

# Energy Possibilities of Thorium and Availability in Monazite Sands

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**Abstract**

Ever since the first working nuclear power plant in Arco, Idaho began operation in 1951, the western world has become fascinated with the idea of nuclear energy, the idea of using radioactive elements for electricity and heating rather than nuclear warheads. Even though the world, and especially United States production of nuclear energy has slowed considerably since the disasters at Chernobyl and Three Mile Island, scientists and governmental organizations, such as the Nuclear Regulatory Commission (NRC) and the Energy Information Administration (EIA), are still looking for a way to make nuclear energy less hazardous and more cost effective. The countries of Australia, Kazakhstan, and the United States have begun to turn towards the use of In-Situ Leaching, a method that is considered to be less damaging to surrounding environments and more cost-effective than traditional mining methods. Some scientists are even promoting the use of the radioactive element known as Thorium, whose most common isotope, Th-232, exists as a naturally fertile isotope. This paper explores the possible use and development of Th-232 from Monazite sands.

Thorium was first discovered in 1828 by a Swedish chemist named Jons Jakob Berzelius. Even though it was discovered by Berzelius and later classified on the Periodic Table by Dmitri Ivanovich Mendeleev in 1869, it did not find any practical purpose until Auer von Welsbach used thorium oxide to construct the first incandescent gas light mantle in 1884. In fact, not until 1898, when Gerhard Carl Schmidt (and later Marie Sklodowska-Curie) realized that thorium was in fact a radioactive element, did anyone begin to realize the true potential of Thorium.

Later on, starting around 1939, the United States began development of a nuclear bomb, a weapon that would use radioactive isotopes in order to split apart atoms and cause total devastation to an area. Since thorium was so abundant (it shows up in standard soil typically as 6 parts per million but can reach up to 30% in monazite sand) and appeared almost exclusively as a fertile isotope (with the addition of a neutron to Th-232, which was the most common form of thorium, it becomes the fissile U-233), many nuclear scientists wanted to use thorium as fuel for the nuclear bomb. However, they soon discovered that Th-232 was so difficult to separate from contaminant isotopes, like Xenon-135, that it would be next to impossible to be able to use thorium as a source for nuclear weaponry.

Uranium, of course, had the potential for nuclear weaponry and was subsequently pursued and further researched. In fact, one of the primary reasons that thorium was not pursued instead of uranium for use in nuclear reactors was the fact that thorium does not create any by products that can be used in the production of explosive materials; whereas Uranium-235 does (U-238 turns into Pu-239 after being irradiated in a nuclear reactor). Little research was done on the use of Thorium in nuclear reactors throughout the rest of the 20th century even though most scientists claimed that it was a much cleaner and more abundant source of energy than uranium.

Today, thorium is beginning to be used more as a nuclear energy source being used alongside what was formerly nuclear waste in liquid fluoride thorium reactors. Liquid fluoride thorium reactors, or

LFTRs as they are called, use a small quantity of fissile uranium or plutonium in order to ignite a chain reaction that causes Th-232 to transform into the fissile U-233 and subsequently undergo fission. As a bonus, this uranium and plutonium does not necessarily have to be high-grade material. LFTRs can use old nuclear warheads or spent fuel rods to power the reaction. LFTRs have other advantages too, they produce no long-term waste. On average, the waste from a LFTR is estimated to be safe in about 350 years. For comparison, high-level waste from uranium reactors can last anywhere from 10,000 to 1,000,000 years. This means that these reactors can assume a janitorial position and actually make nuclear waste less hazardous. These reactors even cost less to build than typical nuclear reactors as they use fluoride salts for cooling rather than the typical pressurized water, as a result they are much safer to be around, and there is almost no chance of a nuclear meltdown. These innate safety features make additional ones less necessary and thus can greatly reduce the cost of building a reactor.

An ongoing concern is that LFTRs make use of a non-renewable fuel source and as a result will eventually stop being useful. This also means that if money were to be put towards these reactors, it would take away from investment in renewable energy sources like wind and hydroelectric. An additional concern is that LFTRs may encourage the building of nuclear warheads as they provide a use for warheads that have not been used during times of conflict

Despite all of the criticism, LFTRs still have a much more abundant source of energy than typical nuclear reactors, which use U-233 or Pu-239 as their fuel source. Approximate world supplies of U-233 will reach only about 37,828 tonnes. However, since almost all thorium is the isotope Th-232, the world supplies for Th-232 will reach somewhere around 2,610,000 tonnes. Of course, some U-238 can also be transformed into Pu-239 with the addition of 1 neutron, but Pu-239 is not a naturally-occurring substance.

