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RADIOLOGICAL EVALUATION OF BRICKS MADE WITH NORM RESIDUE

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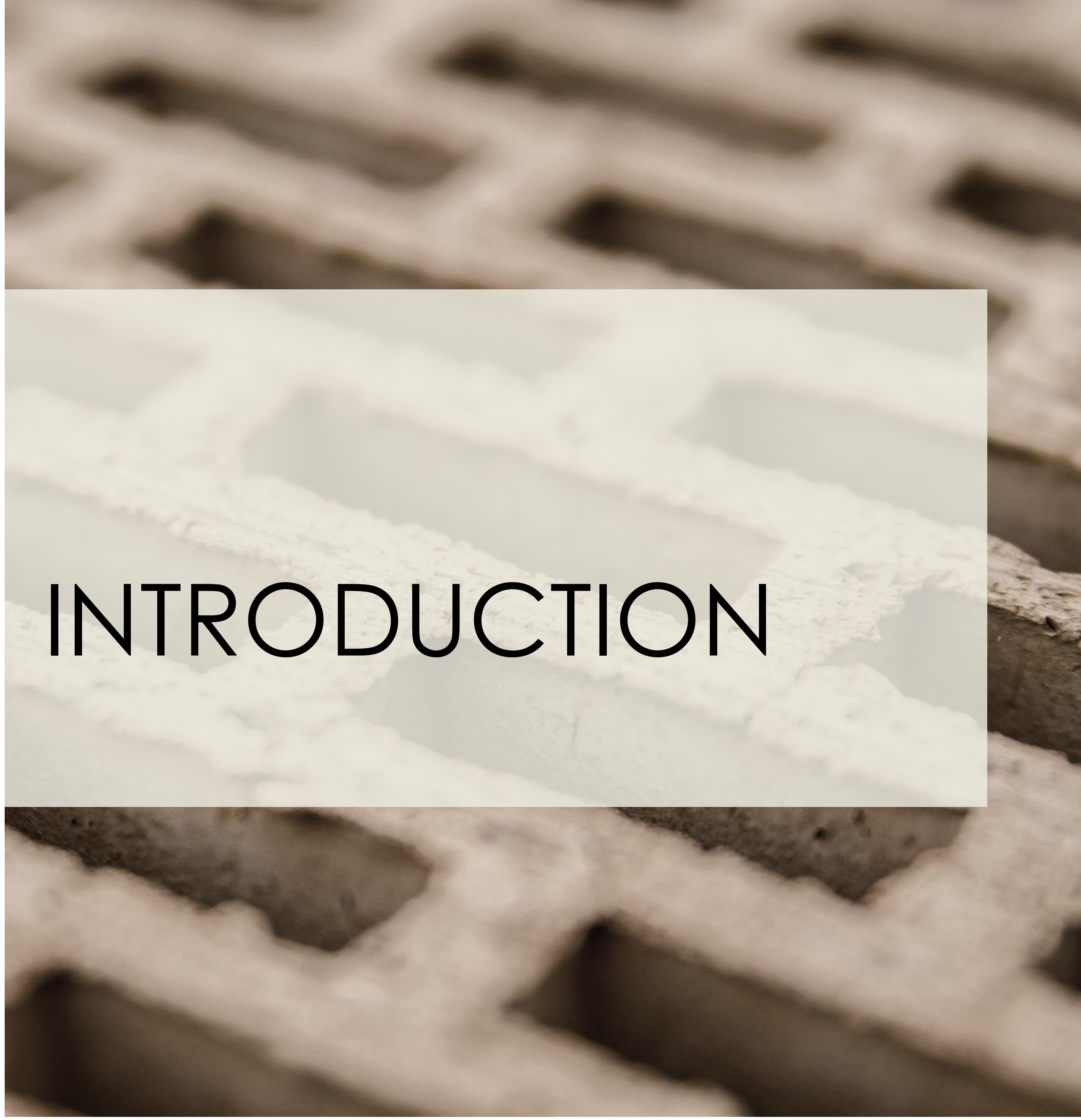
1. INTRODUCTION



- ✓ The increased use of secondary raw materials in construction is a crucial step that enables the world to tackle the depletion of primary raw materials.
- ✓ A NORM residue that is produced in large quantities by the phosphate industry is phosphogypsum.
- ✓ Worldwide, 170 million tons of phosphogypsum are disposed annually.
- ✓ Recycling rate is still very low, less than 5%, while the global production is increasing.

