Investigating possibilities for radiation detection in food when using a Geiger Counter

www.vptec.narod.ru/homebrew/geiger-en.htm

Goal of this document:

The goal of the present document is not to provide a method for assessments about compliance of food with pending regulations in terms of radiation. A Geiger Counter does not allow to measure radioactivity levels significantly lower than all recommended different radioactivity levels which usually apply for such goods. However, in cases where suspicion of a quite significant pollution is justified, it will be possible to detect contaminated food as soon as its long term consumption becomes potentially harmful. This means that contamination rates bringing the radioactivity level above the admitted level (or 2 times the admitted level, depending on food type and applied regulations) will be detectable, provided that the proposed measurement method is applied with the relevant care.

Targeted radionuclides:

Main significant and detectable radionuclides in contaminated food and water are:
- Caesium-137 (Beta and gamma emitter)
- Iodine-131 (Beta and gamma emitter)

The possibility of detecting beta or gamma emissions will be evaluated by taking into account the following data:

Nuclide	Energy of beta particles	Energy of gamma particles
Caesium-137	0,511 Mev (94%)	0,662 Mev (89%)
Iodine-131	0,606 Mev (90%)	≥ 0,364 Mev (89%)

The preliminary theoretical evaluation will first show if detection of single gamma radiation is sufficient to reach our expectations. If not, beta particle detection will be studied. (Levels are above 0.25Mev, so we can consider that we are in presence of high energy beta-rays, called "hard beta").

It is at least expected to be able to start detecting at a distance of 1~2cm that the activity of the sample under test reaches or exceeds 100Bq/kg. Detecting smaller levels without having the possibility of identifying isotopes would have no meaning anyway, since natural radioactivity levels of some products might reach this level.
Reference: banana containing natural potassium isotope K-40(*), giving 15Bq for a 150g banana. This corresponds to 100Bq/kg.

Starting detecting radioactivity at this level is not ridiculous, when compared to the currently admitted limit of 600Bq/kg for meat in Western Europe.

(*) K-40 emits beta particles at 1.3 Mev (89%) and gamma particles at 1.5 Mev (11%). Therefore banana radioactivity has to be detected by our method in bananas if the assumptions are correct.

Evaluation of possible gamma detection:

Initial conditions are the following:

- Distance to GM tube: 1~2cm
- GM tube sensitive area facing the sample under test over its whole surface
- Sample activity level: ~100Bq/kg
- Roughly estimated sample mass: 0.15kg, flat form (practical limitations)
- Net count rate (*) considered as valid if greater or equal to 1/20th of GM tube background (3 minute long counting process, before and after sample presence)

(*) The net count rate is defined as follows:
Count rate with sample present MINUS Cout rate without the sample (background only)

The point source hypothesis should be slightly more pessimistic (in terms of measurement sensitivity) than the described situation. It can be used for rough estimation:

Sample induced dose rate in R/h on GM tube is $Dr = 0.55 . A . E / d^2$
with A = activity in Curies, E energy level in Mev and d expressed in meters.

Taking into account that $1\ Ci = 37.10^9$ Bq, then $A = 4.05.10^{-10}$ Ci

This gives as lowest possible value: $0.55 \times 4.05.10^{-10} \times 0.364Mev \times 0.89 / (0.02)^2 = 0.18uR/h$

Assuming a commonly acceptable background of 1 cps for the GM tube, this means that the required GM tube coefficient must allow to get a net count rate of 0.05cps for 0.18uR/h.

This means that sensitivity should be above 0.05cps / 0.18uR/h = 277,777.7 cps / R/h
This is totally impossible. Even errors caused by the pessimistic approximation cannot explain a so irrealistic requirement, taking into account that this value usually reaches 10,000 cps / R/h maximum for standard GM tubes characterized under gamma radiations. (Ra-226 = 0.65Mev)

Therefore gamma particle detection cannot be used for detection food contamination, even if assuming that the measurement enclosure is perfectly shielded against natural background. Any GM tube detecting only gamma-rays is useless for that purpose.

Evaluation of possible beta detection:

GM tubes defined as sensitive to "hard beta" radiation should detect beta particles having an energy level higher than 0,25Mev. For our evaluation the same measurement setup as previously is kept:

- Distance to GM tube: 1~2cm
- GM tube sensitive area facing the sample under test over its whole surface
- Sample activity level: ~100Bq/kg
- Roughly estimated sample mass: 0.15kg, flat form (practical limitations)
- Net count rate considered as valid if greater or equal to 1/20th of GM tube background (3 minute long counting process, before and after sample presence)

