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URANIUM AND THORIUM POTENTIAL FOR INDONESIA'S FUTURE ENERGY SECURITY

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ABSTRACT

Uranium and Thorium are natural elements known for their radioactive properties that can be used as a source of nuclear power. Both Uranium and Thorium are new energy sources, and are classified as alternative nuclear fuels, they are known as green nuclear. Uranium is not a rare metal, it is estimated that there are 5.7 million tons of uranium reserves in the world in 2015 in the Red Book of The Organization for Economic Co-operation and Development-Nuclear Energy Agency (OECD-NEA). As for Thorium, which is a heavy metal content in the earth's crust, it has reserves of 6.3 million tons in the world. Compared to Uranium, Thorium has a more even distribution and one of them is found in Indonesia. The National Nuclear Energy Agency (BATAN) stated that Indonesia has 79,830 tons of uranium reserves and 136,966 tons of Thorium, which are scattered in the Bangka Belitung Islands, Kalimantan Island and Sulawesi Island. The purpose of this paper is to examine the potential of Uranium and Thorium in Indonesia, including the amount of reserves, their distribution and future prospects in order to support the nation's energy security, because in Indonesia, nuclear is used for peaceful purposes, namely as a power plant.

KEYWORDS: Uranium, Thorium, Potency

1. INTRODUCTION

Uranium and Thorium are nuclear materials that can be used as energy fuels. Both uranium and thorium are natural materials with very strategic economic value in the future [1]. Uranium and thorium fuels have their own features. Currently, Uranium is the most important element in nuclear fuel for nuclear power plants (NPP), mainly in generating heat. The sustainability of a nuclear power plant is highly dependent on the supply of uranium ore. The balance between demand and supply of uranium is the lifeblood of every nuclear power plant that operates. The occurrence of a nuclear accident at the Fukushima nuclear power plant, Japan, in 2012 made several developed countries in the world start looking for alternative sources of nuclear energy that are safer, both in terms of the utilization process and the waste generated.

Until now, Thorium is still used in research trials, namely as a fuel for research reactors in India, Russia, Japan, the United States and Canada. These countries are developing thorium so that it can also be used as nuclear fuel as a substitute for uranium. Although until now there is still not a single country in the world that has used thorium for power generation. The technology for thorium utilization is still being explored, especially since thorium cannot be used directly as a fuel but must be mixed with uranium as an initiator.[2]. In terms of demand, the amount of thorium needed for reactor fuel is less than uranium, this further shows the advantages of thorium as a fuel compared to uranium.

II. PURPOSE

This paper aims to examine the extent to which the potential of Uranium and Thorium owned by Indonesia, including the number of reserves and their distribution locations as well as the prospects for the future in order to support the nation's energy security.

III. BASIC THEORY

Worldwide Uranium Reserves

Uranium is a heavy metal symbolized by U with atomic number 92. It was discovered in 1789 by a German chemist named Martin Klaproth. Uranium has a characteristic form of silvery gray metal and will turn black when exposed to air or known as the oxidation process. Uranium is weakly radioactive because all its uranium isotopes are unstable with isotope half-lives ranging from 159,200 years to 4.5 billion years. The most common isotopes at 99% in natural uranium are uranium-238 (which has 146 neutrons) and uranium-235 (which has 143 neutrons). Primordially, the element uranium has the highest atomic weight. The density of naturally occurring uranium in a low concentration situation in soil, rock and water, which is then extracted. The result is uraninite which is known as the result of commercially carried out uranium extraction [3].

Figure 1. Distribution of Worldwide Uranium Reserves [4]

It is estimated that there were 5.7 million tonnes of uranium reserves in 2015 in the Red Book of The Organization for Economic Co-operation and Development-Nuclear Energy Agency (OECD-NEA). Uranium itself has various types of deposits [5], such as:

1. Sedimentary phosphorus type (referred to as Phosphorite type) with the largest number of global (worldwide) resources.
2. Black shale type of 4.4 million tons with low levels of 50-400ppm originating from old sedimentary basins
3. Hosted Sandstone type which is deposited as uraninite or coffinite, the result of deposition from formation water (basinal brines) which interacts with reductants such as carbonaceous material, hydrocarbons and sulfide minerals (by 1.5 million tons)
4. Other types of deposits associated with magmatism (intrusive/ plutonic related) are:

a. IOCG (Iron Oxide Copper Gold) – global resource of 900,000 tonnes, eg Olympic Dam (Australia)
b. Intrusive – pegmatite hosted – global resource approx. 290,000 tonnes, examples in Greenland, South Africa, and new discoveries in Rossing (Namibia).
c. Volcanic – caldera associated – 210,000 tons, as in Dornot (Mongolia), Xiangshan (China), McDermit (USA)

