Canadian Nuclear Society
Naturally Occurring Radioactive Material fact sheet
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NORM?

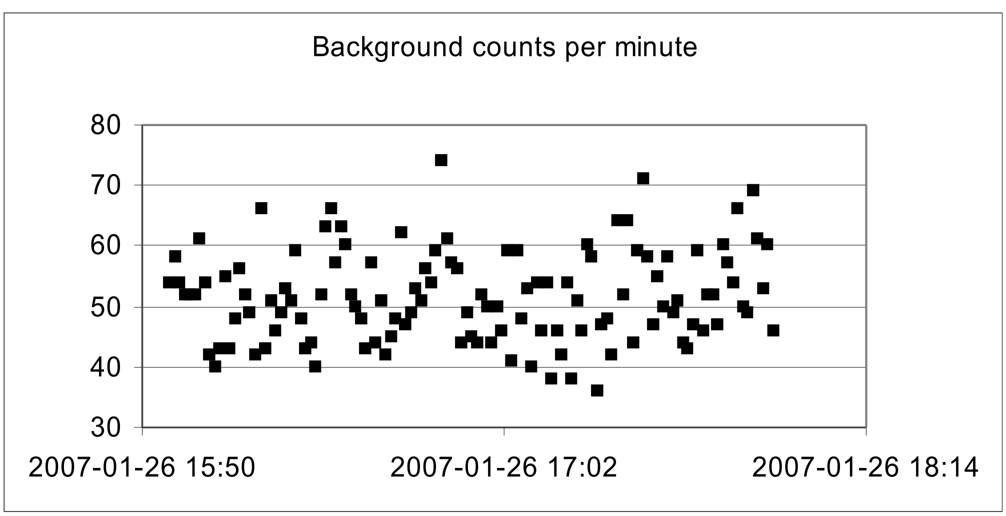
Naturally Occurring Radioactive Material, NORM is everywhere around us and in us. Some materials have a sufficiently high concentration of naturally occurring radioactive isotopes that they may be readily detected relative to background radiation. The Periodic Table of the Elements lists about 108 elements. Of these, uranium is the most massive naturally-occurring element (atomic number 92, mass 238). All elements in the table have radioactive isotopes although many are not found in nature due to their short half-lives. The **Chart of the Nuclides** [1] identifies 3166 isotopes (some of the elements are not yet named).

Background Radiation

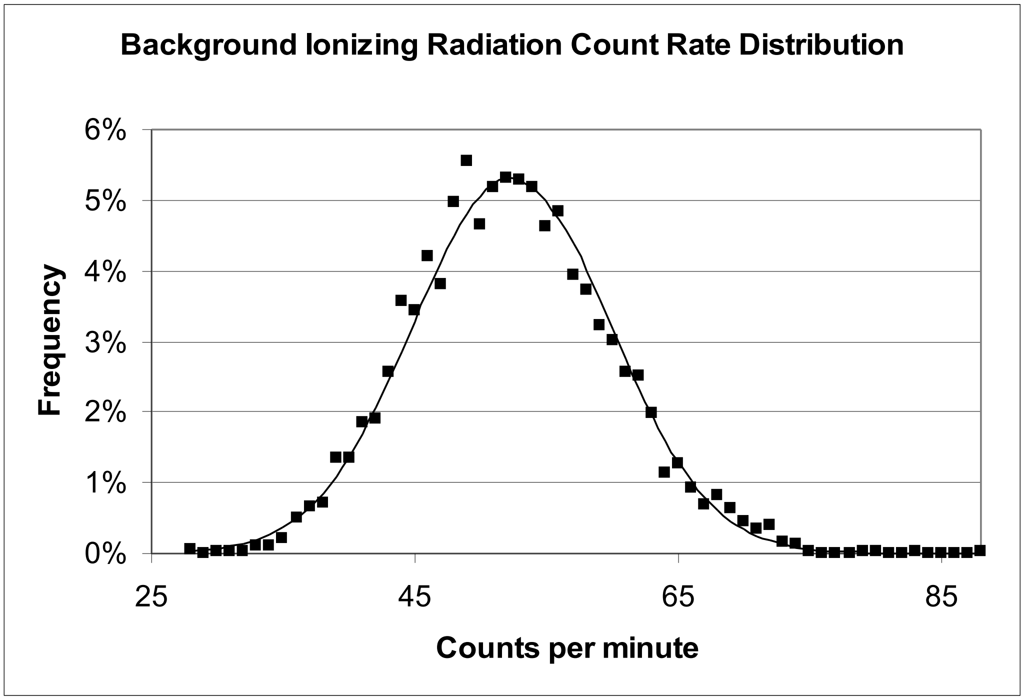
Background radiation is generated by the naturally occurring radioactive isotopes present in ordinary materials nearby, the decay of radon gas atoms that formed locally or has blown in on the breeze, cosmic rays [2], and “fallout” from the atmospheric testing of nuclear weapons (prior to the test ban treaty).

