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"SISRADIOLOGIA" - A NEW SOFTWARE TOOL FOR ANALYSIS OF RADIOLOGICAL ACCIDENTS AND INCIDENTS IN INDUSTRIAL RADIOGRAPHY

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ABSTRACT

According to the International Atomic Energy Agency (IAEA), many efforts have been made by Member States, aiming a better control of radioactive sources. Accidents mostly happened in practices named as high radiological risk and classified by IAEA in categories 1 and 2, being highlighted those related to radiotherapy, large irradiators and industrial radiography. Worldwide, more than 40 radiological accidents have been recorded in the industrial radiography area, involving 37 workers, 110 members of the public and 12 fatalities. Records display 5 severe radiological accidents in industrial radiography activities in Brazil, in which 7 workers and 19 members of the public were involved. Such events led to hands and fingers radiodermititis, but to no death occurrence. The purpose of this study is to present a computational program that allows the data acquisition and recording in the company, in such a way to ease a further detailed analysis of the radiological event, besides providing the learning cornerstones aiming the avoidance of future occurrences. After one year of the "*Industrial SisRadiologia*" computational program application – and mostly based upon the Workshop about Analysis and Dose Calculation of Radiological Accidents in Industrial Radiography (*Workshop sobre Análise e Cálculo de Dose de Acidentes Radiológicos em Radiografia Industrial - IRD 2012*), in which several Radiation Protection Officers took part - it can be concluded that the computational program is a powerful tool to data acquisition, as well as, to accidents and incidents events recording and surveying in Industrial Radiography. The program proved to be efficient in the report elaboration to the Brazilian Regulatory Authority, and very useful in workers training to fix the lessons learned from radiological events.

1. INTRODUCTION

With the technological advances in the nuclear energy applications, the national landscape has undertaken a meaningful role in the market, as well as in the population life quality, both in the power generation (Angra 1 and 2 Power Plants, 3 to come) and in industrial applications, with the employment of industrial radiography for quality control purposes, polymerization and security inspections in metallurgy, naval, aviation, automotive, mining, chemical industry, paper and cellulose, metalworking and civil construction areas, among others.

Industrial Radiography constitutes one of the most adopted non-destructive techniques in the inspection of welded, molten and molded ferrous and non-ferrous materials, where industrial sector quality requirements compel the avoidance of structural discontinuities in pieces and components of equipment, which could, somehow, upset their performances, as well as their useful lives, posing a risk to both high valued heritages and the safety of human lives.

As postulated in the Regulatory Authority Regulation -National Commission of Nuclear Energy Comissão Nacional de Energia Nuclear)- CNEN NN-6.04 (1989) item 6 paragraph "i" and in the Regulatory Positions 004:2011 and 007:2011 from CNEN Regulation NN-3.01 (2011), "every accident or emergency situation must be registered in an appropriate form at the same day of the occurrence, and all reports and communications must be filed in the company Radiation Protection Service, along with the outcome of the carried out investigations." Thus, a computational program to fulfill such requirement was developed, in the basis of "Methodology for Analyzing Radiological Accidents in Industrial Radiography" (*Metodologia de Análise de Acidentes Radiológicos em Gamagrafia Industrial*) (DA SILVA – 1990).

The occurrence of radiological incidents – and even accidents – is usual in several companies, but not always the detailed registers are performed. The follow-up, evaluation and register of the doses received by the Occupational Workers comprise the main document to be kept by the employer in their files, in order to ensure the evaluation of the OW´s, in order to assure the worker health maintenance and safety. Such register can avoid foul play acts by professionals, aiming to achieve extra benefits from the company or the government, by means of the labor legislation, which benefits workers subjected to risks that are included in the statutory regime or in the Labor National Legislation.

An internal investigation must be started up at once, whenever the company receives a report from dosimetry laboratory, reporting dose results in one or more personal dosimeters above limits established by CNEN standards, in order to determine the incident circumstances.

The development of the computational program for data achievement will make the Radiological Protection Service investigation report drawing up easier, faster and more consistent, regarding actual – or even presumed - received doses, in radiological accidents or incidents due to Industrial Radiography practices, aiming the fulfillment of CNEN Regulation CNEN NN 6.04 – "Operation of Industrial Radiography Services" (*Funcionamento do Serviço de Radiografia Industrial*), as well as a more extensive info collection, in order to avoid future relapses.

