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Assessing the potential production of uranium from coal-ash milling in the long term

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ABSTRACT

Uranium-bearing coal deposits are occasionally mentioned as a potential source of supply for nuclear fuels. The production of uranium from coal-ash has remained sub-economic for decades, but the emergence of new projects has once again raised a number of questions. How much coal-ash do we have? Are the coal deposits all rich in uranium? Can the uranium content always be recovered?

This study shows that there are significant quantities of uranium in the ash produced by the world coal consumption: between 7 ktU and 13 ktU in 2012. Yet, most of this ash correspond to very low grade ores and potential production capacities should not exceed 700 tU/yr in today's economic conditions (between 40 and 70 $/lbU_3O_8$ for both spot and long-term price over the period 2011–2014 (Ux Consulting, 2015)), i.e. approximately 1% of current needs. On the long-term, the sensitivity of the production potential to economic factors (cut-off grade, uranium price) and coal-consumption scenarios is moderate. Economic production from coal-ash should not exceed a couple of percents of uranium needs.

Introduction

In 2012, the world uranium requirements were approximately 68 ktU though production amounted to 58 ktU (World Nuclear Association, 2014). The market relies on secondary sources (stockpiles, MOX fuel, etc.) to supply the remainder. If the rising Asian demand is confirmed, however, the uranium mining industry will have to develop new projects, maybe exploiting unconventional resources. The world uranium demand in 2035 is estimated between 72 ktU and 122 ktU (OECD/NEA and IAEA, 2014). Among the unconventional resources readily available, the uranium content found in coal deposits could potentially relieve some of the pressure on the market.

Uranium as a by-product of coal used to remain sub-commercial. Rather recent press releases mention, however, the promising field tests conducted by Sparton Resources Inc (World Finance, 2010). This Canadian company and its Australian competitor Wildhorse Energy Ltd could start operating the first ash leaching plants to be seen in over 40 years. In 2006, Sparton announced that the Yunnan Chinese region could produce 150 tU/yr from three coal-fired power plants (Sparton Resources, 2006). Although these three coal power plants could almost suffice to supply a nuclear power plant, it is hard to tell how many of the 2300 coal power stations in the world could provide uranium.

Since uranium is considered as a by-product in this specific application, two aspects need to be assessed within a prospective approach before estimating the production capacities and the resources:

– First, the future production and resources of the primary product, i.e. coal;
– Second, the corresponding potential production and resources for uranium.

Assessing the economic potential of this unconventional source of uranium over the long term is the main goal of this paper. This is particularly strategic issue for Asian countries whose nuclear power demand is expected to grow over the coming century while its current uranium resources are deemed insufficient to face this demand.

Other issues, such as health hazards and environmental concerns, should also be considered as potential triggers and barriers to producing uranium from coal-ash.

The first part of this paper summarizes and discusses the main current and historical issues and challenges facing uranium production from coal-ash. The second part describes the key

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parameters in detail, as well as the data and methods on which this study is based. The method is explained through the calculation of a specific case: the world production potential based on 2012 historical data. The preliminary results are then presented in the third part. The same methodology is also used to obtain the other results provided in the third part.

Contextual background

Uranium in coal deposits

Coal is essentially an organic material but it also includes minerals and trace elements. Thus, uranium, thorium and their decay products (including radium and radon) are naturally found in coal as well as other radioactive elements in minor quantities (e.g. potassium, lead). Uranium is known to have a specific affinity with organic matter. In central Asia, 82% of uranium sandstone deposits coexist with oil-gas or coalfields (Liu et al., 2007). Yet coals have low uranium grades (generally less than tens or hundreds ppm); their reducing power precipitates uranium at the border of the geological formation but the low permeability of coals and lignites allows little penetration (Valsardieu and Cuney, 2001). While thorium in coal is concentrated in phosphate minerals (monazite, apatite), uranium is found in both mineral and organic fractions (U.S. Geological Survey, 1997). The US Geological Survey also points that uranium seems to be more concentrated in fine fly-ash particles.

Past production

Uranium has already been produced from coal-ash in the past. It should be pointed out that this occurred in very specific historical situations, mostly due to the Cold War. Thereby, the United States produced more than 380 tU in the 60s' by milling coal-ash (Hurst, 1981) and more than 1000 tU until 1995 (World Finance, 2010). Yet at the time, uranium was not exactly a by-product of coal: coal and lignite fields were burnt in place to recover the ashes without any power production. Brown coal was just burnt in place to recover the ash. At the same time, the United States produced 17 times more uranium from phosphates.

