*2009 International Nuclear Atlantic Conference - INAC 2009*
*Rio de Janeiro,RJ, Brazil, September 27 to October 2, 2009*
*ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN*
**ISBN: 978-85-99141-03-8**

# DISCUSSION ON POSTING AND LABELING FOR RADIOPROTECTION

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## ABSTRACT

The radioprotection aims the protection of people against exposure to ionizing radiation or radioactive substances as well as the safety of radiation sources. As ionizing radiation is not perceived by human senses, the warning signs and labels on radiation sources and the safety posters in controlled and supervised areas have an important role to keep the doses and risks as low as reasonably achievable, to prevent radiological accidents and to mitigate their consequences. In Brazil, several technical regulations require such safety labels and posters, however, despite their importance, there is quite few guidance about their format or contents. In this paper the posting and labeling requirements for radiological control existing in Brazilian technical regulations are discussed, confronting them with national, foreign and international technical standards and by drawing up a parallel with requirements of technical regulations from other countries. Changes are suggested in some parts of the national regulations, to prevent some differences in the current guidance, allowing the optimization of posting and labeling programs of radiological facilities.

## 1. INTRODUCTION

The radioprotection of a practice should be based on systems and procedures to maintain the radiation source under control, avoiding or minimizing the exposure to radiation, i.e. with a prevention function. In situations that may result in a scenario of loss of control over the source, a second level of protection can be achieved with measures to interrupt the unwanted sequence of events, or to limit their consequences, i.e., with a mitigation function. The safety signing is important in both prevention and mitigation, however, it should not be the first nor the only way to control the radiological risk, it should have a complementary role to other control systems of the radiation source.

The safety signing is that one which provides information or prescription related to safety and/or health, by means of signs, colors, light or acoustic signals, verbal communication or hand signal. It may have the purpose of communicating information related to protection or safety in order to promote safe behavior, reducing the risk and preventing health problems or property damage, or it may indicate the presence of protective equipment, as well as, in emergency situations, can provide information to reach a safe condition [1].

To be effective, the safety signing should draw attention to the contents of its message or information in a rapid and intelligible way. The visual safety signs can achieve this efficacy by the use of graphic symbols, colors, geometric shapes or keywords in order to convey ideas in a succinct and clear way. This implies that the meanings of the safety properties of these signs are pre-established and known by their public. The use of symbols, colors and shapes with similar meanings to other types of public signs, that is known even by non-trained people, as those used in traffic signs, can make communication more intuitive, but it does not eliminate the need of a formal agreement about the properties of signing specific for safety.

The safety signing contents can be classified into four distinct types: descriptive, when it identifies a risk source or unsafe practices; prescriptive, when it determines any action to be taken; proscriptive, when it either restrain or prohibit certain actions; or informative, when it provides information about general safe practice or, for example, when it indicates escape routes or emergency exits or the type and location of protection equipment available on site.

The development of a graphic symbol to represent specifically the ionizing radiation risk goes back to the 1940s and today the basic symbol, known as trefoil, is adopted by several countries [2]. The trefoil is an abstract icon, that is, uses graphic elements that do not keep resemblance to real-world objects, so its meaning has to be memorized. There is an international technical standard which normalizes the design and proportion of the trefoil, though it does not set its color nor the contrast color to be used as background, but it defines its scope as to signify actual or potential presence of ionizing radiation and to identify objects, devices or materials that emit such radiation [3]. The adoption, by a given country, of a safety symbol internationally accepted is favorable to protection and safety, because it facilitates the understanding of a relevant fact for safety, regardless of words or language, allowing the quick recognition of the associated risk.

The international technical standard that defines the trefoil allows the use of other graphic symbols and words in a supplementary way, provided that they do not detract from the clarity of the basic symbol [3]. The adoption of colors, geometric shapes and keywords with special safety meanings also results in quicker understanding of the message, minimizes the need for additional words to achieve that understanding and, consequently, condenses the information, occupying less space. The combination of a graphic symbol, a color and a geometric shape in order to transmit a particular safety message, is known as a safety sign [4]. The safety sign can be applied to posters, placards, tags, labels or directly on the surface to be signaled.

In a way even more compact, a safety meaning can be directly assigned to a specific color, known as safety color, and use it to delimit risk areas or objects, to identify safety equipment or to differentiate pipelines that conduct fluids of interest to safety. A safety marking is that one which uses safety color and/or contrast of safety colors to transmit a safety message or to make a location or object conspicuous [4].

