Environmental Science & Technology

Viewpoint

pubs.acs.org/est

To Extract, or not to Extract Uranium from Phosphate Rock, that is the Question

Nils Haneklaus,*,[†] Yajie Sun,[‡] Roland Bol,[‡] Bernd Lottermoser,[§] and Ewald Schnug[∥]

[†]Institute for Reactor Safety and Technology, RWTH Aachen University, Aachen, Germany

[‡]Institute of Bio- and Geosciences, IBG-3: Agrosphere, Forschungszentrum Jülich GmbH, Jülich, Germany

[§]Institute of Mineral Resources Engineering, RWTH Aachen University, Aachen, Germany

[∥]Institute of Crop and Soil Science, Julius Kuehn-Institute, Braunschweig, Germany

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.[1] The implementation of sustainable development across all human activities also requires responsible extraction of our mineral resources. Raw materials can no longer be extracted based on economic grounds alone, social and environmental aspects must also be equally considered. Consequently, good practice guidelines for mining and processing of mineral resources should aim for minimal environmental impacts, protection of human health, total resource use, and zero waste mines.

Phosphate fertilizers are essential for modern agriculture to support an ever increasing world population. These fertilizers are produced from phosphate rock. It is well-known that phosphate rock contains considerable amounts of accompanying uranium, of which the great majority (80−90%) transfers to the final fertilizer product during mineral processing and is thus dispersed on agricultural soils, leading to the contamination of topsoils as well as ground- and surface waters.

Uranium is generally mined using underground and open pit methods as well as in situ leach (ISL) operations. Some uranium has been and still is recovered as a byproduct from the treatment of gold and copper ores or from phosphate rock deposits. From the 1980s to the mid-1990s approximately 20% of mined uranium in the United States was a byproduct of phosphate fertilizer production in Florida and Louisiana, before decreasing uranium prices made extracting uranium from phosphate rock unprofitable. Kim et al.[3] estimate that right now 10% of uranium required for peaceful usage in the U.S. could come from its phosphate fertilizer production chain and Gabriel et al.[4] estimate that more than 15% of uranium required for peaceful purposes worldwide could directly come as a purified byproduct from phosphate fertilizer production. Uranium concentrations in natural phosphate rock vary significantly from deposit to deposit and may exceed uranium concentrations of commercially mined uranium deposits. At the Santa Quiteria and Itataia mines in Brazil, both uranium concentrate (U_3O_8) for subsequent nuclear fuel production and diammonium phosphate (DAP) fertilizers will be simultaneously produced in the very near future.[2] This is monetarily profitable due to the relatively high uranium concentration (0.08%) in the mined phosphate rock.

After a decade of falling mine production to the early 1990s, production of uranium has generally risen since then to a total of 60 496 t in 2015 with further growing demand identified by OECD and IAEA[2] for the foreseeable future. Nonetheless, the uranium spot price (U_3O_8) has continued to steadily decrease to a new low since 2007. Solvent extraction can be used to obtain uranium from phosphoric acid, which is an intermediate product during phosphate fertilizer production.[5] This technology is already proven on an industrial scale, with all large U.S. phosphate fertilizer plants having used solvent extraction in the past. The technology achieves high uranium recovery rates exceeding 90−95% and obtains as an endproduct U_3O_8 at costs of U.S.$44−61 per pound. In this context, uranium spot market prices have varied between U.S.$18−40 from 2013 to end of 2016 and are thus still too high to cover the aforementioned production costs. Improved ion exchange technology, which is currently tested on a pilot plant scale, promises even better recovery rates at lower costs of U.S.$33−54 per pound U_3O_8.[3]

Responsible extraction of uranium resources should not only be based on economic grounds. It should also consider the social and environmental impacts of mining and any potential legacy costs incurred. Traditional uranium open pit mining for example leaves a significant environmental footprint and requires mine closure and site remediation, whereas ISL uranium mining does not generate any tailings repositories and waste rock dumps. Thus, one of the factors on the

Received: October 31, 2016
Published: December 28, 2016

DOI: 10.1021/acs.est.6b05506
Environ. Sci. Technol. 2017, 51, 753−754

environmental impact of nuclear energy is the way uranium is mined. The extraction of uranium from phosphate rock represents a more environmentally and socially responsible form of uranium mining, as phosphate rock is mined anyway for its phosphate component. Thus, it is postulated that extracting uranium from already mined phosphate rock, as schematically described in Figure 1, would lead to cleaner fertilizers with greatly reduced uranium content and to greener nuclear power with its fuel taken from mineral resources that cause a smaller environmental impact.

