Determination of Uranium in Phosphate Industry Effluents UsingWDXRF: Concentration Assessment and Environmental Implications.

Abstract

Phosphate industry effluents contain significant levels of uranium, posing chemical and radiological risks to the environment. This study develops a method based on Wavelength-Dispersive X-ray Fluorescence for uranium determination in phosphate effluents. Samples were filtered, homogenized, and diluted to minimize matrix effects. Uranium concentrations were found to be approximately 10 ppm**,** with a coefficient of variation of 4 %, indicating moderate reproducibility. These results emphasize the potential environmental impact of uranium in phosphate effluents and support the use of WDXRF as a rapid, cost-effective monitoring tool.

Keywords: Uranium, Phosphate effluents, WDXRF, ICP-OES, Environmental risk

Introduction

The phosphate industry plays a key role in global fertilizer production. Wet-process phosphoric acid production generates liquid effluents containing dissolved salts, heavy metals, and naturally occurring radionuclides [1,2]. Among these, uranium is particularly concerning due to its chemical toxicity, radiological hazard, and mobility in water and soil [3,4].

During the acidulation of phosphate rock, uranium partially dissolves into the liquid phase, leading to its accumulation in industrial effluents [5]. These effluents, if released without treatment, can contaminate surface and groundwater, bioaccumulate in aquatic organisms, and impact soil and crop quality [6,7]. Uranium also represents a strategic resource, and its recovery from industrial effluents is gaining attention [8].

Accurate determination of uranium is critical for environmental monitoring and resource management. Techniques include spectrophotometry, alpha spectrometry, and plasma-based methods such as Inductively Coupled Plasma Optical Emission Spectrometry [9]. While ICP-OES offers multi-element detection with good precision, it requires complex sample preparation and may suffer from matrix effects.

X-ray fluorescence spectrometry, especially WDXRF, offers rapid, non-destructive analysis with minimal sample preparation, making it suitable for industrial monitoring [10,11]. Previous studies have successfully applied WDXRF to trace element analysis in complex matrices [12,13]. Optimizing sample preparation and calibration ensures accurate uranium measurements in phosphate effluents [14,15,16].

This study aims todevelop a WDXRF method for uranium quantification in phosphate effluentsand discuss the environmental implications of uranium at detected levels.

1. Experimental

1.1 Materials

- Spectrometer

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An X-ray fluorescence spectrometer (Magix 3kW, PW2403, PANalytical) was used for the determination of the uranium; it is a sequential spectrometer with wavelength-dispersive with a channel of measure based on a single goniometer covering the complete range of measure. It isequipped with an X-ray tube which is the X-ray source, the anode of the X-ray tube is in rhodium.

- scintillation detector

It is constituted by a crystal of iodide of sodium in which the atoms of thallium are distributed in a homogeneous way (NaI; Tl), by a photocathode and by a tube photomultiplier.

It works by converting the X-ray in light which is then measured with a photomultiplier.

1.2 Sample preparation

The phosphate industry effluent samples were analyzed directly, without any prior chemical treatment, only filtration through 0.45 µm membranes and homogenization. Each sample was placed in a specialized liquid sample holder with a polymer film at the bottom, allowing direct exposure to the incident X-rays. In our setup, an inverted optical configuration was used, with the X-ray tube positioned beneath the sample.

A critical factor in this arrangement is the mechanical strength of the film. Film breakage during analysis could result in liquid leakage and potential damage to the instrument. Therefore, it is essential to select a film that is sufficiently resistant while minimizing X-ray absorption and avoiding additives that might interfere with the measurement.

For this study, we used MYLAR® X-ray film (63.5 mm diameter), which has minimal X-ray absorption and no effect on the analytical matrix. Each sample of phosphate industry effluent (3 g, measured with 0.1 mg precision) was placed in the cup. Measurements were conducted under a helium atmosphere at 900 hPa to prevent boiling under vacuum conditions.

1.3 **Measurement conditions**

Measurement conditionsusing WDXRF aresummarized as follows;

•Atmosphere: Helium (900 hPa pressure)
•Power: 60kV, 50 mA
•Crystal:LiF220
•Collimator: 150microns
• X-ray: U-Lα1 line of 13.631 keV energy.

