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Radiation Protection In the Application of Ionizing Radiation In Industry

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Abstract

There is a substantial increase in the use of ionizing radiation in industry throughout the country especially in the last five years or so. With this growth in the number of users and activity of sources used, and together with the introduction of the new Atomic Energy Licensing Act (AELA) in 1984, the question of radiation safety and protection of workers and members of the public in general, can no longer be taken lightly. It has to be dealt with effectively. In this paper, a general discussion and clarification on certain practical aspects of radiation protection as recommended by the International Atomic Energy Agency (IAEA) is presented. Amongst the topics chosen are those on area monitoring, personnel monitoring, leak testing of sealed sources and training of personnel. Also presented in the paper is brief discussion about UTN's experience in giving out radiation protection services to various agencies throughout the country.

1.0 INTRODUCTION

Sources of ionizing radiation have been in use for a considerable time in this country, but their application in industry are only now increasing markedly and have become very diverse. This is evident from an initial survey made by UTN in 1983 and from records of users applying for licenses in 1986 (Table 1). If in 1983 the total number of users was only 62, then by 1986, just within three years, this number has increased to almost 7 times.

With such significant increase in the number of users and radiation sources used and realizing the fact that radiation can cause harmful effects, it is most relevant and timely that the question of control and protection of both workers and members of the public from unnecessary radiation exposure be discussed here.

In this paper only a few important aspects of radiation protection will be discussed namely those that are directly related to the services offered by the Nuclear Energy Unit (UTN).

2.0 BASIS FOR RADIATION PROTECTION

In terms of legal requirements, radiation protection in this country is based on the National Regulations on Atomic Energy which, at present, is found in the Atomic Energy Licensing Act of 1984 (2). This Act replaces the Radioactive Substances Act 1968. The Act is intended to ensure the safe application of atomic energy for peaceful purposes and in particular addresses the control and licensing of nuclear installation and activities, the liabilities of nuclear damages, radioactive waste disposal, and some aspects of health and safety, but gives no detail information about radiation protection procedures.

Those details are to be given in subsidiary legislations made by the Minister as provided for in the Act (2). The most basic subsidiary legislation applicable to radiation protection is the basic safety standard regulations. Other regulations will be made applicable for controlling, supervising and licensing the production, application and use of atomic energy, and for regulating the various aspects of 'dealing' (defined in the Act) of radioactive materials and radiation sources. It is expected that the general principles of radiological protection and basic requirements in radiation protection such as dose limits, personnel monitoring etc. will be specified in the basic Safety Standard regulations. As with the regulations in other countries, it is most likely that these regulations will be prepared based on the recommendations of the ICRP (9) and IAEA (4). In its publication no. 26, ICRP introduces a new concept of radiation protection which emphasises more on systematic and qualitative approach of protection. The main objectives of radiation protection under this new concept are:

(a) to prevent acute radiation effects

(b) to limit the risks of cancer and genetid effects to very low level (to levels deemed acceptable).

To achieve these objectives the ICRP(8) has introduced a system called dose limitation system which comprises three main features that can be summarized as follows:

(a) no practice involving radiation exposure must be adopted unless its introduction brings a positive net benefit;

(b) all exposures must be kept at the lowest level reasonably achievable, account being taken of economic and social factors; and

(c) the dose equivalent for individuals must not exceed the limits given in Table 2.

The radiation dose limits set by the ICRP (as given in Table 2) are intended to be maximum values and under no circumstances they are allowed to be exceeded.

Apart from regulations, there has also been an indication (13) that the Board (formed under the Act) may prepare subsidiary documents to the regulations which may be called Code of Practice. As Code of Practice, these documents are generally couched in much more undertandable terms than the regulations governing it. They can explain the reasons for certain procedures included and can provide the appropriate details how to go about complying with certain terms and clauses in the regulations. These code of practice, in other words, will become an aid to the workers towards achieving compliances with the regulations.

Regulations and Codes of Practice provide a general framework for the radiation protection requirements. It is expected that each establishment, by virtue of the experience and knowledge of its operating problems, will use these guides as a basis upon which to develop detailed safety procedures and standards to meet its particular requirements.

3.0 PERSONNEL MONITORING

As soon as an establishment or a company commence operation, the monitoring of its personnel will be an essential part of the radiological protection system. This entails the determination of body doses for the occupationally exposed persons. The dose received, as far as possible, must be maintained at the lowest achievable level (ALARA principle) and under no circumstances should it exceed the annual dose limits given in Table 2.