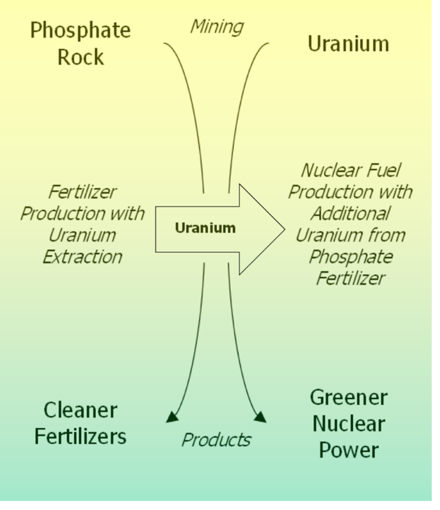

Figure 1. Phosphate fertilizer production with uranium extraction leading to cleaner fertilizers and greener nuclear power that has a smaller environmental impact.

If we neglect to recover uranium (as well as other relevant resources such as rare earth elements) from phosphate rock during fertilizer production, then these resources are lost to the fertilizer product or phosphogypsum waste stream (a slurry consisting of calcium sulfate and water that shows low levels of radioactivity and is thus of limited use). Such a loss of resources is potentially even more damaging for the environment since nonextracted uranium preferentially (80−90%) transfers to the phosphate fertilizer products that are dispersed on agricultural soil and not the phosphogypsum that is mostly stacked near fertilizer plants. Dispersion of the radiotoxic element uranium with fertilizer leads to impacts on the environment and human health. Overall uranium loads on agricultural land are steadily increasing as uranium-bearing phosphate fertilizers are still being used. Liesch et al.[6] for example, recently presented a study in which the uranium content of 1935 groundwater samples in Southern Germany was analyzed. It was found that phosphate fertilizers cause significant increase of uranium concentrations in groundwater at low concentration levels where they can best be measured. The extraction of uranium during phosphate fertilizer production could thus protect future water quality and subsequently human health. Moreover, the extraction of uranium during fertilizer production would reduce the total radiological dose received by workers and the public during phosphate fertilizer production, as studies from Oak Ridge National Laboratory for the Environmental Protection Agency have shown in the 1970s.[7]

Consequently, we believe that uranium extraction from phosphate rock should not only be pursued for economic reasons, but also for the sake of sustainable resource use and protection of human health.

In view of the technological improvements of extracting uranium from phosphate rock, which puts uranium extraction from phosphates on the edge of being profitable, additional research on uranium extraction may focus on further reducing costs for uranium recovery as well as simultaneous extraction of uranium and rare earth elements. Regarding the fate of uranium dispersed with fertilizers, additional research may consider the behavior of uranium in agricultural soils and underlying aquifers as well as uranium transfer to the agriculture landscapes at large and crops specifically including health effects of ingesting these crops.

Incentives such as subsidies for “cleaner fertilizers” or “greener uranium mining” that support the economic profitability of uranium extraction from phosphate rock can be introduced. Alternatively, legal limits for uranium in fertilizers can be implemented, as it was done for cadmium some time ago.[8] In the end, the policymakers and government authorities that already did push for legal limits of cadmium in mineral fertilizers in their countries will also have to decide, ‘whether to extract, or not to extract uranium from phosphate rock’.

AUTHOR INFORMATION

Corresponding Author
*E-mail: nils.haneklaus@rwth-aachen.de.

ORCID
Nils Haneklaus: 0000-0002-0673-0376

Notes
The authors declare no competing financial interest.

REFERENCES

(1) The World Commission on Environment and Development (WCED). *Our Common Future*; Oxford University Press: Oxford, U.K., 1987.
(2) OECD Nuclear Energy Agency and International Atomic Energy Agency. *Uranium 2016: Resources, Production and Demand*; OECD, 2016.
(3) Kim, H.; Eggert, R. G.; Carlsen, B. W.; Dixon, B. W. Potential uranium supply from phosphoric acid: A U.S. analysis comparing solvent extraction and Ion exchange recovery. *Resour. Policy* **2016**, *49*, 222−231.
(4) Gabriel, S.; Baschwitz, A.; Mathonnière, G.; Fizaine, F.; Eleouet, T. Building future nuclear power fleets: The available uranium resources constraint. *Resour. Policy* **2013**, *38*, 458−469.
(5) Beltrami, D.; Cote, G.; Mokhtari, H.; Courtaud, B.; Moyer, B. A.; Chagnes, A. Recovery of Uranium from Wet Process Phosphoric Acid by Solvent Extraction. *Chem. Rev.* **2014**, *114*, 12002−12023.
(6) Liesch, T.; Hinrichsen, S.; Goldscheider, N. Uranium in groundwater − Fertilizers versus geogenic sources. *Sci. Total Environ.* **2015**, *536*, 981−995.
(7) Davis, W.; Haywood, F. F.; Danek, J. L.; Moore, R. E.; Wagner, E. B.; Rupp, E. M. *Potential Radiological Impacts of Recovery of Uranium from Wet-Process Phosphoric Acid*; Oak Ridge National Laboratory: Oak Ridge, 1979.
(8) Chaney, R. L. Food safety issues for mineral and organic fertilizers. *Adv. Agron.* **2012**, *117*, 51−116.

DOI: 10.1021/acs.est.6b05506
Environ. Sci. Technol. 2017, 51, 753−754