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

Potential of Ionizing Radiation Application for Reducing Environmental Risks Related to Solids Residues

S.I. Borrely[1], M.V. Vogt[2], S. Aquino[1] and J. Pachado[2]

[1] *sborrely@ipen.br, Instituto de Pesquisas Energéticas e Nucleares, IPEN/CNEN-SP*
[2] *veronicavogt@cnea.gob.ar, Gerencia de Aplicaciones y Tecnologías de las Radiaciones, Comisión Nacional de Energía Atómica (CNEA), Argentina*

1. Introduction

The capacity of ionizing radiation for controlling microorganisms in diverse type of matrices is recognized in the world. Radiation dose, dose rate, type and level of contamination are essential parameters to be known for a suitable radiation processing [1]. During the last decade ionizing radiation applications for the abatement of organic and biological pollutants demonstrated important data in wastewater and effluents. On the other hand, there is lot of work to be done in terms of solids residues and their decontamination considering that ionizing radiation causes damage and alterations in the DNA of organisms, inactivating them. Today it is imperative the care to be taken not only with aquatic resources but also with the solids residues policy. Irradiation of vehicular air filters were carried out for fungi control [2].

Animal waste is made up of organic material and water, but also bacteria, viruses, fungi, and parasites that have the potential to cause diseases of animals and man can are present. This is the reason why it must be properly controlled and managed to avoid polluting the environment. Of special concern are the waste obtained from installations where animals are raised for experimentation which are considered hazardous waste, and the hazardous microorganisms must be eliminated before of for disposal [3].

In this study, some data from Argentina and Brazil will be discussed and with irradiation applied at different material and disinfection was the purpose for the treatment, both used gamma rays obtained from ^{60}Co sources. The objective of this work is to analyze the effect of radiation applied at vehicular filters for reducing microorganisms, allowing a second use of irradiated filters, and applied irradiation at biological residues from animal facilities to eliminate pathogenic microorganisms to produce a soil amendment.

2. Methodology

Irradiation of vehicular filters:

Irradiator characteristics were evidenced at Figure 1. A. Dose rate was 5.5 kGy.h-1

Irradiations and microbial identification were carried out at Instituto de Pesquisas Energéticas e Nucleares, IPEN-CNEN/SP, (Figure 1. A).

Irradiation of animal residues:

The effect of gamma radiation on rat bedding waste (RBW) was studied. The material was obtained from an Animal facility, that produces rats (Rattus rattus) for experimentation. The irradiation was done in the Semi Industrial Irradiation Plant (PISI) in CNEA, Argentina (Figure 1. B). The dose rate was 20 $kGy.h^{-1}$ and installed activity was 820 kCi. Macroscopic composition and microbiological characterization of the residue was done in the Microbiology Laboratory of CNEA. The D_{10} value was determined to obtain the radiation dose necessary to decrease the population by one log. After eliminating the microorganisms, the RBW was composted together with household waste and worms of the genus *Eisenia* were incorporated to accelerate the decomposition process. After 15 weeks, a substrate was obtained that was used as an organic amendment and was tested in a pot assay for germination and development of plants such as *Calendula officinalis*.

Figure 1. Multipurpose irradiator facility A: IPEN/CETER; B: PISI CNEA.

3. Results and Discussion

A wide diversity of fungi was detected in all untreated filters samples (> 90 units). There was a direct correlation between durty materials and dose-response, nonetheless gamma radiation application drastically reduced initial contamination (bioburden). Ten different fungi genera were detected in these samples before any treatment. The control group (0 kGy) revealed the presence of *Alternaria alternata, Aspergillus flavus, Aspergillus fumigatus, Aspergillus niger, Aspergillus terreus, Cladosporium* spp., *Fusarium* spp., yeasts, *Penicillium* spp., *Phoma* spp., *Rhizopus* spp., *Rhodotorula* spp. and *Trichoderma* spp. The vacuum cleaning samples showed 11 fungal genera, the same 10 genera found in control samples, but with two more such as *Mucor* spp. and *Nigrospora* spp. The cleaning and chemical treatment samples showed 10 fungal genera (with *Phoma* spp.). Non-sporulating Fungi (NSF) is that fungi that produce only hyphae under the microscope examination. It is necessary the production of spores to identify the fungal genera. In this case, the NSF can be any filamentous fungi. DNA sequencing techniques were used for the confirmation of fungi which survived after 15 kGy.

