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AN ATTEMPT TO EVALUATE THE RISKS ASSOCIATED WITH RADIOLOGICAL TERROR

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ABSTRACT

The evaluation of the risk of a terrorist attack has been made frequently by multiplying the probability of occurrence of a terrorist attempt by the probability of its success and a quantity which represents the consequences of a successful attack. In the case of a radiological attack the consequences will vary in case the action will be active or passive. Thirteen radionuclides were examined for their potential uses in credible threats or terrorist attacks based on their availability from laboratories and hospitals. Taking into account the dose conversion coefficients published by the International Atomic Energy Agency, those radionuclides with higher dose effectiveness for ingestion are the following: ^{210}Po; ^{226}Ra and ^{241}Am. Other radionuclides which can be used in threats and terror attacks, like ^{137}Cs for example have also been examined. The risks associated with the selected radionuclides have been tentatively ranked as high, medium, or low. The probability used to evaluate risks depends on the motivation of the terrorist and the capacity, which implies availability or the actual possibility of obtaining a particular radionuclide. On the other hand, whenever a list of radionuclides to be used in a malevolent action is available to a terrorist, the choice of the most adequate will depend also on the action to be undertaken. This work ranks risks associated with radiological terror based on physical, chemical, radio-toxicological and other relevant data on radionuclides, which were either already used in terror attacks, or were pointed out as adequate to be used in such malevolent actions.

Keywords:Radionuclides, radiological risk, terrorism

Note: This article has been written over the year of 2010. At that time, Dr Alselmo Sales Paschoa was affiliated to the State University of Rio de Janeiro. He deceased on 24/03/2011 while participating on a meeting of the Commission for the Evaluation of the Brazilian Nuclear Programme.

1. INTRODUCTION

The subject of nuclear terror has been discussed in a number of published and unpublished studies, before and after the 9/11 tragic episode in the United States. Radiological terror, on the other hand, has not received as much attention, with the exception of the so called Radiological Dispersion Devices (RDDs).

The episode of ^{210}Po poisoning of the former Soviet spy Alexander Litvinenko, who died in London on November 24, 2007, raised suspicions that a number of radionuclides may be used in criminal acts, or even terrorism. The episode of Litvinenko poisoning is emblematic in the sense that still today there are doubts regarding the *modus operandi* of the perpetrator(s).

The Scotland Yard said at the very beginning of the investigation that "traces of ^{210}Po were found at the Itsu sushi restaurant in Piccadilly, the Millennium Hotel, Grosvenor Square, and at Mr. Litvinenko's home in Muswell Hill, London." At that time the Scotland Yard did not elaborate further. Later on, the head of the radiation protection branch of the Health Protection Agency (HPA), Roger Cox, said in an interview that "a large quantity of alpha radiation from ^{210}Po was found in the urine of Mr. Litvinenko."

Speculations have been around to understand why ^{210}Po was chosen to poison Mr. Litvinenko. Most of them are related to the apparently difficulty to detect traces of ^{210}Po in a person who has ingested it. Such speculations can only be made by persons who are not familiar with the great deal of research carried out since the years 1960s regarding the metabolism and biological effects of ^{210}Po, and its presence in nature [1, 2].

It is enlightening to read the summary of Mr. Litvinenko's post-mortem data presented recently [3]. The body intake was estimated to be 15 GBq. A germane question is – how such high ^{210}Po activity (corresponding to about 0.09 mg of ^{210}Po) would end up within Mr. Litvinenko's body?

In an interview for the Sunday Telegraph published on July 17, 2007 the waiter at the Itsu sushi restaurant declared that it was likely that ^{210}Po was added to a pot of green tea. Taking into account that 0.09 mg of ^{210}Po was found in Mr. Litvinenko's body, the concentration of ^{210}Po in the tea had to be rather large, or he had to drink a quite large volume of tea. The authors could not find any clue about the ^{210}Po concentration found in the tea.

On the other hand, the concentration of ^{210}Po in coastal waters has been extensively studied. It varies from about 0.3 up to 35 Bq.m^{-3}, thus encompassing three orders of magnitude [4, 5, 6, 7]. Taking into account that the concentration factor (CF) for ^{210}Po from water to plankton, including seaweed, is of the order of 10^4, one can easily make a scenario that a sushi diet enriched in ^{210}Po is a strong candidate for poisoning Mr. Litvinenko. Data on ^{210}Po concentration factor of the order of 10^4 have been published several times in the open literature [7, 8, 9, 10, 11, 12]. There are claims that ^{210}Po had been taken clandestinely from the Sarov city (the former Arzamas-16 secret weapons laboratory), which if this was true it would make credible the whole scenario presented here.

