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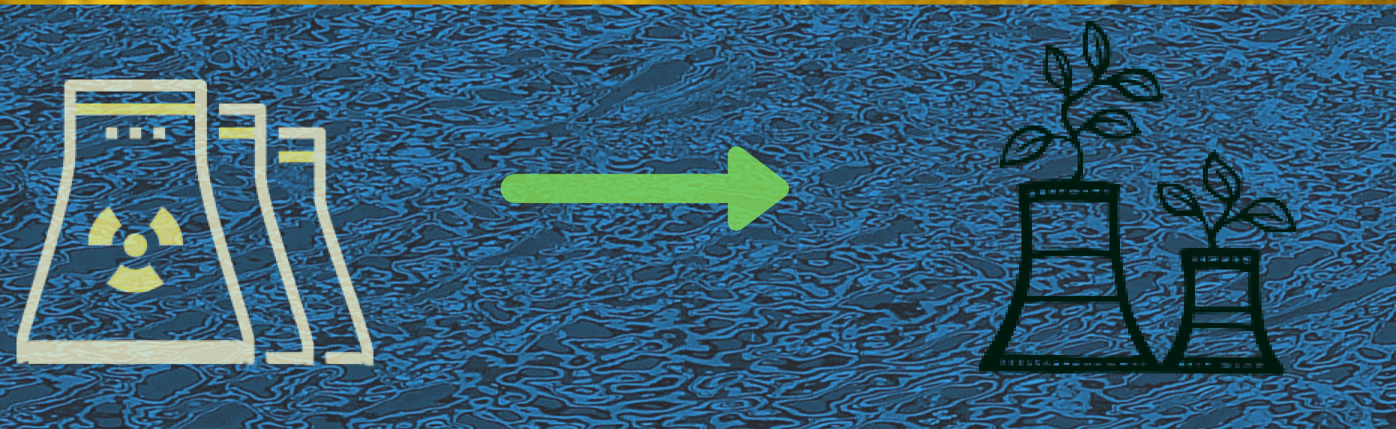


nUeBe
All you need to know about Nuclear Energy

Letter From The Founder

In all my conversations about nuclear energy within and outside of the field, the topic of uranium as a radioactive element has remained quite elusive. Some consider uranium to be dangerous while others consider it to be a powerhouse.

The feature article - *Mining, Milling and Refining of Uranium* - has been written specifically to address the concerns regarding uranium in its early mining phases. Going through each stage, this article will take you on a journey that uranium undertakes from underground mines to a power plant.

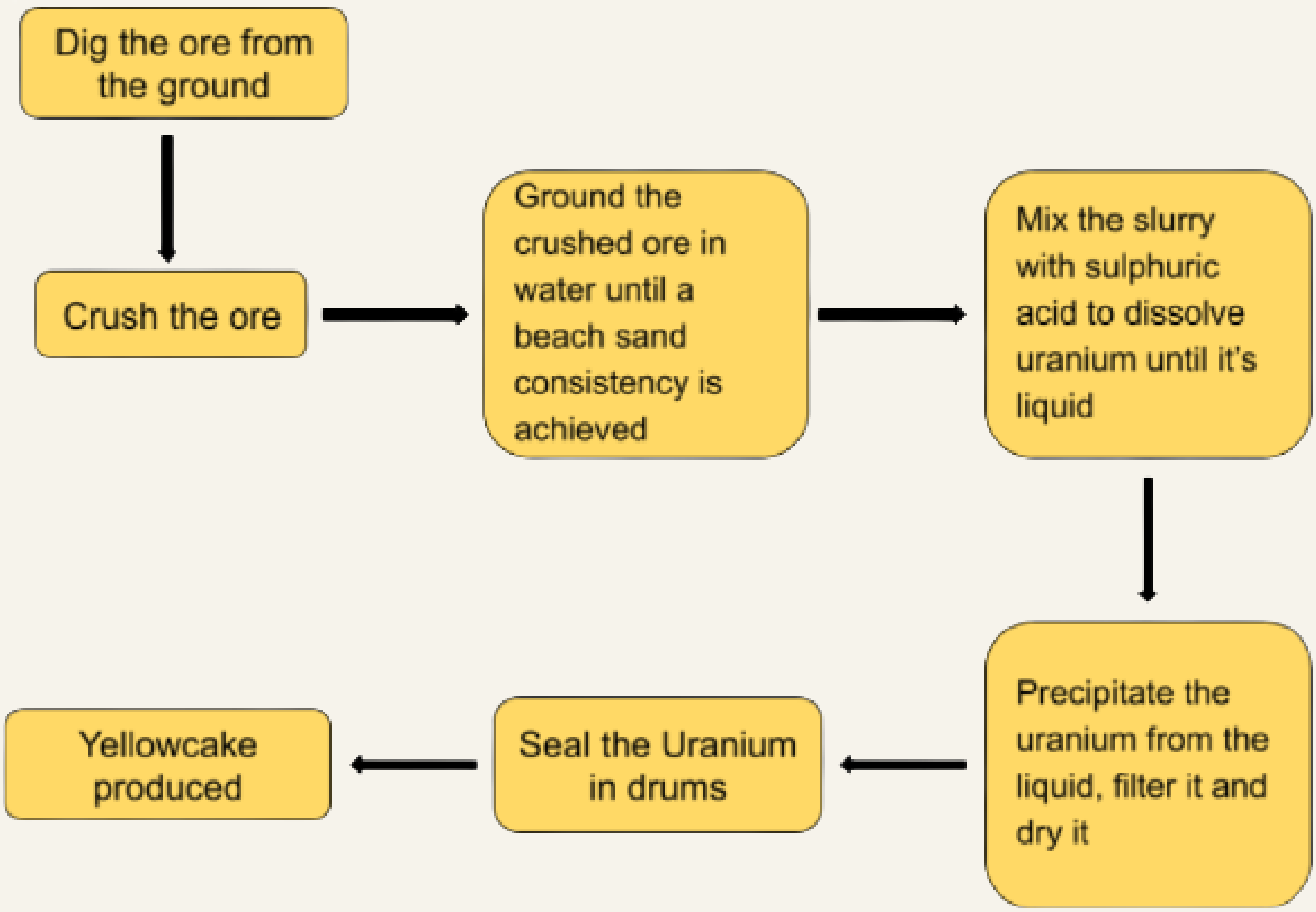
Transitioning from fission to fusion, our member Nilormi Das took a dive into China's recent experiment with a fusion reactor that has created history. *The Rumored Record Breaking Chinese Artificial Sun* will tell you everything you need to know about China's historical fusion experiment.

