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A Citizen's Guide to Monitor Radioactivity: Around the Energy Department's Nuclear Facilities

The Initiative for Social Action and Renewal (ISAR)

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A Citizen's Guide to Monitor Radioactivity

Around the Energy Department's Nuclear Facilities

- A report on Russian investigations at Paducah, Kentucky and Portsmouth, Ohio in 2003



May 2005

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Purpose

This is a “how-to” Guide for citizens, groups, and communities who neighbor U.S. Department of Energy facilities. This Guide is for those who want their own independent information about artificial radioactivity in their surroundings. This Guide follows the story of an actual expedition by an independent Russian scientist to Paducah, KY and to Portsmouth, OH. Step-by-step instructions explain how to use inexpensive equipment to discover radiological conditions of your daily life. Start-up equipment and supplies cost about \$1,500.

Contents

	<u>page</u>
Organizational background of this project	2
Introduction to the 2003 SSGR study at Paducah and Portsmouth	3
Before starting	6
Background to Paducah KY and Portsmouth OH	7
A car ride with the Inspector	9
On foot with the Inspector	12
Sample selection	16
Sample collection	20
Sample preparation	21
Ingrowth and decay with the Inspector	23
Nfoils with the Inspector	27
Analysis and interpretation	30
Results of 2003 SSGR survey	33
On beyond the Inspector	33
Equipment list	34
Credits	37
Glossary	back cover

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Organizational background of this project

ISAR facilitates training, technical, and informational exchanges between individuals and organizations in the U.S. and the former Soviet Union. ISAR supports citizen activists and grassroots nongovernmental organizations in their efforts to create just and sustainable societies by building advocacy skills, supporting community environmental problem-solving initiatives, galvanizing international environmental campaigns, and increasing public participation in environmental decision-making.

For more information:

www.isar.org

In 2000, ISAR sponsored an exchange conference between Russian and U.S. women who live in nuclear manufacturing communities. There were many similarities between the Russian and U.S. communities regarding public health and environmental quality. An evident difference was the superior scientific background of the Russian women, compared to the American women. Discussion of inviting Russian scientists to the U.S. to assist and teach local citizens how to monitor and sample radioactive contaminants continued through 2002.

In response to requests from citizen-activists in Paducah, Kentucky and Portsmouth, Ohio, **ISAR** arranged for the Russian non-governmental organization, Siberian Scientists for Global Responsibility (SSGR), based in Novosibirsk, Siberia to visit those sites in November 2003.

A group of scientists in Siberia formed Siberian Scientists for Global Responsibility (**SSGR**) in 1996, based on experience from cooperation with the British organization, Scientists for Global Responsibility. SSGR's central mission is environmental protection through radiation monitoring of polluted territories and informing the public of the pollution. SSGR teaches its partners how to carry out radiological investigations of polluted areas to obtain reliable information. SSGR shares its experience by working with youth and mass-media, organizing seminars, and training programs. SSGR has about 50 volunteers, of whom 15 are students and scientists, and 30 of whom are lawyers and public activists.

Sergey Pashenko, founding Director of SSGR, holds a PhD in physics and mathematics. Sergey is a senior scientist at the Institute for Chemical Kinetics and Combustion for the Siberian Branch of the Russian Academy of Sciences. Sergey began his special focus on radioactive aerosols in 1992, when he measured emissions from the Beloyarskaya atomic power plant. He has investigated radioactivity in the environment around six Russian nuclear facilities and six American nuclear facilities. Sergey is an educator who teaches radiation monitoring to high school students, graduate students, and concerned citizens; see Fig. 1 on the next page.

Fig. 1. Sergey Pashenko explains SSGR's work in Siberia, to community members at Paducah. [SSGR]



Elena Pashenko organizes all SSGR seminars, training programs, and expeditions. Elena has an advanced education in philology and has ten years experience in the environmental movement. In 2000, she was a travel coordinator for the Government Accountability Project (GAP) and SSGR international project to investigate radiation in four Siberian cities. Elena began working with ISAR in 1997. In 2000, she participated in an ISAR exchange program, "Women, Radiation Safety, and Population Health." In 2002, she served as a technical coordinator of ISAR's seminar, "Nuclear Disarmament and Radiation Safety: The Projects and Strategies of NGOs in Conflict." Elena is responsible for SSGR's connections with mass-media and youth.

