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Extracting Uranium from Seawater: Benefits, Risks and Policy Implication

Aznan Fazli Ismail[a,b], Matthew L. Marsh[c,d] , Man-Sung Yim[a,c*]
[a]*Department of Nuclear and Quantum Engineering (NQe), 291 Korea Advanced Institute of Science and Technology (KAIST), 373-1 Guseong-dong, Yuseong-gu, Daejeon 305-701, South Korea.*
[b]*Nuclear Science Program, School of Applied Physic, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Malaysia*
[c]*Nuclear Nonproliferation Education and Research Center, KAIST, Republic of Korea*
[d]*Department of Biochemistry and Cellular Molecular Biology, University of Tennessee Knoxville, TN 37996, United States*

[*]*Corresponding author: msyim@kaist.ac.kr*

1. Introduction

The future of nuclear energy depends on a variety of factors such as the trend in energy market, domestic energy policies, safety records of nuclear power plant, the public perception of nuclear risk, and perhaps even the concern of nuclear proliferation. A large difference in nuclear development projections can be seen in the developed versus the developing world. Counties like China is embarking on a large scale expansion program to increase its nuclear capacity to 58 GWe by 2020, while India ambitiously targeting to build 20-30 of new reactor by 2030 [1].

One of the key issues that need to be addressed regarding the future of nuclear power is the availability of uranium. The most economical way to this day of providing uranium for nuclear energy has been through conventional mining. However, the current projection of the well-known, easily obtainable sources of uranium indicates that global nuclear industry can be supported through the end of the century under the once-through cycle. It, however, could be extended up to 250 years if the speculative uranium sources are taken into account [2]. Uranium is also available in seawater. The theoretical amount of uranium available in seawater is about 4.5×10^9 tonnes (U~3.3ppb, ocean volume ~ 1.37×10^9 km^3), which is roughly about thousand times larger than the estimated conventional uranium reserves [3]. Utilizing uranium from seawater thus opens up the possibility of virtually unlimited supply of nuclear fuel. The effort of extracting uranium from seawater has begun since 1960s which were primarily focused on the development of high efficiency of adsorbent materials that were capable to extract uranium in the presence of other ions. The current-state-of-the-art adsorbent is amidoxme-based material with has high affinity in chelating uranyl ions in seawater [4]. Nevertheless, the latest estimate of the cost of extracting seawater uranium ranges from \$1230/kg to \$660/kg based on a large underwater area uranium farm concept. These are still very high compared to the cost of uranium from the conventional uranium mining method (around \$70/kg) [5]. Along with the efforts to improve the adsorbent performance, alternative approaches using electrosorption technique with activated carbon electrode has been introduced [2]. Even though this technique involves the use of electricity energy to extract uranium, it has better uranium uptake at much shorter time periods as well as much lower adsorbent fabrication cost compared to the amidoxime-based material. As the technologies improve, the mode of obtaining uranium through seawater extraction may become competitive and feasible in the near future. Considering that, it is imperative to view the implications of the development of uranium seawater extraction technology.

2. Methods and Results

In this section the current state of uranium seawater extraction technology development are described. The implication of uranium extraction from seawater and safeguarding uranium seawater extraction technology are discussed and proposed.

2.1 Current state of Uranium Seawater Extraction Technology

R&D activities in Japan

Recent research primarily focusing on the development of amidoxime-based adsorbent materials. These adsorbent materials were reported to have high affinity in chelating uranyl ions in seawater [6]. Marine test has been carried out using both stack and braid collection system. Still, the cost of extracting uranium was 13 times higher than that of conventional uranium mining [7], mainly due to the low uranium uptake (poor adsorption performance) and high production cost. Both stack collection systems and braid collection systems are shown in Fig. 1 and Fig. 2, respectively.

R&D activities in US

Recent developments in the United States currently have focused on the development of amidoxime-polymeric adsorbent materials based on Japanese adsorbent technology. In August 2012, Oak Ridge National Laboratory (ORNL) released a statement claiming successful reduction of the uranium extraction costs to USD660/kg, about half of the cost reported by Japan. The finding was considered a major breakthrough in uranium recovery research even though this cost is still high compared to conventional mining. In addition, set of field column experiments were performed at the Marine Sciences Laboratory of the Pacific Northwest National Laboratory (PNNL) using amidoxime-based polymeric adsorbent developed at Oak Ridge National Laboratory (ORNL) [8].

