

## EVOLUTION OF DOSES IN THE IEA-R1/NRR ENVIRONMENT AND TENDENCIES BASED ON THE CURRENT RESULTS

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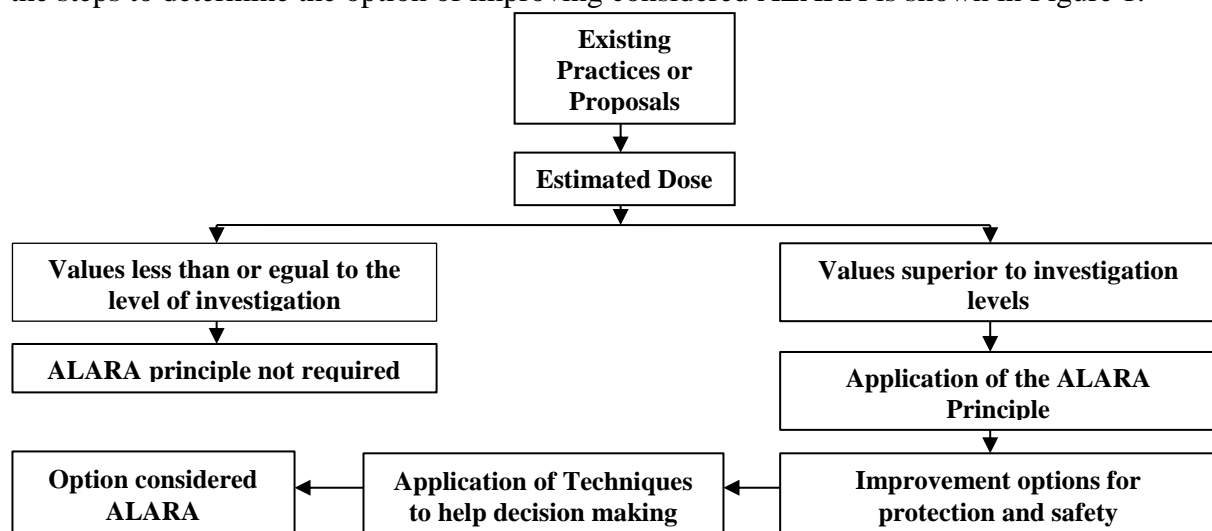
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### ABSTRACT

The IPEN / CNEN-SP has a Nuclear Research Reactor-NRR named IEA-R1, in operation since 1957. Until 1995 the reactor operated daily at a power of 2,0 MW. From June of that year, after a few safety modifications the reactor began operating in continuous way from Monday to Wednesday without shutdown totaling 64 hours per week, also the power was increased until 4,5MW in 2012. Because of these changes, continuous operation and increased power, workers' doses increased. In the past, several studies were conducted seeking ways to reduce the workers' doses. The purpose of this paper is to analyze the individual doses of OEI (occupationally exposed individual), considering the changes in reactor operation mode and to suggest the viable protection and safety options, in the first instance to reduce the doses in question aimed at the goal of reaching acceptable region, that is, lower or at most equal to 5 mSv / year for the International Commission on Radiological Protection(ICRP)[1].

### 1. INTRODUCTION

The IEA-R1 Reactor, having over 50 years of operation, has undergone several modifications to suit the current standards of nuclear safety and nuclear security [2]. The ALARA concept was introduced in practices that are associated with the operation of the reactor. In the case of practices involving radiation exposure, it is whether the doses are ALARA or not. A sketch of the steps to determine the option of improving considered ALARA is shown in Figure 1.



**Figure 1: The sketch of the steps to determine the option of improving considered ALARA.**

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The safety and security management system used in the reactor includes the application of international and national standards, quality programs, approval procedures and monitoring as well as a response system for emergency events systems, demonstrating that there is a commitment to good protection against the harmful effects of radiation. In practice, through the implementation of ALARA individual doses of radiation are minimized. In addition to the dose limits, there is local control levels of taxes. The Facility for Reactor , established a reference level (RL) limiting doses to 3.0 mSv / year for ionizing radiation . Supply this RL was established an individual monitoring program of the ionizing radiation that allow the assessment of compliance with the reference level and make it possible to provide information about changes in exposure values that require corrective action. Then we will detail how the Radiological Protection Service maintains these controls describing the equipment used, the methods used and the results obtained.