The distribution of uranium reserves in the world is shown in Figure 1. The largest world uranium reserves are in Australia (29%), followed by Kazakhstan (13%), Russia (9%), Canada (9%), South Africa (6%), Namibia (5%), Nigeria (5%), Brazil (5%), China (5%), Ukraine (2%), Mongolia (2%), Uzbekistan (2%), USA (1%), Botswana (1 %), Tanzania (1%), and the rest (5%) spread all over the world including Indonesia. In addition to talking about reserves, as several nuclear power plants in the world have already operated, then it is known that the supplying countries which in this case carry out uranium production, there are three largest producing countries, namely Kazakhstan, Canada and Australia.

Worldwide Thorium Reserve

Thorium is a radioactive nuclide that was first discovered in 1829 by Jons Jakob Berzelius, a Swedish scientist. With the symbol Th and atomic number 90, this element has a half-life of 14 billion years, which is thought to be much older than the age of the earth. The half-life is the time it takes for the amount of a substance to be reduced to half its initial value [6]. It is a bright silvery, paramagnetic, slightly soft radioactive actinide metal. Pure thorium is very malleable and like most metals it can be malleable and shaped. The hardness of thorium is the same as that of mild steel, which when heated can be rolled into sheets and drawn into wire [6].

Figure 2. Distribution of Worldwide Thorium Reserves [7]

The content of this heavy metal in the earth's crust is approximately 3-4 times more than uranium (10 ppm versus 2.5 ppm) [8]. In 2015, thorium reserves were identified worldwide at 6.3 million tonnes, and unlike uranium, they are more evenly distributed. India, China, Brazil, the United States, Australia, Egypt and Turkey have thorium reserves of more than 300 thousand tons. The largest availability of thorium reserves in continental distribution in the world is in Asia (>40%), then America (27%), Europe (12%), and Africa (10%) and Australia (10%). Thorium is found in small amounts in some rocks and soils. The amount of thorium in the earth's crust is three times more than lead [9]. Soils generally contain an average of about 12 ppm thorium. Thorium is found in several minerals, including thorite (ThO2), thorianite (ThO2+UO2), monazite (Ce,La,Th)PO4, zircon (ZrSiO2), xenotim (YPO4) and alanite (Ca, Ce, La,Y)2 (Al, Fe)3(SiO4)3(OH) [8,9]. Thorianite is a mineral that contains about 12% thorium oxide. Monasite contains 2.5% thorium, 0.1-2% alanite and 0.4% zircon [10]. In general, there are 3 (three) types of monazite with different compositions that do not always contain radioactive elements such as thorium or uranium [10], namely:

1. monazite-(Ce) with the formula $(Ce,La,Nd,Th,Y)PO_4$.
2. monazite-(La) with the formula $(La,Ce,Nd)PO_4$.
3. monazite-(Nd) with the formula $(Nd,La,Ce)PO_4$.

Uranium and Thorium as Future Alternative Energy Sources

Alternative energy is a term that is often heard over all types of new energy that aims to replace conventional fuels, namely fossil fuels such as coal and oil. The reason is clear because the use of hydrocarbon fuels results in environmental damage due to high carbon dioxide emissions, which greatly contribute to global warming.

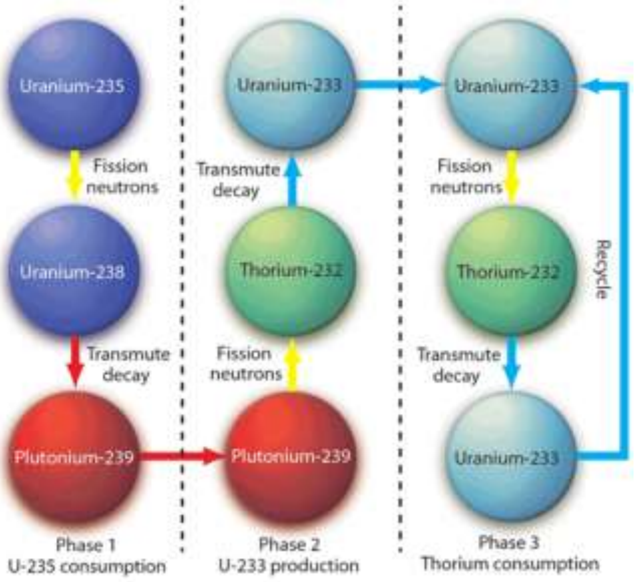

Figure 3. Two phases in a uranium reactor [11]