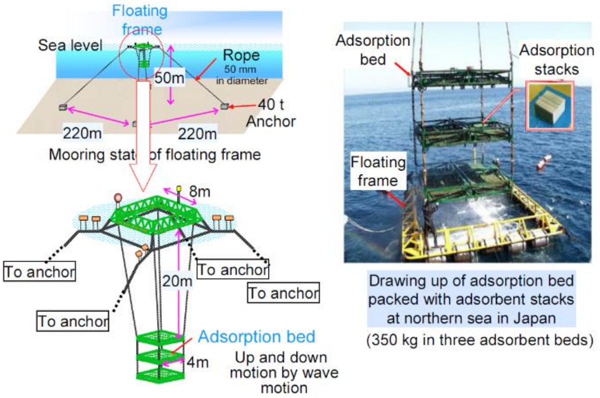

Figure 1. Stack collection system developed in Japan for marine experiment [9]

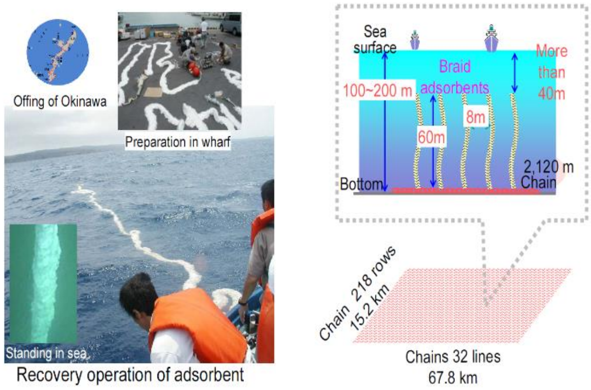

Figure 2. Braid collection system developed in Japan for marine experiment [9]

R&D activities in India

Laboratory studies have been performed by several research groups at Bhaba Atomic Research Centre (BARC). India has successfully developed amidoxime-based adsorbent material in the form of a membrane and hydrogel and also has been carried out an engineering scale study on the production of polymeric adsorbents [10]. The conceptual design of the contactor assembly for uranium recovery from seawater has been developed [11]. India, through BARC also has collaborated with CEA (Commissariat à l'Energie Atomique of France) to study the extraction of uranium from the brine discharge of desalination plants in a research program named RUSWapp (Recovery of Uranium from Seawater Pilot Program) [12].

R&D activities in South Korea

A lab scale study has been carried out in Korea Advanced Institute of Science and Technology (KAIST) using electrosorption technique activated carbon electrode with by using activated carbon electrode. The study showed that the electrosorption-based approach by using activated carbon electrode as adsorbent material can achieve the comparable or better uptake level of uranium at much lower cost at much shorter time periods [2]. The uranium uptake using this technique was reported to be 3.4 kg-U/Ton-Adsorbent.

2.2 Implication of Uranium Extraction rom Seawater

Advantages

The obvious benefit of utilizing uranium from seawater is the guarantee of the sustainability of uranium supply for the future. The inventory of uranium amount in the entire ocean is greater than that of the terrestrial uranium about a factor of 1000. This may be more than enough to fuel all the nuclear reactor in this planet as well as to meet the long-term uranium supply requirement. This situation may also be translated into relief from processing of spent fuel. Since now uranium sources are abundant, there is no need to reprocess the spent fuel. Spent fuel are reprocessed primarily in order to recoup uranium where usually 95% of uranium are still available, even though, the percentage is much depended on the burn-up factor. Since extracting uranium from seawater would benefit the global uranium supply for at least a millennia, it would dispel the argument a state can make to reprocess for lack of uranium resources. Thus there is no need for nuclear materials recycling from the resource utilization point of view. Reducing incentive for nuclear materials recycling translates into potential proliferation risk reduction. It also provides the benefit of reducing overall health risk of nuclear fuel cycle. Risk from uranium mining dominates the risk associated with nuclear fuel cycle in terms of both mortality and morbidity to the workers. It also poses highest risk to the public among all nuclear fuel cycle stages when no major accidents are involved. The abundance of uranium sources may also beneficial in the environmental aspect. For example, the increase in nuclear generating capacity is not possible if uranium supply could not provide the future uranium requirement. If this is true, the uranium fuel supply will be the limiting factor in nuclear power development. Nevertheless, extracting uranium from seawater will dispel these factor. Expanding nuclear generating capacity certainly will reduce the emission of greenhouse gas (GHG).

