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Attribution of Uranium Ore Concentrates by Rare-Earth Element Signature

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Identifying the source of uranium ore concentrates (UOCs) has become a research hotspot in nuclear forensics. In the present study, the applicability of rare-earth element (REE) signature for attribution of UOCs has been investigated. The REE patterns have geographical signatures, and hardly change during the leaching processes. With the help of statistical analysis, UOCs from different sources, which have different REE signatures, can be distinguished.

In this paper, the database was established by 89 uranium ores REE concentrations data from 9 countries (including Australia, Canada, China, Finland, France, Kazakhstan, Namibia, Russia and Zambia), which was cited from published articles to ensure the reliability. REE concentrations of uranium ores were transformed to REE ratios that showed a stronger indication. Different statistical analysis methods (PCA, PLS-DA, OPLS-DA) were tested and the results showed that only OPLS-DA could distinguish samples from a certain source to the others by several iterations, because OPLS-DA has a pre-treatment before PLS-DA, which can eliminate the impact of within-group variance (such as samples from certain country have different types, etc) to out-group variance (such as samples from different countries). Basing on the results of iterative OPLS-DA, uranium ores from certain country contained a distinct REE composition and an decision tree of attribution was generated. Four UOC samples were measured by ICP-MS and attributed to their country according to the decision tree. The method of attribution was demonstrated.

The study verified that REE signature is an indicator when identifying the source of UOCs, and the result of experiments showed OPLS-DA has better potential in nuclear forensics comparing to PCA and PLS-DA. The study will provide a support to the fighting against nuclear trafficking.

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