One of the future alternative energy sources is by utilizing nuclear power as an energy source that is relatively cheaper, safer and does not pollute the environment. Uranium-fueled reactors are the first step towards using nuclear energy because only uranium containing isotopes can work. The fission of 1 g of uranium or plutonium per day yields about 1 megawatt (MW). This is equivalent to 3 tons of coal or about 600 gallons of fuel oil per day, which when burned produces about 1/4 tonne of carbon dioxide [12]. As an illustration, a nuclear plant with a capacity of 1,000 MW, takes 21 tons of uranium to produce electricity for 1.5 years, and of those 21 tons of uranium, only a third of it becomes waste [13]. However, it is difficult to release all the uranium energy and the uranium must be converted into plutonium and consumed by fission in a reactor with fast neutrons. Thus, the thorium-fueled reactor is allegedly more fuel efficient to operate because it uses U-233 and chemically processes the fuel at high efficiency, a task that can be handled by liquid fluoride reactors.

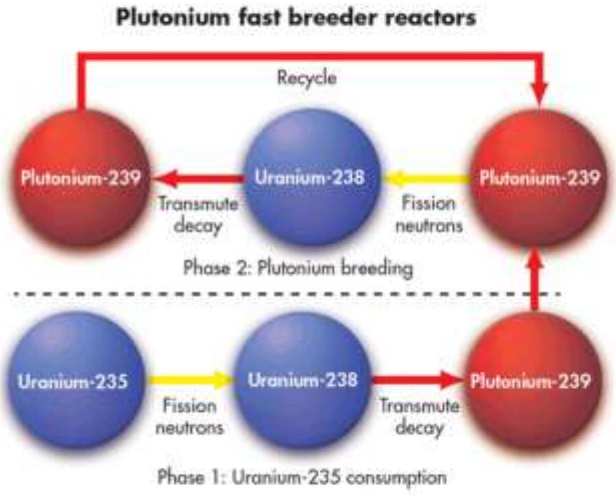

Figure 4. Three phases in a uranium reactor [11]

The need for U-233 remains, and the separation of plutonium in liquid-fuel reactors containing thorium is the bridge between the two, permanently removing plutonium from the first phase of nuclear energy while producing the U-233 needed for the next phase. In this way, the full potential of thorium can be harvested, and this will greatly help increase public acceptance of thorium technology. One tonne of thorium can produce as much energy as 35 tons of uranium in a liquid thorium fluoride reactor. Regarding the conversion of thorium into electrical energy, thorium is considered more efficient because 90% of thorium fuel will react to produce electricity when compared to uranium which is only 3%-5%, so it will produce much less radioactive waste [14].

IV. METHODOLOGY

Research methodology

The research method used is literature study which is a series of activities related to the methods of collecting library data, reading and taking notes, and managing research materials [15].

Data collection

This paper uses a secondary data collection methodology in the form of books, journals, literature reviews, scientific articles related to reserves and distribution and utilization of uranium and thorium as alternative energy sources in the future.

DISCUSSION

Identification of Indonesia's Potential Uranium and Thorium Reserves.

The dose rate of environmental gamma radiation levels in some of these locations generally comes from gamma radiation emitted by primordial radionuclides from the soil. The variation of the dose rate is highly dependent on the geological structure, the type of rocks, and the soil contained in the measurement location, for example a location containing a lot of granite, feldspar, monazite sand will provide a relatively high dose of gamma radiation [17]. In 2007, the Center for Radiation Safety and Metrology Technology of the National Nuclear Energy Agency (PTKMT-BATAN) carried out environmental radiation measurements, and obtained a high natural dose rate value in an area indicating the presence of radioactive elements contained in rocks, such as uranium (U), thorium (Th), and potassium (K) or the presence of decay elements. In general, the presence of radioactive elements, especially U and Th, is closely related to rocks with acidic compositions, both plutonic (granitic) and volcanic (rhyolitic).