GM tubes (as single components) are often not characterized as beta detectors, even if they are said "hard beta sensitive". This is why in this approach we'll assume that when hit by beta particles the tube detects the half of them. This rough assumption covers the case of windowless tubes having thin metallic walls (like aluminium or other low mass metal) and being sensitive all along their body. The walls are expected to stop the half of incident beta radiation with such energy levels, assuming that the wall thickness is for example 0.25mm of aluminium. It is expected that particles entering the tube inner part are much more likely to trigger it than gamma particles whitch can pass through without ionizing any atom. Overall detection under gamma exposure is generally estimated at 1% of the particles passing through, while it is close to 100% with beta particles.
(Source: http://www.me.iitb.ac.in/~stj/lmanual/theory.htm)

Therefore, since occurences of alpha and beta emissions per desintegration are quite the same for the targeted nuclides, the same sample activity will induce a much stronger response by the GM tube: (100 / 1) / 2 = 50 times more cps.

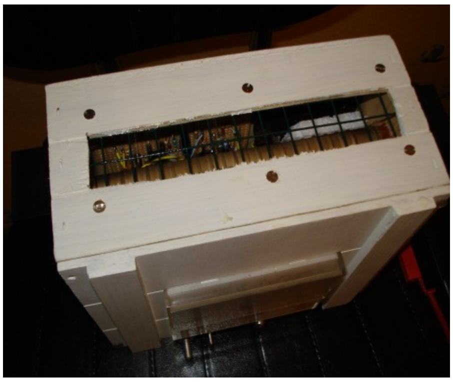
This means that a GM tube characterized under gamma radiation at less than (277,777/50) cps/R/h will just start detecting beta radiation at our expected radiation level:

Coefficient = 5,555 cps/R/h

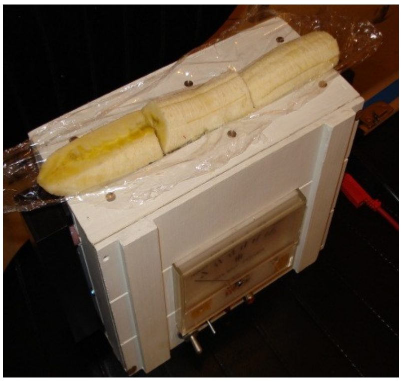
Practical tests will allow to know if this value is really the strictly acceptable minimum sensitivity or if measurement conditions can improve detection. (Attenuation calculation based on distant point source calculation might be pessimistic, but beta attenuation inside the sample was not taken into account).

Experimental test: the "banana calibration"

In our example of test measurement setup, we are using a windowless GM tube having a length of 195mm and a sensitivity of 4600 cps/R/h (a little bit less than required). This russian GM tube SBM19 is used as part of a home made geiger counter.
(Refer to **www.vptec.narod.ru/homebrew/geiger-en.htm**)



GM tube visible through aperture



pieces of banana in place

The entire banana could not be placed on the measurement area but only the half of it. However, pieces have been formed and placed in the best possible way for irradiating the GM tube (itself 1.5cm under the protection grid). Only a thin film of polyethylene is used to avoid direct contact of food samples with the device. Therefore attenuation of beta particles is very limited.

The measurement process is repeated three times, as evocated earlier:

- 3 minute background measurement
- 3 minute background + sample activity measurement
- Computation of the net count rate

A computer program (also provided on the website in case of use of the proposed GM counter) was available for this purpose.

The results in CPM were the following:

Test #	1	2	3	Average
Backg.	71,66	66,66	62,00	66,77
Sample	74,66	73,66	69,33	72,55
Net count	3,00	7,00	7,33	5,78

Results are very satisfying, even with a GM tube sensitivity of 4600 cps/R/h and a specified inherent background of 2cps max. No shielding enclosure was necessary.

Even with the half of the banana theoretically giving only 7.5 Becquerels as a typical activity, the net count rate remained significant at each test. Its average value represents 8.6% of the average background count rate.

The rough evaluations were finally close to reality, and just a little bit too pessimistic in terms of sensitivity as previously assumed.

Conclusion:

With equipments having similar characteristics to the device proposed in this evaluation report, it will be possible to check easily food contamination by strong beta emitters such as Caesium-137 and Iodine-131, for activity levels reaching 600Bq/kg or even slightly less.

In absence of true laboratory reference samples, a simple banana can help obtaining a realistic order of magnitude for calibration of the measurement setup. ;-)

<u>Remark</u>: This experiment does not mean that bananas are dangerous. Indeed living organisms have evolved during billion of years while containing the same proportions of potassium isotope than bananas. However, if organs containing potassium are insensitive for ages to this resident radiation source, this is not the case for other ones which have never contained naturally present radionuclides and might be for example suddenly subject to contamination by iodine-131. Generally, radiation from bananas as well as the "Banana Equivalent Dose" are occasions for promoting the expansion of nuclear power in a funny way. However, in case of nuclear fall-out our stomaches are not able to digest these thousands of tons of equivalent bananas...