2. MATERIALS AND METHODS

Some Radionuclides available for radiological terrorism

When one mentions radiological terrorism a Radiological Dispersion Device (RDD) comes usually to the mind. However, as it has been already explained a radiological attack can be either active or passive [3]. The choice of a radionuclide to be used depends on the type of attack that the terrorist intends to deflagrate. Table 1 lists a selection of radionuclides considered adequate for radiological attacks. It must be mentioned that there are quite a variety of radionuclides which can also be used for terror attacks, but most of those listed in Table 1 are fairly easy to obtain either in hospitals, or research and industrial laboratories.

Table 1: A selection of radionuclides with potential to be used in terror attacks

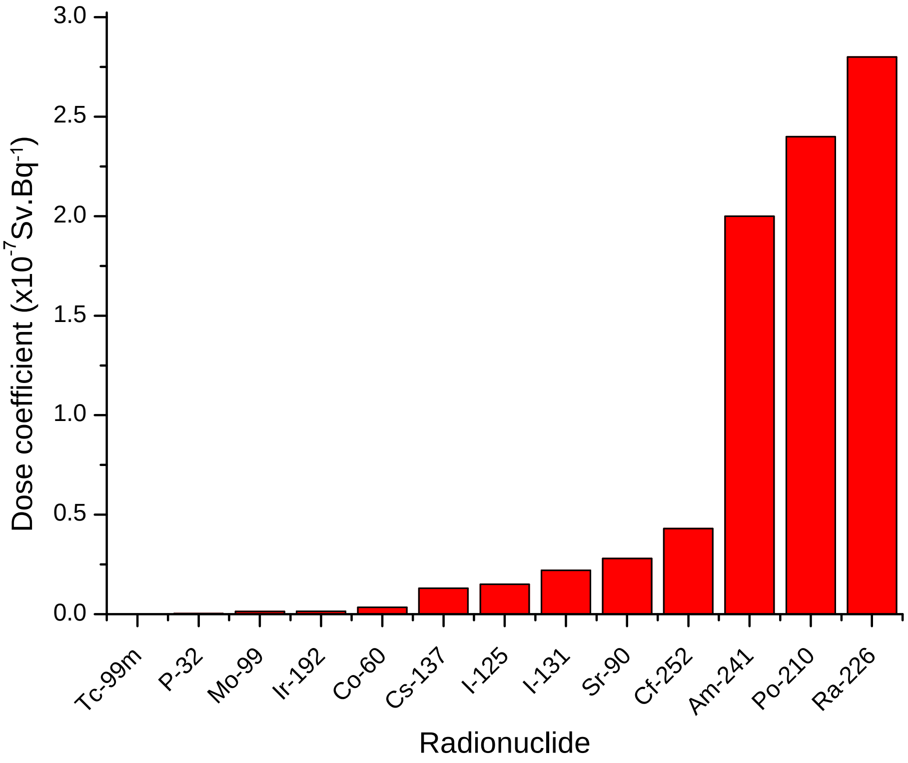
Radionuclide		[a]**Half-life (years)**	[b]**Specific activity (GBq.g^{-1})**	[c]**Dose coefficients (Sv.Bq^{-1})**		**Source**
				[d]**Inhalation**	**Ingestion**	
1	^{241}Am	432	1.18 x 10^{2}	3.9 x 10^{-5}	2.0 x 10^{-7}	Lab[e], Ind[f]
2	^{252}Cf	898	2.4 x 10^{4}	8.3 x 10^{-6}	4.3 x 10^{-8}	Lab
3	^{137}Cs	30	3.6 x 10^{3}	4.8 x 10^{-9}	1.3 x 10^{-8}	Lab, Hosp[g], Ind
4	^{60}Co	5.3	4.1 x 10^{4}	9.6 x 10^{-9}	3.4 x 10^{-9}	Lab, Hosp, Ind
5	^{125}I	0.16	6.3 x 10^{5}	1.4 x 10^{-8}	1.5 x 10^{-8}	Hosp
6	^{131}I	2.2 x 10^{-2}	4.4 x 10^{6}	2.0 x 10^{-8}	2.2 x 10^{-8}	Lab, Hosp
7	^{192}Ir	0.20	3.4 x 10^{5}	6.3 x 10^{-9}	1.4 x 10^{-9}	Lab, Hosp
8	^{32}P	3.9 x 10^{-2}	1.1 x 10^{7}	3.2 x 10^{-9}	2.3 x 10^{-10}	Lab
9	^{210}Po	0.38	1.7 x 10^{5}	3.9 x 10^{-6}	2.4 x 10^{-7}	Lab, Ind
10	^{226}Ra	1.6 x 10^{3}	37	3.2 x 10^{-6}	2.8 x 10^{-7}	Lab, Ind
11	^{90}Sr	29	5.6 x 10^{3}	1.5 x 10^{-7}	2.8 x 10^{-8}	Lab
12	^{99m}Tc	6.8 x 10^{-4}	1.9 x 10^{8}	1.2 x 10^{-11}	2.2 x 10^{-11}	Hosp
13	^{99}Mo	7.5 x 10^{-3}	1.7 x 10^{7}	9.7 x 10^{-10}	1.3 x 10^{-9}	Lab

