

Heavy mineral sands exploitation and exposure to ionizing radiation in Mozambique

F. Conceição^a, F. Catuane^a, S. Taímo^a,

F.P. Carvalho^b, J. M. Oliveira^b, M. Malta^b

^a Ministério dos Recursos Minerais e Energia, Direcção Nacional de Geologia e Minas, Praça 25 de Junho Caixa Postal 217, Maputo, Moçambique

^b Laboratório de Protecção e Segurança Radiológica, Instituto Superior Técnico, Universidade de Lisboa, Estrada Nacional 10, km 139, 2695-066 Bobadela LRS, Portugal

Introduction

- Coastal deposits of heavy mineral sands on the shore of Indian Ocean are targeted by extraction industries intensively producing zircon, rutile, garnet, and rare-earth elements.
- Two important coastal areas, at Moma and Angoche, with heavy mineral sand deposits and extractive industries, were investigated for the presence of naturally-occurring radioactive elements and monitored for radiation doses.

Coastal areas



Left: hydraulic separation plant of heavy minerals from coastal sand dunes at Angoche;

Right: arrival of heavy minerals' wet concentrate at the magnetic separation plant, at Moma coastal area.

Results

| Sample description | Site | ^{238}U | ^{226}Ra | U total (g kg^{-1}) | Th (g kg^{-1}) |
|-------------------------|------------|------------------|-------------------|--------------------------------|---------------------------|
| Sand dune-rich layer | Angoche #1 | 428 ± 16 | 324 ± 49 | 0.035 ± 0.001 | 0.25 ± 0.04 |
| Rejected sand waste | Angoche #2 | 29 ± 2 | 24 ± 2 | 0.0024 ± 0.0001 | 0.0057 ± 0.0005 |
| Sand dune-top layer | Angoche #5 | 40 ± 1 | 28 ± 2 | 0.0032 ± 0.0001 | 0.030 ± 0.002 |
| Wet mineral concentrate | Angoche #6 | 727 ± 22 | 936 ± 110 | 0.059 ± 0.002 | 0.80 ± 0.08 |
| Magnetic Ilmenite | Angoche #7 | 86 ± 3 | 212 ± 17 | 0.0070 ± 0.0002 | 0.111 ± 0.006 |
| Non-magnetic fraction | Angoche #8 | 2729 ± 83 | 415 ± 42 | 0.221 ± 0.007 | 0.39 ± 0.02 |
| Sand dune-top layer | Moma #1 | 9.3 ± 0.9 | 7.5 ± 0.6 | $(7.6 \pm 0.8) \times 10^{-4}$ | 0.0048 ± 0.0003 |
| Wet mineral concentrate | Moma #2 | 605 ± 22 | 353 ± 34 | 0.049 ± 0.002 | 0.34 ± 0.03 |
| Magnetic fraction | Moma #5 | 179 ± 5 | 147 ± 13 | 0.0145 ± 0.0004 | 0.21 ± 0.02 |
| Non-magnetic fraction | Moma #4 | 1560 ± 48 | 1076 ± 254 | 0.126 ± 0.004 | 1.0.2 |
| Standard zircon | Moma #11 | 1057 ± 30 | 800 ± 152 | 0.086 ± 0.002 | 0.054 ± 0.001 |

External irradiation

- In the facilities for magnetic separation of minerals, radiation doses were at around 1-3 $\mu\text{Sv/h}$ by workplaces and up to 8 $\mu\text{Sv/h}$ by the piles of non-magnetic mineral fractions.

Conclusions

- **There is an association of thorium and uranium minerals with the heavy mineral fractions (zirconium and rare earth elements).**
- **At some workplaces, the external radiation doses may reach and exceed annual radiation dose limits adopted internationally.**
- **Application of the radiation protection basic safety standards is needed in these industries.**