- ✓ Total amount of phosphogypsum stored will reach 7 to 8 billion tons by 2025.
- ✓ In view of the large quantities of phosphogypsum produced, the construction industry is one of the few sectors that could reuse such huge quantities.
- ✓ However, a key problem restraining the utilization of phosphogypsum in the manufacturing of building elements is its potential radiological effect on the human population.

2. OBJECTIVE

To evaluate the feasibility of using NORM residue in the manufacturing of building materials such as bricks, from the radiological protection point of view.

3. MATERIALS AND METHODS

- ✓ Bricks were manufactured with typical Brazilian clay soil and phosphogypsum from the main phosphate fertilizer producers, in the 9:1 ratio.
- ✓ The bricks are presently being tested according to the Brazilian Standards ABNT NBR 15270-1:2005, to verify the requirements with respect to geometrical, physical and mechanical (strength) properties, but results are not yet available.

LOCATION OF THE FIVE LARGEST BRAZILIAN PHOSPHATE FERTILIZER PRODUCERS

SAMPLE	PHOSPHATE FERTILIZER PRODUCER	LOCATION
PG A	CMOC	Catalão/GO
PG B	CMOC	Cubatão/SP
PG C	MOSAIC FERTILIZANTES	Uberaba/MG
PG D	MOSAIC FERTILIZANTES	Cajati/SP
PG E	MOSAIC FERTILIZANTES	Cubatão/SP

Phosphogypsum was provided by the largest Brazilian phosphate fertilizer producers: **CMOC** and **Mosaic Fertilizers.**

3. MATERIALS AND METHODS

PARAMETERS USED FOR THE RADIOLOGICAL EVALUATION OF THE BRICKS

- ✓ Activity concentration of natural radionuclides in the components of the bricks;
- ✓ Radon exhalation rate;
- ✓ Radium equivalent activity and alpha index.

EVALUATION OF THE RADIUM EQUIVALENT ACTIVITY

$$C_{Ra,eq} = C_{Ra} + 1.43 C_{Th} + 0.077 C_K$$

where

$C_{Ra,eq}$ is the radium equivalent activities (Bq kg^{-1}),

C_{Ra} is the activity concentrations of ^{226}Ra (Bq kg^{-1}),

C_{Th} is the activity concentrations of ^{232}Th (Bq kg^{-1}),

C_K is the activity concentrations of ^{40}K (Bq kg^{-1}),

EVALUATION OF THE RADON EXHALATION RATE

$$J_D = C_{Ra} \lambda_{Rn} f \rho L \tanh(d / L)$$

where:

J_D is the radon exhalation rate of ^{222}Rn (Bq m^{-2} h^{-1}),

C_{Ra} is the activity concentration of ^{226}Ra (Bq kg^{-1}),

λ_{Rn} is the decay constant of ^{222}Rn (h^{-1}),

f is the emanation fraction,

ρ is the density (kg m^{-3}),

d is half-thickness (m),

L is the diffusion length (m^2).

EVALUATION OF ACTIVITY CONCENTRATION INDEX

$$I = [(C_{Ra} / 300) + (C_{Th} / 200) + (C_K / 3000)]$$

Where:

$I\gamma$ is Activity concentration index,

C_{Ra} is the activity concentrations of ^{226}Ra (Bq kg^{-1}),

C_{Th} is the activity concentrations of ^{232}Th (Bq kg^{-1}),

C_k is the activity concentrations of ^{40}K (Bq kg^{-1}),

EVALUATION OF THE ALPHA INDEX

$$I\alpha = \frac{C_{Ra}}{200}$$

where:

$I\alpha$ is Alpha index,

C_{Ra} is the activity concentration of ^{226}Ra (Bq kg^{-1}).

