Murthy</td>
<td>2000</td>
<td>Region surrounding the Ganga river</td>
<td>Water Pollution</td>
<td>Both Cost of illness and Contingent Valuation. Epidemiological studies to support the cost of illness.</td>
<td>Calculated the cost of illness due to water pollution and also the willingness to pay for improving the Ganga river pollution.</td>
</tr>
<tr>
<td>Abubacker</td>
<td>1994</td>
<td>Tiruchirapalli Tamil Nadu</td>
<td>Indistrial pollution due to cement industries</td>
<td>Cost of Illness approach</td>
<td>The workers were affected with respiratory illness and had high costs of illness.</td>
</tr>
<tr>
<td>Parikh et al</td>
<td>1997</td>
<td>Mumbai</td>
<td>Air Pollution</td>
<td>Cost of Illness approach with data from pollution control Board</td>
<td>The study provided estimates of health damages due to air pollution and argued that it could be a component of the system of National Accounts</td>
</tr>
<tr>
<td>Cropper et al</td>
<td>1987</td>
<td>Delhi</td>
<td>Air Pollution</td>
<td>Cost of Illness approach using US dose response data</td>
<td>The deaths associated with air pollution resulted in more life years to be lost.</td>
</tr>
<tr>
<td>Smith et al</td>
<td>2000</td>
<td>Indoor Air Pollution</td>
<td>Disability Adjusted Life Year Approach</td>
<td></td>
<td>The study concluded that indoor air pollution contributed to 4-6% of the Indian national burden of disease, placing it as a major risk factor in the country.</td>
</tr>
<tr>
<td>Dasgupta</td>
<td>2001</td>
<td>Delhi</td>
<td>Water Pollution</td>
<td>Health production function and Cost of Illness approach</td>
<td>The study found that people were affected by water pollution and their cost of illness was high in the case of diarrheal diseases.</td>
</tr>
</tbody>
</table>
1.8 The Research Problem and Researchable Issues

As seen in the above review of studies on radiation and health, a major part of the coastal areas of Kerala are abundant in mineral sands like ilmenite and monazite, which emit radiation. Mining is undertaken here by these factories to extract valuable radioactive compounds like thorium. The two factories located in the coastal area viz. the Indian Rare Earths Limited and the Kerala Minerals and Metals Limited are Government undertakings that do mining and then extract the radioactive compounds in the factories. These compounds are highly valued high in the market and earn huge export revenue and are also useful for the production of valuable compounds like chlorides. Although, there is a private benefit to the government and the factory by the mining of these radioactive compounds, it involves a social cost to the local fishermen community and the workers in the factories, in terms of a negative externality, a unidirectional one, which is the health effects, caused by radiation induced pollution. The benefits accrued by the factory or government does not reach the poor local community who bear the brunt of radiation pollution. It can also be seen from the above review of International and Indian studies that the economic analysis of pollution has mainly concentrated on air and water pollution. They have mainly used the contingent valuation and cost of illness approach to measure the economic costs due to such pollution. The dose response functions are well developed in the developed countries and they have been used for studies in the developing countries also. There are only few studies, which have used the epidemiological methods to find out the health effects of pollution and then analyze the economic costs. There is only one study, which has looked into the economic analysis of radiation-induced pollution (Frischknecht et al 2000). Hence, there is a need to examine
the economic effects of radiation-induced pollution on the population of a radiation-affected area. Therefore, the present study is an attempt to value the negative externality caused due to the radiation-induced pollution to the local community and factory workers in terms of the health effects and cost of illness.

The following issues arise due to the presence of radiation-induced pollution among the workers and local fishing community. What are the direct and indirect health costs incurred by the local fishing community and workers in the factories due to radiation induced pollution? How many working days and wages are lost due to their exposure to radiation? Are and to what extent are the households in the radiation-affected area indebted due to the diseases caused by radiation-induced pollution? What is their health care pattern? Are the fishermen willing to pay for health insurance to cover for their health expenditure if affected and what are the factors influencing their willingness to pay for health insurance? These are some of the questions, which require valid and adequate probing. This will give an insight into the burden of the radiation-induced pollution on the local fishing community and the workers on the factories. Hence it is essential to study the economic analysis of radiation-induced pollution especially in terms of cost of illness to the affected population.