Indonesia, as a ring of fire country, has 127 active volcanoes which makes the relationship of uranium deposits with magmatism very possible. Although not all uranium is associated with volcanoes because sedimentary rocks can be a source of deposition of uranium-containing minerals [18]. Depositions resulting from mountain erosion of igneous rocks that initially contain uranium will be filtered naturally. Indonesia as a country with very complex tectonic conditions, of course, has the potential for this uranium to exist, namely in an active volcanic environment that allows uranium traps to exist. Thorium reserves in Indonesia are generally closely related to the potential monazite pathway that follows the path of the richest tin deposits in the world, which stretches from southern China, Myanmar, Thailand, Malaysia, and continues to Indonesia. The route in Indonesia leads from north to south, namely from Karimun Island, Kundur Island, Singkep Island, Bangka Island, Bangkinang (central Sumatra) and there are signs of them in the Anambas, Natuna, and Karimata Islands [19, 20, 21].

The exploration process for these two radioactive elements in Indonesia began with uranium exploration in the early 1960s, which continued and experienced the most active exploration period from 1976 to 1985. In 1996, exploration was concentrated in the Kalan area and its surroundings on the island of Borneo, which was thought to be related to the path of metamorphic rocks. Only then, in the period 2006 to 2010, exploration activities continued and expanded to the Kawat area, East Kalimantan, using a magmatic approach that follows the path of volcanic rocks. Exploration activities continued, until in 2011 to 2012 it expanded to Papua Island.

Figure 5. Map of Radioactive Mineral Resources: Uranium and Thorium in Indonesia [22]

Figure 5 shows a map of radioactive mineral sources in Indonesia, it is known that from the results of existing uranium exploration activities, there is a classification of areas that are suspected to be sources of uranium reserves [22], which include:

1. Speculative Resources Area (SRA), is an area marked as a reserve resource based on exploration from secondary data, the symbol in yellow is for SRA uranium
2. Indicated Resources Area (IRA), is an SRA that has been equipped with geological synthesis results from field studies that show positive reserves availability, including radiometric results or geochemical anomalies and indications of mineralization, symbolized in green IRA uranium
3. Potential Resources Area (PRA), an IRA that has been equipped with more detailed mineralization both on the surface and on the surface, red symbol for PRA uranium, with maroon color symbol for PRA thorium

Indonesia's Uranium Reserves

Through tracing traces of uranium exploration in Indonesia which has been started since 1960, the results obtained are in the form of the area in each province in Indonesia which is alleged to be a potential area in uranium reserves as in Table 1.

Regarding the distribution of uranium reserves in Indonesia, both measurable: m (based on data that meet the requirements for exploration), indicated measurable: ii (based on data that meet the requirements for prospecting), hypothetical: h (based on data that qualify for a review survey), in full can be seen in Figure 6 which is described in more detail in Table 2.

Figure 6. Distribution of Uranium and Thorium Reserves in Indonesia [17]

Table 1. Stages and Coverage Area of Indonesia’s Uranium Exploration [22]

Island of Research Exploration	Stages	Coverage Area km^2
Sumatera	General reconnaissance and prospecting	146.523
	Systematic detail and prospect	1.686,25
	Exploration	2.805
Jawa	General reconnaissance and prospecting	2.125
	Systematic detail and prospect	10
Kalimantan	General reconnaissance and prospecting	230.140
	Systematic detail and prospect	83.178,2
	Exploration	62.461,02
Sulawesi	General reconnaissance and prospecting	36.190
	Systematic detail and prospect	107
Papua	General reconnaissance and prospecting	7.815
	Systematic detail and prospect	240
Bangka Belitung	General reconnaissance and prospecting	9.487
	Systematic detail and prospect	4

Table 2. Uranium Potential Areas and Reserve Status in Indonesia

Island of Indonesia	Province	City /Districts	Potential of Uranium		
			m	i i	h
Sumatera	NAD	Nels Gumpang, Aceh Tenggara	√		
	Sumatera Utara	Hatapang, Labuhan Batu	√		
		Aloban, Sibolga	√		
	Sumatera Barat	Harau, Limapuluh Kota	√		
		Upul, Sijunjung	√		
	Jambi	Rantau Pandan, Muara Bungo	√		
	Lampung	Way Publan, Lampung Tengah	√		
	Kepulauan Riau	Singkep,	√		