Disadvantages

Utilizing uranium from seawater may also translate into increased burden of repository disposal as the abundant supply of uranium increases the production of spent nuclear fuel. This, overall may affect the public opinion and perception on the nuclear energy itself. United States for example is still struggling to convince public on the permanent nuclear waste repository site in Yucca Mountain even after having invested US$9 billion on the project [13]. This indicates that increased supply of uranium needs to be met with sustainability method of waste management, including waste disposal and perhaps recycling.

Seawater uranium technology could also pose environmental risks, mostly through disrupting marine ecology. Certain marine flora and fauna may experience disadvantage due to the technology. For instance, the uranium extraction farms concept (technology proposed by Japan) needs vast and deep sea area which may disturb marine ecology. Recent study has reported that seawater uranium farms would decrease ambient currents from between 4-10% of the usual speed compared to the kelp forest that can reduce currents up to 50% [14]. Therefore, the addition of seawater uranium farms could introduce new dynamics to currents that may impact other strata of oceanography.

Even though seawater uranium extraction technology can be considered as low proliferation risk, but one should keep in mind that obtaining uranium is probably considered as the first step in acquiring nuclear weapons. Therefore, the increase in uranium supply may also require stricter control over the access to enrichment technology. It should also be kept in mind that the more and stricter safeguards that are put in place can be correlated directly to restricting commercial operation growth that finally will limit the technology development – factor that not desired in the nuclear industry.

2.3 Safeguarding Uranium Seawater Extraction Technology

Even though, extracting uranium from seawater poses a minimal proliferation treat, any part of the fuel cycle that is unregulated or insecure still considered to contribute to proliferation risk and must be regulated. In this aspect, to address non-proliferation issues, an appropriate policy should be proposed to safeguard the uranium seawater extraction technology. Therefore, a trusted and independent international body such as IAEA (International Atomic Energy Agency) must take the role to manage all safeguards and evaluates facilities for proliferation risks that related to this technology. A reasonable mechanism for safeguards of uranium extraction technology is illustrated in Fig.1. To achieve non-proliferation state, all the proposed aspect (facilities inspection, security feeds at extraction facilities, open and transparent of information, nuclear export control and licensing of extraction technology) shall be followed. To explain in general, uranium seawater technology could be equated somewhat to uranium mining facilities. The **facilities inspection** would involve random visit from an independent international body (e.g. IAEA). An independent regulatory body shall carry out inspections of facilities and activities to verify that the authorized party is in compliance with the regulatory requirements and with the conditions specified in the authorization. The facilities also would be subject to be monitored (inspected) through security positioned to deter any illicit trafficking of nuclear material. The **security feeds** at extraction facilities here, is referred as physical barrier protection. Since physical parameters would be difficult to keep, an enduring presence of security would be essential. A state or company that involve in the extraction must demonstrate the capability to secure the extraction plant by providing armed security on-site. A country with the technology also has the necessity to clarify the clear (**open and transparent**) information about the extraction activities to the International Body (e.g. IAEA). **Export controls** here are related to bilateral agreements between states and require monitoring the nuclear material exported throughout its entire use of the fuel cycle. Nuclear export control is required (as highly recommended by IAEA) in order to documented all transfers of nuclear materials or extraction technology. Australia as one of the main uranium exporter has taken a lead in creating policy and safeguard provisions to ensure any of its uranium exports never been used to develop nuclear weapons. Finally, since the uranium seawater extraction technology might be easier to obtain and developed once it becomes feasible, licensing would provide an added deterrence to covert proliferation.

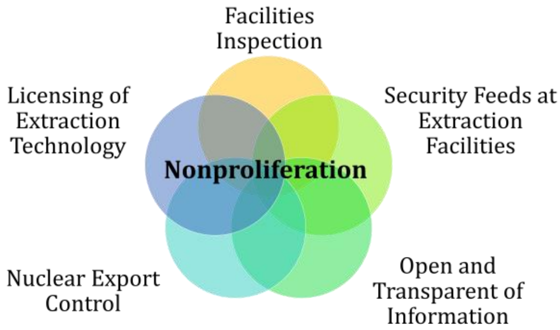

Fig.1 Proposed mechanism for safeguards of uranium extraction technology

3. Conclusions

Extracting uranium from seawater has both pros and cons. The only main obstacles at this point is it not economically competitive compared to the conventional mining. Solving this issue will open up a new era of the way of extracting uranium to meet the future requirement of nuclear energy. As the uranium seawater extraction technology is rapidly being developed and might become feasible in the near future, an appropriate mechanism are required to safeguard the extraction technology. The emergence of uranium seawater extraction technology would reduce the need claims for several states to acquire reprocessing permission or technology, that proven to be more high proliferation risk and difficult to safeguard.

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