Introduction to the 2003 SSGR study at Paducah and Portsmouth

On November 7, 2003, Sergey Pashenko of SSGR and Lucy Henry of ISAR arrived at the Paducah, KY airport and were greeted by Corinne and Pete Whitehead. So they began 6 days (and nights!) of intensive introductions and meetings; surveys, measurements, sampling, sample preparations, and more measurements; review of official documents; and more meetings. Between November 13 and 19, Sergey repeated this process at Portsmouth, OH.

SSGR's main objectives for the project at Paducah and Portsmouth were: (1) to involve the communities in the process of scientific monitoring, (2) to begin building a coalition between the affected communities and between the communities and their Russian counterparts, by facilitating information exchange and skills-building, and (3) to provide citizens with a final product that clearly explains the outcomes of the project: *how, what, and where*.

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By March 2005, SSGR had provided a narrative of the work around Paducah and Portsmouth to ISAR, along with background descriptions, and analyses-in-progress of samples. That information is available from ISAR as, "**SSGR REPORT: Initial Investigation of Radiation in the Vicinity of the Paducah and Portsmouth Gaseous Diffusion Plants.**"

ISAR contracted The RadioActivist Campaign (**TRAC**) to compile the information into a citizen's Guide for monitoring radioactivity around Department of Energy (DOE) nuclear facilities. TRAC staff had worked on the GAP and SSGR project in 2000, gaining familiarity with SSGR methods and practices. TRAC has also had experience with much of the equipment SSGR used at Paducah and Portsmouth.

For more information:
www.radioactivist.org

TRAC interpreted SSGR methods into a Guide for citizen activists in the U.S., particularly around DOE's Paducah and Portsmouth Gaseous Diffusion Plants (GDPs). This undertaking required substantial modification of some of the Russian methods to make them suitable for American conditions. TRAC has also provided validation and explanations.

TRAC has relied, as much as feasible, on information in the SSGR REPORT to prepare this Guide. Where TRAC has modified methods, graphics, or other information substantially from the SSGR REPORT, changes have been noted as "Modified from SSGR" or have been attributed to "TRAC".

TRAC has tried to present the flavor of SSGR's *get-involved! hands-on! do-it!* approach to radiation monitoring, to inform the concerned public. On the other hand, levels of artificial radioactivity around U.S. nuclear facilities are usually lower than around Russian nuclear facilities. This necessitate greater care and attention to detail to identify radiological problems in the U.S. TRAC has modified the Russian methods to improve sensitivity and accuracy for American situations.

This Guide is arranged stepwise. Early sections explain what you can do, and how, to gain a basic understanding and to develop good techniques. In the first sections of this Guide, the basis for decisions is spelled out, often in terms of the precautionary principle: *If you're not sure, turn back*. There are also rules of thumb, like avoiding places where radioactivity exceeds four times natural background counts.

Later sections explain more complicated methods that you can learn and then apply to your advantage, after you have gained some basic understanding and have practiced with the equipment and procedures.

When you are working with those more advanced methods, you will begin to face different kinds of questions. For example, in the Section, "Ingrowth and decay with the Inspector," you will have to make decisions at Steps 7 and 8: Should you continue with more counts to better establish radioactive ingrowth or decay? Should you properly dispose of the sample and move on? Should you archive the sample for future reference? Should you move on to analyze the sample, by methods described later in this Guide? -- In short: *How* should you decide what to do *next* with a sample?

At that point in your work, the answers will be literally in your hands, and more generally in your capabilities that you will have acquired through careful practice. The ways you will have learned to use the Inspector and other equipment will help you decide what to do next. When in doubt, the next step is to figure out what you need to learn in order to decide what you should do next. That is to ask yourself: How can I apply what I have learned, so I can decide what to do next?

If nothing comes to mind, place your bagged sample into a Ziploc® freezer bag to provide a second barrier, and place it into adequate storage, until you decide what to do next. At Steps 7 and 8 in the Section “Ingrowth and decay with the Inspector,” your default is to wait two weeks. Time is on your side.

Volunteer-based organizations have a certain advantage over paid-staffed organizations in the use of *time*. Although people who volunteer often have more commitments (and less *free time*) than paid-staff has, volunteer time usually does not have to be accounted as tightly as does staff time or consultant time. Visiting scientist-activists and government scientists have to work against a clock and to produce results by the hour or by the dollar (or ruble!). The professional has made a commitment to a timeline; whereas, the volunteer can decide whether to take more time to explore something interesting that might be important. The volunteer can decide to commit a day, or a month, or a year to something paid staff can only justify and account an hour.

