OCCUPATIONAL EXPOSURE IN PRODUCTION OF RADIOPHARMACEUTICALS AND LABELED COMPOUNDS

Amador Balbona Z. H, Pérez Pijuán S., Soria Guevara M. A

Centre of Isotopes, Ave. Monumental y carretera La Rada, Km. $3_{1/2}$, Havana, Cuba.

zabalbona@centis.edu.cu

Abstract

The purpose of this paper is to assess the occupational exposure from radiopharmaceuticals production and labeled compounds in the Center of Isotopes of the Cuban Republic. Data belong to the period 1996÷ 2010 are processed and a total of 668 workers are controlled. Percentage distributions of the annual effective dose (E), equivalent dose to the hands (Hp (0.07)) and equivalent dose to the lens (Hp(3)) are showed. Annual mean values of these dosimetric magnitudes are plotted. Bioassay results are processed. Handling annual activities for the radioisotopes which have the largest contribution and their relation with collective dose (S) distribution are evaluated. ALARA principle is implemented and maintained considering qualitative and quantitative analysis as it is required. There are 58÷98% of the monitored workers for E, 80÷100% for Hp(0.07) and 80% for Hp(3) that received lower than 10% of the annual exposure limits. The staff belonging to departments of Radiopharmacy and Quality Control is the most exposed. The maximum value registered for S is 87 man-mSv y^{-1} and this occurs in 2010. In spite of this, the maximum handling activity of ^{99}Mo was in 2009 and a year later for ^{131}I. There are identified as the most useful tools from the point of view of the optimization of protection the use of electronic dosimeters, an additional shielding for the collection of radwastes and the internal shielding components in hot cells. It is obtained a dose reduction between 10÷27%. It is demonstrated the exposure of workers related with radiopharmaceuticals production in Cuba is acceptable low.

Keywords: occupational exposure, radioactive facility, radiopharmaceuticals, labeled compounds, ALARA.

Introduction

During the period 1996÷2010, the Center of Isotopes (CENTIS) of the Cuban Republic has produced radiopharmaceuticals and labeled compounds with ^{201}Tl, ^{131}I, ^{32}P, ^{99}Mo/^{99m}Tc, ^{125}I, ^{90}Y, ^{188}Re y ^{153}Sm. Analysis of processing data from individual radiological surveillance and of handling radioactive inventory for radioisotopes of bigger contribution to occupational exposure are presented in this paper. There are shown the main findings in ALARA principle application. Results reflect exposure of workers have been maintained below of the applicable dose constrains.

Materials and methods

- Processing data from registers of occupational exposure

As a part of radiation protection programme is implanted individual radiological surveillance. Through credit dosimetry, are controlled during 15 years the effective doses (E) of a total of 668 workers and 45 as annual average. Among 1996÷2000 in our country exists film dosimetry, control period of tree months and minimum detection level was 200 µSv. Nevertheless, since 2001 is used TLD dosimetry and control period is monthly, with 100 µSv as minimum detection level.

The reported uncertainty is less than 20 %. Determinations of the committed effective dose (E(50)) are including for controlled workers. Average distributions of effective dose (E), equivalent dose to the hands (Hp (0.07)) and equivalent dose to the lens (Hp(3)) are analyzed among intervals of their annual limits [1] as: <10%, ≥10% y <30%, ≥30% y <60% y ≥60% y <Annual Limit (AL). The effective collective dose (E) is calculated as: $S = \Sigma_i E_i N_i$ [2], where E_i

is the annual mean E for a group i and Ni is the amount of persons in this group. There is S determined for work group and the total staff. The contribution to annual total S of S for E $\geq$ 2 mSv is calculated as a percent.

- Analysis of handling radioactive inventory

Registers on the operation of opening packages [3] with solutions of ^{131}I, ^{99}Mo and ^{32}P are analyzed, because these radionuclides are the most contribution to occupational exposure. Their activities are calculated. For Radiopharmacy group is evaluated its distribution of S, since this group handling that inventory, with respect to the rest of staff and its relation with activities of these radioisotopes.