A Geiger-Mueller counter features a gas-filled metal chamber with a high voltage electrode inside [3]. This detector has a thin metal or mica window to allow ionizing radiation of various types covering a wide range of energies to penetrate and interact with the gas. The ionizing radiation interacts with one or more gas atoms to ionize each atom by scattering an electron free from its attraction to the atomic nucleus. The scattered electron is accelerated by the electric field near the electrode and it in turn causes other gas atoms to ionize. This cascade of ionization causes the chamber to arc – conducting a sufficiently large discharge current that the associated electronics are able to detect the event. The interaction of a **single** energetic photon, alpha particle (a helium atom nucleus), or beta particle (a high energy electron) with the chamber can be detected. The chamber cannot respond to subsequent ionization events if they occur within its “dead time” (the time after initiation before it can respond again, typically 30 to 40 μs).

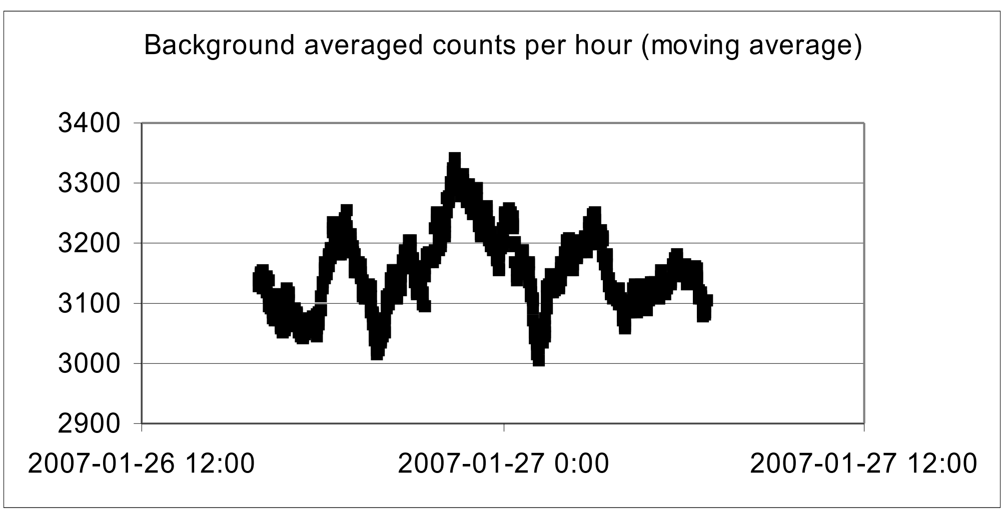
The background radiation in the basement of a home in Deep River, Ontario was monitored for 3807 minutes over a span of several weeks. A computer recorded the number of detection events in each minute (RM80 Geiger [3]). The events counted in each minute over a two hour interval are plotted below.



The count rate varies from minute to minute, making it difficult to interpret. A frequency distribution (a histogram) of the counts per minute for the whole data set is plotted below along with a “normal” distribution having the same mean and standard deviation. (This is not a best fit distribution, but is an easy one to generate in a spreadsheet program – as is the histogram.)