The concerned citizen can set the Inspector to count a sample for a day and leave the Inspector counting unattended. This gains a factor of **12** in precision of the result, compared to 10 minute (CP10M) results that were practicable for SSGR. Once you discover the ways that time is on your side, you can apply your time most effectively.

As you develop your own radiation monitoring program while you learn the capabilities of your equipment, you will become a specialist in the all important details of the radioactive environment around your neighboring nuclear facility. If you are patient and observant, you can expect to discover important radioactive pathways into *your* environment, pathways that regulators may not know about and may not have told you about.

Finally, you will discover new ways of looking at your (naturally and artificially) radioactive surroundings. Take your time and, as Sergey invites, use your imagination!

Before starting

! CAUTION !

- **Energetic radiation (~radioactivity~) is harmful to you.**
 - If you are monitoring radioactivity, you are *looking for* hazards.
 - Plan ahead. Look ahead, so you can stop or take precautions before you get into trouble.
 - Be cautious in sample collecting and handling, sample preparation, sample analysis and sample archiving or disposal. Be cautious rather than adventurous. Be safe rather than regretful.
 - Read all of this Guide carefully before beginning citizen-based radiation monitoring around any nuclear facility or intensive source of natural radioactivity.
 - Obtain the reference books in the “Equipment list” section of this Guide, or get access to them.
 - Take warnings seriously; heed them.
 - Be carefully protective of yourself, of your family, friends, co-workers, your neighbors, and your equipment.

! CAUTION !

- **Begin your plan by getting informed about radioactivity and its dangers.**
 - Take personal responsibility to become well enough informed about radioactivity in the environment and human health consequences.
 - Begin to familiarize yourself with the contents of “Environmental Radioactivity,”
in the “Equipment list:” Look over the *introduction* in Chapter 1, *radiation protection* in Chapters 2 and 3, *pathways* in Chapters 4 and 5, and *sources of exposure* in Chapter 10.

! CAUTION !

- **Use good sense.**
 - Become informed. Consider how what you have learned applies to what you plan to do in your particular situation. Carefully apply what you have learned. Learn more from your experiences. —This is good sense. Good sense is *uncommon*.
 - Remember that most exposures to radioactivity are permanent. Avoid exposing yourself, others, and your equipment to radioactivity.

! CAUTION !

- **Be consciously aware of and guard against the three main pathways by which radioactivity will harm you.**
 - Inhalation.
 - Ingestion.
 - Track off (taking contamination with you, on hands, clothing, and shoe soles).

! CAUTION !

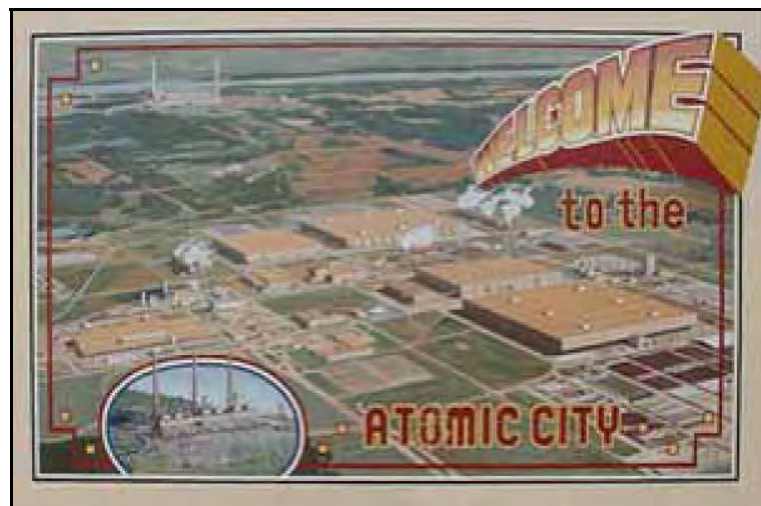
- **Use your Inspector as your guide, your guard, your backup.**
 - Use this rule of thumb: Follow high Inspector readings to sampling sites, but stop before the Inspector reads four times your *natural background* readings; see the Glossary.
 - As you approach a *hot-spot*, slow down. Be increasingly cautious and careful.
 - Avoid getting contaminated. Limit contact with contaminated materials. Prepare in case you might become contaminated. If you might have been contaminated, wash the contamination off with lots of water and change clothes. Until your hands are clean, don't eat anything.
 - As you leave a *hot-spot*, check yourself and others for contamination, with your Inspector. Wash it off or bag it. Do not spread contamination.
 - After leaving a contaminated area, check that your Inspector readings return to background levels to be sure your Inspector is not contaminated.