Applying the benchmarking technique, occupational exposure of CENTIS is compared with from the Nuclear Research Institute (IPEN) of Brazil in 1980. Average annual effective dose (E) of 1.46 mSv and the respective handling activity of ^{131}I as 1.22E+13 Bq from IPEN are used as references to analyze the behavior for CENTIS [10]. The plant of radiopharmaceuticals of IPEN is the best in Latin America.

- ALARA principle application

The principle ALARA (as low as reasonably achievable) is used taking into account quantities and qualities analysis in function of the case [4]. For assessment exposure by operation and the control the most risk, are used electronic dosimeters DOSICARD from Eurisys Mesures (France). With this dosimeters are measured personal deep equivalent dose Hp(10) from 1µSv up to 10mSv and rate doses to 1 Sv/h. They have light and sound alarms. It low register level and alarms haven been very useful when new practices are evaluated and control the most risk operations.

In the other hand, operations in hot cell for Molybdenum are evaluated to reduce exposure during operations, with additional shielding and considering the recollection of radioactive wastes during elution of generators. For reduce Hp(0.07) from beta emitters, which are more use in the last 3 years, are necessary evaluate the use of syringe protectors and these are introduced in practices.

Results

In tables 1 and 2 are shown the percent distribution of E and Hp(0.07). As it can see, 58-98% of monitoring workers for E and 80÷100% for Hp(0.07) receive less than their annual limits of exposure [1].

For Hp(3) up to 2010 we were applied the old annual limit and 100% of monitored workers received less than 10% of this. Nevertheless, in this moment we have adopted a new annual limit of 20 mSv by year [1]. Taking this value, the 80% of controlled workers received the 10% of the new limit.

In figure 1 are plotted annual mean values for E and Hp(3). The same is presented in figure 2 for Hp(0.07). The maximum values are in 2005 and 2008.

To reduce occupational exposure, we applied some measures. For instance, when will handle beta emitters, as ^{32}P and ^{90}Y, we introduce the use of syringe protector of 5 mL and 10 mL. This allows with shielding of 5 mm of Lucite obtain a reduction of rate dose in contact equal to 8.59E-05 (reduction factor) [5].

Table 1. Percent distribution of workers by range of the annual effective dose

Range of E	E< 2 mSv	(2 ≤ E< 6) mSv	(6 ≤ E< 12) mSv	(20≤ E < 50) mSv
1996	77	13	0	0
1997	82	6	0	0
1998	75	14	0	0
1999	66	17	0	0
2000	63	13	0	3
2001	74	5	0	0
2002	47	32	3	0
2003	62	19	0	0
2004	77	5	0	0
2005	73	7	2	0
2006	81	4	2	0
2007	78	2	0	0
2008	98	3	0	0
2009	90	10	0	0
2010	72	28	0	0

Table 2. Percent of workers by range of Hp(0.07)

Range of Hp(0.07)	Hp(0.07) < 50 mSv	(50 ≤ Hp(0.07) <150) mSv	(150 ≤ Hp(0.07) < 300) mSv	(300≤ Hp(0.07) < 500) mSv
1996	100	0	0	0
1997	100	0	0	0
1998	100	0	0	0
1999	100	0	0	0
2000	83	17	0	0
2001	88	12	0	0
2002	86	14	0	0
2003	84	16	0	0
2004	86	14	0	0
2005	80	20	0	0
2006	85	12	3	0
2007	86	14	0	0
2008	83	14	3	0
2009	93	5	2	0
2010	98	2	0	0

