# XXVII. DAYS OF RADIATION PROTECTION

## CONFERENCE PROCEEDINGS

LIPTOVSKÝ JÁN, LOW TATRAS, SLOVAKIA

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# Mathematical Simulation of Gas Pressure in Fibre-Reinforced Concrete Container at Radiation and Biological Decomposition of Cellulose, Bitumenized and Concrete Radwastes

*Jozef Kuruc, Peter Kvito*
*Department of Nuclear Chemistry, Faculty of Natural Sciences, Comenius University, Mlynska dolina CH-1, 842 15 Bratislava, Slovakia, kuruc@omegainfo.sk*

Fibre-reinforced concrete container (FRCC) are used for long-time repository of radioactive wastes (radwastes). FRCC were developed by French company SOGEFIBRE [1], in the Slovak Republic are produced by the VYZKONT Ltd., Trnava [2]. Dimensions of FRCC are 1.7 x 1.7 x 1.7 m, with inner dimensions 1.450 x 1.450 x 1.430 m. Thickness of side wall is 0.100 m, bottom 0.125 m and top 0.145 m (mean 0.112 m). Total mass of empty FRCC is 4240 kg. The FRCC is filled with cement grout up to 30 mm from upper brink; this represents so-called free volume of FRCC.* On the Fig. 1 the FRCC filled by barrels with pressurised cellulose wastes and barrels with bitumenized radwastes is shown. The remainder inner volume of FRCC is filled with active or not active cement grout. The portion of individual types of wastes deposited in FRCC (middle values) are on the Fig. 2.

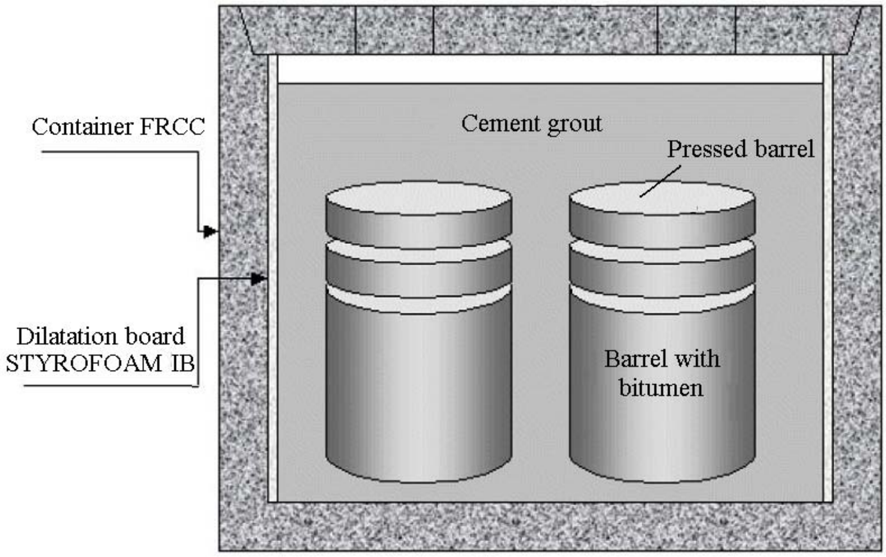


**Fig. 1.** The FRCC filled with barrels with pressurized celullose wastes and with bitumenized radwastes.

Low- and middle-active radwastes from operation of the NPPs V-1, V-2 Jaslovske Bohunice, Mochovce NPP and from decommissioned NPP A-1 (Jaslovske Bohunice) are treated in the plant SE-VYZ in Jaslovske Bohunice [3] and after immobilisation are deposited in National Radwaste Repository Mochovce (RU RAO ) [4]. After filling of the RU RAO, FRCC will be stored during 300 years. During this time the integrity of the FRCC must be guaranteed.

* Free volume of FRCC in the present time increases by storage of dilatation layers of extruded polystyrene on the inner side and on bottom of FRCC (2 cm thickness, 5 sides of FRCC).