[a] Based on ICRP Publication 38 [14]
[b] http://www.iem-inc.com.toospar.html
[c] IAEA Safety Guide RS-G-1.2 [15]
[d] All except I-125 and I-131 have AMAD = 1μm
[e] Lab = laboratory
[f] Ind = industry
[g] Hosp = hospital

3. RESULTS AND DISCUSSIONS

Fig. 1 is a graph of the Dose Coefficient (Sv.Bq^{-1}) as a function of radionuclide. One can easily see from Table 1 and Fig.1 that the radionuclides ^{226}Ra, ^{210}Po, and ^{241}Am have much higher dose coefficients than all other listed. This means that these three radionuclides have higher dose effectiveness per Bq ingested. Other radionuclides like ^{252}Cf, ^{90}Sr, and ^{137}Cs deliver also high dose effectiveness per Bq ingested, but to a lesser extent.

Figure 1: Comparison of dose coefficient (x10^{-7}Sv.Bq^{-1}) for selected radionuclides



Thus, for an attempt which would involve ingesting a radionuclide, the three radionuclides of choice should be ^{241}Am, ^{210}Po, or ^{226}Ra. The final choice would depend on how easy or difficult would be to obtain one of these three selected alpha emitters.

Extreme care should be exercised when those radionuclides are stored in any place. If a terrorist (or a group of terrorists) has access to an amount of a radionuclide which can deliver doses many times higher than the dose limit for a particular radionuclide, the way to deliver a fatal dose by means of ingesting this radionuclide becomes a matter of choice and capability to obtain it.

Taking into consideration that 4.5 Sv is a reasonable assumption for a fatal dose, Table 2 lists the body burden activities of ^{241}Am, ^{210}Po, or ^{226}Ra plus the same for ^{252}Cf, ^{90}Sr, and ^{137}Cs, which would have to be ingested to cause a person to die from radiation.

Table 2: Body burden of selected radionuclides to cause the death of a person

Radionuclide	Fatal body burden (MBq) – mass (µg)	[a]Mode of attack
^{241}Am	22.5 – 190	Active or passive
^{210}Po	18.8 – 0.11	Active or passive
^{226}Ra	16.1 – 440	Active or passive
^{252}Cf	105 – 4.4	Active
^{90}Sr	161 – 29	Active
^{137}Cs	346 – 96	Active or passive

[a]See Steinhäusler et al [3] for potential effects

Table 2 lists the radionuclides which can be used in radiological attacks per body burdens necessary to deliver fatal doses, as well as the mass of each radionuclide associated with the respective fatal body burden. Such data allows one to rank in accordance with fatal body burden (^{241}Am < ^{210}Po < ^{226}Ra < ^{252}Cf < ^{90}Sr < ^{137}Cs), and by mass needed to attain the fatal dose (^{210}Po < ^{252}Cf < ^{90}Sr < ^{137}Cs < ^{241}Am < ^{226}Ra). Considering together these two ranks ^{210}Po presents the intrinsic advantage of small body burden and small mass to achieve a fatal result.

4. CONCLUSIONS

Taking into account the information available in the open literature, this work presents a innovative version of the *modus operandi* of the perpetrator(s) in the episode of poisoning Mr. Alexander Litvinenko.

Those radionuclides considered to be better choices for a radiological attack by means of ingestion are ranked in accordance with fatal body burden (^{241}Am < ^{210}Po < ^{226}Ra < ^{252}Cf < ^{90}Sr < ^{137}Cs), and based on the amount of mass corresponding these body burdens (^{210}Po < ^{252}Cf < ^{90}Sr < ^{137}Cs < ^{241}Am < ^{226}Ra). It becomes clear that ^{210}Po ranks well in both ways. This does not imply that ^{210}Po was chosen to poison Mr. Litvinenko because of its ranking. However, the ranks presented here may be helpful in the discussion of pre-emptive counter measures to be taken to decrease risks associated with radiological terror.

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