Until next time, Happy reading!

Mining, Milling and Refining of uranium

Author: Nirupama Sensharma

We often do not pay much attention to the pathway of nuclear fuel prior to its feeding into a commercial nuclear power plant. Talks about the nuclear fuel cycle almost always focus more on fuel fabrication techniques, power production and finally reprocessing/waste management. The first step, however, is often skipped. So here we are, going into the nook and crannies of the primary step of the nuclear fuel cycle - Mining, milling and refining.



Mining

The nuclear fuel cycle starts with Uranium mining, which is the process of extraction of uranium ore from the ground. Currently, Kazakhstan, Canada and Australia dominate the market for uranium extraction, collectively contributing to approximately two-thirds of the world's production of uranium from mines (World Uranium Mining Production - world-nuclear.org). The total amount of uranium mined in 2019 amounted to 53,656 tonnes and nearly all of it was used for nuclear power production.

Traditionally, uranium was extracted from underground mines and then delivered to an on-site mill where it was crushed and grinded before further processing. Sulfuric acid (sometimes alkaline solutions also used) was then used as a leaching solution to dissolve the uranium oxides within the mineral (remaining rock and other minerals remain undissolved). This process helped in the extraction of almost 90-95% of uranium from the ore. Some other heavy metal constituents like molybdenum, vanadium, selenium, iron, lead, and arsenic are also extracted as by-products.

With time however, underground mining has slowly been changing in the favor of in-situ leaching (ISL) extraction where the ore is left in the ground but the minerals are extracted (leached) from it using chemical treatments. The most commonly used ISL technique involves injecting water with oxygen and circulating it through the uranium ore. The uranium solution so-produced is then pumped to the surface. The ISL method does not contribute to any waste rocks or tailings and causes minimal surface disruption. Consequently, the ISL method has slowly been on the rise and contributed to 57% of uranium mined in 2019.

