XA0300151

IAEA-CN-90/22

NEW SAFETY PERFORMANCE INDICATORS FOR SAFETY ASSESSMENT OF RADIOACTIVE WASTE DISPOSAL FACILITIES. CUBAN EXPERIENCE.

J.L. Peralta Vital[1]; R.G. Castillo[1]; J. Olivera[2]

1 Center for Radiation Protection and Hygiene (CPHR)
2 Geophysics and Astronomy Institute (IGA)
e-mail: Peralta@cphr.edu.cu

Abstract

The paper shows the Cuban experience on implementing geological disposal of radioactive waste and the necessity for identifying new safety performance indicators for the safety assessment (SA) of radioactive waste disposal facilities. The selected indicator was the concentration of natural radioactive elements (U, Ra, Th, K) in the Cuban geologic environment. We have carried out a group of investigations, which have allowed characterising the concentration for the whole Country, creating a wide database where this indicator is associated with the lithology. The main lithologies in Cuba are: the sedimentary rocks (70 percent of national occurrence), which are present in the three regions (limestone and lutite), and finally the igneous and metamorphic rocks. The results show the concentrations ranges of the natural radionuclides associated fundamentally to the variation in the lithology and geographical area of the Country. In Cuba, the higher concentration (ppm) of Uranium and Radium are referenced to the Central region associated to Skarn, while for Thorium (ppm) and Potassium (%), in the East region the concentration peaks in Tuffs have been found. The concentrations ranges obtained are preliminary, they characterise the behaviour of this parameter for the Cuban geology, but they do not represent limits for safety assessment purposes yet. Also other factors should be taken into account as the assessment context, time scales and others assumptions before establishing the final concentration limits for the natural radionuclides as a radiological and nuclear safety performance indicator complementary to dose and risk for safety assessment for radiological and nuclear facilities.

1. Introduction

Cuba has been committed to the peaceful applications of ionising radiation in agriculture, medicine, industry and research in order to achieve social-economic development in diverse sectors. Consequently, the use of radioactive materials and radiation sources, the production of radioisotopes, may generate radioactive wastes which require safe and proper management. The Center for Radiation Protection and Hygiene (CPHR) is responsible for developing and implementing a national strategy about the management and safety assessment of radioactive wastes. The current approach is to disposal those wastes in two near surface concepts, a vault repository for low and intermediate radioactive waste and a borehole concept for the spent sources.

In the safety assessment, the use of safety indicators is the endpoint. a measure of the capacity of the isolation system for man and the environment from the risks associated to a radiological and nuclear practice. Safety indicators allow to compare the results obtained regarding national and international standards and regulations and to estimate the possible impact in the human and natural environment for a practice. In the radiation protection field, the common safety indicators are the dose and the risk, which are not suitable for all nuclear practices. They can be affected for different assumptions about the critical group, time schedule, uncertainties in the risk associated methodology fundamentally for long term safety assessment for radioactive waste disposal. Our experience in these subjects [1,2,3,4] shows the necessity to use and normalise new safety indicators, complementary to dose and risk, in order to reduce the uncertainties in the analysis. The new safety indicators would be less influenced for factors such as: critical groups, consumption habits, pathways, etc., whose behaviour is difficult to predict for long-time scales, and facilitate the defence of the results in a safety assessment. In relation with the safety assessment activities and the radiological protection principles [5], Cuba has been participating in two Co-ordinated Research Projects (CRP) with the IAEA on the topics of safety assessment and safety indicators ("Improvement of Safety Assessment Methodologies for near surface disposal facilities for radioactive waste" (ISAM) and "Use of safety indicators, complementary to dose and risk, in the assessment of radioactive waste disposal") [6].

Natural concentrations of radionuclides can provide an indication of the potential effect on humans and their environment, are quite stable in time and easy to implement as a safety indicator in the SA methodology. For this study, we have adopted as new safety indicator, the natural radionuclides concentration in the geologic environment, creating a wide database where this indicator is associated with the different lithologies in the Country.

