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Methodology for Establishing National Strategy for Radiation Safety of Nucleonic Gauges in Cambodian Industry

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1. Introduction

Nucleonic gauges (NGs) have been widely used in many countries by various industries to improve the quality of products, optimize the process, and save energy and materials [1]. Generally, NGs consist of a suitable radioactive source and detector, and it is a kind of measuring and analysis instrument using the interaction between ionizing radiation and matter. Because all NGs use a radioactive source and are often used in harsh environmental conditions, many countries have a regulation of radiation practices for the protection of workers and the surrounding environment.

Each country has its own unique legislation framework and national regulations, because they have to reflect domestic conditions in order to implement a strategy or a policy. In case of radiation safety, almost of all national standards for radiation protection comply with the hierarchy of rulemaking. As shown Fig. 1, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) or the Biological Effects of Ionizing Radiation (BEIR) provide a scientific evaluation or an evidence for provision using a scientific data collected from recent research activities. The International Commission on Radiological Protection (ICRP) develops, updates, and consolidates the recommendations for a system for radiological protection supported by the UNSCEAR, BEIR, etc. The International Atomic Energy Agency (IAEA) establishes basic safety standards and provides them for member states to enable the country to safely use radiation sources for beneficial purpose and ensuring that people and the environment are protected.

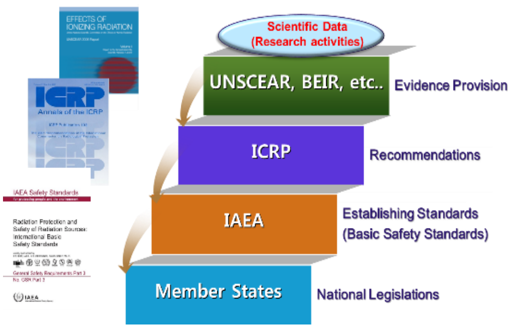

Fig.1. Hirachy of national legislations

Although Cambodia does not yet operate a nuclear power plant, nuclear research reactor, and a large radiation facilities, we need to regulate radiation protection and manage occupational exposures in our country because we have used some radioactive materials in the field of nuclear medicine, industry, construction, and agriculture etc.

Particularly we have used the NGs in a few of our industrial fields, we need to ensure safe operation and to protect the radiation workers from the risk of ionizing radiation by formulating and implementing effective regulations.

Therefore, Cambodia need to legislate national rules and/or standards that comply with the IAEA's current radiation protection standards with reflecting our domestic conditions. Particularly we need to establish our own national strategy and policy to manage the usage of radioactive sources used in NGs.

This paper reviews some principles of radiation protection and standards for radiation safety associated with the use of NGs and discusses our national setup of regulatory framework for occupational exposure management.

2. Principles and Materials

2.1. Principles of Radiation Protection

The primary safety objective is to protect radiation workers and the surrounding environment from harmful effects of ionizing radiation while operating NGs. The principles of radiation protection relevant to NGs are as follows;

- System of radiation protection: justification, optimization, and dose limitation (ICRP 103) [2].
- Regulatory requirements (IAEA/GSR Part 3) [3].
- Designation of controlled areas and of supervised areas (national regulations).
- Dose limits and investigation levels.
- Other related principles.

The essential regulatory requirements for protection from ionizing radiation are specified in the IAEA/GSR Part 3. In order to achieve the objective without unduly limiting the operation of NGs or the progress of industrial activities using NGs that give rise to radiation risks, a system of radiation protection founded on basic principles is needed. These principles will be achieved by the following requirements:

- Justification of practices: No application of radiation should be undertaken unless justified.
- Dose limitation: The dose limits for workers and the public are given below, although doses to

gauge operators are expected to be significantly below these levels during normal operation.
- Optimization of protection and safety: All doses should be kept "as low as reasonably achievable (ALARA)", economic and social factors being taken into account.

The IAEA/GSR Part 3 specifies the doses to individuals from occupational exposure should not exceed;
- an effective dose of 20 mSv per year averaged over 5years and not more than 50 mSv in any single year,
- an equivalent dose to the lens of the eye of 150 mSv,
- an equivalent dose to the extremities (hands or feet) or the skin of 500 mSv in a year [3].

