Norm who? Is there a place for NORM in your science classroom?

««« By Bryan White

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Curriculum Connection: Senior Physics, 11U/12U.

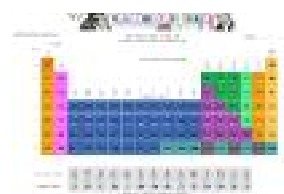
NORM is an acronym for Naturally Occurring Radioactive Material. You might be asking yourself: "Why would anyone want some NORM in their classroom? What would I do with it? Where would I get it if I wanted some?" This article addresses these questions – and a few more.

Who's radioactive?

You are! So is your grandmother, your dog, cat and goldfish too.

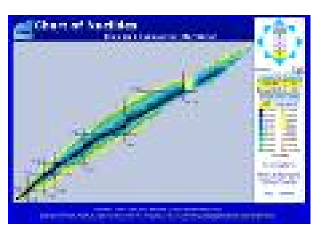
Members of the Canadian Nuclear Society (CNS) are concerned that in general, the public is unaware that we all are naturally radioactive beings – a consequence of living on a radioactive planet in a radioactive universe. This is understandable since most people do not have personal experience with ionizing radiation apart from medical and dental X-rays. The CNS encourages science teachers to introduce students to ionising radiation using NORM in their classes. With personal experience they will develop an improved understanding of the phenomena and be better able to make rational choices about the role of nuclear technologies in their futures.

Who's responsible for this NORM stuff?



Not me, I'm just the messenger. The Periodic Table of the Elements (**http://www.radiochemistry.org**) has about 108 entries (and counting). Each element is identified by its Atomic Number – the number of protons in the nucleus of the atom. The Periodic Table is arranged to group the elements by their chemical characteristics. Each element has more than one isotope, each isotope having the same Atomic Number, but a different Atomic Mass. The integer difference between the Atomic Mass and the Atomic Number identifies the number of neutrons in the nucleus for that isotope. Some isotopes are stable – they aren't observed to undergo radioactive decay, while others are so unstable they aren't found on earth outside of scientific experiments.

There is another table analogous to the Periodic Table: the Chart of the Nuclides (**http://www.nndc.bnl.gov/chart**). Each nuclide is plotted as Atomic Number vs. neutron number. Presently, it has 3168 entries. Most of these are radioactive; however, only a minority of the radioactive isotopes are found in detectable quantities in nature.



Some of these have very long half lives, and have been decaying since they were generated in the stellar novas or supernovas that contributed material to the formation of our solar system over 5 x 10^9 years ago. The radioactive isotopes potassium (^{40}K), uranium (^{238}U and ^{235}U), and thorium (^{232}Th) have long half lives and their decays contribute significantly to the background radiation on earth. Other isotopes, such as carbon (^{14}C) have much shorter half lives, but are generated continuously in the Earth's atmosphere by cosmic rays interacting with gas atoms – and also contribute significantly to background radiation.

There's NORM in ME?

Yes, there's a little NORM in everyone. Each person has a sufficient amount of NORM in their body that within a typical adult, *over 8000 atoms undergo radioactive decay in each second, on average*. This amount of activity is described as 8 kilobequerel, or 8 kBq. About half of this radioactivity represents ^{40}K. At this time on Earth, 0.0117% of potassium atoms are the isotope ^{40}K. (^{39}K abundance is 93.1%, ^{41}K is 6.88%, and both are stable). ^{40}K has a half life of 1.277 x 10^9 years. (4.5 billion years ago, when the Earth was young, there were over 11 times as many ^{40}K atoms as there are today.)

^{40}K has 3 decay modes:

- 89.28% are **beta –** (electron) decay to calcium (^{40}Ca) (plus an antineutrino)
- 10.72% decay by **electron capture** to argon (^{40}Ar) (plus a neutrino) with gamma emission
- ~0.001% are **beta +** (positron) decay to (^{40}Ar) with gamma emission (plus the added bonus of a positron annihilation soon after for dramatic effect.)

It is interesting to note that while calcium is a metal somewhat similar to potassium, argon is a noble gas. *(Foreshadowing!)*

The other major contributor to the 8 kBq in each person is carbon (^{14}C). ^{14}C has a 5700 year half life and undergoes beta - (electron) decay to nitrogen (^{14}N) (stable).

How does that radioactive potassium and carbon get in me?

Mostly, it enters into your body through the food you eat. Radioactive isotopes of potassium and carbon are naturally present in the environment. Both elements are important in biochemical processes. A healthy body regulates its potassium concentration. The Health Canada website (http://www.hc-sc.gc.ca) states that the daily intake (and loss) of potassium is about 4.7 g. This corresponds to 150 Bq of ^{40}K. Carbon intake is excreted and also exhaled as CO_2 – but if you eat too well, your body stores it away in fats.

But, polonium? Surely there's no ^{210}Po in me?

Well, yes actually there is – but only a little. Polonium (discovered by Marie Curie) made the news with the infamous death of former Russian agent Alexander Litvinenko in the UK in 2006.

There are many other radioactive isotopes that are present in people in very small quantities. Most of these originate with the decay series for uranium and thorium. The series of decay steps for these heavy metals consist primarily of alpha and beta decays – with some gamma emissions (this makes detection easier for prospectors). Ultimately the series of radioactive progeny terminate with decay to stable isotopes of lead. The last (alpha) decay for the ^{238}U series is ^{210}Po to ^{206}Pb. Along the series there are several intermediate radioactive isotopes, most of which are also heavy metals, with the exception of radon (the ^{238}U series includes ^{222}Rn and ^{218}Rn, while that for ^{235}U includes ^{219}Rn, and the ^{232}Th series includes ^{220}Rn sometimes called "thoron").

