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New filter for iodine applied in nuclear medicine services

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HIGHLIGHTS

- Production of a new filter for use in nuclear medicine clinics.
- Application of radioactive tracers to evaluate the efficiency of filters.
- Production of gases containing radioactive iodines: Methyl Iodide (CH_3I) and elemental iodine (I_2).

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ABSTRACT

In Nuclear Medicine, radioiodine, in various chemical forms, is a key tracer used in diagnostic practices and/or therapy. Medical professionals may incorporate radioactive iodine during the preparation of the dose to be administered to the patient. In radioactive iodine therapy doses ranging from 3.7 to 7.4 GBq per patient are employed. Thus, aiming at reducing the risk of occupational contamination, we developed a low cost filter to be installed at the exit of the exhaust system (where doses of radioiodine are handled within fume hoods, and new filters will be installed at their exit), using domestic technology. The effectiveness of radioactive iodine retention by silver impregnated silica [10%] crystals and natural activated carbon was verified using radiotracer techniques. The results showed that natural activated carbon and silver impregnated silica are effective for I_2 capture with large or small amounts of substrate but the use of activated carbon is restricted due to its low flash point (423 K). Besides, when poisoned by organic solvents, this flash point may become lower, causing explosions if absorbing large amounts of nitrates. To hold the CH_3I gas, it was necessary to use natural activated carbon since it was not absorbed by SiO_2+Ag crystals. We concluded that, for an exhaust flow range of (145 ± 2) m^3/h, a double stage filter using SiO_2+Ag in the first stage and natural activated carbon in the second stage is sufficient to meet radiological safety requirements.

1. Introduction

Professionals from the medical area may be exposed to radiation during dose preparation, patient administration or image capturing. The external or internal doses received during the preparation of the compound to be administered vary according to the adopted procedure.

Radioactive iodine is one of the most used elements in Nuclear Medicine for carcinogenicity studies of the thyroid gland, due to its great affinity to the thyroid gland tissue. The thyroid gland absorption rate is of approximately 30% of the inhaled iodine (Thrall and Ziessman, 1995).

The great volatility of this element increases the risk of incorporation during administration by the professionals who exercise this occupational activity. The routine manipulation of solutions containing radioactive iodine involves significant internal contamination hazards of these professionals.

For iodine manipulation it is necessary to have exhaust hoods, with specific filtering elements for each exhausted element. These filtering elements are imported, produced for nuclear power plants or nuclear fuel reprocessing industries but have a short service life, and thus must be monthly changed. These facts increase their cost hampering their acquisition by Nuclear Medicine Clinics (NMC).

Air extraction systems are complex because volatile molecules are not captured by conventional air filters. In general, in these

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environments (NMC), there are filters known as HEPA (High Efficiency Particulate Air) used in laboratories' fume hoods. HEPA is a type of filter that only retains particulates of up to 0.3 μm (aerosols, post-toxics, bacteria, mites, fungi, etc.), IAEA (1970). To retain the gases generated by volatile solutions (much smaller sizes), special filters are required for capturing specific gases, such as CH_3I molecules with a density of 2.28 g/cm^3 (organic molecules) and I_2 with a density of 4.93 g/cm^3 (representative of inorganic molecules).

In this context, this research aimed to develop a new, low cost, element regenerating filter capable of efficiently immobilizing the volatile radioactive iodine compounds (CH_3I and I_2) present in the environment of a nuclear medicine clinic using domestic technology (Herraman et al., 1991; Lee et al., 1991; Funabashi et al., 1994; Takeshita and Takashima, 1995; Lee and Park, 1996; Sakurai et al., 1997; Park et al., 2000; Kornienko et al., 2004; Lin et al., 2006).

To evaluate the efficiency of radioactive gas retention in the filter, we used the tracer technique known as "Stimulus–Response", which consists of adding a quantity of marked material (radioactive) in a given system and register it through meters (radiation detectors). The detectors shall be properly positioned, one at input and the other at the system output. The passage of the radioactive cloud, recorded by detectors, generates functions known as Residence Time Distribution (RTD). These functions permit the analysis of the efficiency of filter element retention, as well as the calculation of the average residence time of the radioactive gas, and its flow (IAEA, 1990; Danckwerts, 1953; Ramos, 2006).

The radiotracer technique allows choosing between continuous or instant injection. Due to the formation of continuous pulse in the production unit, a carrier gas is required, which ends up generating radioactive vapors that also reach the filter and are adsorbed at the entrance of the filter. Contaminated vapors help increase the background of measures, making it impossible to carry out successive measures. The instant injection process, which does not use carrier gas, does not generate these fumes, only producing radioactive gases and, therefore, the instantaneous injection process was used in most experiments.

2. Equipment and methodology

For the acquisition of experimental data, we needed a set of essential equipment for each detector. Each set was connected to the ADC (Analog to Digital Converter) converter board and coupled to a microcomputer to process data. The manufacturer and model of the electronics used in the experiments are listed below and represented by the block diagram shown in Fig. 1.