2. METHODOLOGY

According to the item IV of the article five of the 1988 Brazilian Federal Constitution (*Constituição Federal Brasileira*), every professional has the right to perform and present a study in the most convenient way from their standpoints. Nevertheless, a tool for guidance, information, standardization and quickness is proposed in this study, to the development of operational activities.

A methodology is introduced here, applied in the computational program development, in such way that it provides a suitable tool for analysis, recording and reports releases of radiological incidents and accidents in industrial radiography.

2.1. The Computational Program

The computational program comprises a protocol of action and data acquisition concerned to the contingency of an incident or accident, in which all information can be digitalized and filled, allowing the release of reports and graphics, along with its ulterior use as a baseline in the involved professional background research, in the event investigation itself and in the lessons learned in order to avoid relapses. The *"Industrial SisRadiologia"* is intuitive, with fields to be filled with fact-finding purposes, and some suggestions on action taking to be performed, besides supporting the evaluation and assessment of the dose received by the occupational worker in job routine or in emergency/accidental situations, aiming the detailed analysis of causes and consequences, and ulterior corrective and coercive measures, as well as to provide the necessary information to the planning of the training program in the institution and, as a consequence, to decrease doses or even avoid them.

The data bank can be fed with accidents/incidents background information, in order to keep their records available in the system. It can be loaded with available information to facts ascertainment, supporting the Radiation Protection Officer (RPO) in a dose assessment report drawing up.

2.2. Description of the Program Data for Data Collection

The program structure is divided in three components: occupational worker registry, equipment registry and dose assessment report notification, as showed in figures 1, 2 and 3. According to CNEN Regulation CNEN NN 6.04 (1989), Industrial Radiography enterprises must have at least two Radiation Protection Officers in the staff, even more, according to CNEN evaluation. Furthermore, at least two radiography technicians for each facility must be available; being one of them qualified by CNEN and the other trained by a RPO in Industrial Radiography, with minimum workload of 80 hours-classes. To opened facilities, at least one Opened Facility Responsible is required in the staff.

The occupational worker registry comprises fields to be filled in with personal data, like: full name, ID, CPF, date of birth, phone number, home address, professional qualification as stated in CNEN Regulation CNEN NN 6.04, present enterprise admission date, ionizing radiation work start date, last employer name, Dangerous Material Transportation authorization, update and supplementary courses, as well as any additional information regarded as relevant by the enterprise. These data are presented in Figure 1.