Defining the most suitable design and type of signaling for use in a place or situation is not a trivial task, so it should be developed a safety signaling program for each radiological and nuclear facility.

## 2. RADIOPROTECTION SIGNING PROGRAM

The development of a radioprotection signing program for a radiological or nuclear facility requires some preliminary actions to know their needs for safety signing. Besides the availability of engineering projects and maps, it is essential to make visits through the entire area to be signed. These visits will not only to allow identify the buildings and radiation sources, but the activities conducted there, the basic movement pattern of workers, materials and visitors, and other relevant information to the program.

The radioprotection signing should be based on a radiological risk analysis of practices implemented in the facility and it should also be covered by the principle of optimization, so the signings should be provided for the relevant risks identified in the risk analysis and have their type, shape and intensity suitable for the situation. Signs required by other types of risk, such as industrial safety, should be provided in addition to that for radioprotection.

The main issues to be addressed in the radioprotection signing of a radiological or nuclear facility, but not limited to them, are:
- Access to controlled and supervised areas, and their boundaries;
- Safety procedures applicable to the area as the permits to access, the use of protection equipment or proscribing of food;
- Types of practice, radiation sources and activities on site;
- Area delimitation for development of activities;
- Radiation sources location, including radioactive waste and contaminated surfaces;
- Areas subject to relevant dose rates and surface and/or air contamination;
- Devices used to expose the radiation source, such as buttons to trigger shutters or X-ray tubes, or open shields;
- Safety devices, such as emergency stop buttons;
- Safety equipment such as eye-wash, stretchers or first-aid kits;
- Available radioprotection infrastructure, including radiation monitors and decontamination facilities;
- Delimitation of routes for internal movement of materials, vehicles and workers;
- Escape routes, emergency exits and meeting places for emergency situations; and
- Identification of packages and vehicles for transport of radioactive material.

Besides the main issues listed above, an example of another issue that the radioprotection signing program could address is the identification of measurement points of the monitoring program.

The signing program should also anticipate the discovery of new radiological hazards not previously detected or temporary additional risks that may arise, as a faulty equipment or a floor contamination. In such cases, the program should provide appropriate temporary signs until a permanent solution can be implemented. These signs should be provided with adequate urgency to the risk level and should be periodically updated if the situation changes, and should be removed as soon as they are no longer needed.

The signing basic features may also be included in the program, as the trefoil proprieties or the determination that the materials used in the preparation of posters, labels, placards and tags be resistant to expected environmental conditions on site without significant

deterioration of its properties. If this degradation is not avoidable, the program should provide routine checks of the signing for its maintenance or replacement.

The trefoil by itself does not inform the risk level, nor the radiation type involved, or if there is just irradiation risk or if there is also radioactive contamination risk. Depending on the safety message to be transmitted it is necessary the use of additional graphic symbols or words to achieve the objective, but it should be done with caution, because the proliferation of different graphic symbols for similar contexts may compromise the desired universal understanding of the safety messages [5]. Therefore, it is interesting to adopt an international technical standard to normalize the safety colors and the principles to design graphic symbols for safety purposes [4].

A standardization of how such additional information will be aggregated to the trefoil is also desirable because it is a way to ensure that it will not interfere with the trefoil view and recognition or with the comprehension of the information to be transmitted, avoiding gaps in the understanding. The lack of standardization can lead to confusion, risk situations or even accidents [4]. Again, the adoption of an international standard, which prescribes the application of the safety signs for accident prevention, fire protection, health information and emergency evacuation is desirable [6], however, caution is needed in adopting such technical standards, because some of their requirements may differ from the technical regulations in force in the country.

## 3. TECHNICAL REGULATIONS

The technical standard is a document that provides rules, guidelines or characteristics for activities or their results, which is established by consensus, approved by a recognized body and its adoption is voluntary. A technical regulation, although its form and contents are similar to a technical standard, it differs from that by its legal attribute. Technical regulations are issued by State authorities and establish the characteristics of a product or process and production methods, including the applicable administrative provisions, with which compliance is mandatory. Often a technical regulation or legal provisions require the adoption of a technical standard for a particular activity, so that standard becomes mandatory too [7].

In Brazil, there is not a specific technical standard or regulation for radioprotection signing, but there are several technical regulations that establish some requirements that such signing shall comply. Some of these regulations are issued by the Nuclear Regulatory Authority, and other ones are issued by authorities in sectors of activity that make use of radiation sources or are related to them at some point, as the regulations for transport of dangerous goods. In any case, the radiological or nuclear facility shall comply with all applicable technical regulations, and all technical standards referenced in these regulations.

