2024 International Nuclear Atlantic Conference – INAC 2024
Escola de Guerra Naval, Rio de Janeiro, RJ, May 6 - 10, 2024

ISBN: 978-65-594-1256-3

Sampling of Radioactive Materials via Laser Ablation

G. S. P. Pompei*, M. P. Raele, P. Matos, R. F. da Costa and G. P. P. da Silva

**gabriel.pompei@usp.br, Nuclear and Energy Research Institute, IPEN-CNEN/SP, Av. Prof. Lineu Prestes, 2242, Cidade Universitária, São Paulo, SP, Brasil.*

1. Introduction

The characterization of radioactive contaminated materials as well as their disposal is a subject that can be of major interest to industries where the management of materials of radioactive nature is part of their routine (for instance, the medical industry, which uses ionizing radiation based technologies like CT scan machines). Thus, considering the problem, comes the challenge of finding ways to develop and test methods of surface and material decontamination as a means to reduce the amount of radioactive activity and make the process of disposal (or containment) of the material easier and more environmentally friendly.

An established method for this purpose is known as the wipe test [1] where a piece of appropriated paper is rubbed against the surface of interest in which non gamma emitters could be present. In this process some percentage of the isotopic inventory is transferred to the paper, which can be analyzed later in the laboratory. However, it is impossible to ensure that the different contaminants have been transferred in the same ratio due to chemical affinities, for instance. The removal of contaminated surfaces in materials using lasers has been reported [2-4] to be an efficient method for this purpose, one possibility could be to evaporate the very surface using laser ablation [5] and eject the contaminants, which can then be captured. It is reported in the literature [6] that for intensities above 10^9 W/cm^2 the ablation is considered stoichiometric, ensuring that the ejected material represents the surface of interest. For a brief summary, in this method a nanosecond pulsed laser can be used to transfer a portion of energy to a sample, causing the contaminated surface to evaporate due to the high intensity of the laser beam during the process and can then be collected by an aspiration and filtration system.

In the following study, the main goal is to evaluate the radioactive material transferred from a contaminated surface to a HEPA filter using laser ablation.

2. Methodology

During the preparation for the experiment, the team chose from a collection of samples that were previously contaminated utilizing electrodeposition, three of the ones with the highest count of Beta-Gamma radiation, in order to get a more precise visualization on how the amount of radioactivity would be affected before and after the experimental procedure. The Beta-Gamma radiation of the samples was measured using a Ludlum Measurement, Inc model 2929 with model 43-10-1 detector, whose background radiation was measured twice, the first time during one hour and the second time during five minutes. After measuring the background radiation (or BG, as we will refer to in the tables) of the detector, the team measured, during five minutes, the initial Beta-Gamma activity of the samples (labeled S1, S2 and S3) that were chosen.

The experimental arrangement (Fig. 1) consisted of a Q-Switched Nd:YAG laser (Quantel Ultra 100) set to utilize a fluence equivalent to 10 J/cm^2; the laser is integrated with a collection of lenses positioned to focus the laser beam into the contaminated sample. At a distance of approximately 3 mm (Fig. 2) from the support of the sample there is a structure (Fig. 1) built to suck the contaminated particles that are evaporated during the laser ablation; the suction system consists of a brown "L" shaped PVC part with a opening to let the laser beam pass through, which is also connected to a white PVC part that contains the filter responsible for collecting the evaporated materials. The mentioned structure is connected to a vacuum that will help suck the contaminated particles to the HEPA filter.

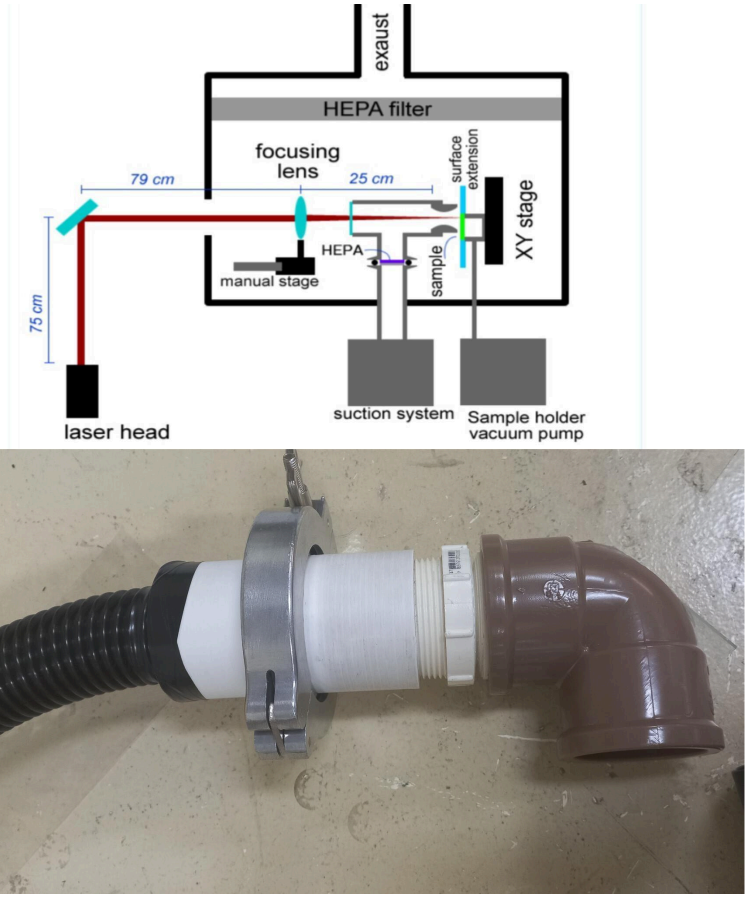

Figure 1: Diagram of the experimental arrangement (top) and structure used in the suction system (bottom).