2.2. Current status of radioactive material in Cambodia

Cambodia has not yet used much of radioactive materials as shown Table 1, but a sharp increase in usage is expected in near future. Also, more and more NGs are used in various industries with the development of research in the field of nucleonic control systems as follows;
- Civil engineering: to determine the soil moisture and density during the construction works. Recently, this facility has three Troxler Portable Gauges, one is working (use) and another two devices are not work.
- Beverages industry: to control the level of water in can of Coca-Cola, beer, etc.
- Cement industry: to determine the cement density
- Tobacco industry: to determine the density

Table 1: Radioactive materials used in Cambodia

industry	applications	sources	activity
Hospital	brachytherapy	^{137}Cs	1.70 GBq
	teletherapy	^{60}Co	198 TBq
	linear accelerator	6 MeV	-
Construction	soil density	^{137}Cs	0.33 GBq
	soil moisture	^{241}Am/Be	1.48 GBq
Company	liquid level	^{241}Am	1.57 GBq

2.3. Categories of Radioactive Sealed Sources

The physical properties of the source, the application that the source is used in, the shielding provided by the device, portability, security and other principles are all considered when choosing an appropriate source. It is very important to understand all these categories when planning, handling, and management of a disused radioactive sealed source (RSS). Table 2 shows the five categories of RSSs

Table 2: Categorizations of RSSs based on its risks

Cat. No.	Degree	Risks
1	Extremely dangerous	Even relatively short exposure *(a few minutes ~ an hours)* to materials may very well cause permanent damage including death
2	Very dangerous	Short exposure *(an hours ~ days)* to materials may very well cause permanent damage including death.
3	Dangerous	Exposure *(days ~ weeks)* to materials may very well cause permanent damage including death.
4	Unlikely to be dangerous	It is unlikely that anyone would be permanent fatal accident by this source. Nevertheless, this amount of radioactive material still dangerous if not safely managed or securely protected, the relatively exposure *(up to many weeks)*.
5	Most unlikely to be dangerous	No one could be permanently damaged by this source. This amount of radioactive material, if dispersed, could not permanently injure anyone.

The dangerous RSSs (Categories 1, 2 and 3) are used as irradiators for radiation processing: consumer products, food, health-care, blood/tissue, in radioisotope thermoelectric generators (RTGs), tele-therapy machines, industrial radiography, high dose brachytherapy, as well as in logging and in some industrial gauges. On the other hand, some less dangerous RSSs (Categories 4 and 5) contain radionuclides with long half-lives, such as ^{226}Ra at 1,600 years and ^{239}Pu/Be at 24,100 years. Even though the activity of these radioactive sources is low level, they will still causes a potential long-term waste management issue.

There are many different kinds of industrial gauges that use radioactive material with the most common being level and thickness gauges which are used in process control. These gauges present one of the largest challenges in terms of disposal because of their number and wide-ranging use. These RSSs used in industrial applications are mostly in Category as 3 and 4 (Table 3).

Table 3: Applications of RSSs for industrial gauges.

Applications	Radionuclide	Half-life	Cat. No.
Industrial gauges	^{60}Co	5.3yr	3
	^{137}Cs	30.1yr	3 or 4
	^{252}Cf	2.6yr	3 or 4
	^{85}Kr	10.7yr	4
	^{241}Am	432yr	3 or 4
	^{244}Cm	18.1yr	4
	^{147}Pm	2.6yr	4

3. Results and Discussion

3.1 Design the National Strategy and Policy

Cambodia does not yet have a nuclear law and regulatory body. The Ministry of Mines and Energy (MME) is being drafted the nuclear law of the Kingdom of Cambodia by having the facilitating term from IAEA. The MME is not a nuclear regulatory body, but the MME is a national focal point authority, which is responsible for making policy and strategy and planning for radioactive sources and nuclear material in the country. Cambodia has recognized the necessity of a framework to regulate protection and manage occupational exposures due to applications of radioactive sources used in our industry.

Regulating radiation safety is a national responsibility, many countries have adopted the IAEA's safety standards for use in their national regulations. According to the fundamental safety principle 2 of IAEA/SF-1 [4], an effective legal and governmental framework for radiation safety must be established. The structure of government responsibility and functions are specified in IAEA/GSR Part 1 [5]. The IAEA's current radiation protection standards are contained in IAEA/GSR Part 3.

Considering the above mentioned the IAEA's fundamental safety principle and radiation protection standards, our government framework for regulating radiation safety could be suggested to establish an "office of nuclear safety, security, and safeguards". Fig. 2 shows the initiatives of our Cambodian government framework suggested in this study.