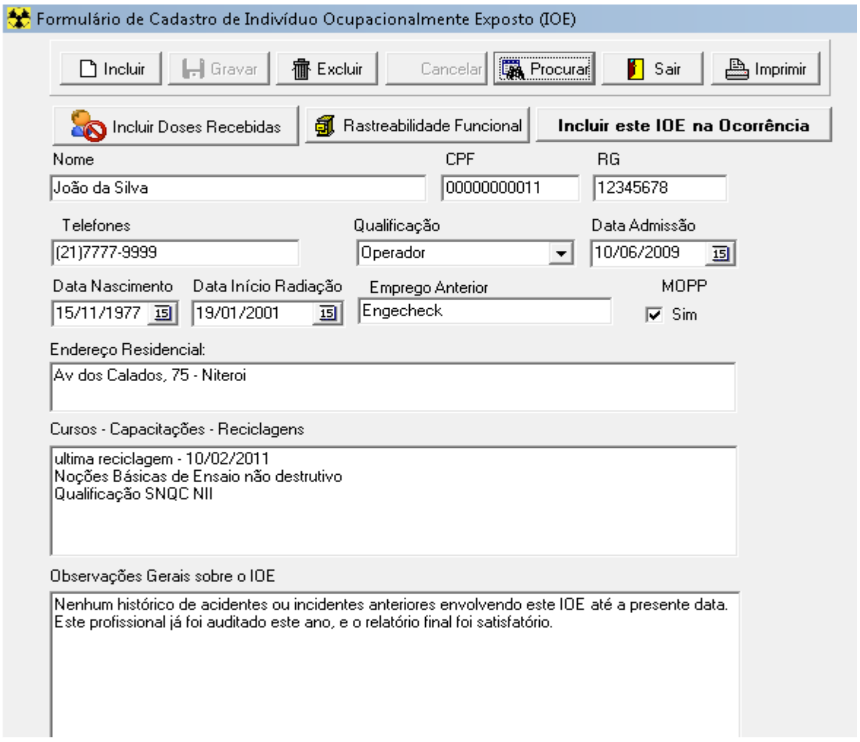

Figure 1: Screen for Occupational Worker Register

The *"Industrial SisRadiologia"* program provides a specific field to register the ionizing radiation equipment, as can be seen in Figure 2. X-ray devices are described in the first field, comprising serial number, model, trademark, operational beam (directional or panoramic), energy range (kV), operational current (mA), besides additional information, as, for instance, maintenance and work schedule background. To sum up, the most relevant device features and background data are stated in this field.

Both irradiator devices and gamma sources are registered in the second field, and the information input must include: irradiator device serial number, trademark and model, radioisotope (^{192}Ir, ^{75}Se, ^{60}Co), activity (GBq), plus additional information, if applicable.

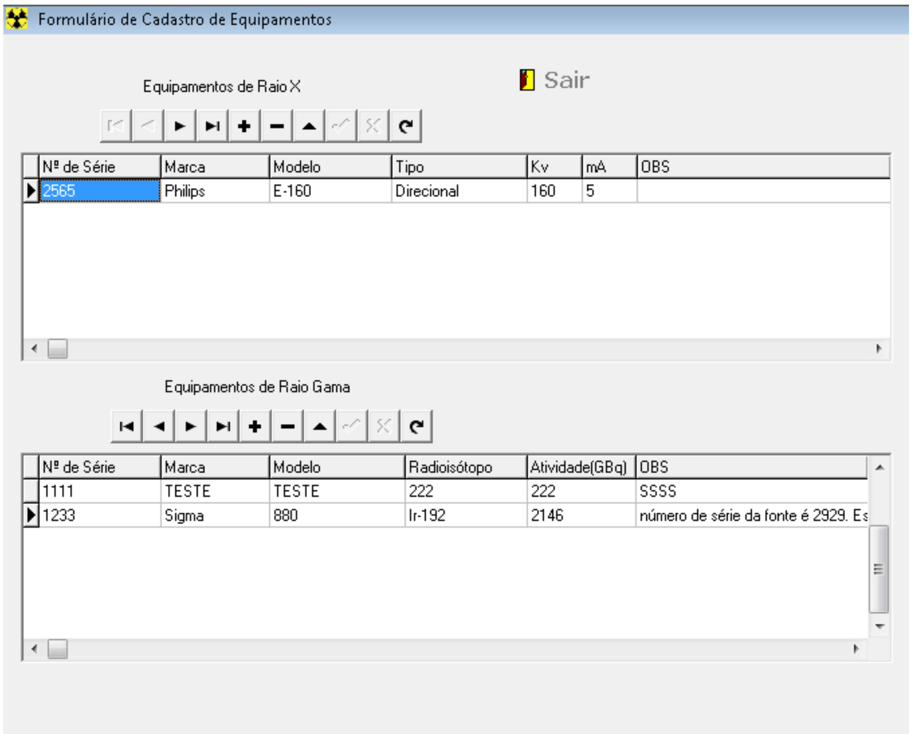

Figure 2: Screen for Equipment and Radioisotope Register

Figure 3: Screen for Data Collection and Analysis

The main screen Dose Assessment Report NOTIFICATION (RID) must be accessed in order to start up an event register. Following CNEN requirement, all national dosimetry laboratories must report, at once and individually, monthly doses of 4mSv or higher both to the requesting institution and CNEN itself. Then, the requesting institution must inform at once CNEN about its awareness of received doses results, as well as the initial measures taken. Likewise, the requesting institution must commit to send a detail report about the concerned investigation to CNEN. Following CNEN requirements, adopted by the Ministry of Labor and Employment, every monthly dose of 1mSv or more must be inquired.