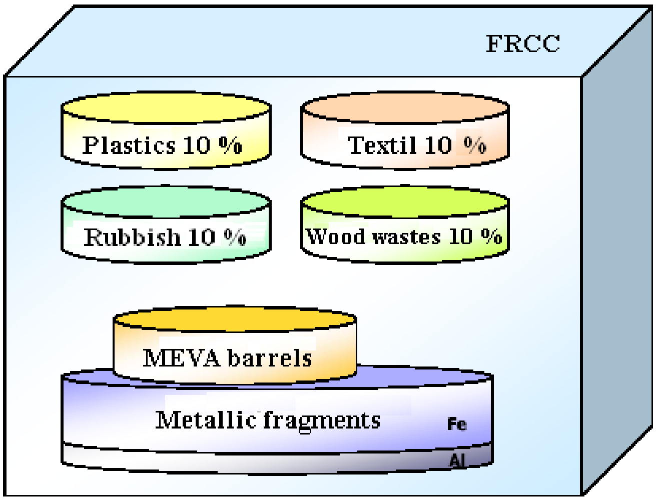


**Fig. 2.** The portion of individual types of wastes deposited in FRCC (middle values).

## Autoradiolysis and biological decomposition of wastes in FRCC

By the influence of autoradiolysis of the cellulose and bitumenized radwastes as well as in cement grout the gases are formed, mainly the hydrogene, methane and carbon dioxide. In the case of presence of available water ($a_w \geq 0.63$) and in presence of microbes and moulds at appropriate conditions the biological decomposition of cellulose materials may proseed with formation of $H_2$, $CH_4$ a $CO_2$. With increasing of developed gases may increse pressure in FRCC, that may initiate the loss of integrity of the FRCC with following endangering of radiation safety of the RU RAO, respectively of the territory over the repository.

By this reason *Kuruc*, *Macášek* a *Kolarová* viewed the rate of biological and radiolytical decomposition of radwastes deposited in FRCC and simulated course of pressure conditions within FRCC [5]. It was find out that some cellulosee radwastes contain microbes and moulds, which can initiate the formation of gaseous products in suitable conditions. Consecutively *Kuruc* developed new mathematical model of pressure of gases in FRCC and in deposited barrels with cellulose and bitumenized radwastes [6]. Derivation of the mathematical model as well as detail description of mathematical functions and important chemical reactions were presented during the conference 7th Banska Štiavnica days [7] and detailed published [8].

## Mathematical Model of Gas Pressure in Fibre Concrete Container

On the Fig. 3 the scheme of mathematical model of gas pressure in the FRCC is represented. The maximal specific rate of microbial formation of gases [5] (in anaerobic conditions) is $a$ = 0.002 cm$^3$ g$^{-1}$ day$^{-1}$. From the data on radwastes deposited in FRCC [5] it results that the total mass of radwastes, $m_s$, including bitumen and grout reaches: $m_c$ – mass of cellulose in FRCC ≈ 250 kg; $m_b$ + salts – mass of bitumen and radioactive salts ≈ 1020 + 30% salts ≈ 1,326 kg; $m_z$ + salts, mass of cement grout and radioactive salts ≈ 2,860 + 16% salts ≈ 3,318 kg; together $m_s$ ≈ **4,894 kg.** From the maximal permissible activity 74 TBq/FRCC [9] arises, that specific activity can reach 74 TBq/4,894 kg = 15.12 MBq g$^{-1}$. From this specific activity and energy of $^{137}$Cs we obtained [8] the dose rate $\dot{D}_{max}$ ≈ 3.3 mGy s$^{-1}$, which is the maximal permissible value in FRCC. Used initial input parameters and the qualified conservative assessment of critical parameters are presented in our previous paper [8].

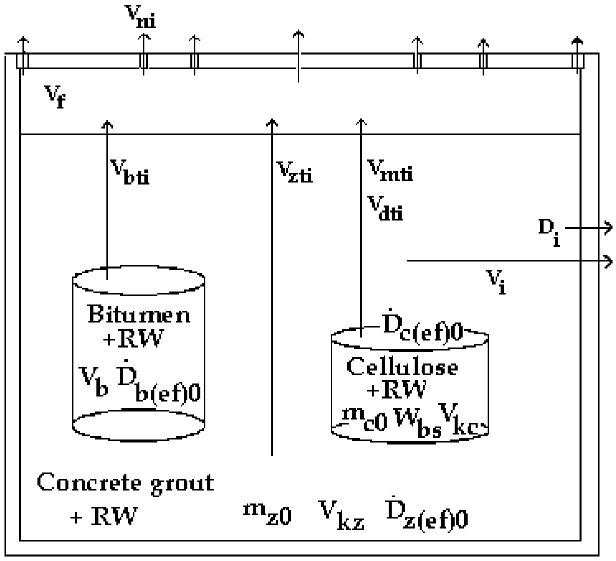


**Fig. 3.** Scheme of the mathematical model of gas pressure in FCC.

The mathematical model of gas pressure in FRCC is programmed in MS Excel 2000™ (the total number of variables is 25, and 46 equations). In this mathematical model the diffusion through the walls of FRCC is the main process responsible for decreasing of the pressure. According to [11] the diffusion constant of tritium in concrete is equal to 5.49 x $10^{-11}$ $m^2$ $s^{-1}$. Relative to molecular mass of tritium and main gaseous products of decomposition $H_2$, $CH_4$ and $CO_2$, according to the relation (1) their diffusion constants in concrete (A = $^3H_2$ = $T_2$; B = $H_2$, $CH_4$, $CO_2$ and CO) are