Finally, two other countries are known to have produced uranium from coal in the past: 2 sites in China together with 3700 tU produced in East Germany from 1947 to 1955 and from 1968 to 1989 (OECD Nuclear Energy Agency, 2006). Unfortunately, there is little information available on these projects.

Key issues

Before assessing the production capacities, it is important to stress some of the strong implications involved in producing uranium from coal-ash, which are mainly strategic and environmental.

Strategic challenges

First and foremost, we should question whether coal-ash can be considered as a significant source of uranium for the future. As stated in the previous paragraph, small amounts of uranium were produced when expectations, e.g. for military purposes, were high. But for the 21st century after a period of military uranium de-stocking, the question is: can significant amount of uranium be recovered from coal-ash in the case of renewed pressure on global supply?

This issue is all the more pressing for China and other large coal producers, not to mention uranium consumers, e.g. the United States or Russia. China is the world's top producer of coal with approximately 50% of the total global production and its uranium demand is growing quickly. China has also an ambitious nuclear development program with 29 reactors under construction (33 GW) and 59 (64 GW) more being planned (World Nuclear Association, 2014). In 2013, the uranium needs reached 4800 tU while domestic production was only about 1450 tU (OECD/NEA and IAEA, 2014). In 2035, demand could reach 20,500 tU (OECD/NEA and IAEA, 2014). The challenge in China is not only to increase domestic production, but also to step up production as quickly as possible. As way comparison, a typical mine (about 1000 tU/yr) needs around 10 years[1] to be developed and start producing while ash leaching plants (with a production capacity of around 150 tU/yr) are said to be operational in 3 years (World Finance, 2010). They could probably take advantage of this fast lead time, as was the case of the in-situ leaching facilities in Kazakhstan.

Environmental considerations

The use of coal-ash also raises a number of environmental and health concerns. Several studies have highlighted the impact of some coal power plants on the radiation dose received by the surrounding population (Gonzalez and Anderer, 1989; Pandit and Sahu, 2011; U.S. Geological Survey, 1997). This is why it is relevant to question whether milling the ashes to recover uranium can be considered as a benefit with regard to health hazards and environmental issues. On this point, and since coal fly-ash piles and their radioactivity are a source of controversy, it is worth pointing out the following considerations:

- Milling the ashes would not stop the emission of fumes and thin particles at the coal power plants. In the fumes, radon is the decay product responsible for additional dose on the surrounding population. The thin particles come from the 1% fly ash that is not trapped by electrostatic precipitators. As thorium seems to be more concentrated in fly ash than bottom ash compared with uranium, radium, potassium and lead, Th-232 has the highest additional dose among fine particles[2], though certainly limited compared with radon. Thus, the recovery of uranium may not impact the main source of additional dose.
- Removing uranium from the ash would reduce the radioactivity of these piles, but the resulting handling operations would increase the levels of occupational exposure.
- The chemical toxicity of uranium represents another health risk.

It must be remembered that this paper investigates neither the pros and the cons, nor the costs of removing toxic elements from coal-ash. It only points out that with regard to uranium, the ash piles (not the flue gases) represent more toxic hazards than radioactive doses. In contrast, the ash contains other toxic elements such as arsenic, selenium and mercury, which have a higher level of toxicity than uranium. Therefore, removing uranium only would not solve the issues at hand. In the end, there is no serious argument that milling coal-ash would help decrease radiation hazards.

The most important environmental benefit of milling coal-ash is more likely to concern the flue gases of coal power plants. As it is explained in the following section (Milling process), the milling process could recover the SO_x gases from the fumes to reduce the acid consumption. This would have a positive impact on both the environment (reduce the emission of pollutants) and on savings (the process requires large quantities of acid, representing a significant part of the operational expenditure (opex)). Unlike carbon tax or tradable emission-permits, the regulations on SO_x (when any exists) do not always impose limits on cumulative emissions. The restriction

[1] Generally, after first discovery of a resource, it takes 8–15 years to reach production. (World Nuclear Association, 2013).

[2] This result stand for the three Indian coal-fired plants under study (Pandit and Sahu, 2011).