Although most of these elements are obtained from sandstone and standard mining methods, they are both found in another location, monazite sands. Monazite has a resinous, waxy, or vitreous luster to it along with a typically monoclinic crystal structure. It often forms in pegmatites and metamorphic rocks, and sometimes in veins. It is also often found among beach and river sand and shows up even more often in the heavy mineral deposits found in sand. Monazite is a mineral that belongs to the phosphates group and follows the chemical composition  $(\text{Ce, La, Nd, Th, Y})\text{PO}_4$ . It is important to mention that Monazite is actually more than one kind of mineral, but the differences between the three main varieties are so small that the varieties are usually just lumped together and classified as “Monazite

The most common form of Monazite is Monazite-(Ce), which follows the chemical composition above. This variety is very rich in the element of Cerium. Another variety is Monazite-(La), which follows the chemical composition of  $(\text{La, Ce, Nd})\text{PO}_4$  and has a great enrichment of lanthanum. Finally, we have the monazite known as Monazite-(Nd), which follows the chemical composition  $(\text{Nd, La, Ce})\text{PO}_4$  and contains high amounts of neodymium.

North Carolina is a place of considerable interest when observing Monazite, first discovered by C.U. Shepard in 1849. Later on, a man named W.E. Hidden, who was doing research for Thomas Edison at the time, uncovers the fact that Monazite was a common detrital mineral in gold placers in parts of Alexander, Burke, McDowell, Rutherford, and Polk counties (Hidden later went on to famously discover the mineral Hiddenite). On November 20th, 1880, Hidden extracted more than 50 pounds of concentrate from Capt. J.C. Mills Gold Mine with more than 60% Monazite in it. This marked the first production of Monazite in both North Carolina and the United States.

Less and less interest has been focused on monazite as of late, as no secure and completely efficient mining method has been developed for the process. Separation techniques, such as using

Sodium Polytungstate or some other non-toxic heavy liquid would be far from cost-efficient due to the recent interest in using such materials for scientific experimentation and the subsequent price spike in Tungsten. However, using things like sluices, dry tables, and magnetic separators, the monazite can be isolated very well. Throughout this, monazite is used almost exclusively for the extraction of rare earth metals and little attention is paid to the Uranium and Thorium in the mineral. This is probably because these two elements make up a very small portion of the monazite and so are often refined entirely as a byproduct.

At the McEniry Building of the University of Carolina at Charlotte, samples of heavy minerals taken from two different sections along the beach at Cape Lookout were subjected to a cleansing in order to isolate the Monazite sands. The two different samples were first placed into separate beakers and were filled with water and left to settle. This process allows for the heavier minerals, such as ilmenite, magnetite, and monazite to settle to the bottom of the beaker as the water takes the lighter minerals, such as salt, to the top. Once the settling finishes, the newly salted water is poured out and the heavy minerals remain. This process is repeated several times in order to thoroughly cleanse the heavier minerals from salt contaminants. Next, all water is poured out of the beaker and the beaker is set on a hotplate set to 200 degrees Fahrenheit (93.3 degrees Celsius) and is left on the hotplate for approximately 2 hours in order to dry the minerals completely.

Once all of the minerals are dried, a sample of 7.09 grams is measured out and an apparatus is set up to separate the sand. The apparatus uses a funnel with a tube running out the base of it into an empty beaker. The lower half of the tube is pinched airtight with a clip and is left so. Following this, the funnel and subsequent tube are filled with a solution of Sodium Polytungstate. Sodium Polytungstate is a non-toxic heavy liquid with a density of 2.89 and is often used in such separation experiments. Once the funnel is filled to the top, the sample of beach sand is slowly poured onto the Sodium Polytungstate.