Exclusively within the scope of this study, the terms radiological accident and incident will be distinguished between one another by the following features:
A radiological accident is defined as an unexpected event occurred during a practice, due to human error or equipment failure, from which real and potential consequences are relevant to Occupational Workers, members of the public and/or environment. A radiological incident may have the same origins, but with no straightaway radiological consequences, though being potentially able to prompt a radiological accident. The expression damage to human being can be understood as a radiation dose that exceeds the established level in Regulatory Legislation, as of the CNEN NN-3.01 (2011), as shown in Table 1:

Table 1: Dose Annual Limit According CNEN NN-3.01Norm (2011)

Quantity	Occupational Worker	Member of the Public
Effective Equivalent Dose	20 mSv*	1 mSv
Skin Equivalent Dose	500 mSv	50 mSv
Eye Lens Equivalent Dose	20 mSv*	15 mSv
Extremities Equivalent Dose	500 mSv**	--------

(*) Arithmetic mean of 20 mSv/y, during a period of 5 consecutive years, as long as 50mSv is not exceeded in any of them.
(**) Extremities meaning hands and feet.
Source: CNEN Resolution 114/2011updated.

The investigation process gets started when the icon RID (Dose Assessment Report) is clicked, and a sequential number with date and time is generated. At this point too, the event is classified as a radiological incident or accident. In these fields, relevant data must be provided, as place of occurrence – that is, the hiring company address – and right below the hired company data, that is, the one which is responsible for the industrial radiography services, with juridical person national register code (CNPJ), as well as, its branch of activities, according service authorization issued by CNEN. Once these data have been recorded, the access to MENU will be granted, in order to fill the following fields, as seen in Figure 4.

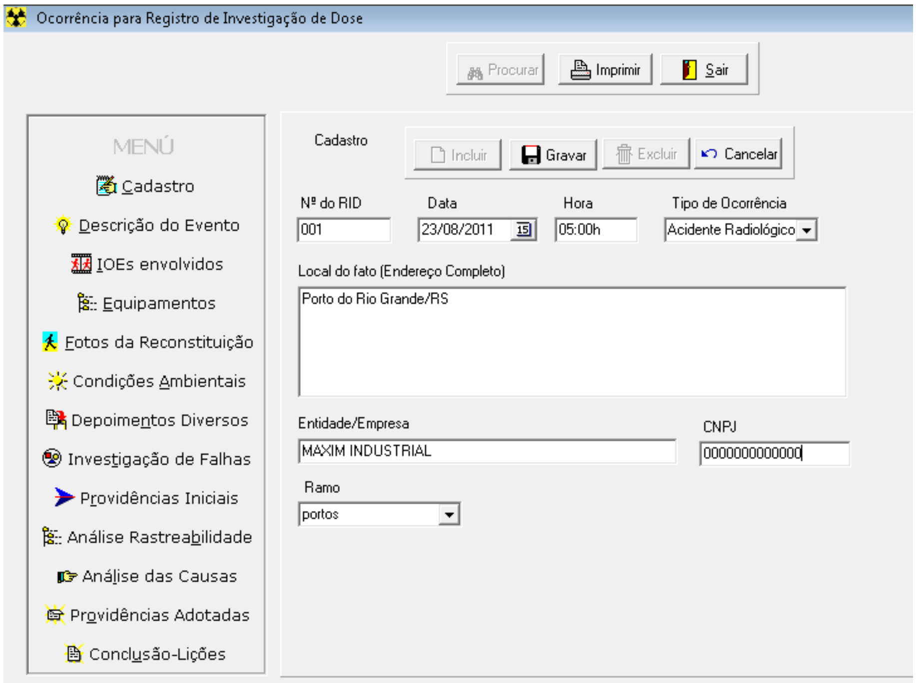

Figure 4: Screen for RID Register – Dose Assessment Register

Hereupon, the icon additional information (*informações complementares*) is clicked, in order to proceed with register and analysis of specific information related to a selected Occupational Worker, as shown in Fig. 5.

Complementary information comprises specific items related to the dose received by the Occupational Worker, as, for instance, affected body regions, substantiation of the accident occurrence, culpability analysis, worker testimony and mostly, individual dosimeter readings, as well as both in loco estimated doses and results subsequently achieved by cytogenetic analysis.

