Radiation hazard indices in the application of phosphogypsum mixtures as a building material: proposal for a regulation

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Phosphogypsum (PG), a waste by-product derived from the production of phosphoric acid, is being worldwide stockpiled, posing concerns about the environmental problems originating from this practice. Considerations about the viability of the safe reuse of this material have been raised, among them its potential use in civil construction. However, as PG can contain natural radionuclides in significant concentrations, using it as a building material has radiological implications, which have prevented such application.

Recently, a working group was established at the national regulatory level in Brazil, aiming to define a policy for using PG in this way. The adopted approach was to limit the concentration of PG to be mixed with natural gypsum, based on ^{226}Ra and ^{228}Ra concentrations found in PG.

In this study, the procedure described by Steger et al. (1992) to assess the hazard indices is employed, taking as input data concentration of Ra-226, Th-232 and K-40 in the material, radon exhalation fraction (ε) from the internal walls, the density (ρ) and thickness (d) of the walls.

The following values were adopted for the assessment: ε = 0.1, which is a realistic figure considering that only 10% of the radon is emanated from the walls (Steger et al., 1992; Bossew, 2003); d = 0.1m, since this figure is above of the maximum admissible thickness for gypsum plates, according to Brazilian regulation, which is 15 cm. This value is equal to the width of the only gypsum brick model currently found to be produced in Brazil, compliant to the applicable engineering regulation.

For the density, ρ = 1750 kg.m^{-3}, that is the greatest density experimentally found for gypsum bricks, was assumed, and is also above of the maximum density allowed for plasterboard, which is 933 kg.m^{-3}.

In the present study, radionuclides giving rise to gamma rays, by itself or by its progeny, were selected. In order to apply the assessment procedure, several hypothetical mixtures of PG and mineral gypsum were assumed, varying the PG percentages *p* in the mixtures.

The hazard indices were assessed for the following ^{226}Ra and ^{228}Ra concentrations in PG, as follows:

^{226}Ra: 50, 100, 150, 200, 300, 400, 600, 800, and 1000 Bq.kg^{-1}.

^{228}Ra: 50, 100, 200, 300, and 400 Bq.kg^{-1}.

For each *p* value, the activity concentrations of ^{226}Ra and ^{228}Ra in the mixture were calculated.

In adopting such values, the criterion of fixing the upper limits of each range in values above of the typical experimental values from each main PG stockpile in Brazil was employed, in order to allow a well defined classification of PG in each range.

For mineral gypsum, the following fixed values were adopted, based in previous experimental data: 2.8 Bq.kg^{-1} for ^{226}Ra, and 1.7 Bq.kg^{-1} for ^{228}Ra. For ^{40}K concentration, 50 Bq.kg^{-1} was adopted for all PG/gypsum mixtures, as no analyzed PG in Brazil presented concentration above this value (Nisti et al., 2013).

Allowable PG percentage adopted, for each ^{226}Ra and ^{228}Ra concentrations pair, was the highest possible so that the resulting effective dose was below 1 mSv.

Based on these assumptions, it was concluded that PG from the largest Brazilian deposits, could be used, from the radiation safety point of view, in all the range of percentages from 0% to 100%. In the extreme situations, being C(^{226}Ra) and C(^{228}Ra) the activity concentrations of the respective nuclides, PG should not be mixed for use at all if C(^{226}Ra) > 1000 Bq.kg^{-1}, and could be used in a percentage as high as 100%, in the following conditions:
C(^{226}Ra) $\leq$ 100 Bq.kg^{-1} and C(^{228}Ra) $\leq$ 50 Bq.kg^{-1}; or
C(^{226}Ra) $\leq$ 50 Bq.kg^{-1} and C(^{228}Ra) $\leq$ 100 Bq.kg^{-1}.

These results show that the use of phosphogypsum in civil construction, especially mixed with natural gypsum, is actually viable and should be carefully considered and taken into account, in view of the positive impact on the environment by reducing the PG deposits.

References

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