### 3.1. Nuclear Authority Technical Regulations

In Brazil, the Nuclear Regulatory Authority issues specific legal guidelines for radioprotection and nuclear safety [8]. Although some documents issued by the Nuclear Regulatory Authority are named as experimental standard or nuclear standard, they are formally technical regulations because their compliances are required by law. The technical

regulation that currently defines the basic radioprotection guidelines in Brazil establishes the shape and proportion of the trefoil and defines that its color shall be magenta or purple, with yellow contrast color [9]. There are no exceptions provided for those colors in the regulation text. With respect to radioprotection signing, that same regulation also provides that:
- The controlled areas shall have their access posted with the trefoil and with words stating the radiation sources used there, and
- The supervised areas accesses shall have their posters with the words "supervised area".

Another technical regulation that addresses the radioprotection signing is the one which defines the role and responsibilities of radioprotection services of radiological and nuclear facilities [10]. This regulation prescribes that the controlled and supervised areas shall be signed focusing on the following:
- Posters on the accesses of the supervised and controlled areas with their identification, classification and the trefoil;
- Location of radiation sources;
- Identification of radiation sources and radioactive waste on their packagings, containers or shields;
- The dose rates and measurement dates in signifying points close to radiation sources and in workplaces;
- Warning about the presence and identification of contamination and high levels of radiation, with the dates of measurement;
- Delimitation of routes and accesses in normal working conditions and in emergency situations;
- Location of safety equipment and radiation monitors;
- Procedures to be followed in case of accident or emergency, and
- Systems for audible and visual alarms for accident or emergency situations, or to working conditions involving high levels of exposure.

The management of radioactive waste in radiological facilities is addressed in a specific technical regulation [11] and there are some safety signing requirements for radioactive waste:
- Presence of trefoil in containers for segregation, collection, transport and storage of radioactive waste;
- Those same containers shall be marked with the facility name and its radioprotection responsible, the waste identification, contents description and its physical state, radionuclides present and their activities, type of packaging, its mass and dose rate on the surface and at one meter; and
- Appropriate procedures for handling the radioactive waste, exhibited on walls, to minimize exposure in places for provisional radioactive waste storage.

The technical regulation for radioactive waste management does not fix colors, shapes or proportions to the trefoil, but it just requests the use of the "international symbol for radiation presence" [11].

The specific technical regulation for transport of radioactive materials is issued by the Nuclear Regulatory Authority and it determines the mandatory safety signings for transport units and packages of radioactive materials [12]. That regulation prescribes:
- White I, Yellow II or Yellow III risk labels for each package, tank, freight container or overpack containing radioactive materials, except for the exceptive packages;

- The word "radioactive" on each instrument or article in a exceptive package or, if the content is diverse, in an internal surface readily visible when the package is opened;
- The trefoil, in the outside of each type B package by means of embossed metal or other means resistant to fire and water;
- Placards for vehicles used to transport labeled packages. Three risk labels with black trefoil in yellow contrast color and four safety panels with the shipment UN number in black in red contrast color.

The specific technical regulation for transport of radioactive material requires a black trefoil on safety labels, and the contrast color may be white or yellow, depending on the package category. In the case of the trefoil applied to the surface of type B packages, the regulation does not prescribe its specific color; it just determines its shape and proportions [12].

There are also Nuclear Regulatory Authority technical regulations for specific practices, such as radiotherapy [13], nuclear medicine [14] and industrial radiography [15]. In such cases the requirements for radioprotection signing are complementary to those from general regulations. For example, in nuclear medicine, when the activity administered to a patient is greater than 1.11 GBq of I-131, the daily exposure rate at 1 meter from the patient shall be affixed next to his bed, and the room's door shall be marked with the following information [14]:
- The trefoil and the area classification;
- Name and activity of the administered radionuclide;
- Date, time of administration and daily record of the exposure rate at 1 meter from the patient; and
- Name, address and telephone number of the person responsible for radioprotection.

In industrial radiography, there are additional safety signing requirements for irradiation and sources storage places, as well as for the transport of packages (gamma projectors) [15]. For the transport, it is determined that the packages shall be placed in a metal box, locked and attached to the vehicle, so that its position remains unchanged throughout the transport, and it shall have the following information engraved or painted on its outside:
- The trefoil;
- The words "Danger, Radioactive, contains radioactive source of (name of radioisotope), it shall be handled only by persons who have received proper training and instruction";
- Company name; and
- Telephone number for communications.