$$D_B = D_A \Big/ \sqrt{M_B / M_A} \qquad (1)$$

respectively: $D_{H_2}$ = 9.51 x $10^{-11}$ $m^2$ $s^{-1}$, $D_{CH_4}$ = 3.36 x $10^{-11}$ $m^2$ $s^{-1}$, $D_{CO_2}$ = 2.03 x $10^{-11}$ $m^2$ $s^{-1}$ and $D_{CO}$ = 2.54 x $10^{-11}$ $m^2.s^{-1}$ (the values are calculated by us). This model was developed in two basic variants:

1. Mathematical model of gas pressure in FRCC as function of dose, Fig. 4.

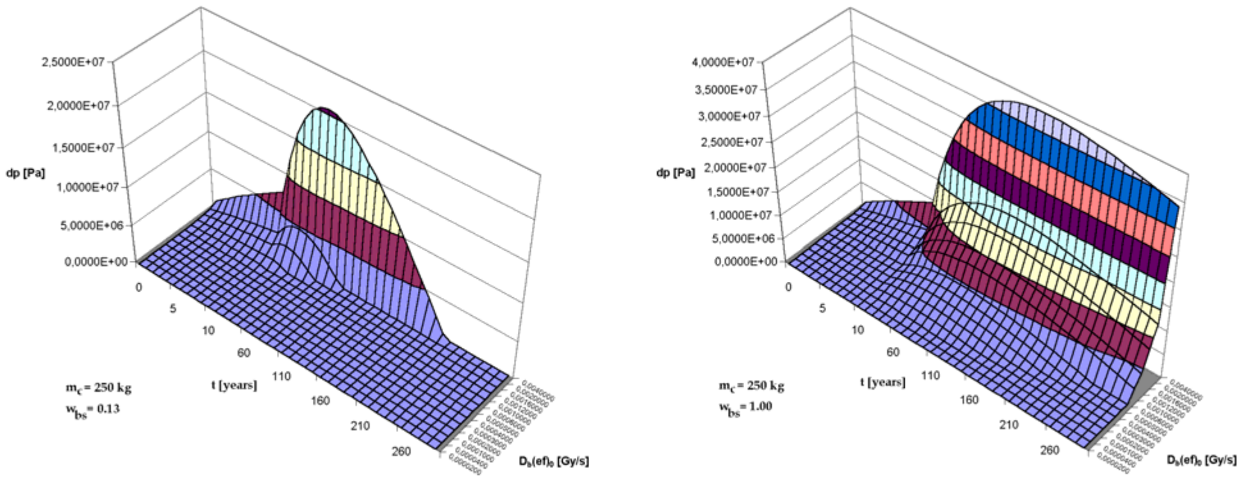


**Fig. 4.** Pressure simulation inside of FRCC in dependence on dose rate at initial mass of cellulose wastes ($m_c$) and available water ($w_{bs}$)

2. Mathematical model of gas pressure in FRCC as function of mass of cellulose, Fig. 5.

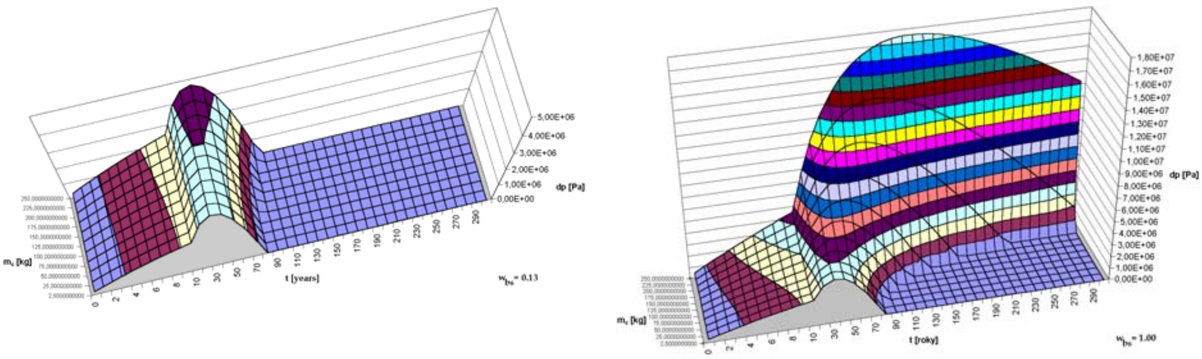


**Fig. 5.** Pressure simulation inside of FRCC in dependence on initial mass of cellulose $m_c$ and available water ($w_{bs}$)

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