CHAPTER 1 INTRODUCTION

1.1 Environmental Pollution and Radioactivity

Environmental pollution is caused basically by man's inability to dispose of waste in ways that do not change the natural balance of the environment. The most serious pollution effects are caused by waste chemical substances entering and accumulating in ecosystems and food chains. Biological life and human health can be affected, and the quality of the environment becomes degraded. Radioactivity in the environment can be considered as one kind of chemical waste contamination of the environment. [1]

In very general terms, pollution causes degradation and/or damage to the natural functioning of the biosphere. The damage caused may be briefly summarized as follows:

1. Damage to human health caused by specific chemical substances and radioactivity present in the air, food and water,
2. Damage to the natural environment that affects vegetation, animals, crops, soil, and water,
3. Damage to the aesthetic quality of the environment caused by smoke, chemical fumes, dust, noise, the dumping of waste and rubbish, and dereliction and
4. Damage caused by long-term pollution effects that are not immediately apparent. The insidious effects are caused by low-level pollution absorbed into the body over long periods of time, *e.g.*, carcinogenic substances, radioactivity, and excessive noise.[1]

Radioactive atoms produce radiation continually, and this can be measured in *Becquerel* (Bq) in SI system, where one Becquerel is one transformation per second.

For any one type of radioactive atom, the decay process occurs at a constant rate over a specific period of time. [1-3]

The decay rate is expressed in terms of the 'half-life', which is defined as the period of time within which half the nuclei in a sample of radioactive material undergo decay. Half-lives of different radioisotopes range from parts of millionth of a second to millions of years. [1-3]

This decay process and the rate of emission of radioactivity cannot be altered or prevented. Once a radioactive substance is released into the environment, it continues to give out radiation for a period of time commensurate with its half-life, until all the atomic nuclei have disintegrated. [1-3] The types of nuclides, or nuclear species that may be released into the environment are shown in Table 1.1.[1]

The nuclear disintegration produces so-called radiation that consists of alpha and beta particles, gamma rays, and neutrons. An alpha particle has a positive charge and consists of two neutrons and two protons. Beta particles are high-energy electrons with a negative charge. Gamma rays are high-energy electromagnetic radiation that behaves in a similar manner to X-rays. Gamma rays, like X-rays, constitute a considerable biological hazard.[1-3]

Nowadays, our environment is facing pollution problems due to increasing population density, expansion of city area, decreasing energy resources, increasing energy consumption, *etc.*[4] The increasing development of nuclear energy is producing more radioactive waste to be disposed of in the environment. It contains various radionuclides with long half-lives.[1-5]

Table 1.1 Some environmentally important nuclides[1]

Source	Nuclide symbol	Nuclide name	Type of radiation	Half-life
Background radiation	Rn	Radom-222	alpha	3.9 days
	Ra	Radium-226	"	1622 yrs
	C	Carbon-14	beta	5570 yrs
	K	Potassium-40	"	1.3×10^9 yrs
	U	Uranium-238	alpha	4.5×10^9 yrs
	Th	Thorium-232	"	1.4×10^{10} yrs
Nuclear weapon testing	I	Iodine-131	beta/gamma	8.1 days
	Sr	Strontium-89	beta	53 days
	Sr	Strontium-90	"	28 yrs
	Cs	Cesium-137	beta/gamma	30 yrs
	C	Carbon-14	beta	5570 yrs
Nuclear reactors and airborne discharges	Ar	Argon-41	beta/gamma	1.8 hrs
	Xe	Xenon-133	"	5.3 days
	I	Iodine-131	"	8.1 days
	Kr	Krypton-85	"	10.8 yrs
	H	Tritium-3	"	12.3 yrs
	C	Carbon-14	beta	5570 yrs
Fuel reprocessing and airborne discharges	I	Iodine-131	"	8.1 days
	Kr	Krypton-85	"	10.8 yrs
	H	Tritium-3	"	12.3 yrs
Others	Cm	Curium-244	alpha/neutron	17.6 yrs
	Pu	Plutonium-238	alpha	86.4 yrs
	Am	Americium-241	"	458 yrs
	Pu	Plutonium-240	"	6.6×10^3 yrs
	Am	Americium-243	"	78×10^3 yrs
	Pu	Plutonium-239	"	2.4×10^4 yrs
	Pu	Plutonium-242	"	3.8×10^5 yrs
	Np	Neptunium-237	"	2.2×10^6 yrs

1.2 Sources of Radiation

Human and living organisms can be affected by several sources of radiation. Sources of radioactivity can be divided into two categories such as natural and man made. Atmospheric radiation emanates from both natural and man-made sources.[1, 3, 5-6]

1.2.1 Natural Sources of Radiation

The entire global population receives so-called background radiation from three natural sources in the environment which are (i) cosmic rays, (ii) rocks, soil and airborne, and (iii) food and water. [1, 3, 5-6]

1.2.2 Man Made Sources of Radiation

There are three types of man-made radiation sources.