## 2. MATERIALS AND METHODS

All OIE are monitored individually by two types of dosimeters:

- a) Thermo-luminescent dosimeters
- b) Electronic dosimeters

Thermo-luminescent dosimeter (TLD) are provided by dosimetry Instituto de Pesquisa Energéticas e Nucleares (IPEN) laboratory and is used by Occupationally Exposed Individual( OEI) for a period of one month, after this time it is returned to the laboratory to determine the dose value and outputs a report. The report is available to the regulator [3], if the CNEN-Headquarters, to the sector where the OIE works and to the radiological protection service. The IPEN uses thermo-luminescent dosimeter as an official and therefore does not account for doses less than 0.20 mSv / month because it is the national record level. To sum effects in the year its value is regarded as zero. This created a problem for implementation of the reference level adopted 3.0 mSv / year. If a OIE received 0.19 mSv in the twelve months of the year the annual dose would be 2.28 mSv, but as we have seen to be below the record annual level would be computed as zero. This complicates the analysis of the evolution of the OIE doses below 2.28 mSv / year as it gives the impression that if computed as zero no procedure should be taken to prevent the OIE reaches the value of 3.0 mSv / year .The solution was to introduce a dosimeter that allows obtain values less than 0.20 mSv per month and could also serve as a warning dosimeter has the to function related to the task. At the time it was acquired an electronic dosimeter manufacturing Eurisys called Dosiscard. Currently the manufacturer is to Canberra. The individual DOSICARD electronic dosimeter has the appearance of a credit card, see figure 2.



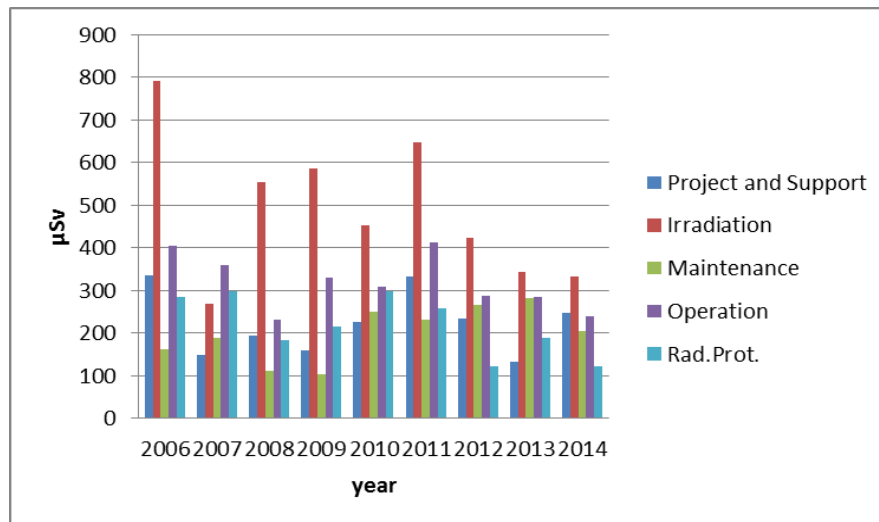
**Figure 2: Model of dosiscard Dosimeter.**

The keys features of dosimeters are:

- Having A solid detector (a silicon diode), a series of analog and digital phase processing signal,
- Having a high capacity non-volatile memory connected to a micro controller that controls the recording of radiation doses received according to a programmable schedule.
- Establishing the values for alarm management system,
- Owning a monitor and a keyboard with standard button, all powered by a single battery
- Using Windows system for infrared communication with a badge reader.

### 3. RESULTS AND DISCUSSION

The electronic dosimeter "dosicard" was adopted in 2006 and with it we could identify the activities and OIE who received the highest doses of radiation. That is why this work examines the doses from that date. The activities at the reactor were divided into: Project and support , irradiation, maintenance, operation, Radiological Protection. At that time OEI groups were responsible for each activity and some activities were carried out by people who operated the reactor as those to water treatment, operation and radiation protection. Presently the group receiving the highest dose was the irradiation group. Is given the average dose of ionizing radiation per activity, see Figure 3.

