**Preliminary investigations on an experimental setup for nuclear graphite dissolution in the respiratory tract**

Martina Mazzi1\*, Alessandro Antonio Porta2, Fabrizio Campi2, Marco Derudi1

*1 Politecnico di Milano, Dip. di Chimica, Materiali e Ingegneria Chimica “G. Natta”, via Mancinelli 7, 20131 Milano - Italy; 2 Politecnico di Milano, Dip. di Energia, via Lambruschini 4, 20156 Milano - Italy*

*\*Martina Mazzi E-Mail:* *martina.mazzi@polimi.it*

**1.Introduction**

This abstract aims to describe the preliminary study of an experimental setup to analyze the dissolution of nuclear graphite particles after accidental inhalation during decommissioning operations of graphite moderated nuclear reactors. Graphite is widely used for nuclear applications for its adequate properties, such as chemical inertness, high conductivity, good irradiation performance, corrosion resistance, good machinability, and good mechanical properties at high temperatures (Luo et al., 2004).

Despite of the fact that the first unit was shut down more than thirty years ago, nowadays most worldwide graphite moderated shutdown reactors are not dismantled and are just in a ‘safe store’ condition (Inno4graph, 2022). Tools for dismantling of components are usually safe and remotely operated, but workers could be present on site, and the eventuality of accidental exposure to highly contaminated graphite dusts must be considered.

The ICRP (International Commission on Radiological Protection) provides different dosimetry and biokinetic models, and ICRP Publication 66 and Publication 130 give a description about the Human Respiratory Tract Model. Inhaled contaminated particles can deposit on the upper or on the lower respiratory tract according to their size. The particle clearance is possible by two main mechanisms: absorptive (dissolution and adsorption to blood) and non-absorptive (physical mechanisms involving the transport to the alimentary tract with consequent excretion) (Keller et al., 2020).

The research focuses on the finer fraction of particles, which can reach alveolar region of lungs, and deposit in the lung extracellular environment or are engulfed by alveolar macrophages (Hettiarachchi et al., 2019). Therefore, mechanisms of dissolution in these two conditions have been investigated.

Solubility of inhaled particles or compounds is an important parameter that affects the uncertainty in a hazard evaluation of airborne that deposits in the respiratory tract. Indeed, the dissolving rate of a material can affect the extent and the rate at which it remains in the site of deposition, transported to other sites (e.g. target organs) or excreted (Ansoborlo et al., 1999).

Inhalable particles can be classified into three categories according to their dissolution rate: Fast, Moderate and Slow. This classification is a result of the assumption that each material that can be inhaled is characterised by a rapid dissolution fraction (fr) with the dissolution rate sr and a slow dissolution fraction (fs) with dissolution rate ss, their values are reported in Table 1 (Paquet, 2019).

**Table 1.** Dissolution fractions and rates values according to classification of ICRP Publication 130

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | fr | fs | sr (day-1) | ss (day-1) |
| F | 1.0 | 0 | 30 | - |
| M | 0.2 | 0.8 | 3 | 0.005 |
| S | 0.01 | 0.99 | 3 | 0.0001 |

In vivo data are the most reliable since the lung is a dynamic system, but developing an in vitro model has a really high importance because it could simplify the collection of data about different compounds and currently there are not standard procedures for in-vitro dissolution simulation. Moreover, it would be coherent with 3R concept (Replacement, Refinement, and Reduction in the use of animals in science) with the aim of avoiding the infliction of unnecessary pain and other significantly unpleasant feelings to animals (Fröhlich, 2021).

**2. Methods**

The developed experimental setup is dynamic to better reproduce lung environment.

The system consists of two chambers, which are part of a circuit, and, in both of them, a membrane is inserted at a certain height.

The chambers are designed with the aid of the software Solidworks and 3D printed.

On the membrane the compound of interest is deposited and above it a fluid is inserted. In one chamber the fluid is SUF (Serum Ultrafiltrate Fluid), which simulates extracellular fluid of alveoli with pH 7.2-7.4; in the other chamber PSF (Phagolisosme Simulant Fluid) is inserted, and it simulates the environment inside macrophages with pH 4.5. Under the membrane, Human Body Plasma Simulant (HBPS) circulates for the presence of a peristaltic pump and removes dissolved particles, acting as blood in pulmonary capillaries.

The system is validated using as reference material BaSO4, since in literature lots of in-vivo studies and data about dissolution of this compound can be found. The concentration of BaSO4 in HBPS samples is assessed with the aid of ICP-OES to evaluate the dissolution during time.

The aim of this experimental campaign is to assess the dissolution of contaminated graphite particles from Politecnico di Milano research reactor L-54M. The radioisotopes that are present are the following: 14C, 3H, 152Eu and 108mAg. In this case, to analyze dissolution, activity of the radioisotopes present in the samples have to be evaluated. The assessment is possible with the aid of a GEM p-type Coaxial Detector.

**3. Results and discussion**

HPBS samples were collected in different time instants and analyzed by ICP-OES technique to assess concentration of the compound in the fluid, and to build BaSO4 dissolution curve.

The results of validation are promising, since the calculated displacement between dissolved BaSO4 experimentally determined mass and the one assessed during an in-vivo study using the same compound on rats (Konduru et al., 2014) is less than 4%.

**4. Conclusions**

Since the results of the preliminary research on the setup were encouraging, further experimental campaigns will be carried out for the validation of the system and the procedure. After the validation phase, it is planned to assess lung dissolution of contaminated graphite dust.

**References**

1. X. Luo, J. C. Robin, Y. Suyuan, Effect of temperature on graphite oxidation behavior, Nuclear Engineering and Design, 227 (2004) 273–280
2. Inno4graph, n.d., accessed March 2022, <www.inno4graph.eu/objectives-results/>
3. J. G. Keller, U. M. Graham, J. Koltermann-Jülly, R. Gelein, L. Ma-Hock, R. Landsiedel, M. Wiemann, G. Oberdörster, A. Elder, W. Wohlleben, Predicting dissolution and transformation of inhaled nanoparticles in the lung using abiotic flow cells: The case of barium sulfate, Sci. Rep. (2020) 10: 458
4. E. Hettiarachchi, S. Paul, D. Cadol, B. Frey, G. Rubasinghege, Mineralogy Controlled Dissolution of Uranium from Airborne Dust in Simulated Lung Fluids (SLFs) and Possible Health Implications, Environ. Sci. Technol. Lett. (2019) 62–67
5. E. Ansoborlo, M. H. Hengè-Napoli, V. Chazel, R. Gibert, R. A. Guilmette, Review and Critical Analysis Of Available In Vitro Dissolution Tests, Health Phys 77 (1999) 638-645
6. F. Paquet, The new ICRP biokinetic and dosimetric models, BIO Web of Conferences 14 (2019)
7. E. Fröhlich E., Replacement Strategies for Animal Studies in Inhalation Testing, Sci. (2021) 3, 45
8. N. Konduru, J. Keller, L. Ma-Hock, S. Groters, R. Landsiedel, T. D. Donaghey, J. D. Brain, W. Wohlleben, R. M. Molina, Biokinetics and effects of barium sulfate nanoparticles, Particle and fiber toxicology (2014) 11, 55.