These are X-rays used in medicine and dentistry, fall-out resulting from nuclear weapon testing and industrial emissions mainly from nuclear reactors and processing installations. X-rays are as penetrative to the body as gamma rays, and they provide the greatest man-made radiation contribution.

Nuclear weapon tests produced significant quantities of nuclear fission products such as carbon-14, strontium-90, iodine-131, and caesium-137.

The third man-made source of radiation is from the increasing use of radioisotopes in industry, research, and medicine and from the use of nuclear reactors for power and electricity generation.

The quantity of nuclides used for other than nuclear reactors is relatively small, and so their contribution to environmental radiation is not significant. The largest contribution arises from the operation of nuclear reactors, and the complementary nuclear fuel processing. Various types of nuclear reactor wastes are produced containing nuclides of varying quantities and radioactivity levels. An additional hazard is the possibility of accidental leakage of radiation into the environment from an accident. However, it is certain that nuclear reactor

contamination can be more widespread, and have very long lasting effects upon the environment. [1, 3, 5-6]

1.3 Difficulties of Radioactivity Monitoring

The amount of radioactive materials in water varies considerably, depending on the nature, location and history of the water. The determination of radionuclides in environmental samples is complicated, because several radionuclides of a number of elements may be involved. Both quantitative and qualitative studies may be needed, and a carrier may have to be identified. [1-2, 6-9]

With the development in the knowledge of the atomic nucleus and with the improvement in the detection methods for radioactive substances, there has been a corresponding development in instrumentation. For many years the measurement of radioactive phenomena was uncertain, troublesome and, because of unknown radiation effects, frequently dangerous. The skill of the observer and the subjective judgement often required in such measurements, greatly influenced the results.[6]

Nowadays, very sensitive and reliable measuring equipment is available commercially in many types, and it is possible to learn its operation with much less specialist training and operating experience than formerly.[6] However, the price of equipment is still very expensive to buy for developing countries.

1.4 Commonly Used Radioisotopes as Indicators for the Environment

Cs-137, I-131, and Sr-90 are most commonly used as indicators for environmental radioactivity monitoring because of their characteristic that they come from nuclear fission processes. [1, 5-6, 8-9]

Cs-137 (half –life of 30 years) emits γ energy at 662 keV region and it can affect the environment over a long term. I-131 (half-life of 8 days) emits γ energies mostly in 364 and 638 keV regions and it can affect the grass-cow-milk food chain. Sr-90 (half-life of 28.1 years) produces β particles in 196.1 keV energy region and it is important in the environment owing to metabolism in the body. [1, 5]

1.5 Radiation Detection Techniques

Many environmentally important radionuclides are produced by the fission process. Many of these are γ-ray emitters so the need for γ-ray spectrometry has increased. The most common application for it in the radiation-protection field is to identify radionuclides.

Radiation detection methods can be classified as follows: -

1. α-ray spectrometry
2. β-ray spectrometry
3. γ-ray spectrometry
4. X-ray fluorescence (XRF)
5. Neutron activation analysis (NAA), *etc.*

Cs-137 and I-131 can be measured using the single channel γ counter. However, a liquid scintillation counter may be needed for the measurement of Sr-90 and such equipment is expensive, especially for developing countries.[6]

1.6 Radioactive Sample Pre-concentration and Separation Methods

Usually, environmental radionuclide measurements concern species in very low concentrations.[6] As some of the concentrations of the nuclides of interest are too low for determination, preconcentration and separation may be necessary.[10]

Separation methods can be classified as follows: -

1. precipitation
2. extraction
3. chromatography
4. ion exchange
5. distillation, and
6. electrodeposition[6, 11-14]