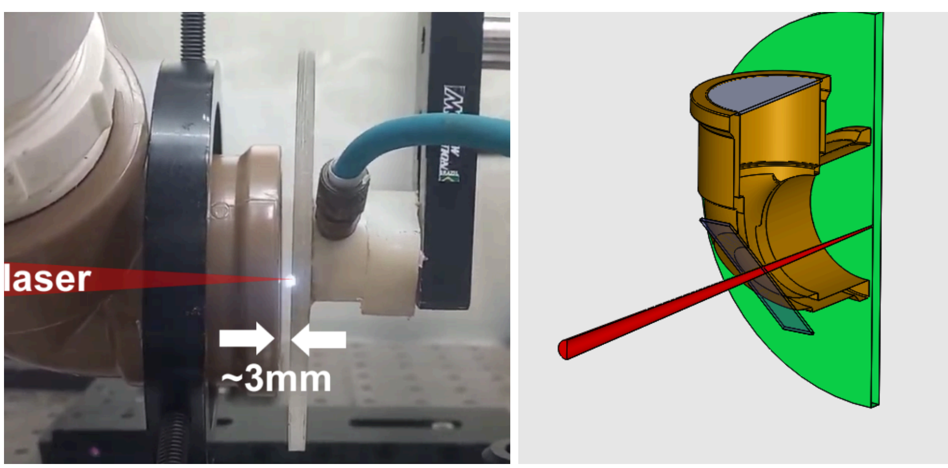

Figure 2: View of the suction system

As mentioned during the introduction, the procedure adopted during this research consists of ablating the material utilizing the laser and then collecting the evaporated material from the sample in a filter. The main goal of the team was to verify how much contaminated material the method would be able to transfer to the HEPA filter from the sample given the configuration built in the experimental arrangement for the ablation. To achieve this, the team chose to utilize a HEPA filter as the collector for the ablated material, considering that in previous studies [7] it was found that the HEPA filter was the most capable of capturing the contaminated particles that were ejected from the samples; the procedure adopted during the experiment was to ablate each of the three samples and then measure the levels of Beta-Gamma radiations of the samples and the HEPA filter. The results obtained from the levels of Beta-Gamma radiation of the samples and the HEPA filter after the ablation would be able to tell, by comparing with the initial measurements of radiation, further insights on the effects of the ablation method for decontamination as well as how effective the arrangement of the experiment is for transferring the contaminated material into the HEPA filter for later disposal.

3. Results and Discussion

After realizing the experiment for each sample chosen for the experiment, the results regarding the radioactivity of the decontaminated samples as well as the activity that was transferred to the HEPA filter can be seen in Table I. Each sample had their contaminated particles transferred to their respective HEPA filters during the ablation with the help of the vacuum suction. We will denote by FS1, FS2 and FS3 the filters that collected the materials from the samples S1, S2 and S3 respectively.

Table I: Radiation measurements before and after.

	ALPHA	BETA-GAMMA	TIME OF MEASURE
BG1	29	465	5 min
S1(BEFORE)	12	4968	5 min
S2(BEFORE)	9	5100	5 min
S3(BEFORE)	12	1448	5 min
S1(AFTER)	8	4762	5 min
S2(AFTER)	17	5253	5 min
S3(AFTER)	3	1136	5 min
FS1	98	470	5 min
FS2	90	306	5 min
FS3	232	872	5 min

By observing the final results of the samples and each of their HEPA filters, it is safe to say that the filters managed to absorb a substantial amount of the radioactivity, indicating that the experimental arrangement was successful at being able to transfer the evaporated material from the ablation with the help of the vacuum suck into the filters of each sample. The final slight dark colorings as well as the Beta-Gamma values of the HEPA filters are a good sign that they were able to contain a portion of the radioactive particles. Analyzing the data gathered in Table I, it can be seen that each filter has collected a fraction of the sample's radiation, as shown by their acquired Beta-Gamma activity after the procedure. To understand how much of each sample was captured by each HEPA filter, the team verified the percentages of the initial Beta-Gamma activities of the respective samples that were retained in the filters after the experiment (dividing the filter's amount by the initial Beta-Gamma activity of the sample); it follows that FS1 retained 10%, FS2 retained 6% and FS3 retained 60% of their respective samples, approximately.

Although the final appearance of the samples and the measurements of the HEPA filters show that the application of the ablation method in the proposed experimental arrangement worked, it is still possible to see that, besides samples 1 and 3 (S1 and S3), sample 2 (S2) had his final Beta-Gamma radiation readings above their initial values, which means that the sample was not effectively decontaminated during the experiment. Samples 1 and 3, however, had a significant reduction in their final Beta-Gamma radiation reading, showing that the sample was substantially decontaminated.

4. Conclusions

Considering the results obtained from the experiment done, it was evident that the experimental arrangement thought for this project was capable of decontaminating samples and transferring the radioactive particles ablated from the material into the HEPA filters. For future experiments, the objective is to investigate the causes of the increase of the final Beta-Gamma activities in the samples, in order to fix the issue and manage to decontaminate all samples more effectively, and also, increase the amount of contaminated material transferred from the samples to the HEPA filter.

Acknowledgements

The authors acknowledge the support given by the Brazilian National Council for Scientific and Technological Development – CNPq, grants 465763/2014-6, 407077/2023-5 and Sisfóton 440228/2021-2.

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