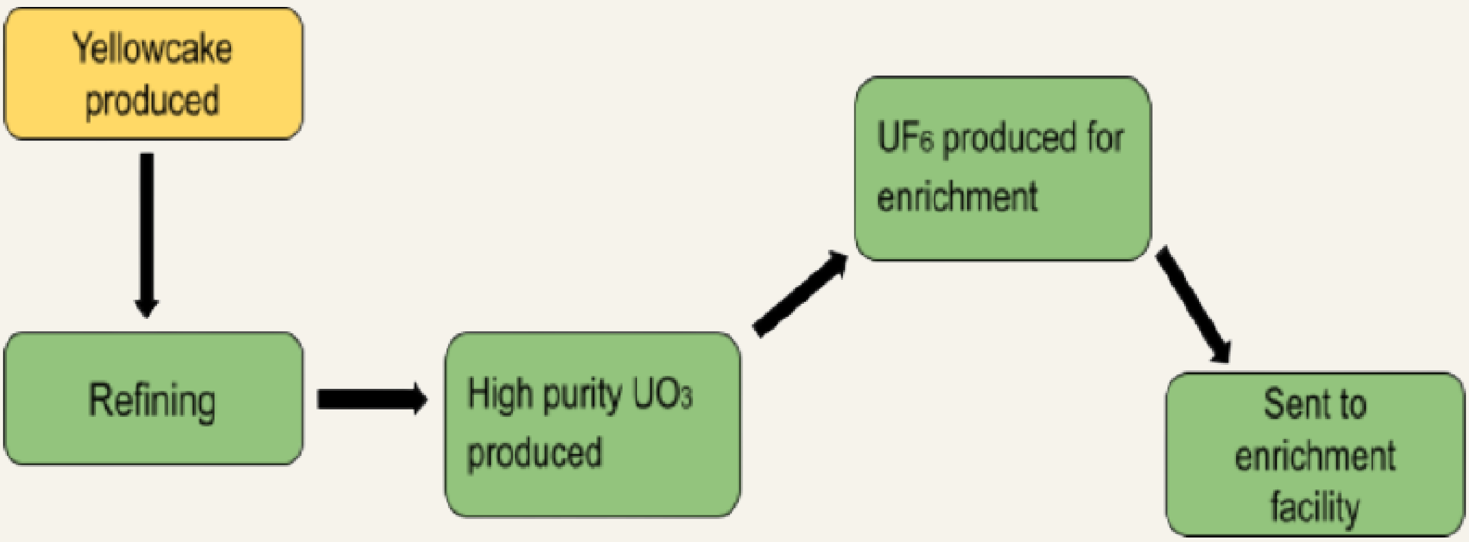
Milling

The next step is to concentrate the extracted uranium (using an ion-exchange process) to produce a material called Yellowcake. Also called Urania, Yellowcake is a solid form of mixed uranium oxide produced after the uranium milling process as a coarse powder with a pungent odor. This powder is insoluble in water and contains approximately 80% uranium oxide. Depending on the temperature at which the material is dried, Yellowcake can take up different colors including yellow, orange or dark green.

Present day Yellowcakes produced by modern mills are usually black or brown in color. The name 'Yellowcake' is however still commonly used owing to the traditional yellow color produced in the early days of uranium milling.

Chemically, yellowcake is referred to as U3O8 as that chemical compound historically comprised the majority of the yellowcake produced by uranium recovery facilities utilizing conventional milling methods (nrc.org).

The constituent uranium in yellowcake is U-238 (>99% by concentration). U-238 has a half-life of 4 billion years i.e., it emits radiation at a very low rate and therefore yellowcake has very low radioactivity. Yellowcake thus has the same radioactivity as the uranium ore underground. Yellowcake is however extremely dangerous if inhaled.



Refining

The last step of the uranium mining process is refining. The yellowcake so-produced in the previous step is transported to a uranium conversion facility, where it is refined, processed and fabricated into fuel rods to be used in nuclear power reactors.

The first step involves dissolving yellowcake in nitric acid to allow for the selective extraction of pure uranyl nitrate. The pure uranyl nitrate is then converted into highly pure uranium oxide (UO3).

The next step is to extract U-235 which is the isotope needed by nuclear reactors. Uranium, as found in nature, contains only 0.7% of U235. The rest is stable U238. Modern day nuclear reactors need upto 3-5% of U235. The process to increase the concentration of U-235 from 0.7 to 3-5% is called Enrichment. The enrichment process requires the uranium to be in gaseous form. The highly pure UO3 is therefore converted into uranium hexafluoride (UF6) which is a gas at relatively low temperatures. Flowing UF6 through rapidly spinning centrifuges, U-235 enrichment is achieved. (https://www.world-nuclear.org/nuclear-essentials/how-is-uranium-made-into-nuclear-fuel.aspx)

The enrichment process marks the end of the mining, milling and refining stage of the nuclear fuel cycle. Post enrichment, the fuel is sent to fabrication facilities where it is pressed to form small fuel pellets, filled in fuel rods and then transported to a reactor facility for power production.

References:

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2. *Production of Yellowcake and Uranium fluorides - PROCEEDINGS OF AN ADVISORY GROUP MEETING ORGANIZED BY THE INTERNATIONAL ATOMIC ENERGY AGENCY AND HELD IN PARIS, 5 - 8 JUNE 1979*

238.029 ← Atomic Weight

U ← Symbol

Atomic Number → 92

URANIUM

MOST COMMON ISOTOPES

$^{238}_{92}U$

- Stable Uranium
- Approx 99% of natural uranium.

$^{235}_{92}U$

- Radioactive Uranium
- Only 0.72% of natural uranium.