		Kepulauan Riau		
Kepulauan Bangka Belitung	Bangka Belitung	Pulau Bangka	√	√
Kalimantan	Kalimantan Barat	Kembayan, Sanggau	√	
		Nanga, Kapuas Hulu	√	
		Kalan, Melawi		√
	Kalimantan Tengah	Katingan	√	
		Mentawa dan Darab		√
	Kalimantan Timur	Kawat, Mahakam Hulu		√
Sulawesi	Sulawesi Tengah	Bangkir, Donggala	√	
		Kuwali, Sigi	√	
	Sulawesi Barat	Pasangkayu, Mamuju Utara	√	
	Sulawesi Selatan	Masamba, Luwu Utara	√	
		Bamu, Bantimala		

		, Maros Gowa	√
Kepulauan Maluku	Maluku Utara	Pulau Talibu, Kepulauan Sula	√
Papua	Papua Barat	Rasiki, Manokwari	√
	Papua	Biak	√

Indonesia Thorium Reserve

Thorium reserves in Indonesia are often found in granite associations. This confirms that the majority of thorium deposits are found in the tin pathway [23]. It is known that primary monazite deposits are formed through several phases, namely:

1. pneumatolytic phase, is the process of chemical reactions of gases and liquids from magma in an environment close to the magma. From a geological point of view, this is called contact-metamorphism, because there are signs of contact between older rocks and newer magma. This contact mineral can occur when hot steam with high temperature from magma contacts with reactive wall rock. The contact minerals formed include: wollastonite ($CaSiO3$), amphibole, quartz, epidote, garnet, vesuvianite, tremolite, topaz, actinolite, tourmaline, diopsite, and skarn [24].
2. high pneumatolytic–hydrothermal contact phase, is the process between the final product of the pneumatolytic phase with the remaining aqueous solution of magma as a result of magma differentiation. This high hydrothermal is rich in relatively light metals, and is the largest source (90%) of the deposit formation process.
3. the last phase is hypothermal–mesothermal, this is the most important phase in mining because it has economic significance where a solution containing tin and monazite with the main component of silica ($SiO2$) fills traps in fault lines, joints, and other weak zones.

Secondary monazite deposits are known to be formed from primary monazite deposits that have been weathered, eroded, transported, and deposited as colluvial deposits, alluvial fans, river alluvial, and offshore alluvial deposits. Primary monazite deposits are generally found in granite rocks, while secondary monazite deposits are found in old rivers and valley bottoms both on land and at sea. Granite is the source rock and alluvial deposits are places for secondary monazite accumulation.

Geological features in Southeast Asia show Thorium deposits stretching along Malaysia, Bangka Island, Belitung, and West Kalimantan (Karimata, Ketapang, Rirang, Tanah Merah). In addition, research on thorium resources was carried out in the Mamuju area, West Sulawesi, Mamuju area is a new exploration area that is quite intriguing, because it has high levels of Th and U (Figure 6). The details of the location and status of potential thorium reserves are presented in table 3 as follows:

The Center for Nuclear Geology Development (PPGN), BATAN has mapped thorium reserves where in 2017 the largest potential for thorium reserves was Bangka Belitung Island, which amounted to 126,821 tons of thorium, followed by Kalimantan Island with 7,007 tons of thorium, and Sulawesi Island with 3,138 tons of thorium (figure 7).

Figure 7. Distribution of Potential Uranium and Thorium in Indonesia (BATAN, 2017)

Uranium and Thorium as Alternative Energy Sources for the Nation

Law No. 17 of 2007 concerning the National Long-Term Development Plan (RPJPN) contains the mandate for the construction of nuclear power plants with a high level of safety to meet electricity needs, presumably starting in the 2015-2019 period. Energy savings and diversification policies as well as greater attention to the development of safe and affordable new energy sources and nuclear energy in the 2020-2025 period are real steps in responding to energy scarcity [23].