2. General geologic characteristics of Cuba

The Cuban geology is very complex, due to their physical form and geographical position, an island is considered [7]. The country is geological constituted, in a general approach, for sedimentary formations of carbonated rocks (more 70%), which are represented for different lithologic transitions, the most representative rocks in this formation are the limestone, clay and sandstone. The 30 % remaining, is mainly formed, for metamorphic and igneous geologic formations, conformed for skarn, schist, granite and serpentine. For this reason, we have divided the Country in 3 regions (see Figure 1).

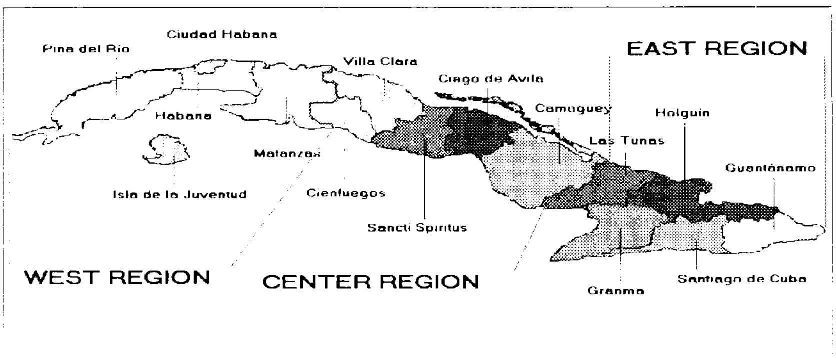

FIG.1. Studied regions. Map of Cuba

West region: this region has been created by the provinces of: Pinar del Río, Havana City and Matanzas. The area is geologically formed of Limestone, Sandstone, Schist and Lutites.

Central region: this region includes the provinces of: Villa Clara, Sancti Spiritus, Ciego de Avila and Camaguey. This area is geologically formed of Limestone, Serpentine, Skarn, Granite, Tuff, and Schist.

East region: this region includes the provinces of Holguín, Gramma, Guantánamo, and Santiago de Cuba. This area is geologically formed of Limestone, Schist, Tuff, Granite and Serpentine.

3. Investigations carried out for data collection

The investigations were based fundamentally on airborne gamma spectrometry for the Republic of Cuba and subsequent confirmation of anomalies in the terrestrial surface. Other data sources were the site selection studies for radioactive waste repository. For determining radionuclides concentration, gamma spectrometric and laboratory techniques were used. We have the information of the gamma spectrometric anomalies contained in each geological survey carried out in the country and some data of the radioactive anomalies detected in surface and wells. Data of flights do not exist in the province of Havana City: we are yet working on this data.

4. Results obtained

Table I shows the data collected overall Cuba, wide U, Ra, Th, K (ppm and %) distributions and Iγ (μR/h), giving the minimum/maximum values and the background of the total anomalies measured in the different regions (West, Central and East) of the Republic of Cuba, see Figure [1]. The maximum and minimum values have been referred to terrestrial, logging well, samples and anomalies gamma spectrometric airborne, carried out in different regions of the Republic of Cuba. The minimum values of Iγ correspond with the normal background for each region, taken directly of measurements carried out in different field itineraries.

Table I. Distribution of anomalies of Iγ, U, Ra, Th and K in the surface of the earth, logging wells, hole and the flights airborne gamma spectrometry.

Radioactive elements		REGIONS					
		WEST		**CENTER**		**EAST**	
		Aerial	**Terrest.**	**Aerial**	**Terrest.**	**Aerial**	**Terrest.**
Iγ (μR/h)	Minimum	0.66	5	0.54	4.6	0.60	5.75
	Maximum	5.25	643.3	3.31	268.00	5.59	11.25
U (ppm)	Minimum	0.73	0	1.40	1.00	0.93	1.25
	Maximum	9.6	1182	9.70	428.2	15.89	72.5
	Background	4.30	80.88	3.51	92.1	0.91	15.95
Ra (ppm)	Minimum	-	22	-	2.00	-	2.00
	Maximum	-	1067	-	917.00	-	87.5
	Background	-	71.53	-	191.53	-	13.89
Th (ppm)	Minimum	0.96	0	0.78	0	0.37	1.91
	Maximum	19.1	29.50	7.70	47.5	61.98	41.00
	Background	6.86	8.37	2.27	8.95	9.65	13.83
K (%)	Minimum	0.26	0	0.28	0.05	0.31	0.1
	Maximum	2.03	3.75	2.51	3.42	5.17	5.3
	Background	0.50	0.99	0.54	1.48	1.13	2.23
Studied lithologies		Limestone, Sandstone, Schist and Lutites		Limestone, Serpentine, Skarn, Granite, Tuff, and Schist		Limestone, Schist, Tuff, Granite and Serpentine	