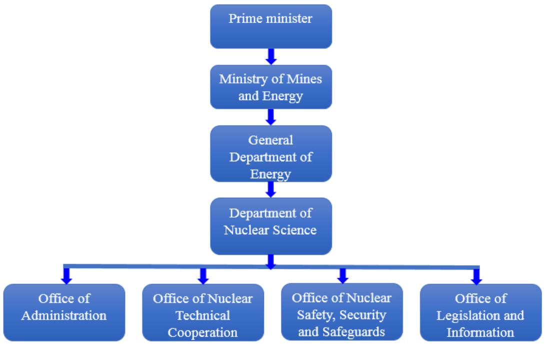

Fig. 2. Initiatives of the government framework of Cambodia

3.2 Regulatory Framework in Cambodia

Cambodia should develop a necessary regulation in the country regarding radiation protection practices. Many countries have formulated their own national regulations that are consistent with the international nuclear safety standards. In this study, Cambodian regulation on radiation protection based on the IAEA/GSR Part 3 and our national experiences is suggested as follows;

- General provisions (purpose, scope, definitions, radiation units etc.)
- Radiation protection programs
- Designation of radiation protection officers
- Occupational and public dose limits
- Quantity and concentration of radioisotopes
- Survey and monitoring
- Control of Exposure from radioactive sources
- Storage and control of licensed materials
- Prevention of hazards to environment
- Waste disposal
- Recording and keeping
- Report and notification of incidents
- Enforcement

The main feature of this regulation includes that no practice shall be licensed or authorized unless it produces sufficient benefit to individuals to be exposed or to society to offset the radiation harm that it might cause, taking into account social, economic, and other relevant factors. Another key issue addressed in this regulation is requirements for designation of radiation protection officers at facilities. This regulation also may provide radionuclide contamination levels in foods or agricultural and marine products. If necessary, guidance levels for patient doses are also provided in this regulation

Recently, The U.S. Nuclear Regulatory Commission (US/NRC) received some petitions for rulemaking requesting that the NRC amends its "standards for protection against radiation" regulation and changes the basis of the regulation from the Linear No-Threshold (LNT) model of radiation protection to the radiation hormesis model. The radiation hormesis model provides that exposure of the human body to low levels of ionizing radiation is beneficial and protects the human body against deleterious effects of high levels of radiation. Whereas, the LNT model provides that radiation is always considered harmful, there is no safety threshold, and biological damage caused by ionizing radiation is directly proportional to the amount of radiation exposure to the human body. Particularly, the LNT model drives the public's concerns for radiation in their imagination (radiophobia) and all radiation should be avoided at all costs. According to this assertion by health physicist, the ALARA should be removed entirely from the regulation. They have insisted that alternative approach based on new philosophy of radiation protection is needed and also the new concept of regulation would facilitate studies using low dose radiation for preventing and treatment of diseases. At present, the NRC is examining the issues to determine whether they should be considered in rulemaking. The NRC is also requesting public comments on this issue for rulemaking.

3.3 Inspection Program of Authority

The inspection program of authority comprises on various types of inspection like planned inspections, reactive inspections, announced and unannounced inspections, periodic inspections, etc. These regulatory inspections will be conducted by an independent regulatory body along with specified responsibilities, clearly allocated, and functions (requirement 2 of IAEA/GSR Part 3). Such inspections will be conducted for licensed users (company) to verify that regulatory safety standards are comprehensively observed by the operators. The checklists are as follows;

- availability of personal protective equipment
- qualified radiation protection officer
- personal and area monitoring equipment
- radiation dose records
- physical protection and security measures.

4. Conclusion

The utilization of NGs in Cambodian industry will be rapidly increased in near future due to many advantages. Considering our domestic conditions to industrialize, Cambodian government have to establish a fundamental radiation protection regulatory framework in our country that comply with the IAEA's basic safety standards. Also, we have to a comprehensive mechanism for implement-tation of this framework.

Our national regulations relevant to NGs should align with the IAEA's general safety requirement and then the annual occupational exposure should be limited up to 20 mSv. However, an external exposure monitoring all radiation workers of our NG facilities in Cambodia should be in place before we decide this limit of 20 mSv.

In this study, we suggest the office of nuclear safety, security, and safeguards under the MME as the government framework for regulating radiation safety. The structure of government responsibility and functions are based on the IAEA/GSR Part 1 and our national conditions. In a word, Cambodia has to formulate our national regulations that are consist with the international nuclear safety standards.

Recently, even though some health physicists insist that the ALARA should be removed entirely from the regulation for radiation protection, there seems to be no need to consider the matter in our rulemaking due to controversial issues up to the present.

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