1.9 Setting for the Study

The coastal area of Kerala is selected as the study area for the present study. As mentioned above the World Health Organization (1959) identified this area as having one of the highest radiation levels, medical and epidemiological studies have been undertaken here to look into the health effects of radiation. The review of studies on radiation and
health in coastal Kerala as seen in earlier section clearly shows that this area is abundant in radioactive minerals like ilmenite and monazite from which compounds like thorium can be extracted. The review has also shown that the health effects due to radiation have also been high in the coastal areas of Kerala. Within coastal Kerala, Karunagapally Panchayat is selected for the current study, as the problem of radiation-induced pollution is more acute here. The population residing very near the mining sites and processing factories and the factory workers in the study area provide an excellent sample and are ideally suited for the conduct of the present study on the economic costs of radiation-induced pollution.

1.10 Objectives of the Study

The primary objectives of the present study are:

1. To assess the various health hazards faced by the people of coastal Kerala due to radiation-induced pollution.
2. To evaluate the total costs of health hazards borne by the population of the study area due to the radiation induced pollution.
3. To estimate the costs incurred by the workers due to radiation exposure in the factories.
4. To analyze the factors influencing the willingness to pay for health insurance of the local community affected by radiation induced pollution.

1.11 Hypotheses

(a) The economic loss due to the ill health of the people affected by the radiation-induced pollution is significantly higher than that of the people living in the non-radiation area.

(b) The temporary workers in the factories are affected more by radiation-induced pollution than the permanent workers.
1.12 Data and Methodology

The study was conducted in Karunagapally panchayat in coastal Kerala. Secondary data was used to analyze the health effects of radiation induced pollution in the study area based on data from earlier studies. Primary data for this study was collected by a household survey using a structured questionnaire covering 300 households from two wards in Chavara Panchayat in Karunagapally taluk of Kollam district. A control group of 100 households was selected from Perayam panchayat in Kollam taluk, which has not been reported of any radiation problem and with the same socio economic characteristics of the study group. From the two factories, i.e. India Rare Earths Limited and Kerala Minerals and Metals Limited, 100 workers including 65 temporary and 35 permanent workers were selected. A Contingent Valuation survey was also undertaken along with the socio economic and morbidity survey to find out the factors affecting the willingness to pay for health insurance by the households affected by radiation induced pollution.

1.13 Limitations of the study

The study confines to the economic effects of radiation-induced pollution in Karunagapally taluk although other places such as Kanyakumari district in Tamil Nadu,
and Jadugoda in Bihar have radiation problems. Estimation of radiation levels in the area and a detailed epidemiological study could not be possible due to resource and time constraints. So, secondary data was used for identification of the area with high radiation levels. Morbidity data was collected from the people of this area where the perceptions about the disease conditions may vary between individuals in the area. This is likely to be an influencing factor for either under reporting or over reporting of ailments. The classification of the workers into those exposed to high and low radiation would have been a better measure than the classification into permanent and temporary workers. This was not possible since the factory management did not allow for detailed surveys to be conducted inside the factories.

1.14 Chapter Scheme for the thesis.

The second chapter concentrates on the theoretical and analytical framework, along with the methodology of the study. Chapter 3 analyses the secondary data on radiation and health effects in the study area based on the earlier studies and reports. Chapter 4 gives the socio-economic profile of the study and control group households along with the workers considered for the study. While chapter 5 looks into the analysis of the cost of illness and loss of workdays to the study and control group households affected by radiation induced pollution, chapter 6 analyses the cost of illness borne by the workers in the factories. The factors affecting the willingness to pay for health insurance by the local community are analyzed in chapter 7. The last chapter presents the summary, conclusions and policy implications of the study.

24 Gumber and Breman (1998) have analysed the strengths and weaknesses of the morbidity surveys conducted in India. They too raise the problems of collecting data based on self-perceived morbidity by respondents, but nevertheless refer to it as the best possible method in India.