The WDXRF analysis of uraniumis shown in Figure 1.

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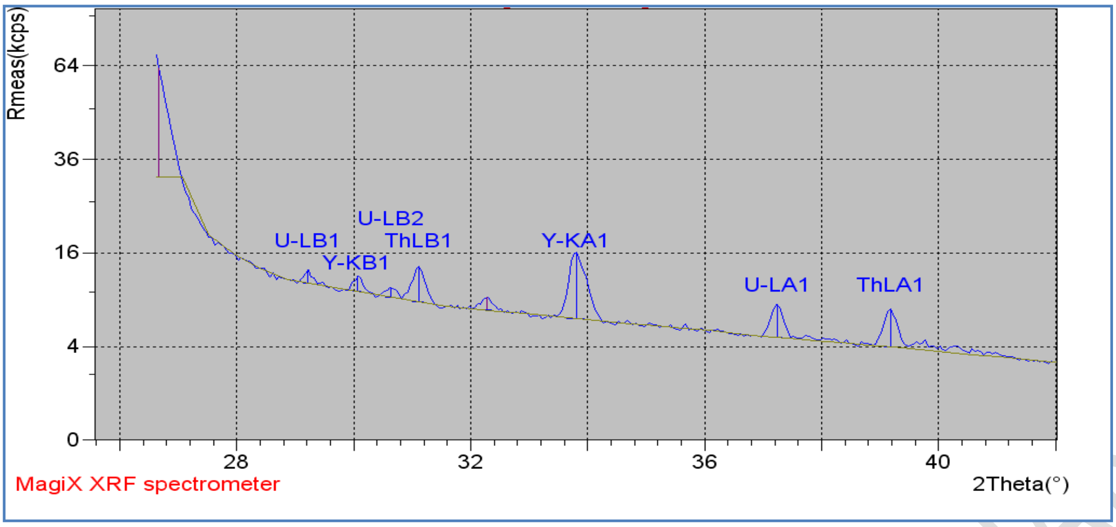

Figure1.Detectionof uraniumpeak usingthecrystalLiF220

- The experimentalangleof the lineof uranium: U-Lα1 (2θ°)[noted U-LA1]: 37.247°

1.4 Results and Discussion

A total of 10 phosphate industry effluent samples were analyzed using WDXRF. The uranium concentrations measured in these samples were approximately 10 ppm, with a coefficient of variation (CV) of 4 %, indicating good precision and reproducibility of the method. The detailed results are summarized in Table 1.

Sample	**Uranium Concentration (ppm)**
1	9.8
2	10.2
3	10.1
4	9.9
5	10.3
6	10.0
7	9.7
8	10.1
9	10.2
10	10.0

The measured uranium levels in the effluents are consistent with previously reported concentrations in phosphate industry wastewaters (e.g., Hatch et al., 2006; Vengosh et al., 2010). The low CV of 4 % demonstrates that WDXRF is a reliable and reproducible technique for direct analysis of liquid effluents without prior preparation.

From an environmental perspective, uranium concentrations around 10 ppm in industrial effluents are of concern. Discharge into surface waters or soil can lead to radiological and chemical contamination, posing risks to aquatic life and potentially entering the food chain. Prolonged exposure may impact soil quality and groundwater, necessitating treatment or mitigation strategies before environmental release.

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Overall, the results confirm that WDXRF is an effective, precise, and non-destructive method for monitoring uranium in phosphate industry effluents.

2. Conclusion

The present study demonstrates that WDXRF is a reliable and efficient technique for the direct determination of uranium in phosphate industry effluents without the need for prior sample preparation. Analysis of 10 effluent samples revealed uranium concentrations of approximately 10 ppm, with a coefficient of variation of 4 %, indicating high precision and reproducibility.

The detected uranium levels highlight a potential environmental risk, as discharges of these effluents into soil or water bodies could contribute to radiological and chemical contamination, affecting ecosystems and human health over time. These findings emphasize the need for regular monitoring and effective treatment strategies to mitigate uranium pollution from phosphate industry effluents.

Overall, this study confirms the suitability of WDXRF for routine monitoring and environmental assessment of uranium in industrial wastewater, providing a rapid, non-destructive, and accurate analytical approach.

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