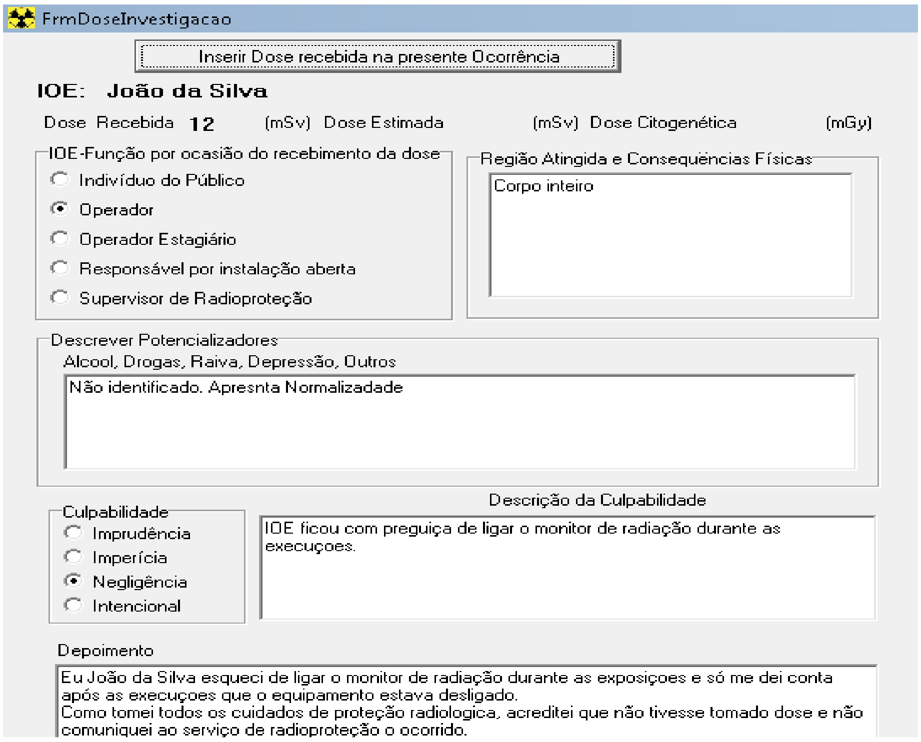

Figure 5: Screen for Additional Information of the Involved Occupational Worker

There are two options to register equipment and/or radioisotopes involved in the occurrence, being them screen in Figure 6 or initial equipment register screen. From the moment the company equipment register is accomplished on, it becomes able to perform a quick search, by inputting its serial number or even a facility operational radionuclide. Then, it will get the characteristics of emission (X-rays or gamma), trademark, model, and so on.

Relevant equipment features – as shield damage, periodic, preventive or remedial maintenance records, or an eventual previous episode of a malfunction that could be related to the event – they can be registered in the same screen, as well.