According to Table I, in the west region, the biggest contribution is associated to the sedimentary rocks. Also, the different regions of the country differ in their results, for example, for the Uranium and the Ra, of the West and Central region had the highest values in the country, quite differentiated from the values of the East region, associates fundamentally to the limestone and skarn respectively. For the Th and the K there are not important variations among the data of the 3 regions, those results are an image of the different geology present in the areas.

As a result of the studies, in the whole country, the concentration distribution for the natural radioactive elements was obtained, associated to the main present lithologies. The variation of the concentrations is associated to the changes in the different lithologies, genesis, etc.

Table II shows the results according the different types of lithologies present in the country and the ranges of variation for the concentration for each element. The concentrations obtained characterise the regions of the country, the main rocks associated with this indicator, which are the main existent types in the Cuban geology.

Table II. Natural radionuclides concentration for rocks type.

Radioactive elements		**Main lithologies**								
		Regions								
		West			**Central**			**East**		
		Limestone	Lutite	Schist	Skarn	Limestone	Schist	Granite	Limestone	Tuff
U	*Min.*	1	33	5	2	8	0.50	5	2	5
(ppm)	*Max.*	673	488	229	3450	160	63	29	14	184
Ra	*Min.*	5	32	5	7	6	26	2	*	2
(ppm)	*Max.*	577	490	134	2500	50	628	22	*	129
Th	*Min.*	0	1	0.14	0.30	0	2.5	5	0.13	2
(ppm)	*Max.*	20	20	28	150	150	16	48	202	202.7
K (%)	*Min.*	0	0.10	0.10	0	0	0.50	0.30	0	0.2
	Max.	4	2	3.50	5	5	4	8.40	1.5	13.86

* not available concentrations in this rock.
Min.= Minimum ; Max.= Maximum

According to the Cuban geology where the sedimentary rocks are the majority (the limestone is included in the three regions), the West region possesses the maximum concentration values for U and Ra; for Th and K the relative peaks are located in the East and Central region. All these variations respond to the different geologic histories of the evaluated regions. For the igneous rocks, the granites possess relatively low values of natural radioelements concentration; the tuffs have interesting maximal values for Th and K. The metamorphic rocks included the Skarn. The Skarn rock has the higher concentration of U and Ra of natural occurrence in Cuba, which are associated to an anomalous area of the Centre of the country. The schist, in the West and Central regions, possess important values of concentration in Ra and U.

The results obtained showed the importance of the data collecting stage, because we obtained a general idea about the country distribution of the environment concentration. Besides, thanks to characterise the results by the main lithologies type for regions, we took into account our complex geology; and this way to avoid possible errors of generalisation of data that could induce to excessively preservative approaches. In others stages, this distribution by lithologies will allow the implementation as safety performance indicator.

5. Next stages

After this preliminary stage of data collecting, we have been analysing the results obtained in order to establish the concentration of natural radioelements as a safety indicator, inside the SA [8,9,10], for nuclear practice. It will be evaluated if the obtained values of concentrations (fundamentally the upper limits) can be defined as limits of concentration environment for a region or area, taking into account in a qualitative and quantitative way the occurrence of a negative impact on the environment and man. The obtained data collection will be incorporated in SA methodology for radioactive waste disposal facility in the Cuban environment, which include different stages such as, assessment context, characterisation system, scenarios generation, modelling and finally the results evaluation. These safety indicators will be the assessment endpoints supporting dose and risk considerations in SA methodology. The assessment should take account the specific characteristics of the geologic conditions, design of the nuclear facilities, etc. The basement of its calculations is the base of experiences of international investigations co-ordinated with the IAEA and the best practices of countries with high development in the nuclear topic. Finally, as a result of the SA, the ranges of variation of the concentration of the natural radioactive elements by lithologic types in the Cuban environment will be established.