Mandatory requirements for personnel monitoring have been stipulated in the Act (2) under Part V. Clause 25(2)(a) of this part requires the wearing of dosimeters by workers who have been or are likely to be exposed to radiation. However the Act does not specify the requirement for internal exposure monitoring. ICRP recommendations, (9) in fact, define personnel monitoring as the determination of body doses from both external sources as well as internal exposure resulting from the intake of radioactive material in the body.

Certain flexibilities are allowed in implementing personnel monitoring requirements. ICRP recommends (9) that individual monitoring be carried out on workers who are working in areas where they are expected to receive annual doses in excess of three-tenths of the annual limits. Those working in areas where it is most unlikely that the annual dose will exceed three-tenths do not require individual monitoring but doses need to be measured only for a small number of workers whose exposure is considered representative of the group as a whole. An example given by ICRP for the first case is personnel who are working in areas or around installation where the exposure rate is greater than 7.5 μSv/hr, or working with radioactive material where the product of radiation energy and activity is greater than 50 MBq.MeV for gamma and beta (with energy below 0.3 MeV), or 5 MBq, for beta (with energy greater than 0.3 MeV). Those working with industrial processes such as thickness or level gauging can be considered to be under the second case provided the equipment and operating procedures are of a high standard (3, 7).

For internal exposures, experience has shown that routine individual monitoring are often needed in industrial applications where large quantities of gaseous and volatile materials such as tritium, radioiodine etc. are handled. Although, theoritically, such monitoring may not be needed in other types of handling, a decision on actual requirement occassionally needed to be made based on the results gained from programs for monitoring the workplace. ICRP (7) recommends that individual monitoring should also be considered if the annual average result of air monitoring is greater than one-thirtieth of the Derived Air Concentration.

3.1 External exposure

Monitoring of external radiation exposure can be accomplished by the use of personal dosimeters (8). These can be worn on the body for whole-body dose measurement, or attached to the hands or fingers, if necessary, for estimation of doses to the hand. These provide integrated dose readings i.e. dose values summed over the total wearing period.

The most commonly use dosimeter at present are film badges, thermoluminescience dosimeters (TLD) and pocket ionization chamber (5). Out of these three, firlm badges have been in for some widespread use for personnel monitoring. The main advantage of film badges is their capability to be used as a document which can be stored for future reference and is not destroyed in the dose determination process. Unfortunately, accuracy and reproducibility of film badges are not very good. Measurement errors of ±30% are to be expected. This is due mainly to the very high dependence of the film blackening on the radiation energy.

The film badge used by UTN has been described elsewhere (1). These badges are of German design and therefore the technique used for dose assessment is different than for previous dosimeters supplied by the Ministry of Health, which were based on British design.

The dosimetry service at UTN started in 1983 with about 40 badges supplied to two agencies. By May 1987, this number increased to 1840 film badges issues to 108 agencies located throughout the country. A steady increase in number of users in one year (from June 1986 to May 1987) can be seen from Fig. 1. There was a changeover of the film badge service for non-medical applications from the Ministry of Health to UTN at the end of 1986 and this has resulted in a sudden increase in the number of users handled by UTN starting from January 1987.

The result of UTN film badge services given to those agencies in Fig. 1 in one year is shown in Table 3. It can be seen from this table that the majority of the workers (about 98%) still received monthly doses below 1.0 mSv. There are, however, a few who have received annual doses exceeding the permissible limit of 50 mSv in a year.

Internal Exposure

The measurement of internal exposure resulting from the intake of radioactive materials in the body is not as easy as external exposure measurement. The techniques used call for highly specialized personnel and equipment. The two common methods used are bioassay and whole body counting (3, 7, 12). The first method is very appropriate for routine monitoring of personnel handling alpha and beta-emitters, such as, U, Pu, Sr-90, and also as a follow-up procedure in cases of accidental intake of radionuclide. The second method, on the other hand, is good for measuring the activities of gamma-emitting radionuclides in the body. This whole body counter, which is technologically sophisticated and expensive, is not normally used for routine monitoring, instead it is of great value for following up cases of persons who suffer from accidental intake of radionuclides.

With the assistance of the IAEA, through its technical assistance program, these two techniques of body burden measurement have recently been established at UTN for services to the country as a whole.