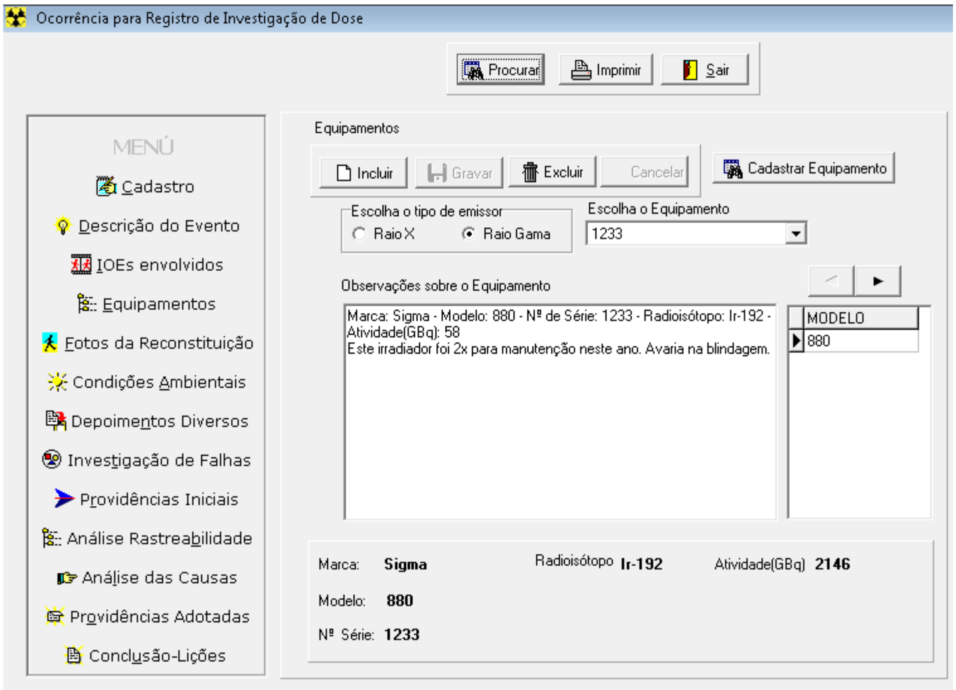

Figure 6: Screen for Occurrence Equipment/Radioisotope

The *Industrial SisRadiologia* computational program allows the insertion of a great deal of information – including the event graphic reconstitution as shown in Figure 7 – and aims to clarify doubts related to the event description and to the involved persons testimonies, besides to achieve additional pertinent data.

The accident reconstruction grants an investigation about the nature of the failure that led to the accident, if human, mechanical or environmental. Figure 8 shows the screen related to environmental conditions. The Radiological Protection Service must define the components of the reconstruction team. And this must be preferentially performed in the event place of origin.