The obtained indicators will allow their incorporation inside the methodology of the SA, in the stage of evaluation of the results as comparison measure to evaluate the possible impact of a nuclear practice. These indicators will establish the limits (concentration) of the natural occurrence of radioelements for different rock types; which should be fulfilled, in certain ranges to guarantee that the nuclear practice has no negative impact on environment and man.

6. Conclusions

- A wide database was obtained for three Cuban regions, characterising the natural elemental radioactive concentration and the range of variation for the lithologic types studied as a preliminary stage in order to use it in the safety assessment.
- In the Country, the main lithologies associated to the safety indicators adopted (Concentrations) are limestone, lutites, skarn, schist, granite and tuff.
- The concentrations of U vary in a wide range from 0.5 to 3450 ppm, the Radium from 2 to 2500 ppm, the Thorium from 0 to 203 ppm and the K from 0 to 14%. For all regions, the Central region has the rock (skarn) with the higher values in concentration of U and Ra.
- The studies carried out allowed to evaluate, for the first time in Cuba, the concentrations as a safety indicator for safety assessment of radioactive waste disposal facilities.

7. Recommendations

- Introduce SA, in order to establish the validity of the results obtained in the data collecting stage and so to establish the variation limits of the concentration of the natural radioactive elements in the environment as safety indicators.
- At these stages, consideration will need to be given to the presentation of natural safety indicators in a manner which is scientifically credible but also understandable by non-technical audiences.
- Do not replace dose and risk with natural safety indicators. Instead, natural safety indicators are considered to be complementary to dose and risk.
- Complete the database with information of the Havana area, in order to cover the whole country.

References

[1] PERALTA VITAL JOSÉ LUIS, GIL CASTILLO R. "Evaluación preliminar del Comportamiento del Diseño conceptual del Repositorio de desechos radiactivos de baja y media actividad". II Taller de Seguridad nuclear y radiológica. Cuba. (1996).

[2] PERALTA VITAL JOSÉ LUIS, GIL CASTILLO R. Y TORRES BERDEGUEZ M.. "Radioactive waste disposal system for Cuba. Safety assessment for a long term". Topical issues on radiation, radiological protection and radioactive waste disposal system. Vienna. Austria. (1998).

[3] GIL CASTILLO REINALDO, PERALTA VITAL J.L., Y BARRANCO. G. "Evaluación del posible impacto radiológico en el hombre ocasionado por el Sistema de evacuación de desechos radiactivos definido en Cuba". Symposium on Globalization of Nuclear activities. Brasil. (1997).

[4] IAEA. Protection of the environment from the effects of ionizing radiation. A report for discussion. IAEA-TECDOC-1091. Vienna. (1999).

[5] IAEA. "International Basic Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, jointly sponsored by the FAO, the IAEA, the ILO, the NEA/OECD, the PAGO and the WHO", Safety Series No 115-I. Austria. Vienna, (1994).

[6] IAEA. "Improvement of safety methodologies for near surface radioactive waste disposal facilities", ISAM Project. 1998.

[7] PERALTA VITAL JOSÉ LUIS Y GIL CASTILLO R.. "Proceso de selección de emplazamiento como criterio fundamental de la seguridad para el emplazamiento del Repositorio de desechos radiactivos en Cuba". (CD-CGEN 0011098) CGEN VII Congreso general energía Nuclear. Asociación Brasileña de energía nuclear. Belo Horizonte-Minas Gerais-Brasil. (1999).

[8] IAEA. Safety analysis methodologies for radioactive waste repositories in shallow ground. Safety Series No. 64. Austria. Vienna. (1984).

[9] IAEA. Safety indicators in different time frames for the safety assessment of underground radioactive waste repositories. First report of the INWAC Subgroup on Principles and Criteria for Radioactive Waste Disposal. IAEA-TECDOC-767. Vienna. (1994).

[10] IAEA. Safety indicators, complementary to dose and risk, for the assessment of radioactive waste disposal. Draft Report. Vienna. (1999).