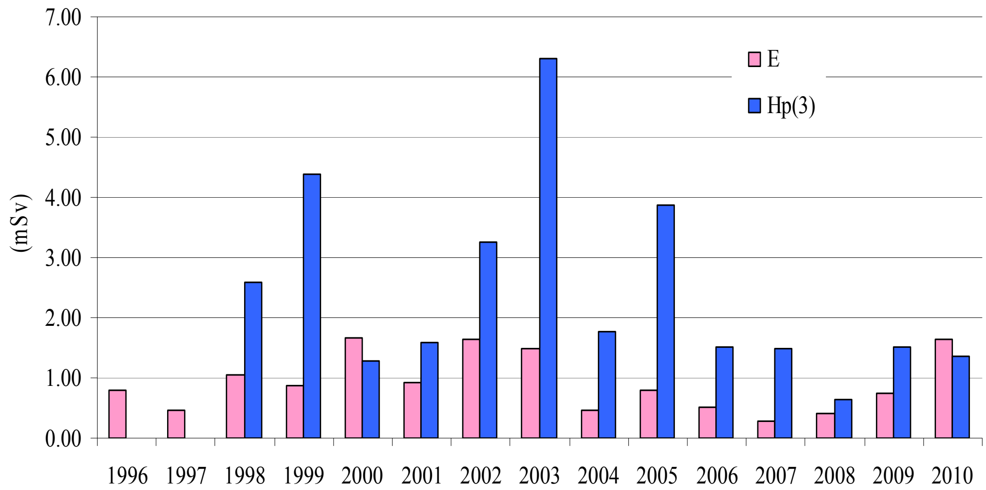

Figure 1. Values of annual mean effective dose and equivalent dose to lens

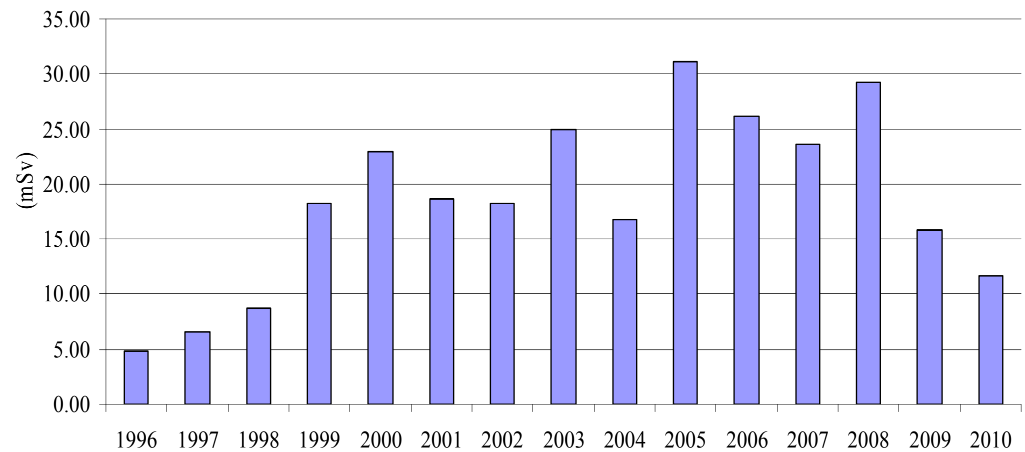

Figure 2. Values of annual mean equivalent dose to hands

The relationship between the maximum annual value of dosimetric quantities and their respective dose constrains can be observe in table 3. There we can see that only in two cases maximum values of E and Hp(0.07) are bigger than their respective dose constrains. These cases are investigated and safety measures were adopted for eliminate their recurrence. In 1996 and 1997 it is indicated as not controlled (NC) for Hp(3). The biggest values appear in year 2000 for E, 2006 for Hp(0.07) and 2003 for Hp(3). It should be appreciated that dose constrains are overcame in these two first moments. A worker of the group of Quality Control made all of the elution of generators and received 25.77 mSv, value superior of the limit as average for 5 years [1]. The work load was redistributed and a shielding of lead with 5 cm was situated. In the second case the procedure of intervention in hot cell with ^{131}I was analyzed. There was an incorrect manipulation for part of worker and this is the cause of the biggest value of Hp(0.07).

Table 3. Maximum values of dosimetric magnitudes and their dose constrains in CENTIS

	E (mSv)	Hp(0,07) (mSv)	Hp(3) (mSv)
Dose constrains	**12**	**200**	**15**
Year			
1996	4.73	8.15	NC
1997	4.02	8.56	
1998	10.27	17.85	2.60
1999	4.85	49.38	4.38
2000	**25.77**	65.43	1.27
2001	3.22	117.97	1.90
2002	7.06	97.94	8.47
2003	5.89	91.47	**12.09**
2004	4.17	73.41	5.14
2005	6.52	145.17	5.89
2006	6.09	**232.71**	3.49
2007	2.96	117.70	3.86
2008	4.28	168.38	2.18
2009	5.32	172.49	4.85
2010	5.14	60.68	3.85

When these values are compared with the project occupational exposure in normal conditions for maximum of E equal 5÷8 mSv y^{-1} [6], we can appreciate in table 3 that there are between 3 to 26 mSv y^{-1}. The biggest value was obtained in quality control activity of Technetium generators, which procedure was rectified due to this case. In the other hand the most reiterative value is around 5 mSv y^{-1}.