Radon is a noble gas (as was argon above). The decay step from a heavy metal atom to a radioactive gas atom provides an opportunity for the radioactive decay process to escape the (chemical) bonds of the original surroundings of the

uranium atom, and move into the environment. We inhale and exhale a little radon with every breath. However, if the radon atom decays while inside our lungs, the heavy metal decay product may be retained within our body. Moreover, when the radon in air decays, the heavy metal atoms may become attached to airborne dust, which can be inhaled. Health Canada recommends that homes having a persistent radon concentration above 200 Bq/m^3 in living areas, be modified to reduce the concentration.

Apart from the uranium and thorium decay series isotopes we otherwise ingest, we also inhale some dust that may be retained in the lungs.

We eat uranium and thorium?

Well, yes actually, we do eat them – but only a little.

Plants absorb heavy metals from the soil. In the case of Brazil nuts, it is possible to detect the radioactivity in a handful of nuts with a little patience. This radioactivity is derived from ^{40}K as well as the uranium and thorium decay series – and so it includes a little Po^{210}. Average dietary intake of uranium is about 2.6 µg in food and 2 µg in water.

So, where do I get NORM sources for use in the classroom?

Fortunately there are convenient, inexpensive NORM sources available in your grocery store:

- ^{40}K: potassium chloride is available as NoSalt®, NuSalt®, water softener salt, or as potash in fertilizer;
- ^{40}K & U/Th series: as most clumping cat litter is made from bentonite clay, its composition includes potassium, but it also absorbs heavy metals if they were available;
- ^{40}K & U/Th series: Brazil nuts.

With a small fan drawing air through a foam filter, it is possible to detect radon progeny – but this takes hours. (In most cases one will detect one alpha and two beta decays – and one can readily observe the combined half lives (3.1 minutes, 26.8 and 19.9 minutes in the ^{238}U series) – with careful planning and artful data processing.

Radium dial watches and clocks are still readily available, but Canadian Nuclear Safety Commission (CNSC) regulations limit the number of intact devices to ten without having a licence.

Why use a NORM source?

NORM sources are inexpensive, and don't require security measures.

These NORM sources (actually NoSalt is refined, so it is a Technically Enhanced Naturally Occurring Radioactive Material – TENORM) are not very strong radiation sources. However, possession of NORM for use as a radioactive source is regulated by the CNSC. There are exemption limits for elements/isotopes listed in the regulation.

Potassium chloride is a conveniently strong source for classroom demonstrations – and it's biologically relevant. Some ceramic tiles may be readily detected above background.

What about a synthetic isotope?

Synthetic or artifical radioactive isotopes are produced in nuclear "research" reactors and particle accelerators. A variety of isotopes are used in nuclear medicine, industrial radiography, and in some industrial process applications. Only a few are used in consumer products.

A synthetic isotope, americium Am^{241} is conveniently available in an ionization smoke detector. It is possible to detect the radioactive source with a Geiger-Müller detector very close to the smoke detector due to the low energy gamma that penetrates the shielding, while the high energy alpha radiation is well-shielded. (Disassembling a smoke detector to expose the alpha source is a violation of the CNSC regulation – greatly exceeding the relevant exemption limit.)

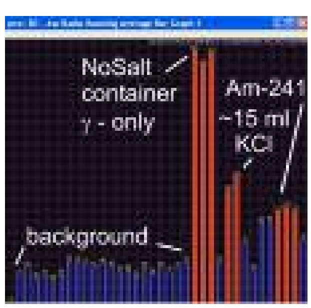
Many "older" (2001) compact fluorescent lamps used magnetic ballasts had "starters" that use a radioactive isotope of krypton (^{85}Kr) to enhance the turn-on characteristics of the lamp. Presently, most lamps use electronic ballasts. ^{85}Kr undergoes beta decay to rubidium ^{85}Rb, and the associated gamma radiation is detectable with the Geiger-Müller detector close to the lamp.

The CNS website has fact sheets on these sources available for download (or in preparation). The tool essential to detecting ionising radiation is a sensitive Geiger-Müller detector.

What kind of detector do I need?

CNS members have found the Aware Electronics RM-80 ® to be effective for detecting ionising radiation from NORM and consumer device sources above background radiation levels. These detectors have a large diameter, thin window Geiger-Müller detector that is effective for alpha, beta and gamma. The larger size of the detector increases the counting rate – giving better statistics, and making class room measurements practical. The detector interfaces with the serial port of a personal computer – and is powered from the computer (no batteries!).

Many newer computers are not equipped with a serial port. A serial port may be added to a desktop computer as an internal interface card, a PCIA adapter in a laptop, or a USB adapter for a laptop without a PCIA slot. The software operates in a Windows or DOS environment. The program produces Geiger "click" noises, an audible alarm at a selectable count rate, logs count data, and plots a time series bar graph.



Where can I get my hands on a detector?

The CNS has demonstrated these systems in booths at STAO 2006, 2007 – and will again in 2008. The CNS also had these at booths at the Ottawa Carleton Science PA Day in 2007, and the Mighty Peace Teachers' Convention in Grand Prairie Alberta in 2008. A booth is also planned for the Alberta Teachers' Association Science Council Conference in 2008.

A hands-on workshop on these measurements will be offered at STAO 2008 on Friday, November 14th, 11:00-12:00. If you miss the workshop, please stop by the CNS Booth.

How do I get one in my school?

The CNS has given four of these systems to schools as draw prizes at previous STAO Conferences, and has donated systems to a few schools where a science teacher has personally requested one. If you're keen, why not ask? Please visit our website for more information: **http://www.cns-snc.ca**

In addition, they are available through Aware Electronics (**http://www.aw-el.com**).