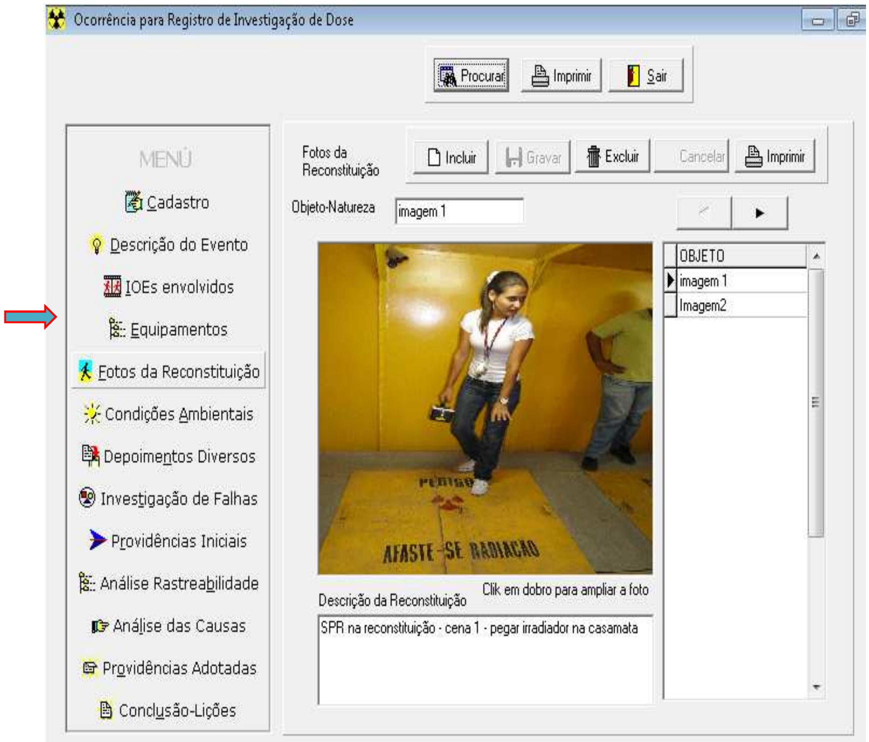

Figure 7. Screen for Reconstruction Pictures

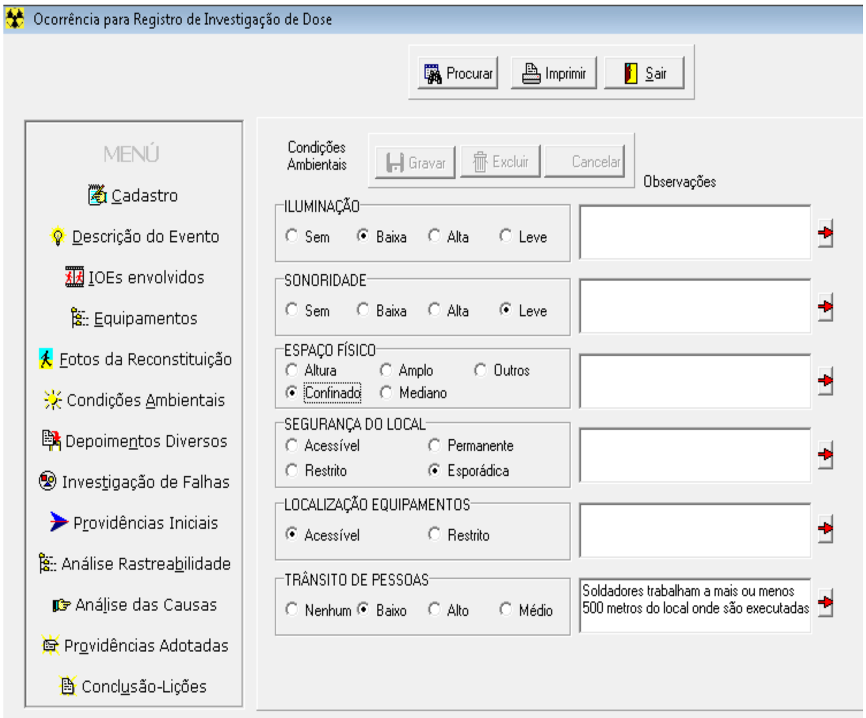

Figure 8. Screen for Environmental Conditions

In order to upgrade the investigation proceedings, some extra fields were included in the screen for failure investigation, as shown in Figure 9, in such a way that oblivions can be avoided.

Several circumstances can, ultimately, result in high doses to the Occupational worker. The most important accidental high doses are due to issues with the radioactive source, being the most common amongst them those comprising mechanic failure or human error during the operation of a x-ray or gammagraphy device.

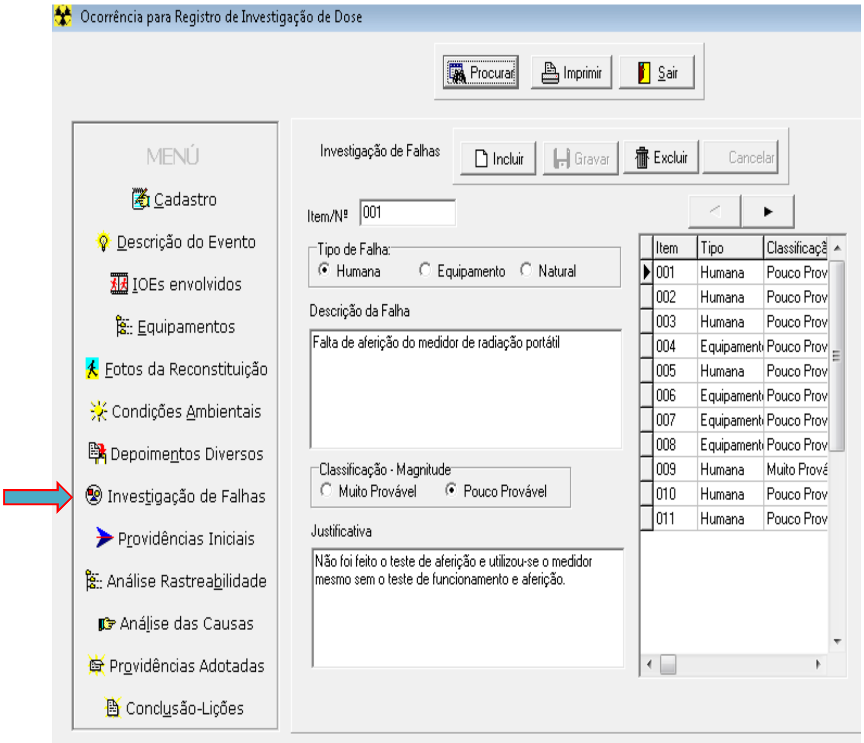

Figure 9. Screen for Failure Investigation

The measures to be taken must be previously conceived on the basis of an analysis of causes, where failures that led to the accident or incident can be identified. It is important to emphasize that, in a high dose event; a preventive break from professional activities should not be imposed to the worker, without a previous analysis of the causes. The worker leave must be accomplished only for medical reasons, always by the occupational doctor, after consultation with the Radiation Overexposure Analysis Group/CNEN (*Grupo de Analise de Doses Elevadas-GADE/CNEN*). The adopted steps main goal is to avoid event recidivism, by remedying the indentified faults.