The use of internal shielding of 3 cm of lead for conditionings solution of Molybdenum in the hot cell of allows reducing in 27% the exposure of operator [7].

After the Technetium generator began, in 2004 are introduced new measures ALARA like the use of shielding of 6mm of lead for radioactive wastes receipts and additional shielding in the table where the generators are eluted [8]. There is a 10 % of reduction of exposure of staff. For this work the DOSICARD was very useful because rate dose and Hp(10) were measured for each operation and their resulting reductions were registered.

In the same way for the used glove box for the labeled compound with ^{131}I was introduced additional shielding of 18 mm of lead for transfers of samples and products in the controlled area.

Figure 3 shows values of S and amount of monitored workers (MW). We can conclude that the last do not determinate the value of S in the majority of the years.

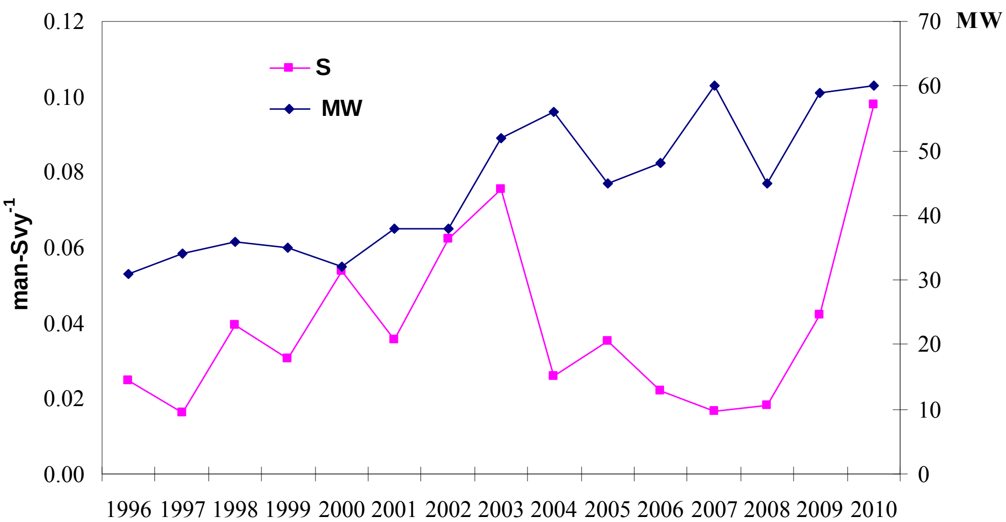

Figure 3. Collective dose vs. monitored workers

Table 4 reflects collective dose (S) by group of workers and it is between (15 y 98) man-mSvy^{-1}. The more exposed groups are Radiopharmacy and Quality Control, and their S for E equal and bigger than 2 mSv is 9÷53 % of the total annual value of S.

The beginning of production of Technetium generators in 2003 is the cause of values of S registered equal a 75 mSv-hombre a^{-1}. In 2010 the increase of handling activity of ^{131}I conduced to maximum value of S for the studied period equal 87 man-mSv y^{-1}. This is less than the initially projected value of 200 man-mSv y^{-1} for all the operations of production of radiopharmaceuticals and labeled compounds [9].

In table 5 are shown handling activities of ^{131}I, ^{99}Mo y ^{32}P, which are the radioisotopes with the most contribution to occupational exposure during 12 years in CENTIS, and the collective dose for all staff. This means that it is for the total of monitored workers.

Mean annual handling activities for ^{131}I, ^{99}Mo y ^{32}P are 4.5 TBq, 14.6 TBq and 0.2 TBq, respectively. Maximum activities were registered in 2010 y 2009, except for ^{32}P, that was in 2000. The annual increases of annual activities of ^{131}I were in 1998, 2001, 2004, 2007 and 2010. The production of Phosphate of Sodium (^{32}P) began in 1999 and its increases were presented in 2000 and during 2007÷10.