The results of characterization of the animal waste showed that the RBW waste is a heterogeneous residue with diverse microbiological composition. Mesophilic aerobic and anaerobic bacteria and spores were detected, including fecal coliforms and *Escherichia coli*. The radiation resistance was determined for the natural microbial population in the RWB. Fecal coliforms bacteria and *E. coli*, were the most sensitive groups, followed by aerobic and anaerobic bacteria. Aerobic and anaerobic spores were the most radioresistant (Figure 2).

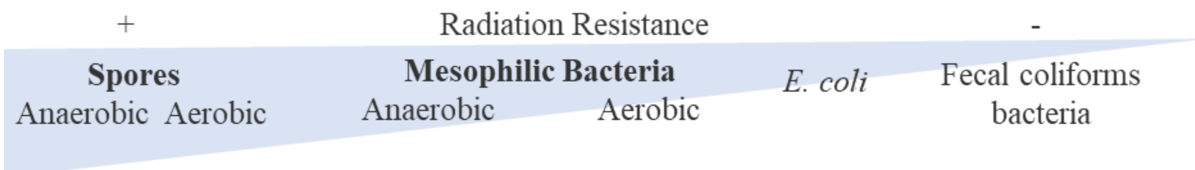

Figure 2. Radiation resistance of the natural microbial population in RBW (D_{10} value).

Although, in microbial assay an absorbed dose of 3.4 kGy was enough to eliminate fecal coliforms and *E. coli*, with 7 kGy no bacteria or spores were found. Subsequently, the residue was irradiated with 10 kGy to have a margin of safety, and then pre-composted in containers with domestic organic waste, then *Eisenia* worms were added to accelerate the bioconversion process (Figure 3 A).

Figure 3. Vermicomposting assay of RBW + 10 kGy in different weeks (A). *Calendula officinalis* 21 weeks old plants grown Ground control and RBW + 10 kGy.

After 15 weeks, the worms were removed, and the material was used as an organic amendment mixed with soil and *Calendula officinalis* seeds were sown. Seeds germinated and after 21 weeks the plants grown with the RBW + 10 kGy substrates appear to have a growth, like the plants developed in the ground control (Figure 3 B). Remained healthy, presenting an abundant quantity of leaves and the formation of inflorescences was observed.

4. Conclusions

The present research highlights the potential use of radiation technology to eliminate microorganisms present in vehicular filters and animal waste, to reuse the filters and make a substrate for plant growth.

Radiation treatment of vehicle filters would allow their reuse, reducing the generation of waste and obtaining a pathogen-free residue from animal laboratories wastes allows its disposal as a common residue that can be used for soil filling, or can be recycled through a vermicomposting process. Fungi diversity and wide environmental presence justify many efforts for identification and control technology.

Acknowledgements

This research was possible with the support of the CNEN, CNEA and the IAEA for their contribution with Project No. F23033: "Radiation inactivation of biohazards using high powered electron beam accelerators".

References

[1] S. Aquino, J.E.A. Lima, S.I. Borrely. “Bioburden proliferation in vehicle air filters waste: the use of gamma radiation on fungal decontamination” *Braz. J. Rad. Sci*., (2021).
[2] S. Aquino, J.E.A. Lima, T.A. Reis, B. Correa, S.I. Borrely. “Mycoflora and DNA sequencing analysis of radioresistant fungi isolated from irradiated vehicular air conditioning filters collected in São Paulo, Brazil”. *Microbiol. Res. Int*. (2021).
[3] M. V. Vogt, J. Pachado. “Microbial inactivation in animal waste with ionizing radiation”. 2021. In: *Microbiologia: Clínica, Ambiental e Alimentos*. Ed. Atena. Brazil. DOI 10.22533/at.ed.5432101203.