4.0 WORKPLACE MONITORING

Workplace monitoring is another essential part of effective radiation protection program. It is important to ensure that the working environment is always in safe working condition and can be occupied by personnel at any time. This type of monitoring is also important to detect signs of deterioration of the control measures enforced in the work areas and to provide information which will facilitate the estimation of individuals' exposure to radiation and radioactive materials. The requirement for this monitoring is stated in the Act (2) under Part V. Clause 25(2)(c) of this part, however, does not give clear indication about the requirement for contamination monitoring.

The extent of the monitoring program for a particular radiation work or facility depends largely on the individual circumstances. Some typical guiding factors which can be considered are the types of facilities, the nature of work with radiations and radioactive materials, and the types and quantities of radionuclides handled. ICRP, for example, recommends that a comprehensive survey should be carried out before a new machine or facility is put into normal operation (11). Such survey will furnish valuable information about the potential risk to which an individual may be exposed. It will show whether the protective walls or barriers are sufficient or not and this is particularly important for the protection of people in adjacent areas. It can also indicate very clearly those places in or around a workplace where there is no risk from radiation and where, therefore, no protective measures are necessary.

After such initial comprehensive survey, some machines or facilities may require follow-up checks and some of them need to be done routinely. The frequency with which routine monitoring should be conducted is determined by consideration of the likelihood of changes occuring in the workplace. If conditions are not liable to change, except as a result of substantial alterations to the machine or the procedures being carried out (which should be followed by a further comprehensive survey), the monitoring is only rarely needed. In many cases annual measurements linked to verification of the continued efficacy of protective devices (locks, interlocks, alarm, warning signs, etc.) will suffice.

In workplaces where both sealed and unsealed radioactive materials are used, ICRP (7) recommends that workplace monitoring should include all measurements made with respect to radiation, surface contamination and airborne contamination. However, since most of the radioactive materials used in industry are in the form of sealed sources (Table 2), such monitoring can, in this, case, be narrowed down to only measuring significant radiation levels in the work areas or surrounding the machine.

Under no circumstances workplace monitoring is intended to replace individual monitoring as required for by personnel working in areas where he is expected to receive doses in excess of three-tenths of the annual limits. It is, in fact, to complement such monitoring program. Nevertheless, ICRP (7) allows the use of this monitoring to confirm radiation exposure received by personnel working in areas where the dose is unlikely to exceed three-tenths of the annual limits.

Workplace monitoring can be carried out using portable survey meters and, in some cases, installed radiation monitors (3, 12). Detail of instrumentation and technique used are to be found in Ref. (10, 12).

5.0 RADIOACTIVE WASTE DISPOSAL

Radioactive waste generation is inevitable as a result of direct use of sealed or unsealed radioactive materials. The wastes, as defined in the Act (2), consists of not only decayed radioactive materials or radiation sources but also substances or items which are contaminated with radioactive materials or other wastes. The minimum activity at the the waste which qualifies it to be called radioactive waste, however, is not specified in the Act. I presume, it will be detailed out in the regulations.

It must be remembered that radioactive wastes contain radioactive materials. Depending on the use and its initial activity, some wastes may still contain significant amounts of radioactive material by the time they are being discharged or disposed. Because of anticipated problem it might create both to workers and members of the public, disposal of the waste is usually done according to guides and procedures as laid down by the appropriate authority. The Act (2) specifies that disposal can be carried out only if one has an authorization to do so from the appropriate authority. Such authorization for waste disposal can be obtained by writting in to the appropriate authority. Technically there are three basic methods commonly used in the disposal of radioactive wastes (10). The first one is delay and decay. For wastes containing short-lived radionuclides, this is usually the best approach. The wastes are simply kept aside for a certain period of time until all activity have decayed to levels at which they can be disposed of as non-radioactive wastes. A decay time of 7 half-lives usually reduces the activity to less than 1 percent of its original value.

The second method of disposal is concentrate and store. It is meant for disposing wastes containing long-lived radionuclides such as Cs-137 with a half-life of 30 years and Sr-90 with a half-life of 28 years. The wastes have first to undergo a serie of treatment processes to reduce their volume before they are finally prepared and stored in a safe place away from any human activity for the entire decay period of the radionuclides.

The third method of disposal is dilute and disperse. This method may be useful for disposing a small amount of wastes containing short half-lived radionuclides. It is important here to obser closely the requirements imposed by the appropriate authority so that the amount released to the environment does not exceed the authorized discharge levels. In this method the waste is first diluted before it is finally discharged, in a control manner, into the sewer or river.