In the table 6 can be appreciated the relationship between CENTIS and IPEN (Brazil) from the correlation activity versus occupational exposure. When activity in CENTIS overcomes the value for IPEN, its exposure maintaining below of the IPEN and this is a good behavior. This not occurs in 2000, 2002, 2003 and 2010, for the before presented reasons. It means that there is an 11 years period of a good performance of radiation safety in CENTIS with respect of a studied a 15 years period.

Table 4. Collective dose by group of workers

Group of workers	S (Sv-hombre) 1E-03				
	Radiopharmacy	Quality Control	Development	Metrology	Radiation protection
1996	9.11	12.23	0.83	0.00	0.93
1997	5.19	5.51	0.64	1.53	1.19
1998	20.04	11.68	0.71	0.97	2.36
1999	18.80	6.59	0.00	1.45	3.43
2000	12.09	29.01	0.47	1.74	3.37
2001	12.88	5.86	0.82	3.77	4.26
2002	24.54	16.52	1.28	5.87	6.28
2003	29.09	22.88	1.49	7.95	4.69
2004	16.33	6.17	0.53	1.14	1.07
2005	19.94	9.46	0.88	1.95	1.45
2006	15.32	5.09	0.36	0.47	0.00
2007	9.76	5.21	0.63	0.16	0.55
2008	13.45	1.73	0.41	0.82	0.83
2009	27.29	6.27	2.70	2.35	1.42
2010	37.99	18.40	10.71	37.99	7.33

Table 5. Handling activities and collective dose for the total staff by year

Year	Handling activity ^{131}I (Bq y^{-1})	Handling activity ^{99}Mo (Bq y^{-1})	Handling activity ^{32}P (Bq y^{-1})	S (man-Sv y^{-1})
1996	No handling	3.20E+11	No handling	0.023
1997	7.33E+11	5.92E+11		0.014
1998	4.90E+12	5.39E+11		0.036
1999	4.87E+12	6.60E+11	1.19E+10	0.030
2000	4.84E+12	5.35E+11	3.64E+11	0.047
2001	4.88E+12	1.38E+12	3.43E+11	0.028
2002	4.60E+12	1.59E+12	2.35E+11	0.054
2003	3.94E+12	1.49E+13	2.35E+11	0.066
2004	4.71E+12	2.73E+13	1.93E+11	0.025
2005	4.08E+12	2.77E+13	9.75E+10	0.034
2006	3.28E+12	2.29E+13	5.45E+10	0.021
2007	4.91E+12	2.52E+13	8.27E+10	0.016
2008	4.33E+12	2.32E+13	2.03E+11	0.017
2009	5.76E+12	4.01E+13	2.24E+11	0.040
2010	7.09E+12	3.19E+13	3.17E+11	0.087

It is appreciated in figure 4 that there is a superior deviation on mean value of S of the Radiopharmacy group in 2002÷03, 2005 and 2009÷2010, due to increase of handling activities before analyzed with the biggest contribution to exposure of the production of Technetium generators.

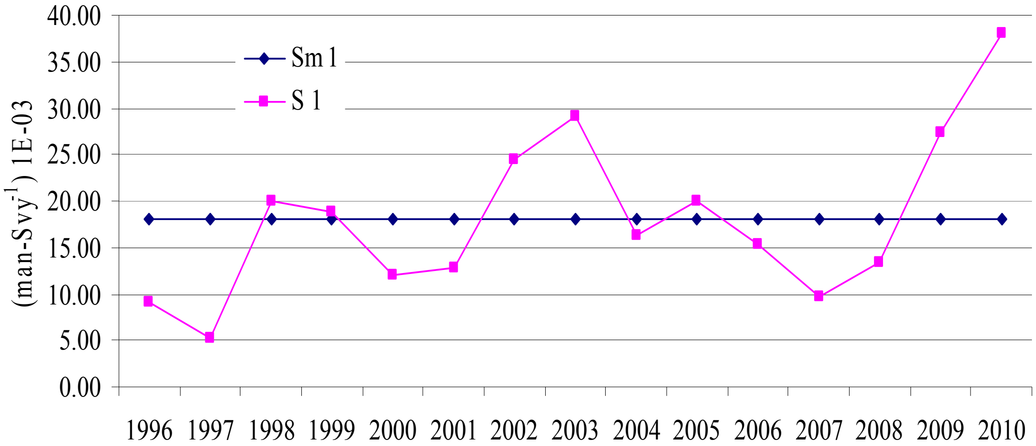

Figure 4. Annual collective dose and mean collective dose for the group of Radiopharmacy