The recommended value for alpha index is 1 to keep indoor ^{222}Rn concentration below 200 Bq m^{-3} (EC, 1999).

4. RESULTS

Activity concentration determined by gamma spectrometry (Bq kg^{-1})

Sample	Ra - 226	Th-232	K-40
PG A	1277 ± 39	445 ± 14	< 26
PG B	839 ± 25	242 ± 8	< 25
PG C	219 ± 7	155 ± 5	20 ± 5
PG D	115 ± 4	34 ± 2	< 15
PG E	393 ± 12	31 ± 2	< 19
Soil	64 ± 2	120 ± 6	155 ± 23
Soil + 10% PG A	173 ± 6	146 ± 7	159 ± 23
Soil + 10% PG B	131 ± 5	134 ± 6	147 ± 22
Soil + 10% PG C	74 ± 3	117 ± 6	144 ± 21
Soil + 10% PG D	59 ± 2	101 ± 5	137 ± 20
Soil + 10% PG E	91 ± 3	97 ± 5	129 ± 19

Radium equivalent activity ($C_{Ra,eq}$), Activity concentration index (I)
Radon exhalation rate, Alpha index (Iα).

Samples	CRa,eq ($Bq\ kg^{-1}$)	I	Radon exhalation rate ($mBq\ m^{-2}\ s^{-1}$)	Iα
Soil + 10% PG A	394	1.36	3.01	0.86
Soil + 10% PG B	333	1.16	2.28	0.66
Soil + 10% PG C	252	0.88	1.28	0.37
Soil + 10% PG D	214	0.75	1.03	0.30
Soil + 10% PG E	240	0.83	1.58	0.46

- ✓ The radium equivalent activity surpassed the recommended level of 370 $Bq\ kg^{-1}$ in bricks made with PG from CMOC – Catalão/GO.

- ✓ By applying the dose criteria recommended by the European Commission for building materials used in bulk amounts, two bricks made with PG from CMOC – Catalão/GO and CMOC – Cubatão/SP exceeded the activity concentration index threshold.

Radium equivalent activity ($C_{Ra,eq}$), Activity concentration index (I)
Radon exhalation rate, Alpha index (Iα).

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- ✓ The results obtained for the radon exhalation rate for all bricks are of the same order of magnitude than those from ordinary building materials, such as sand and concrete. Therefore, the use of PG will pose any additional risk due to radon inhalation for dwellings.
- ✓ Alpha index results ranged from 0.30 to 0.86, less than unity, showing that the bricks cannot produce hazardous levels of indoor radon when used as building material and that the indoor radon concentration is below 200 Bq m^{-3}.

Maximum PG percentage in the manufacturing of bricks that will not exceed the recommended levels of radium equivalent activity and activity concentration index (I)

Sample	Maximum PG percentage $C_{Ra,eq}$	Maximum PG percentage I
Soil + PG A	8.4	2.5
Soil + PG B	14.0	4.5
Soil + PG C	100	39.0
Soil + PG D	100	100
Soil + PG E	55.5	27.0

5. CONCLUSIONS

- ✓ Radionuclides content and radiological parameters were used to assess the maximum amount of PG that could safely be used in the manufacturing of bricks.
- ✓ The radiological parameters can be a fast and easy screening to determine safe levels of reuse of NORM residues; however the criteria were not met for all the PG studied.
- ✓ A proposal is made to define the maximum PG amount that could be used in the manufacturing of bricks in order to attend recommended levels of the radiological parameters.

- ✓ The results obtained in this study will contribute to the establishment of guidelines by the Brazilian Regulatory Agency for the safe use of phosphogypsum as building material.

- ✓ To guarantee that the proposed standards are met, it would be necessary to establish control procedures including regular PG sampling programs and formal notifications from the producers in order to allow the PG entering the public domain, in an approach similar to that already established by the Brazilian Regulatory Agency for the control of using phosphogypsum in agriculture and cement industry.

- ✓ The proposal for employing phosphogypsum mixed with natural soil as a building material, presented in this paper, if adopted nationwide, could have a significant positive impact, by reducing the huge amounts of phosphogypsum disposed.

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thank you for your attention

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