Previously, I believe, most of the radioactive wastes, in particular, depleted sealed radiation sources are required to be returned to their country of origin for disposal. However, with the recent establishment of a national waste treatment centre at UTN, the question of waste disposal should become less critical as ways and means of treating and disposing radioactive wastes are now available at this centre.

The establishment of this centre should be regarded as additional to those alternatives mentioned above and under no circumstances will it be considered as replacement to them. There are, of course, certain advantages that can be drawn from this centralized disposal system. First, it is easier to control and to monitor the wastes, and secondly, it minimizes one's involvement with disposal procedures as required under the Act (2) and, perhaps, regulations later on.

Table IV shows some of the wastes handled by the centre until July 1987. For ease in treatment, the wastes received have been divided into sealed and unsealed radioactive wastes. Unsealed wastes are further classified according to their physical form namely solid aquous and organic liquids. Since it started operation in 1982, the centre has so far received and treated about 11.2, 0.11 and 1.27 cubic meters of solid, aquous and organic liquid wastes respectively. Treated wastes have, so far, been disposed of according to all three methods mentioned above. Sealed sources, on the other hand, have been disposed of according to the second method without going through any treatment process. These wastes are mostly depleted sealed radiation sources from gauging and NDT work.

6.0 LEAK TEST OF SEALED SOURCES

Table 1 clearly shows that the majority of radioactive materials used in industry are in the form of sealed sources. As the name implies, these sources contain radioactive material in a special, tightly sealed capsule or container such that under normal handling only radiation can penetrate through. As long as these sources remain intact the only problem that exist is radiation exposure. However, these capsules may, during transport or in the course of use, develop faults through which the radioactive material may escape into the environment. Such material lost may cause internal hazard through inhalation or ingestion, or may cause contamination of sensitive radiation equipment which can be detrimental to their operation. In view of severe consequences of such an escape, the ICRP (11) and the IAEA (14) recommend that all sealed sources need to be tested before being put into use and periodically thereafter for radioactive contamination and leakage.

The test interval appropriate for a particular source has to be decided by the responsible officer. It normally depends upon the kind and quantity of material present and, to the extent feasible, upon what is known about the likelihood of failure in the particular use for the particular capsule. As a guide NCRP (12) recommends such tests to be performed at least once every six months.

There is a possibility that a person may get significant radiation exposure while performing the test. Because of this anticipated risk involved, it is strongly recommended that leak tests be performed only by qualified personnel using fully equipped facilities. If such conditions are not available, it is important that users make necessary arrangement for the test to be carried out at an approved establishment.

UTN, with the help of a pool of trained personnel and availability of appropriate facilities has managed to become one of the establishments that can offer such service in the country. The service was started in 1985 and until now about 41 sources have been successfully tested (Table 5). The overall response from users of sealed sources with regard to this service is still below expectation. This poor response is clearly shown by the small number of sources received by this centre each year as compared to the actual number of sources expected to be in use throughout the country in the same year (Table 1). There are two reasons that can be attributed to this poor response of the service. Firstly, some users may prefer to have the service from establishments outside the country and secondly many users may not be aware of the strict requirement for the leak test to be carried out on sealed sources.

Leak tests that reveal the presence of 0.05µCi or more of removable contamination can be considered evidence that the sealed source is leaking (11). It should then be withdrawn from use and sealed in a separate container. The source should be returned to the manufacturer or sent to some other qualified establishments for repair or disposal. Our regulations may require notification of the appropriate authority when the contamination measured in a leak test exceeds a stated quantity.

7.0 CONCLUSION

Eventhough it is known that radiation can cause harmful effects, the use of nuclear techniques in industry can still be beneficial if a proper radiation protection program can be established to minimize such effects to both workers and members of the public. The Act which was introduced in 1984 should be used as a guide for the establishment of such programs in the country. Various aspects of radiation protection can and should be implemented to comply with the requirements of the Act. In the absence of certain important regulations as provided for in the Act; radiation protection procedures can be carried out based on ICRP and IAEA recommendations. Consultancy Services on the establishment of some of these procedures can be obtained from UTN.

