Radiation Technologies: Processes and Products

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The **Radiation Technologies: Processes and Products** activities focus on the research, development and demonstration of the interaction of ionising radiation with matter for further application in Industry or other entities. Since 1989 these activities have been closely related to the gamma radiation facility (UTR), whose main applications are the sterilization of medical devices and pharmaceuticals and the decontamination of other products. These activities have been leading to an incremental interest by Industrials that have in turn led to a joint venture in 2003 for the management of UTR by CHIP, with scientific and technical support provided by ITN researchers.

Nowadays, the group has a consultant role on sterilization and decontamination procedures, whenever it is solicited by the authorities or private industries. The group also develops work with the National and International normalization, standardization and certification bodies (IPQ, CEN and ISO).

In order to develop new radiation technology applications, the upgrading and renewal of facilities are being carry out. This project implies ionizing radiation equipment (e.g.: accelerator and gamma experimental facilities), a multidisciplinary laboratory with controlled environment and application of an automation/robotic systems in the facilities. These facilities have the main purpose to be open to researchers of National and International Institutions and Industry for developing radiation technologies and/or need of environmental control areas (clean areas) for their work (under REEQ/BIO/996).

The Group main R&D activities are focused on new technologies for further application of the ionising radiation on Food, Pharmaceutical, Wastewater treatment and other areas.

In order to improve our understanding of the Radiation Procedures, the influence of dose rate and the type of radiation (γ and e-beam) in/on products are being studied using Analytical Methods of Microbiology, Chemistry and Physics.

Other purpose of the microbiological work is to develop and implement validation technologies for inactivation procedures for microorganisms, mainly by ionizing radiation (e.g.: γ and e-beam).

These technologies are based on microbiological studies on the bioburden in/on the products, and aim to improve quality in this field. Molecular Biology techniques are also being developed to detect potential pathogenic microorganisms on environmental samples.

Hazard analysis and the control of critical points in the production lines of the studied products are part of the validation studies, carried out for the Pharmaceutical and Food Industries. Environmental control in surgical operation theatres at hospitals is also carried out.

The training and the know-how diffusion are one of the main issues of this Group, so National and International students are developing work within our projects in order to obtain academic degrees (Graduation, M.Sc., Ph.D.)

The financial support of work and students salaries are based on two IAEA projects, one AdI/FCT project, one LPM/MDN PIDDAC project, one re-equipment FCT project, industrial contribution, two IEFP/FSE grant and one FCT Ph.D. grant.

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Effluents

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Objectives

To implement wastewater and sludge treatment by ionizing radiation in Portugal, R&D work is being developed. This study presents a summary of results that continue to sustain the application of ionizing radiation as complement to biological (2ry phase) and disinfection (3ry phase) on wastewater treatment.

Results

Sets of wastewater, randomly sampled, were analysed by chemical and biological methods after irradiation, at 0.9 kGy.h^{-1}dose rate, with several doses. Results were compared with non irradiated samples.
Instrumental Neutron Activation Analysis and Ionic chromatography (IC) were used to characterize the sludge extractable fraction (soluble) and his potential nutrients.
As shown at Table 1, heavy metal values are below legal limits, for irradiated sludge at low dose rate.

Table 1 - Elemental analysis (INAA) for irradiated (7kGy) and non irradiated sludge (LVE, legal values according to the Portuguese Legislation.

	Concentration (ppm)			
	Cd	Cr	Cu	Zn
Irradiated	5.9±1.2	49.7±1.2	0	579.2±18.8
LVE	20	1000	1000	2500

IC results showed that major sludge solution ion species are Na^+, NH_4^+, Ca^{2+}, SO_4^{2-} and Cl^-. Other important species are K^+ and PO_4^{3-}. Therefore, the leachable components (solution fraction) seem to be rich on the major macronutrients for plants.

To stress the sludge potential as fertilizer, preliminary tests were conducted with clover and maize to evaluate the phytotoxicity of the sludge. The seeds of clover in the water (blank test) germinated at the end of the first day (24 hours) whereas in the sludge treatments the germination only started on the second day. As for the maize, the seeds germination only started one week after the beginning of the experiment. The results obtained in the treatment with the non irradiated and irradiated sludge showed that, till the fourth day after the beginning of the germination, the best results are those with the

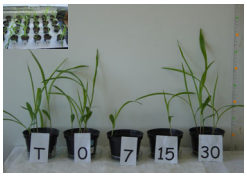

Fig. 1 - Phytotoxicity test using seeds of maize with sludge treatment at 0 kGy up to 30 kGy.

treatment with irradiated sludge at 30 kGy. The pot trial observations are in accordance with these results, as shown in Figure 1.
Microbiological studies showed that microbial populations were heterogeneous with respect to γ radiation resistance. The least resistant organisms appear to dominate the samples, since inactivation was of 99,999 % at 11 kGy, showing an exponential curve with the most resistant organisms present at a tail end at 30 kGy. The predominant bacteria that survived irradiation were gram positive cocci. Comparative kinetic studies were done to compare the growth rate of two isolated strains into wastewater previously irradiated, non irradiated and a standard substrata (TSB) (Fig. 2).