Background to Paducah KY and Portsmouth OH

In 1952, the United States Atomic Energy Commission (–now the U.S. Department of Energy–) selected two sites to enrich uranium for nuclear weapons. Gaseous Diffusion Plants (GDPs) were built at Paducah, Kentucky and Piketon, Ohio. As soon as these plants were completed, the U.S. shifted uranium enrichment from the nation's first GDP, K-25 at Oak Ridge, Tennessee to Paducah and Portsmouth.

The **Paducah** GDP comprises 3,556 acres, located on the former Kentucky Ordnance Works, and is situated 15 miles west of the city of Paducah, Kentucky and three miles south of the Ohio River.

Fig. 2. An historic poster for Paducah, KY. [DOE]



The United States Enrichment Corporation (USEC) leases the Paducah GDP from the U.S. Department of Energy (DOE). The Paducah GDP is the only uranium

enrichment facility currently operating in the United States. USEC employs 1,400 people at Paducah, to produce low-enriched uranium to fuel commercial nuclear reactors that produce electricity in the U.S. and abroad.

DOE's current missions at the Paducah GDP focus on cleanup of contamination from activities during the Cold War. Cleanup addresses migration of contaminated groundwater toward the Ohio River and on remediation of radioactive and toxic wastes on site; see Fig. 3, below.

For more information:

www.paducahky.com/history.html

www.oakridge.doe.gov/factsheets/paducgdp.htm

www.usec.com/v2001_02/HTML/Facilities_PaducahHistory.asp

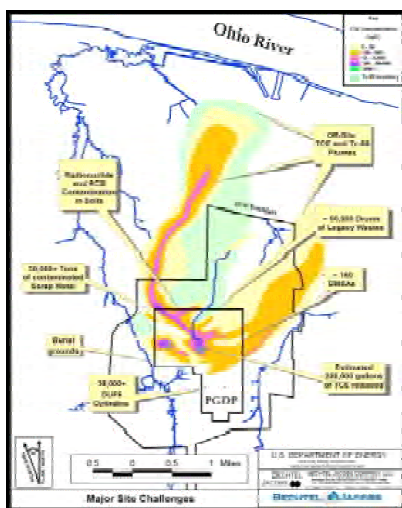


Fig. 3. Contaminants on Paducah GDP site and migrating off-site. [DOE]

The **Portsmouth** GDP comprises 3,714 acres in rural Pike County, Ohio, 22 miles north of Portsmouth, Ohio. USEC leases the Portsmouth GDP from DOE. Bechtel Jacobs Company LLC integrates management and operations between DOE and USEC. About 1,660 personnel at Portsmouth GDP provide a range of specialized technical, operational, and administrative services for DOE. USEC is preparing to demonstrate the next-generation of uranium enrichment technology in the *American Centrifuge Plant*, at Portsmouth GDP.

With DOE's focus at Portsmouth more on new technology, DOE appears to place less attention on residual problems from past operations, in comparison to DOE's Paducah site. This can be seen by comparison of their websites.

For more information:

www.oakridge.doe.gov/factsheets/portsgdp.htm

www.bechteljacobs.com/ports_reports.shtml

www.usec.com/v2001_02/HTML/Facilities_PortsHistory.asp

A car ride with the Inspector

This trip is an introduction to some of the equipment and techniques to obtain useful radiological results from the Inspector. It will provide a useful *first look* around a nuclear facility and help identify areas of concern. If you repeat the operation, you can gain some insights into radioactive pathways off-site and can identify radioactive fall-out events from the site.

For this work, you need an Inspector and its cable and software installed in a laptop computer. You need a way to mount the Inspector on the bottom of a car. You need a bound, solid notebook, and a wristwatch to note times and locations. --See the "Equipment list."

! CAUTION !

Always zip the Inspector into a pint Ziploc® freezer baggie.

Preparation

Steps:

1. Punch the Inspector cable jack through the bag to plug it into the Inspector.
2. Turn the Inspector *ON* in the CPM mode, with your thumbnail, through the bag.
3. Plug the other end of the cable into the laptop, set in the car, Fig. 4A, on the next page.



A.