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Table 1

Use of Radiation Sealed Source In Industry

Radiation Source	Range of Activity	Number of Users		Use of radiation sources
		1983	1986**	
Ir-192	40 Ci - 120 Ci	22	199	NDT
Co-60	0.3mCi - 1.5kCi	4	27	Gauges, NDT, sterilization, calibration
Cs-137	0.01mCi - 2.9 Ci	4	53	Gauges, material analysis, calibration
Sr-90	20mCi - 100mCi	5	79	Gauges
Am-241	0.5mCi - 350mCi	5	13	Gauges, calibration
Pm-147	0.9mCi - 600mCi	6	2	Quality control of electronic components
Tl-204	0.5mCi - 50 mCi	6	2	Quality control of electronic components
Kr-85	250mCi - 50 Ci	10	18	Quality control of electronic components, gauges
Cd-109	1mCi - 50mCi	-	8	Material analysis
Ferum-55	4mCi - 120mCi	-	9	Material analysis
Am/Be	23mCi - 18 Ci	-	31	Gauges, calibration
Ra-226	2.5 Ci - 100 Ci	-	19	Calibration
Th-228	1.7 Ci - 10 Ci	-	5	Calibration
Pu-238	30mCi - 100mCi	-	10	Material analysis
Gd-153	0.1mCi	-	1	Calibration

** Data taken from reference (6)

Table 2

Dose Limit For Occupationally Exposed Worker

Site/type of exposure	Annual dose equivalent limit (1)(2) for Individuals	
	Workers	Members of public
Whole body - uniform irradiation	50 mSv (3)	5 mSv
Partial body or non-uniform irradiation	50 mSv (3)(4) (Effective dose equivalent (7))	5 mSv (4) (Effective dose equivalent (7))
Skin, hands, forarms, feet, ankles, and any single organ or tissue other then lens	500 mSv	50 mSv
Lens of the eye	150 mSv	50 mSv
Planned special exposure (5)	2 x relevant limit above in any single event (6)	-

Notes:

(1) Additional to dose equivalents received from medical or natural radiation.

(2) Where dose equivalent arise from a combination of external and internal irradiation, the limits are intended to apply to the sum of the dose equivalent arising from external irradiation during one year and the committed dose equivalent from that year's intake of radionuclide.

(3) For pregnant women and women of reproductive capacity, the exposure should be confined to an approximately regular rate. Pregnant should also be restricted to working conditions where the annual exposure would be most unlikely to exceed 0.3 x annual dose equivalent limit.

(4) Subject to the overriding limit for single organ or tissued.

(5) Not permitted for women of reproductive capacity of persons who have received abnormal exposure in exceess of 5 x relevant limit.

(6) Subject to life time restriction of 5 x relevant limit.

(7) Effective dose equivalent $= \sum_{T} W_T H_T$

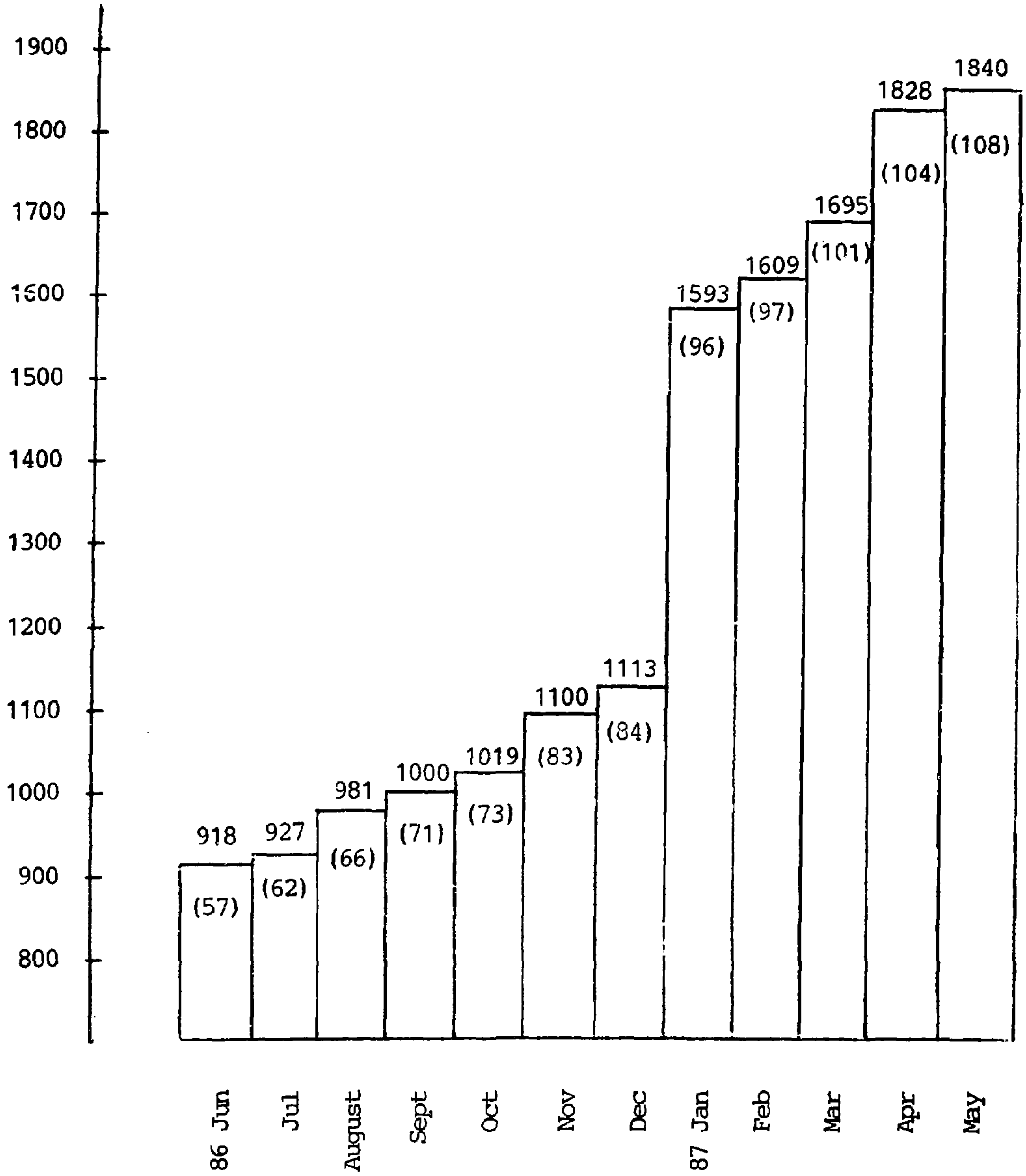
Where H_T = mean dose equivalent in tissue T