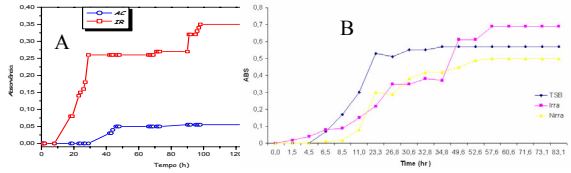

Fig. 2 - Bacterial growth in: A) irradiated and non irradiated effluent and B) irradiated, non irradiated effluent and in TSB.

The results of the irradiated effluent exhibited lower or none lag phase and a lopsided exponential phase whereas the non irradiated effluent displayed a long lag phase and a short exponential phase. The inoculated strain in TSB showed a typical growth curve with a well defined lag, exponential and stationary phase. The biomasses attain higher concentration in the irradiated effluent than in the others subtracts. Therefore, results showed that microbiota microorganisms degrade better the wastewater after irradiation that could be due to a molecular scissor effect, namely at low dose rate.
In conclusion, results point out: 1) according to heavy metal legislation it could be possible to use the treated sludge as fertilizer; 2) can be postulate that sludge has no phytotoxicity effect; 3) γ radiation could lead to the selection of microorganisms that could be useful for bioremediation; 4) sludge irradiation could lead also to fast plant growth.
The overall results, including economical ones, pushed to the benefit of this technology.

Food Irradiation

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This area aims the application of irradiation as a food safety tool. The "Sanitation of chicken eggs by ionizing radiation" (FCT/BD/2942/2000) project aims the development of the application of irradiation technology to shell eggs and egg-products, in order to get a product free from pathogenic microorganisms, without major effects in nutritional and functional egg properties. Egg-products samples were irradiated in a Co-60 facility, at sub-lethal doses (0.2 to 5 kGy) with a dose rate of 1 up to 4.7 kGy/h. The D_{min} of radicidation and D_{values} were determined for total natural contaminants in egg-products; Comparing thermal and γ-irradiation treatment (≥ 1 kGy), the latter shows higher efficiency than pasteurization in the treatment of the liquid yolk. Egg-products irradiated at doses up to 2 kGy show no detectable alterations on the composition of phospholipids, and a decrease in the viscosity and peroxide index similar to that obtained after egg pasteurization. The sponge cakes and mayonnaises prepared with irradiated egg-products were globally classified as good by a non trained sensorial analysis panel. To guarantee organoleptic acceptable and safe egg-products, a radicidation dose of 1.5 kGy is proposed. To identify possible critical control points in the egg production line, it was applied molecular biology typing methods to egg and its environmental strains to assess their genetic similarity and confirm contamination links. The results obtained support the hypothesis that the feed should be assumed as a Critical Control Point. The Project for improvement of quality and safety of minimally processed fruits and vegetables by gamma radiation (IAEA/POR/11682/RDF) is in its final stage. No important differences were found on the overall sensorial and the physico-chemical properties after irradiation up to 1 kGy, although a decrease of natural microbiota was noticed (>2 log) which leads to an extension of the shelf-life of the analysed fruits and vegetables of at least 3 days.

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Environmental Control

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The project on environmental control of surgical rooms at the Army Hospital is being developed. This study focuses on the development and improvement of alternative techniques to control the environment in surgical rooms in Hospitals. The efficiency of the cleaning protocol was evaluated through the determination of the bioburden, before and after the cleaning action in one surgical room, by means of air sampling (biocolector MAS100), floor and equipment surface swabs, and aliquots of the cleaning solutions. The results obtained point out to a 91% reduction on the floor bioburden after the cleaning action. The cleaning procedure shows not to be so effective on the equipment surfaces and in the air. These results indicate that some corrective actions should be established in the hospital cleaning procedure, namely new disinfectants, in order to improve the air born conditions and eliminate potential nosocomial microorganisms. The air bioburden was also determined before, during and after orthopaedics' surgeries using the biocolector MAS100. The results obtained were compared with previous (2004) bioburden values; a reduction was observed in the number of the microorganisms isolated in the different phases of air collection along two years of studies. The obtained hospital data point to the usefulness of the implemented HACCP study to assess infection risk and nosocomial antibiotic and disinfectant resistant strains. The studies are in progress in order to continue the actions to reduce the risk of infection.

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Facilities Upgrade for Radiation Technologies Applications

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In this field, the project "Upgrading of Radiation Technology unit" FCT CONC-REEQ/996/2001[1] was signed at the end of 2005. Since June 2005 work has progressed, namely 1) Meetings were held with collaborators and potential items deliverers 2) -Controlled lab area-a data base for all equipment specifications is being developed; and 3)-Ionizing radiation equipment – dosimeter systems are under study (e.g.: MNCP, Chemicals).

1 Vide Group Projects.