1.6.1 Ion Exchange Method

Ion exchange method is used to preconcentrate ions from relatively large volumes of water. In favorable cases, exchangers can be developed which are highly selective, and hence provide not only large concentration factors, but also good decontamination and specificity. [11] Ion exchange methods can be applied for several purposes as follows:

1. Deionization of water
2. Separation of ions of opposite charge

3. Concentration of trace constituents
4. Chromatographic separations of similar ions
5. Use of chelation resins, and
6. Ion-exchange membranes.[13, 15-17]

For radiochemical separations, chromatographic elution is the more important technique. [8] The greatest use of ion exchange in hazardous waste treatment is for the removal of low levels of heavy metal ions from wastewater. [9]

1.6.2 Ion Exchange Materials

Many naturally occurring substances such as clays, the humic acids in the soil, and some manmade resins have the property of exchanging ions. The most popular exchange materials in use today are the synthetic organic ion exchangers, the majority of which are prepared by copolymerization of styrene and divinyl benzene and are relatively simple. They are more stable toward strong acids and bases than the naturally occurring siliceous materials and have high capacities.[17]

1.6.3 Advantages

Ion exchange methods can be used for several purposes. Ion exchange resin can be used for many times without apparent damage to the resin by regeneration, *i.e.*, using recycle system for resin.[17]

1.7 Environmental Radioactivity Monitoring in Developed Countries

The US Environmental Protection Agency (EPA) operates the Environmental Radiation Ambient Monitoring System (ERAMS) through its Office of Radiation. This is a surveillance program for measuring levels of radioactivity in air, air

particulate, surface deposits, surface water, drinking water, and milk in the United States and its territories.[6]

In Norway, trace elements in natural waters have been studied using instrumental neutron activation analysis in combination with physical separation techniques, such as dialysis and ultrafiltration *in situ* and in the laboratory.[18]

In Russia, the source of environmental pollution by natural and technogenic radionuclides such as H-3, C-14, Kr-85, I-129, Sr-90, Cs-134, Cs-137, Ce-144 and the transuranium elements has been studied. The contents of transuranium elements in environmental samples and the distribution of plutonium in surface ecosystems were investigated.[19]

In Japan, the distribution and behavior of transuranium elements in the environment was studied using isotope exchange methods and anion exchanger column method.[20]

In Switzerland, the radionuclides, Tc-99m, Ru-103, I-131, Te-132, Cs-134 and Cs-137, resulting from fallout from the damaged nuclear power plant at Chernobyl (USSR) were measured several times in the River Glatt (Zurich) and in the adjacent shallow ground water stream.[21]

Many of the numerous current applications of ion exchange study have been developed since 1940. The important series of papers dealing with the use of ion exchange resins for the separation of rare earths on the Manhattan Project provided a strong stimulus for exploiting the use of ion exchange resins for chemical separation problems of all types.[6]

1.8 Requirements for Developing Countries

In order to be able to measure accurately the level of radioactive contamination in various natural materials, including the content and form of occurrence of various radionuclides, simple and efficient methods of determination are required.[19]

Normally, high techniques and methods were applied for radioactivity monitoring system and its cost to operate and maintain is very high for developing countries.[4]

Development of set up and designs for equipment using cheap and local available materials is essential for developing country in terms of their own existing equipment instead of buying new expensive one.

1.9 A Survey of Radioactivity in Water of Chiang Mai Municipality

In Chiang Mai, wastewater is disposed along the waterways including Mae Ping River or Mae Kha canal. Historically, wastewater disposing into the waterways has been the most economical and environmentally acceptable method even with implementation of waste reduction, recycling and transformation technology.

However, many waterways are used for waste disposal and then abandoned without adequate long-term maintenance controls to protect the surrounding environment.

Wastewater can be contained so many things and also depending on the way that passing through. However, in Chiang Mai, the chance of impact from radioisotopes in wastewater to people and its environment is very rare. A survey for radioactivity that contaminated in wastewater will be attempted.

Radioisotopes in water are widely studied in so many ways such as identification, classification, decontamination, etc. This study was begun to work one of the methods to measure the radioactivity in water. Radioactivity survey on water in Chiang Mai Municipality had been studied using a simple procedure in terms of ion exchange method and a simple single channel gamma counting technique.

1.10 Objectives

The objectives of this research were:

1. To set up and design for an instrument to measure radioactivity using less complicated components and
2. To survey radioactivity in water of Chiang Mai Municipality.