The existence of the National Industrial Development Master Plan (RIPIN) in Government Regulation No. 14 of 2015 which regulates this matter also clarifies the government's role in preparing energy for industry in a sustainable manner. The speed of determining and then working on energy preparation will determine whether Indonesia will be in the middle income trap zone in the 2020-2030 period or not [23]. A solid industry supported by energy sources that will be available for a long period of time in the future aims to make Indonesia a strategic investment destination. The provision of energy that is safe, clean, environmentally friendly, sustainable, large-scale, inexpensive and can be built in a short time is absolutely realized as a form of breakthrough and energy that has been and will continue to be pursued now and in the future. In the context of the development of priority industries from 2015 to 2035, it is impossible for Indonesia's electrical energy demand to be met only with coal and gas, whose reserves are very limited [23]. Therefore, it is time for Indonesia to use other natural resources such as uranium and thorium as raw materials for energy sources for the development of priority industries.

BATAN continues to explore to find uranium and thorium reserves in Indonesia. There are two methods used by BATAN to obtain uranium and thorium, namely conventional methods and non-conventional methods [27]. The conventional method is mining, such as underground mining in Kalan, West Kalimantan, to obtain tourmaline and monazite-type uranium ores. Meanwhile, the non-conventional method is by managing associated minerals from a mining, such as managing monazite minerals in Kalan, Bangka Belitung, zircon minerals in Bangka Belitung, xenotim minerals in Bangka Belitung, and slag from PT Timah Tbk in Bangka.

BATAN is also preparing projections for the future development of nuclear power plants in Indonesia. BATAN currently has thorium ore processing technology, including technology for separating thorium from monazite minerals. On the other hand, to meet current clean energy needs, nuclear reactor technology is needed that can be built quickly and is able to extract 100% of the potential of nuclear fuel [25]. This demand can be met using Generation IV nuclear reactor technology or advanced reactors. Advanced reactors have breeding capabilities, which are capable of producing more fissile fuel than they consume. The reactor configuration is designed to be able to produce a high neutron economy, which allows excess neutrons to be used to convert fertile fuels to fissile [26]. So that the value of the use of fuel will increase many times or in other words to realize future resilience, the utilization of nuclear fuel must be optimized for electricity needs in Indonesia. BATAN plans to build a non-commercial power reactor in Serpong, Jakarta. This reactor is expected to become a pilot model for mini nuclear power plants and also be applied to cogeneration plants, such as hydrogen production, desalination, and others [27].

If we compare the total reserves of uranium and thorium 2017 in Figure 7 with the uranium reutilization cycle along with the waste produced, and where 1 Ton of thorium produces electrical energy equivalent to 35 Tons of Uranium, we will get the calculation of Indonesia's electricity availability as shown table 4 below:

Table 4. Conversion of Indonesia's Uranium Reserves into Electrical Energy Needs

Nuclear Energy	Total Reserve	Year Convertion (21 Ton Uranium = Electrical Energy Needs for 1,5 year)	Ton Wasted Generated (1/3 from total consumption)
Uranium	**79.830 Ton**	**5.702 Year**	**26.610 Ton**

When converted, with the calculation that 1 ton of thorium produces electrical energy equal to 35 tons of Uranium, the following results are obtained:

Table 5. Conversion of Indonesia's Thorium Reserves into Electrical Energy Needs

Nuclear Energy	Total Reserve	Year Convertion (1 Ton Thorium = Electrical Energy Needs 2,5 year)	Ton Wasted Generated (1% from total consumption)
Thorium	**136.966 Ton**	**54.786 Year**	**1.369 Ton**

CONCLUSION

1. Uranium and thorium reserves in Indonesia can realize the nation's energy security in the future, if it is supported by a clearly structured road map, starting from the exploration stage to the construction of nuclear reactors for power plants.
2. BATAN through the Center for the Development of Nuclear Geology (PPGN) must continue to explore possible avenues related to uranium and thorium reserves in Indonesia, in particular to be able to get more detail back into the reserves, both measured, indicated, and hypothetical.
3. Realizing a mini reactor development plan by BATAN, so that in the future more detailed calculations can be made regarding the consumption of uranium and thorium to be able to produce electrical energy through the nuclear power plant process, so that the projected exploration and

exploitation activities of uranium and thorium can support nuclear power plant operations in the future. front.

4. It is necessary to formulate further regarding the processing of waste resulting from nuclear reactions after the estimated amount of waste produced is known

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