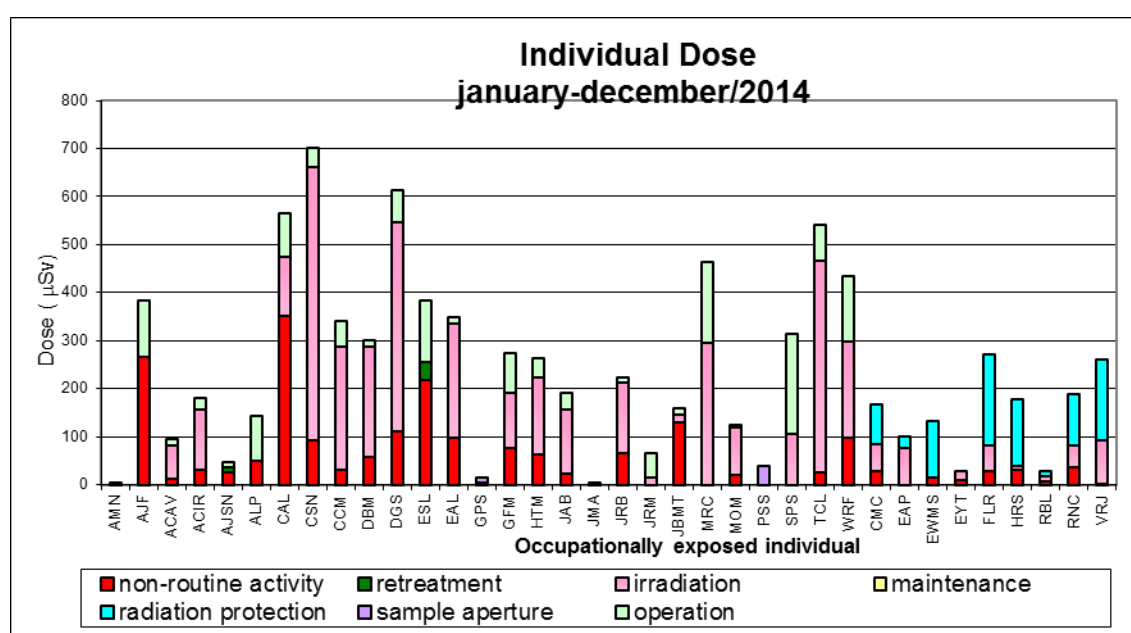


**Figure 3: Average dose of IOE for task .**

Studies have shown that the dose can be divided more equitably if there were people dedicated to each activity. Operations involving the higher doses as the removal of samples had increased the number of people shift working people way. The percentage distribution of dose for workgroup (Table 1) and the cumulative individual dose in a given month per OIE and the contribution of each activity for OEI are shown in Figure 4.

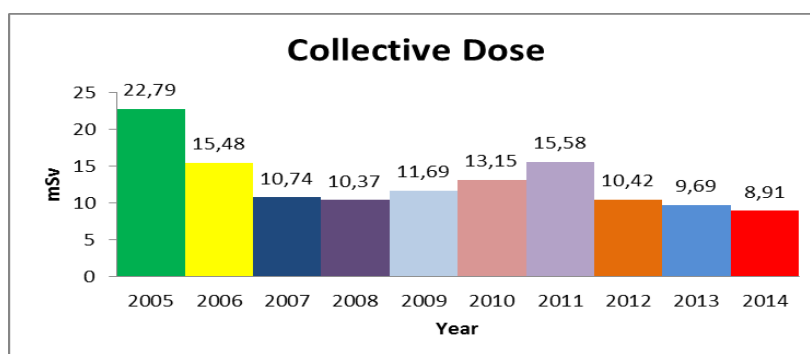
**Table 1: Dose distribution accumulated in a year per working group**

