II. RADIOACTIVITY

FROM URANIUM TO PLUTONIUM — A US PERSPECTIVE

Throughout the Southwestern U.S. (Colorado, Utah, Nevada, New Mexico) there are many uranium mines. Mining uranium ore is carried out, more or less, in the same manner as any type of mining with the exception that uranium is a radioactive element. As an ore it is only mildly radioactive although special precautions, such as wearing dust masks and protective clothing, need to be taken. Uranium in its natural state cannot be used in a reactor. The type of uranium that can be used in a reactor is uranium-235. Natural uranium ore contains 99.3% uranium-238 and only 0.7% uranium-235. Uranium-235 is used for producing a fission reaction in a nuclear reactor. That is why uranium must be "enriched", to increase the relative proportion of uranium-235 from 0.7% to around 4%.

Once the uranium ore has been mined it is taken to a nearby mill where the ore is crushed and ground to dissolve the uranium oxide. This technique is used to separate out and consolidate the uranium oxide from the uranium ore. That is, to extract a concentrated percentage of the uranium oxide from the crushed uranium ore. The powdery substance which results from this process is called "yellow cake". From mine and mill, this substance is then shipped to Production Centers.

There the yellow cake is changed into uranium green salt crystals in a process of chemical transformations. This is part of the process of enrichment. Enrichment requires changing uranium oxide into uranium hexafluoride in its solid state and then changing uranium hexafloride into a gaseous state. By changing uranium oxide into the gaseous state of uranium hexafluoride, uranium-235 isotopes can be sorted out from the uranium-238 isotopes. Separating and concentrating the uranium-235 is the desired goal of enrichment. Uranium hexafluoride in its solid state is called "green salts". Tthese green salts are heated together with magnesium granules for approximately four hours at 1300 degrees Fahrenheit. Once a gaseous state is achieved, the uranium-235 is separated out.

After further processing, the uranium-235 metal, at a red hot heat of 1100 degrees Fahrenheit, is inserted into the uranium metal extrusion press. The press squeezes molten uranium-235 ingots into long tubes. This process produces the long uranium-235 metal tubes which are called "fuel rods". Once cooled these uranium-235 fuel rods are ready to be sent to reactors.

The enriched uranium in the form of fuel rods are loaded into a reactor and undergo a fission reaction by being bombarded with slow neutrons. This reaction is similar to the primary stage of a hydrogen explosion, that stage being mostly comprised of a fission reaction. As a result, there is a vast amount of heat generated, which heats water, turns turbines and provides electricity, but unique to a nuclear reactor is the by-product, plutonium-239.

The plutonium is extracted from the reactor fuel rods and concentrated into plutonium ingots or buttons. Remote control machinery extracts the plutonium from the fuel rods and transports the. The finished product, weapons grade plutonium, is shipped for final fabrication into the plutonium pits. The processes involved in transforming uranium ore into uranium-235 and finally into plutonium-239 make up the front end of the nuclear fuel cycle.

METHOD: THE NUCLEAR CHAIN PUZZLE

MATERIALS: Index cards of the nuclear chain
TIME AND LOCATION: 30 minutes, circle with space in the middle for mapping the nuclear chain

The nuclear fuel cycle can simply be illustrated in several steps. The group is supposed to work out how those steps are connected and where the cycle can be found in the whole system.

Label the index cards with the several steps of the nuclear chain reaction and its waste products.

STEP 1 - BRAINSTORMING

Before you hand out the information it is important to know how much knowledge the participants may already have about the topic. Write “Uranium and the nuclear fuel cycle” on the wall, circle it and ask the participants if anything comes into their mind. Every answer relevant to the topic will be written down and connected to the circle with a stripe. If needed you can ask some questions:

Which countries do have uranium?
Is uranium dangerous?
For what is uranium used?
What is radioactivity?

STEP 2 – ILLUSTRATION

Put the prepared index cards about the steps of the nuclear chain out in front of the group and ask them to use their new knowledge to assemble the nuclear fuel cycle.

STEP 3 – EVALUTATION

In the end you can go through the whole nuclear fuel cycle once again together with the participants to make sure that everybody understood it. You can also use some pictures or videos of each step for illustration. You find them for example at http://strahlendesklima.de/.