The Polytungstate and the minerals are then left to sit for approximately 15 minutes. This will allow all of the lighter density minerals to rise to the top of the Polytungstate, all of the minerals with approximately 2.89 density will remain floating in the middle, and all of the heavy minerals will sink to the bottom of the tube directly above the clipped part of the tube. Once this settling finishes, the clip is removed to allow the heaviest minerals to fall out into the beaker and is quickly closed in order to prevent any other kinds of minerals from falling down as well. The rest of the Sodium Polytungstate is emptied out through a filter and all of the apparatus is cleansed thoroughly with water. [If you have a picture of this experiment this would be a great place to put it and then just text wrap around the picture.](#)

The newly isolated heavy minerals are still surrounded by Sodium Polytungstate, so a **[ENTER SIZE HERE]** filter is put over a funnel, and the funnel is placed over a new beaker. The Polytungstate containing the heavy minerals is then poured into the filter and is once again left to sit so that the Polytungstate seeps into the beaker and the heavy minerals remain in the filter. When this process is complete, the heavy minerals are washed with water and are then set out to dry on a table.

After being left out overnight, a microscope slide is prepared and covered with epoxy resin. Next, a pinch of the now dry heavy minerals is taken and sprinkled lightly around the microscope slide. The epoxy will allow light to pass through it (despite its milky-white appearance) and will force the heavy minerals to remain in one spot despite any sort of wind. This will help to maintain order under the microscope and allow for easier identification of the minerals. The slide is then placed under a cross-polarizing microscope and the light is turned on for the microscope. Cross-polarizing microscopes use two polarizing filters, one set below the sample tray. The other is set by the eyehole and is removable for different viewing options (normal light and cross-polarized). One of the filters is set at an east-to-west polarization, and the other is set to a north-to-south polarization. When both filters are set in, the

filters completely block out the light and allow for the special properties of the crystal structures to reflect light in certain patterns, allowing for identification.

Using a reference book for guidance called *Heavy Minerals in Colour*, the microscope was set to an area to display approximately one-hundred and twenty different heavy sand particles at once. Most of the sand particles were observed to be totally black both under the normal microscope light and under the cross-polarization; this took up about 70-75% of the microscope's view. Unfortunately, the sample used was contaminated by quartz crystals. Most quartz is supposed to float to the top of the Sodium Polytungstate due to the fact that its density, 2.65, is lower than the density of the Sodium Polytungstate, which is about 2.89. The quartz crystals which show up as white to transparent under normal microscope light, but give off a rainbow color when under cross-polarization, making them fairly easy to identify. The quartz takes up about 15% of the total mineral count. Next observed are two andalusite crystals which have a very strong blue color in the center when put under cross-polarization. Several garnets show up under the microscope as well and appear as a dark reddish color under normal microscope light. However, due to the isometric nature of garnet's crystal structure, it goes completely dark under cross-polarization. This makes it very easy to identify the garnets as well. Finally, the ever-pursued monazite is spotted. Monazite is recognizable because it gives off an amber color and has a dark black border under normal microscope light. When put under cross polarization, the monazite gives off a dim rainbow color. In this first sample, only about 4 grains of monazite showed up

A second trial was completed, this time only using about 90 particles. Magnetite and quartz still took up a large portion of the sample, but this time there was no andalusite and approximately 6 particles of monazite. Observing these two trials, about 2.5-7.5% of heavy minerals from beach sand along Cape Lookout were monazite.



These monazite particles do make up a fairly large amount of the heavy sand, but it must be remembered that Thorium usually takes up only around 6-11% of monazite sand and maxes out around 30%. Thorium does have an extremely high energy yield and can produce more power from a smaller amount than can uranium, natural gas, or petroleum. In fact, the energy obtained from using 1 gram of thorium in a LFTR is about 300 times the amount of energy of using 1 gram of uranium in a light-water reactor.

So, if on average, the heaviest minerals in Cape Lookout's sand contain about 5% monazite, and this monazite contains about 10% thorium, it is known that there is about .5% of thorium in the heavy minerals. Since this sample was taken from an initial sand sample of 7.09 grams, the approximate amount of thorium in Cape Lookout's heavy sand is 0.03545 grams. Since, on average, 1 gram of thorium in a LFTR produces about 11 megawatt hours, 0.03545 grams produces about 0.38995 megawatt hours.

Since extraction and isolation of monazite sands is so easy to do, especially with advanced technologies, and because thorium is so high in abundance and energy yield, seeking to commercialize thorium extraction from monazite sands and the use of LFTRs would provide such economic and even environmental (due to less reliance on more environmentally-damaging energy sources) benefits to both North Carolina and the United States. As a bonus, the other rare earth metals in monazite (such as cerium, lanthanum, samarium, praseodymium, neodymium, and yttrium) can also be mined and developed.

**References:**

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