The radiological protection service is supposed to carry out a check and evaluate the efficacy of the adopted measures, in order to make sure that faults were really remedied; otherwise new actions must be taken. An implementation period and a person in charge must be defined to each adopted measure.

Persons in charge must be chosen by the Radiological Protection Service. They can be the facility head, the occupational worker or even the radiation officers. Eventually a section of the company can be nominated as responsible for the adopted measures. A specific screen was developed in the computational program, allowing the inclusion of each step taken in sequential order, including implementation period and person in charge, in order to record the company performance in event remediation. Both the implementation and efficacy evaluation of each action taken must be stated in the observation field.

At the end of the received dose assessment, the program will issue an investigation report with a final proposition, taken into account evidences, information, testimonies and technical opinions. The final proposition is based upon identified errors, steps taken, learned lessons and company recommendations. The main objective is to avoid the repetition of the accident/incident events.

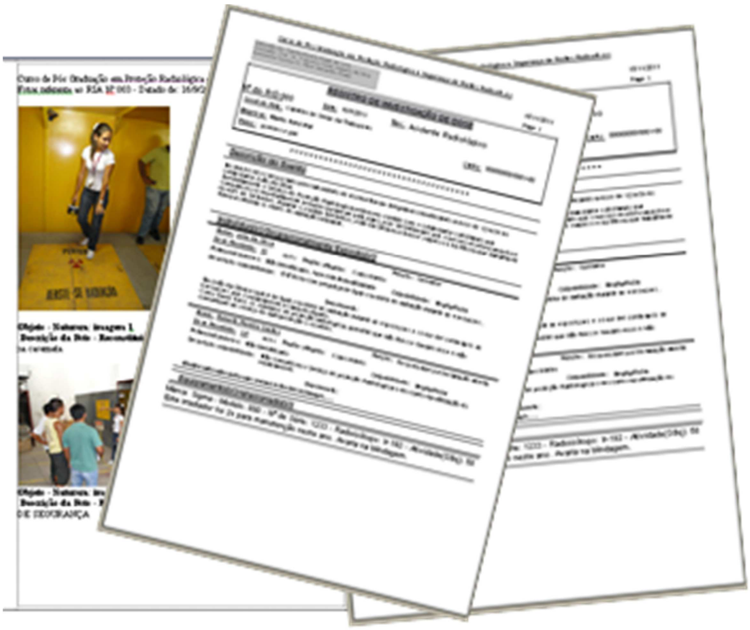

Figure 10: Screen for Report Issue

3. CONCLUSIONS

One year has elapsed since the beginning of utilization of the *Industrial SisRadiologia* computational program and some conclusions can be drawn, based on the gathered experience and on the outcome from the Workshop about Analysis and Dose Calculation of Radiological Accidents in Industrial Radiography (*Workshop sobre Análise e Cálculo de Dose de Acidentes Radiológicos em Radiografia Industrial*), sponsored by the Institute of Radiation Protection and Dosimetry (*Instituto de Radioproteção e Dosimetria -IRD/CNEN*) in 2012, with the attendance of several radiation protection officers.

It can be concluded that the *Industrial SisRadiologia* computational program is a powerful tool to data acquisition, record and studies of radiological accidents and incidents in Industrial Radiography. It has demonstrated to be effective in report elaboration to the Brazilian Regulatory Authority, as well as very useful in workers training to consolidate the learned lessons from such events.

The Assessment Reports enable the prediction of eventual occurrences (Security Analysis), besides issuing standardized reports, according to CNEN Regulation CNEN NN-6.04, enhancing the efficacy and upgrading the development of the tasks to be performed by a Radiological Protection Service in Industrial Radiography companies.

Additionally, the Computational Program also provides the Radiological Protection Service with a specific electronic bookkeeping tool, bringing about an upgrade in the services quality, with a quicker response.

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