- DET—NaI scintillation detector (1″ × 1″), HARSHAW, Integral Line Model;
- AT—High-voltage power, Micronal, Model 1023 A;
- PA—Pre-amplifier, ORTEC, Model 113;
- AMPL—Amplifier with Active Filter, ORTEC, Model 435 A;
- AMC—Single Channel Analyzer, MICRONAL, Model 4010;
- MTC—Count Rate Meter, ORTEC, Model 449-2;
- ADC—Microcomputer and ADC converter board, NATIONAL INSTRUMENTS, Model BNC-2110;
- 1 kV A Variac, Powerstat, Model 116;
- Mini Centrifugal Exhauster from Qualitas, Model MCQ 200 M4.

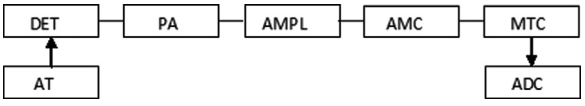

Fig. 1. Set of electronic modules for monitoring the radiotracer.

To be recorded, signals are processed by the set of acquisition and analyzed by an ADC converter board, coupled to a microcomputer, which allows the conversion of data needed to monitor the tracer. The converter board comprises thirty two independent channels, which enable, through the LabVIEW program, multiple acquisitions and adjustment of the acquisition time. Measuring instruments (detectors and associated electronics) were calibrated with sealed radioactive sources, in order to standardize each set of measurement (detector+electronics), in relation to their energy and efficiency, and enable the comparison of counts recorded by detectors.

To simulate the release of radioactive gases characteristic of a nuclear medical environment, a "gas production unit" was used. This unit was produced by Radiotracers Laboratory from IEN/CNEN (RT-IEN-04, 2010). The gas production unit is compact (0.3 l of volume), and is made in Teflon and o-ring for sealing. It has two inputs and one output (nylon duct with a 6.35 mm diameter), which are controlled by a butterfly valve type (open/close). To provide the necessary heat to chemical reactions, we used a Variac coupled to a thermal ribbon (HIGHERFLEX WRTFI-1-1.2), which involves the unit.

The unit shown in Fig. 2 is operationally simple and is sealed by six screws and six nuts and surrounded by a thermal strip which is connected to a Variac. Reagents enter valve 1 through a precision pipette (the latter reagent to be added is the one that contains the marked isotope). Valve 2, which is only open for continuous injection experiments, enters the carrier gas. Valve 3 (for output), when opened, releases the gas coming out under pressure, due to preheating or exothermic reactions occurring within the unit. For continuous injection experiments, valve 3 and valve 2 are opened simultaneously for a given time (1 to 60 s). The instantaneous injection is executed by manually opening and closing valve 3, which remains open for less than 1 s. The whole operation is delayed, always reproducing the heating time and measurement intervals between experiments.

With this unit, there has been three types of gases and, in this production, we selected the ^{82}Br (half-life = 36 h) in the form of methyl bromide (CH_3Br) used to simulate an inert gas and allow the calculation of the system flow, and ^{123}I (half-life = 13.2 h), to verify the capacity of adsorption or absorption on selected substrates. The ^{123}I was used in the form of elemental iodine, I_2 (inorganic) and methyl iodide CH_3I (organic), and these two molecules are most likely found in a nuclear medicine environment (IAEA, 1973).

The ^{82}Br was produced through the neutron activation technique, coming from the irradiation channel, J9, next to the core of the Argonauta reactor from IEN/CNEN, in a continuous flow of 3.2×10^9 neutrons/cm^2 s (RT-IEN-11, 2002). The salt KBr (potassium bromide), when irradiated, produces radioactive bromine, ^{82}Br, and, from this salt, the gas CH_3Br is produced. Being an inert gas, it does not react with the environment or with adsorbents used as porous media in the filter. Several problems occur when the gas reacts with the environment, particularly, changes in the flow profile.

For the synthesis of the CH_3Br gas in the reaction vessel, 6 ml of dimethyl sulfate, $(CH_3)_2SO_4$, were added to 3 ml of sulfuric acid, H_2SO_4 [9 M] and 15 ml of a solution of potassium bromide, KBr [4 M] (RT-IEN-05, 2010). As the chemical reaction is not spontaneous at room temperature, it was necessary to heat the unit from 343 K to 353 K. The Methyl Bromide gas was generated half an hour after the beginning of heating, according to the chemical reaction

$$2K^{82}Br_{(s)} + (CH_3)_2SO_{4(l)} \overset{H_2SO_4}{\longleftrightarrow} 2CH_3{}^{82}Br_{(g)}\uparrow + K_2SO_{4(s)}$$

With this reaction, 1.5 l of radioactive gas were produced, a volume capable of generating up to eight instantaneous pulses