B. Inspector mounted under car

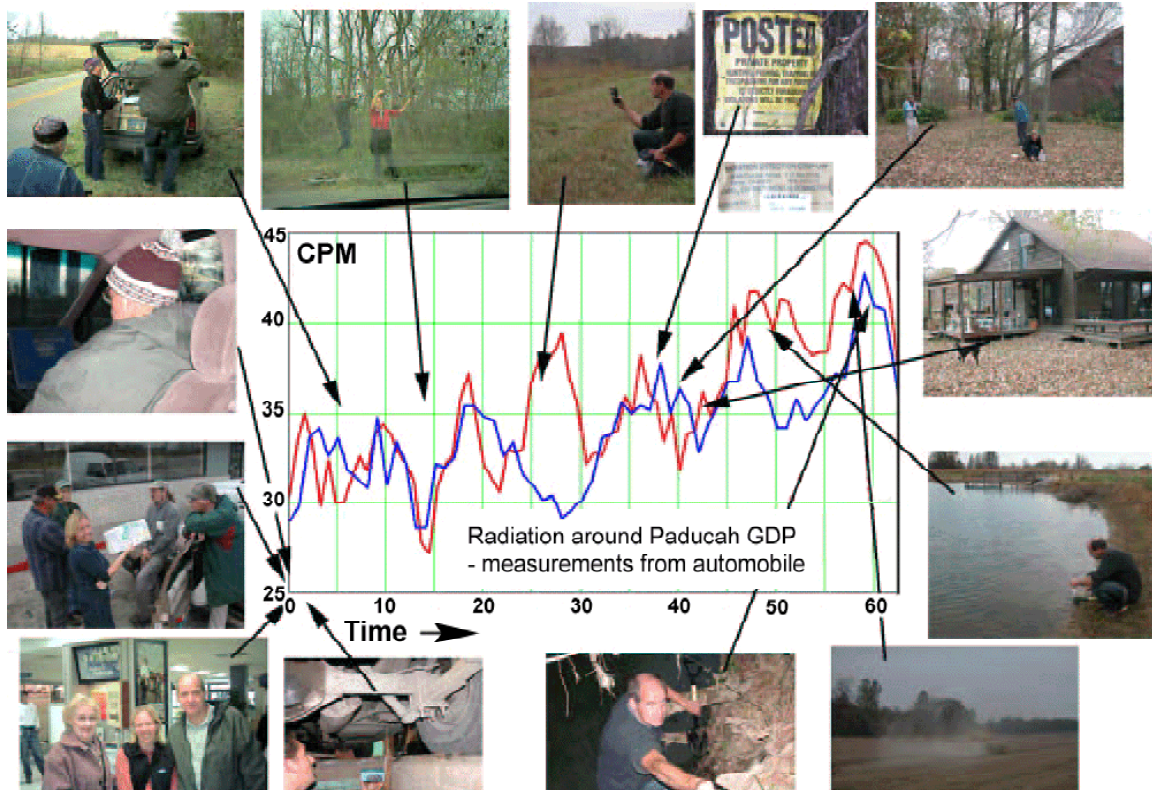
Fig. 4. Connecting the laptop (A) to the Inspector (B) (-should be in a Ziploc®!-), mounted under a car in Russia. Because of time constraints, SSGR mounted the Inspector on top of the car at Paducah and Portsmouth, allowing less sensitive results. [Modified from SSGR]

4. Mount the Inspector (zipped in a bag) under the car, Fig. 4B, with the Geiger counter window pointing down.

Step:

5. Boot up the laptop with the Inspector software; note time and location, and ... start your car.

SSGR drove around Paducah GDP on two different days. The red and blue graphs of CPM readings from the Inspector mounted under the car are the results; see Fig. 5.



--“CPM” means counts per minute. This is the *mode* the Inspector is operating in.

Fig. 5. CPMs recorded during SSGR drives around Paducah GDP, on two different days in November 2003 (red and blue graphs). The group also checked things out at several locations (photos). Such photos provide useful documentation. [Modified from SSGR]

Notice that the two graphs in Fig. 5 are somewhat similar and also somewhat different. How *real* and *meaningful* are these similarities and these differences? —To answer these questions yourself, you will first have to become familiar with the Inspector, so you can interpret its readout counts.

Short answers to these questions of reality and meaningfulness are, as follows: The differences between the red and blue graphs are probably random. The consistently higher readings close to the right side of both graphs are likely real and invite more investigation there.

What is most importantly important, is to appreciate that the answers to these questions would be clearer if SSGR had mounted the Inspector under the car, as shown in Fig. 4. But even with the Inspector conveniently mounted on top of the car, SSGR obtained results worthy of follow-up.