<b>Dose distribution Accumulated in a year by the Working Group</b>				
<b>Activity Area</b>	<b>Collective Doses</b>	<b>Number</b>	<b>Medium Dose</b>	<b>Percentual</b>
	<b>(mSv)/ano</b>	<b>people</b>	<b>(mSv)/ano</b>	<b>Medium</b>
<b>Sample Aperture</b>	0,06	3	0,02	4%
<b>Operation</b>	1,49	27	0,06	12%
<b>Maintenance</b>	0,00	3	0,00	0%
<b>Radiation Protection</b>	0,83	9	0,09	20%
<b>Irradiation</b>	4,14	20	0,21	44%
<b>Retreatment</b>	0,05	2	0,02	5%
<b>Non-routine activity</b>	2,00	27	0,07	16%
<b>Total</b>	<b>8,57</b>	<b>-</b>	<b>-</b>	<b>100%</b>



**Figure 4: Accumulated dose in one year**

From 2011 decreased individual doses and began to assess the collective dose which was not done before (Figure 3). The evolution of collective doses from 2005 to 2014 was sketched in Figure 5.



**Figure 5: Collective Dose from 2005 to 2014**

We observed that the collective dose is also decreasing since 2011, despite the increase in reactor power. We know that the increase in power implies increasing the radiation level in the pool hall, however due to radiological protection procedures adopted by supervisory this factor did not contribute to OEI doses. Studies in the past have shown that a major limitation for operation of a reactor type pool comes from the gamma radiation emitted by the  $^{24}\text{Na}$ . In 1958 Garay [4] described that besides the  $^{24}\text{Na}$  elements such as  $^{28}\text{Al}$  and  $^{27}\text{Mg}$  also contribute considerably to the pool water activity. In 1960, Pieroni [5], conducted similar studies at Columbia University and provided data on radiation levels that are achieved in the pool surface when operating at powers of up to 5 MW. It was observed that work by experimental data that, after 4 hours of operation at 5 MW, the radiation dose rate at the pool surface reached values close to 250.0  $\mu\text{Sv} / \text{h}$ . The water activity after its passage through the reactor core is the result of the following factors:

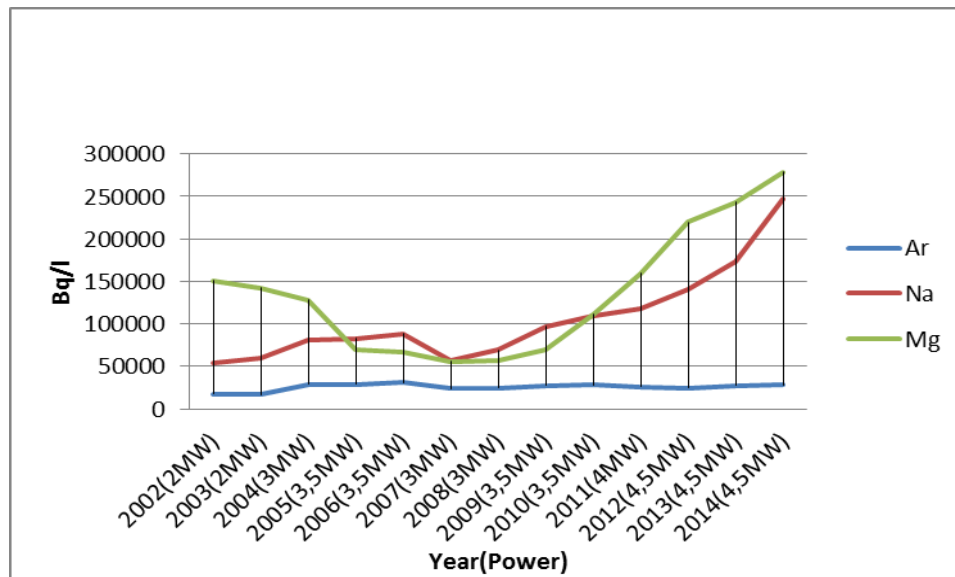
- Enabling own water and dissolved gases;
- Activation of impurities dissolved in the water from the feed water itself and corrosion of materials layered in the pool;
- Decrease of reactions in materials that are in the reactor core and are subjected to a flow of fast neutrons;
- Elements from landslides by radionuclides corrosion has formed in the constituents of the core materials;
- Fission products from the fuel elements through diffusion processes.