### 3.2. Other Technical Regulations

As there are many possible uses for ionizing radiation sources, it is expected that the practices be subject to regulation by other State spheres than the nuclear, in particular by the environmental, health or transport ambits. In Brazil, the radioprotection regulation in medical and odontological radiodiagnosis is explicitly delegated to the Ministry of Health [9] that, through its Secretariat of Health Surveillance, issued a technical regulation with the basic radioprotection guidelines for that area [16].

That technical regulation prescribes a number of safety signings with emphasis on those dedicated to the general public because, unlike other facilities, most people who have access to the irradiation room do not have specific radioprotection training. This emphasis can be

already noticed by the signing requirement for the irradiation room access, which prescribes that the trefoil shall be accompanied by the words “x-rays, restricted access” or “x-rays, prohibit access for unauthorized persons”, and there shall also be a red light above the external face of the access door with the following warning: “when the red light is lit, the access is forbidden”. Moreover, the safety procedures that operators shall comply are reinforced by safety signs with informational contents to the public, as those that shall contain the following words: “It is not allowed to the companion to remain in the room during the radiological examination, unless when strictly necessary and authorized”, “Companion, when there is a need to contain the patient, require and properly use plumbiferous dress for your protection” and “Only one patient shall remain in this room at each time” [16].

The technical regulation for the radiodiagnosis area also defines the design and proportion of the trefoil, but it prescribes that its color shall be purple with yellow as contrast color, and it shall be accompanied by a text describing the ionizing radiation use [16].

In the health sphere, there is also a technical regulation about waste management in health facilities, which includes the radioactive waste generated in this kind of facility [17]. This regulation, although referencing the specific regulation of radioactive waste management of the Nuclear Regulatory Authority, prescribes that the trefoil shall be magenta with yellow as contrast color, although it does not defines its design or proportions.

In the transport sphere, technical regulations for transport of dangerous goods by road [18], railroad [19] and their complementary instructions [20], require a series of requirements for transport of radioactive materials. These regulations, with regard to the safety signing, adopt a national technical standard for identification of packages and vehicles [21].

In the ambit of Safety and Health at Work, a technical regulation of the Ministry of Labor and Employment, which aims to prescribe the safety color that shall be used in workplaces to prevent accidents by limiting areas, warning against risks, identifying the safety equipment and identifying the pipes used for driving liquid and gases [22]. This regulation adopts the purple color to denote the ionizing radiation risk, and it shall be applied to doors of controlled areas, containers containing radioactive materials and light signals used to indicate a radiation emitting equipment. The use of the safety color should be the slightest possible in order to not cause distraction, confusion or fatigue in the worker.

## 4. DISCUSSION

A study conducted by the International Atomic Energy Agency to evaluate the best symbol to represent the radiological risk showed that only 6% of people surveyed in Brazil, India and Kenya recognized correctly the trefoil [23]. This occurs because the trefoil is an abstract icon and shows that, even if the safety signing is well designed, it should be part of a whole radioprotection system, which includes the training of people that access the restricted areas or radiation sources.

Radiological accident scenarios like that in Goiânia [24], where people without radioprotection knowledge were involved, reinforce the need for adoption of a supplementary

warning symbol for ionizing radiation [23], in order to mitigate the consequences of undue access to radiation sources.

The clear definition of a basic symbol for ionizing radiation is an important point for radioprotection signing. The fact that there are several technical regulations defining the trefoil in different ways is harmful because, as their compliance is compulsory, it causes difficulties to the licensees to develop their programs in order to comply with all legal signing requirements. Moreover, the conflicts between the regulations lead to the lack of standardization of the safety signing which affects the association between the trefoil and the radiological risk by the society.

An example of the complications that arises to the licensees from the non-adoption of an international standard is the fact that many radiation sources used in Brazil are imported from countries where it is allowed the use of black trefoil. It follows that the original safety signing of the device is a black trefoil with a yellow or orange background what does not meet the requirements of the national technical regulations.

The Nuclear Regulatory Authority, in its current regulation of basic guidelines, prescribes the color of the trefoil as magenta or purple with yellow contrast color. This conflicts with other technical regulations because it does not provide exceptions to these colors, for example, when the symbol has to be resistant to fire and water, or black, as in the transport regulations. Although there was flexibility in relation to earlier versions of the basic guidelines, which only allowed the purple color [25, 26], there remain certain conflicts. The requirements of regulations and standards should be consistent with the requirements of the basic guidelines.