Table 6. Annual Handling Activity in CENTIS to IPEN Ratio and Mean E for both of them Ratio

Year	Activity CENTIS vs. Activity IPEN	Mean E CENTIS vs. Mean E IPEN
1996	0.03	0.55
1997	0.11	0.32
1998	0.45	0.71
1999	0.45	0.60
2000	0.44	1.15
2001	0.51	0.64
2002	0.51	1.13
2003	1.54	1.01
2004	2.62	0.32
2005	2.60	0.54
2006	2.14	0.35
2007	2.47	0.19
2008	2.25	0.28
2009	3.76	0.51
2010	3.19	1.12

Conclusions

Analyzing data from radiological surveillance of workers of CENTIS we can appreciate that annually 58÷98% of monitored workers for E, 80÷100% for Hp(0.07) and 80% for Hp(3) receive less than the 10% of annual limits of exposure. The Radiopharmacy and Quality Control are the most exposure with their personal which receive E same o larger than 2 mSv, represents the 9÷60 % of the total staff. The biggest value of the collective dose for all of practices for production of radiopharmaceuticals and labeled compounds is 87 man-mSv y^{-1}, which is less than about 0.44 times the initially projected value.

Measures adopted for the application of the ALARA principle have allowed a reduction between 10 and 27 % of occupational exposure. The use of electronic dosemeters, the internal shielding in hot cells and the use of shielding for recollection of radioactive wastes have reported the biggest benefits. In the other hand, shielding of 5 mm of Lucite allows a reduction factor of 8.59E-05 of Hp(0.07) for beta emitters, which are a frequent employ since 5 years ago.

References

[1] International Atomic Energy Agency, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards Interim Edition, General Safety Requirements Part 3, No. GSR Part 3 (Interim), Vienna, Austria, 2011.

[2] Centre of Isotopes, Radiation Protection Department, Manual of Radiation Safety, DSR.DOC.001, Havana, Cuba, 2011.

[3] International Commission on Radiological Protection. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103, 2007.

[4] International Atomic Energy Agency, Optimization of Radiation Protection in the Control of Occupational Exposure, Safety Series No. 21, Vienna, 2004.

[5] Torres Berdeguez M.B., Ayra Pardo E., Falcon L., Doses Rate in Contact with Plastic Syringes of 1, 2 and 5 mL for Different Beta and Gamma Emitter Radionuclides, 12th International Congress of the International Radiation Protection Association, IRPA 12, Buenos Aires, Argentina, 2008.

[6] Perez S., Gatti A.M., Reyes R., Radiological Safety and Protection in the Design of the Centre of Production of Radiopharmaceuticals and Labeled Compounds in Cuba, Journal Nucleus N. 24, p.36-44, Havana, Cuba, 1998.

[7] Perez Pijuan, S., Gonzalez Fernandez, A., Radiological evaluation for preoperational test of Technetium Generators and its application to reduce occupational, Memories of the 1rst Symposium on Applications of Nuclear Technical in Agriculture, Industry and Health, Section III Dosimetry, Havana, 1997.

[8] Centre of Isotopes, Radiation Protection Department, Final Safety Report, CENTIS/DSR-144-001-C, Havana, Cuba, 2011.

[9] Centre of Isotopes, Radiation Protection Department, Final Safety Report, CENTIS/DSR-144-001-B, Havana, Cuba, 2000.

[10] Gerulis E., De Almeida E., Sanches Puga M., Automation Process and Optimization of Radiation Protection in Facility for Production of Radiopharmaceuticals, VI Regional Congress of IRPA on Radiation and Nuclear Safety, Lima, Peru, 2003.