Reactor IEA-R1, since 2001, the pool water is collected and analyzed by a multichannel analyzer belonging to Radio chemical Management, which raises the specter of all radionuclides found. In the following table 2 we list the radionuclides found and their average activities as well as its they rose in 2015.

**Table 2 – Rise and activity of the radionuclides found in pool water**

Radionuclideos	Medium Activity (Bq/l)	Rise
$^{133}\text{Xe}$	66	Fission products
$^{135}\text{Xe}$	215,3	Fission products
$^{88}\text{Kr}$	67	Fission products
$^{85\text{m}}\text{Kr}$	90,3	Fission products
$^{87}\text{Kr}$	43,9	Fission products
$^{88}\text{Rb}$	6,6	Fission products
$^{60}\text{Co}$	1,5	Metal structures
$^{110\text{m}}\text{Ag}$	10,5	Control rod
$^{131}\text{I}$	29,4	Irradiated samples
$^{138}\text{Xe}$	46,1	Fission products
$^{138}\text{Cs}$	68,7	Fission products
$^{56}\text{Mn}$	202,7	Metal structures
$^{132}\text{Te}$	19,5	Irradiated samples
$^{197}\text{W}$	100,2	Metal structures
$^{144}\text{Ce}$	102,8	Metal structures
$^{41}\text{Ar}$	27.117,7	Water impurities
$^{24}\text{Na}$	256.430,1	Water Impurities
$^{27}\text{Mg}$	229.824,9	Water impurities

By the table we can see as already the radioactive elements with more activities and consequently the main contributors in exposure levels at the pool hall are:  $^{24}\text{Na}$ ,  $^{40}\text{Ar}$  and  $^{27}\text{Mg}$ .



**Figure 6: Average Activity of Radionuclides present in the pool water**

The  $^{41}\text{Ar}$  has its origin in the reaction of thermal neutrons with the existing  $^{40}\text{Ar}$  in atmospheric air humidity. This contributes significantly in radiation levels on the surface of the pool, and also has as aggravating the fact loosen up continuously for the environment because it is a noble gas. His influence can be reduced both through exhaust placed in the cooling circuit, such as by placing hoods at strategic points along the surface of the pool. The latter process was chosen in the original Reactor IEA-R1 project. To reduce the influences of  $^{27}\text{Mg}$  and  $^{24}\text{Na}$  in radiation levels on the surface of the reactor pool IEA-R1 the removal of impurities is required by the primary system. This is accomplished by a water system retreatment. It consists of two units each one having the ability to treat 75litros / minute. Each unit consists of an activated carbon filter exchanger followed by a mixed bed ion containing cationic and anionic resins. One of the units is held in reserve, coming into operation when necessary to regenerate the resin unit in use. This circuit works continuously when the reactor is operating. The degree of the pool water impurities is kept in this way at around 2 ppm of soluble substances. Therefore, some impurity remains in the pool water and depending on the operating mode and power of the reactor radiation levels can rise and avoid the permanence of people in this place. Some open pool type research reactors solved this problem by introducing a surface layer system (5) of 1.5m to 2m thick water retreatment system, which has its high temperature  $4^{\circ}\text{C}$  to  $6^{\circ}\text{C}$  over the normal temperature of the pool water. This forms a hot layer free of radioactive material forming a kind of shielding. In conclusion item will be addressed because the IEA-R1 reactor did not adopt this system.

#### 4. CONCLUSIONS

Optimization study [6] found that the hot layer option is not feasible in the current reactor operating rate. It is a costly system and requires constant maintenance. Other procedures such as OIE shifting in the tasks and residence time control in the lobby become more effective pool to decrease the doses. Even with the increased power of the reactor and the consequent increase in activities of water impurities, particularly Ar, Mg and Na, the collective and

individual dose decreased. With this RL set of 3.0 mSv / year has been met and complied with the recommendation of the ICRP which is values equal to or below 5.0 mSv / year. The importance of the monitoring program and full control of the activities of OIEs are essential factors in the ALARA program presents expected results. The economy and security achieved by the Radiological Protection team Reactor resulted in more credibility and led the team to pursue improvements that enables the secure operation and that society can benefit from this activity.

## 5. REFERENCES

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