In the United States, the Code of Federal Regulations deals with the issue defining that the trefoil can be magenta, purple or black, with yellow contrast color, but when the symbol is expected to be submitted to high temperatures the exception is allowed to those colors [27]. Thus, other regulations do not conflict with it.

A solution to these conflicts could be the development of a national technical standard defining the design of the basic symbol of ionizing radiation, its proportion and providing the necessary flexibility of colors. The technical regulations could so just refer to that standard.

In the area of transport of radioactive materials the regulation problems of radioprotection signing become more serious. As the current technical regulation of the Nuclear Regulatory Authority is from 1988, many of the requirements does not follow the new international guidelines for transport, but these new guidelines have been implemented in the national technical regulations for transport of dangerous goods. This causes many conflicts when the licensee will provide the transport signing. One example is the criticality safety index label for fissile material, which is prescribed since 2004 by the regulations of dangerous goods [20], but it does not exist in the regulation of the Nuclear Regulatory Authority [12].

Another point of divergence with respect to transport signing is the placarding applied to vehicles. The regulation of the Nuclear Regulatory Authority prescribes a safety panel that conveys only the UN number in black numerals with red contrast color. The safety panel under the dangerous goods regulations has different size, conveys the risk number and the UN number in black numerals and the contrast color is orange. The adoption of a safety panel different from other dangerous goods classes is clearly disadvantageous for radiological

safety, as the main goal of the safety panel is to inform the first-on-scene emergency teams the nature of the risk and the identification of the product involved in the accident [28]. These teams are trained to recognize the safety panel determined by the regulations of dangerous goods, because such shipments and accidents are in number significantly higher than those of radioactive materials, but the differences between the safety panels may delay the response of such teams when the accident involves radioactive materials.

Moreover, the list of UN numbers attached to the current regulation of the Nuclear Regulatory Authority is outdated, and some of the listed numbers were even extinguished by the United Nations Economic and Social Council's Committee of Experts on the Transport of Dangerous Goods [29]. The revision of the transport regulations should be in a regular basis, to avoid conflicts between the national and international guidelines, which may result in operational difficulties or denial of transportation because of differences in interpretation of requirements. The adoption of a national technical standard for identification of packages and vehicles [21] could avoid the differences between signing requirements of the various transport regulations.

There are cases where technical regulations are directly contradictory on some items, such as about the signaling devices for radiodiagnosis equipments, which one regulation prescribes the use of red light [16] and the other determines the use of purple light [22]. These conflicts show that the preparation of technical regulations by the various spheres of State should be preceded by better studies about the impact that the new requirements may result on the practice and, consequently, on the safety.

The signing of escape routes, emergency exits and meeting points are important for mitigating the effects of emergency situations, so it should be clear and carefully maintained, because its usefulness depends on that it is functional when needed. The signs maintenance should be programmed to be done in conjunction with the periodic verification that there are no obstacles hampering the escape routes, or if the emergency doors are improperly locked.

In general, the radioprotection escape signing is less comprehensive than the fire escape signing, because there are rare situations where the loss of control of a radiation source requires a building evacuation. For this reason, often the radioprotection escape signing is absorbed by the conventional emergency signing. However, there are cases where the radioprotection escape signing should cover a larger area, as in situations of high radiation level alarm in the exit of products of large irradiators that could mean that the conveyor system of irradiated products is bringing out a radioactive source from the irradiation room. In such cases the area to be evacuated may be much larger than that required for a fire in the building, so the radioprotection escape signing should be appropriate.

## 5. CONCLUSIONS

The radioprotection signing is only one element of the protection and safety system of a facility, and often it may be the last recourse of the defense in depth to avoid undue exposure, so that it should not be neglected, nor should it be the sole resource to control the exposure to radiation.

To meet all regulatory requirements of safety signing, the radiological and nuclear facilities should have a program for radioprotection signing, in which are defined its design, implementation, optimization and maintenance.

The effectiveness of the radioprotection signing depends on the level of knowledge of the intended public. Workers in supervised and controlled areas should know and understand the information provided by the radioprotection signing and follow its determinations.

Radiological risk areas where access for persons non-trained in radioprotection is granted should have radioprotection signing more detailed, however, without polluting visually the work environment.

The standardization of radioprotection signing systems has positive influence on safety. Regulations and standards should be cohesive in order to do avoid conflicts between their signing requirements or doubts in their interpretations. When such conflicts are detected, revision of the requirements shall be urgently provided.

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