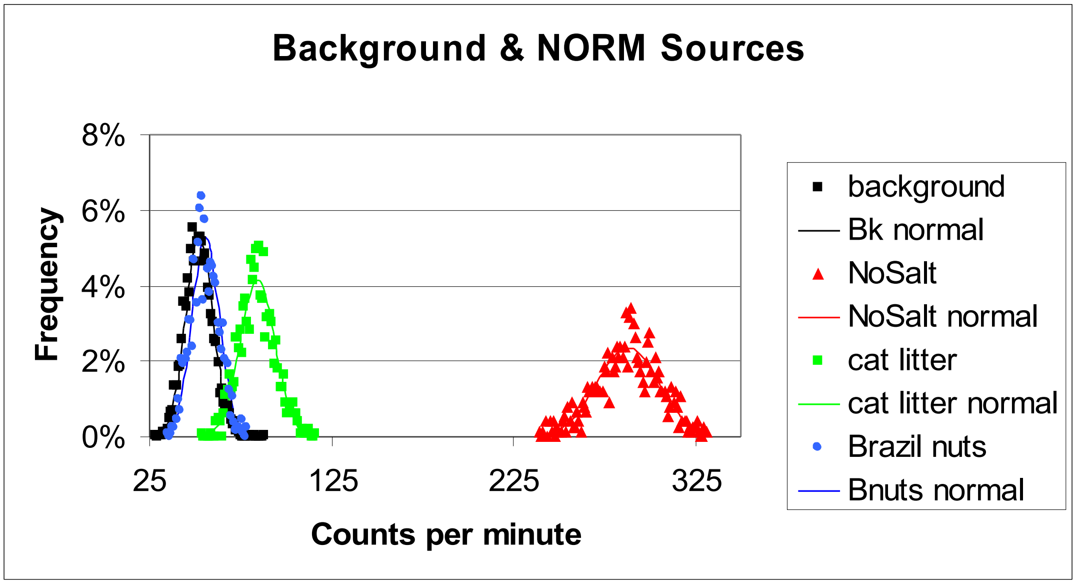
The average count rate is about 52 counts per minute. It is apparent that the data distribution is close to a normal distribution. *Why does it deviate?* The processes that generate the background levels are not constant in time! To investigate this, a digital filter was applied to the data to produce a moving-average one-hour count rate. The filtered time series is plotted below for the longest continuous segment.



The count rate is shown to vary by about 10% peak to peak over several hours. *What factors affect this background?* Wind speed and direction, and home heating system operation can cause the radon contribution to the background to vary. The cosmic ray contribution depends in part on which area of the sky is sampled – which part of the galaxy is overhead is a function of sidereal time.

Detecting a Source

When a source of ionizing radiation is brought near the detector, the radiation from this source is detected in addition to the background. The source may scatter or shield some of the background radiation that would have been detected otherwise. The distributions for a few different counting conditions are plotted below.



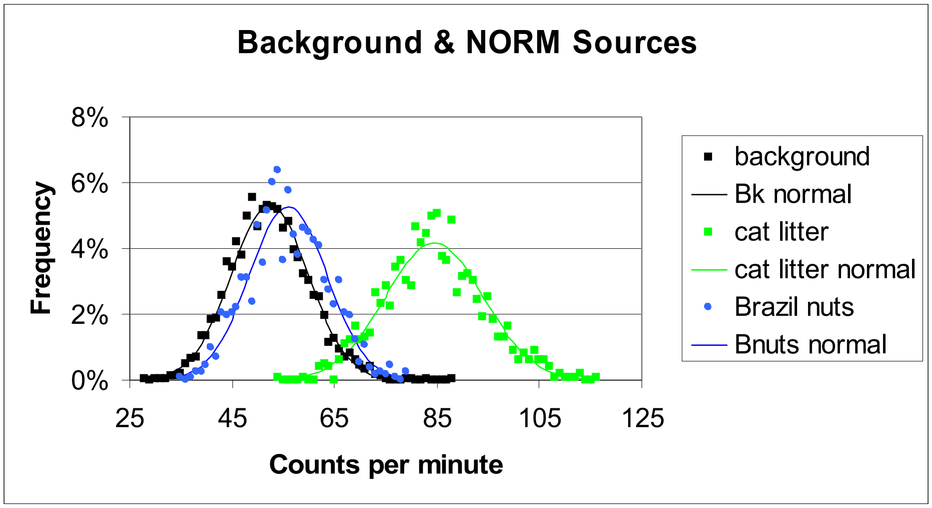
With the scale shown it is difficult to distinguish the separation between the distributions of count rate for Brazil Nuts and the background. However, clumping cat litter is readily distinguishable relative to background, and a container of NoSalt ® produces much higher count rates.