USES OF URANIUM

- as a fuel for generating electricity in Nuclear Power plants
- to detect the age of rocks and soil layers in Archeology (Uranium-lead dating)
- in high power X-ray machines (as target material)
- as a yellow colouring agent* for pottery and glassware! (this use dates back to time before the radioactive nature of Uranium was discovered)

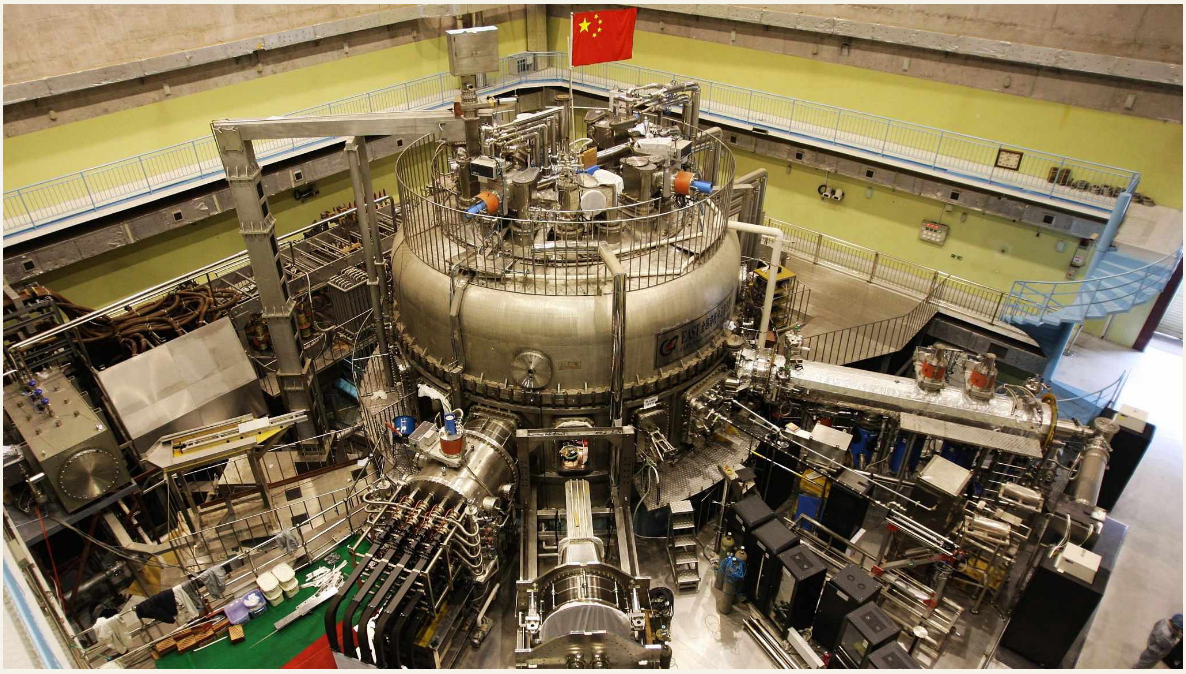
***A 2,000 year old sample was found near the yellow glass of Naples, Italy containing uranium oxide**

The Rumored Record Breaking Chinese Artificial Sun

Author: Nilormi Das

Is China planning to artificially build our nearest star— the Sun!?
In June 2021, when the globe was dominated by the second wave of the deadly pandemic, one fine morning a controversial headline flooded our news feeds claiming that "China's artificial sun sets a new record". It's time to unveil the curtain and unravel the truth.

By "artificial Sun", it implied the Experimental Advanced Superconducting Tokamak (EAST) device, located at the Institute of Plasma Physics of the Chinese Academy of Sciences in Hefei, China which aims to replicate the nuclear fusion process carried out by the sun. EAST has been operational since 2006. The ultimate objective of EAST is to create a phenomenon similar to that occurring within the Sun using deuterium that abounds in the sea. One of the most important criteria for a fusion device is the plasma confinement time at very high temperatures by virtue of magnetic forces. The longer the plasma remains confined, the more viable it is to be a successful nuclear fusion reactor.



EAST has achieved a milestone in recent times by attaining 120 million degrees Celsius plasma temperature for 101 seconds. It has also achieved a peak temperature of 160 million degrees Celsius (~ approximately 10 times hotter than the Sun) for another 20 seconds beating the prior record made by KSTAR (Korean Superconducting Tokamak Advanced Research), the magnetic fusion device of South Korea. This marks a significant step towards unlocking the dream-come-true approach of producing clean energy and a green globe using the phenomenon of nuclear fusion.

The EAST project is also an integral part of the world's largest nuclear fusion research project, ITER (International Thermonuclear Experimental Reactor) facility besides South Korea, Japan, Russia, India and the United States.

The next target for the EAST project is to maintain and stabilize the high temperature for a longer duration.

References:

1. www.downtoearth.org.in
2. www.advancedsciencenews.com
3. www.indianexpress.com
4. Image Source: news.cgtn.com

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