and W_T = weighting factor for tissue T as given below =

Tissue	W_T
gonad	0.25
breast	0.15
red bone narrow	0.12
lung	0.12
thyroid	0.12
bone surface	0.03
remainder	0.30

For remainder, a value of W_T = 0.06 is applicable to each of the five organs on tissues receiving the highest dose equivalent and the exposure of other tissues can be neglected. (It is not intended that skin, hands, fore-arms, feet, ankles, or the lens of the eye be included in the remainder).

Fig. 1: Personal Film Badge Service Given By UTN



Notes:

with bracket - No. of agency
without bracket - No. of personnel

Table 3

Whole Body Dose Distribution

MONTH	NUMBER OF INDIVIDUALS* WITH WHOLE BODY EXPOSURES IN THE INDICATED RANGES (mSv)											TOTAL
	0	0 - 0.2	0.2-0.4	0.4-1.0	1.0-2.0	2.0-5.0	5.1-10.0	10.0-15.0	15.0-20.0	20.0-50.0	50.0-100	100-500	
86													
JUL	456	236	32	19	4	10	3						760
AUG	331	452	6	5	7	1							809
SEP	587	161	60	20	11	4		1					844
OCT	374	207	53	28	7	12	5	3					689
NOV	591	246	19	24	17	12	6	2	1				918
DEC	514	263	28	73	18	6	4		2		1		909
87													
JAN	694	590	29	24	6	18	2		1	1		1	1366
FEB	501	648	80	102	33	7	3				1		1375
MAR	515	617	94	73	16	9	1			1	1		1325
APR	674	733	70	69	11	7	2	1					1567
MAY	546	615	105	65	15	10	2		3				1361
JUN	624	658	100	66	16	5						1	1471

* Individual receiving film badge service from UTN.

Table 4

Radioactive Waste Management Service Given by UIN

Year	Amount of waste received			
	Unsealed Sources (M^3)			Sealed Sources (no)
	Solid	Aquous	Organic Liquid	
1982	0.11	-	2.75×10^{-2}	-
1983	2.32	-	9.0×10^{-2}	3
1984	$5x10^{-3}$	-	6.0×10^{-2}	-
1985	1.4	1×10^{-2}	3.3×10^{-1}	58
1986	5.12	$9.7x10^{-2}$	4.8×10^{-1}	-
1987 (until July)	2.2	$3.5x10^{-3}$	2.8×10^{-1}	11 + 6 (temporary storage)

Table 5

Leak Test Service Given By UTN

Type of Sources	No. of Sources Tested		
	1985	1986	1987
Am/Be	-	-	5
Am-241	-	-	14
Cs-137	-	-	2
Sr-90	20	-	-