NoSalt® is potassium chloride, a refined source of relatively pure elemental potassium [4]. Potassium-40 (^{40}K) is a naturally occurring radioactive isotope. It has an atomic percent abundance of 0.0117% (11 or 12 potassium atoms in every million are this isotope. In the measurement distribution shown, primarily the gamma components of the ^{40}K decays were detected. 89% of K-40 decay events produce 1.3 MeV electrons – β^- decay that are more readily scattered or absorbed than the 1.46 MeV γ that is associated with the 11% electron capture events. ^{40}K has a half-life of 1.277×10^9 years – of the same order as those of the naturally occurring uranium isotopes.

Removing the NoSalt® data and adjusting the X-axis scale makes the separation more apparent as shown on the next page.

Clumping cat litter contains bentonite clay [5, 6]. This has relatively high concentrations of uranium, thorium and potassium. At about $1 per litre, it is an inexpensive source of ionizing radiation. Brazil nuts have relatively high concentrations of the decay chain isotopes of uranium and thorium [7]. Samples of Brazil nut meat and crushed Brazil nut shells gave similar count rates to that shown.

Heavy metal nuclides such as uranium and thorium decay by emitting alpha particles. The majority of the alpha particles are stopped within the material and do not interact with the Geiger detector. The atoms that result from the alpha decays are also radioactive and the resulting “decay chain” is often in equilibrium with the heavy isotope source (unless the material has been processed chemically). Several of these subsequent decay steps emit gamma radiation. It is the gamma radiation that is most readily detected.



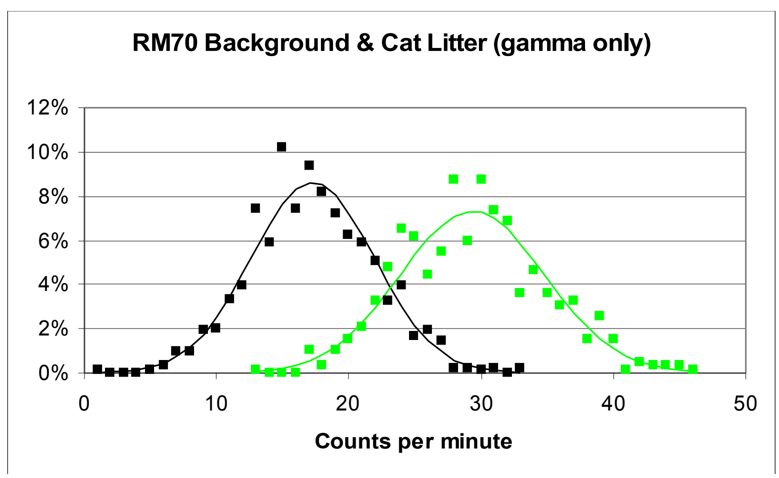
While it is possible to demonstrate readily that NoSalt® and clumping cat litter are radioactive, it requires a longer counting period to demonstrate that weaker sources such as Brazil nuts are radioactive.

Where to obtain NORM sources

All of these NORM sources are available in most grocery stores. The radioactivity they contain originated before the solar system was formed.

> The Nuclear Substances and Radiation Devices Regulations, Canada Gazette Part II, Vol. 134, No. 13, 2000-06-21 (www.nuclearsafety.gc.ca/pubs_catalogue/uploads/Sor207.pdf) stipulates the quantity of any radioactive isotope that one may possess for use as a radioactive source without requiring a license from the Canadian Nuclear Safety Commission. See [4].

Using a less sensitive Geiger Muller detector produces similar results with lower average count rates. These may require longer counting intervals to identify weak sources relative to the background. An RM70 example follows [2].



References:

[1] Chart of the Nuclides: www.nndc.bnl.gov

[2] Natural Radioactivity: www.physics.isu.edu/radinf/natural.htm

[3] Aware Electronics: www.aw-el.com

[4] CNS "Nu-Salt or NoSalt as a radioactive source fact sheet" www.cns-snc.ca/ecc/K40_4pg.pdf

[5] Radioactive Consumer Products: www.orau.org/ptp/collection/consumer products/consumer.htm

[6] Cat Litter: www.orau.org/PTP/collection/consumer%20products/catlitter.htm

[7] Brazil Nuts: www.orau.org/PTP/collection/consumer%20products/brazilnuts.htm