The answers to the question about *reality* and *meaningfulness*, require interpretation of the Inspector’s readings. With observant practice, you’ll gain a sense of what the Inspector is telling you. For the technically oriented activist, here is a somewhat technical note on random variations in CPM counts and lag of the Inspector’s readouts:

A somewhat technical note on interpreting CPMs

In CPM mode, the Inspector accumulates *counts* from the previous half-minute, multiplies those counts by two, and displays those counts as *CPM* readings. Each added count, shown by the flash of the Inspector’s indicator light, registers one detection of radiation by the Inspector. Every 3 seconds, the Inspector updates its display of the counts from the (updated) previous half-minute, multiplied by two. In this way, the Inspector displays a *running average*, in the CPM mode.

- Why worry about random variations? --Inspector readings are a sum of *real values* ± *random variations*. The investigator seeks real values and differences between real values; that is how much *hotter* is one measurement, one location, or one sample than another one? The degree to which Inspector readings represent real values is the degree to which random variations can be minimized in the readings. Random variations are diminished by longer counting times with the Inspector.

$$\text{Random variation} = \sqrt{(2\text{CPM})}.$$

Table 1. How much random variation contributes to CPMs. [TRAC]

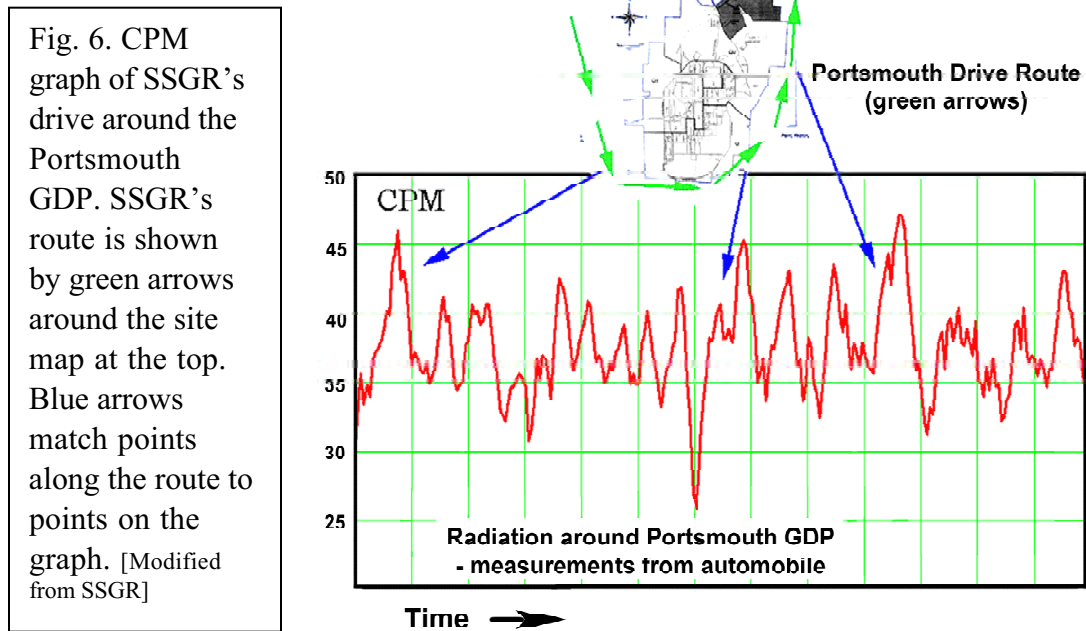
displayed CPM:	18	32	50	72	98	128	162
random variation [CPM]:	6	8	10	12	14	16	18
<i>variation as % of display:</i>	<i>33</i>	<i>25</i>	<i>20</i>	<i>17</i>	<i>14</i>	<i>12.5</i>	<i>11.1</i>

--Notice how the relative inaccuracy (–variation as % of display–) decreases as the CPMs increase. More counts yield less uncertainty, in accord with the *square root law*.

- How do “random variations” relate to “background fluctuations”? --Random variations are a part of background fluctuations. In addition to random variations (of Inspector CPM readings, over time), natural radioactivity differs (“fluctuates”) from one location to another. Differences in natural background radioactivity depend on differences in concentrations of natural potassium-40, natural uranium decay chains, natural thorium decay chains, and natural beryllium-7 at different locations and in different samples.

Note: in CPM mode, Inspector readout lags about 30 seconds.

A week after SSGR measured CPMs around Paducah, SSGR drove around Portsmouth GDP and obtained another set of CPM measurements there. The Portsmouth results are graphed in red in Fig. 6, below.



SSGR interprets this Portsmouth graph, as follows: “The gamma-radiation on the roads [around Portsmouth GDP] is NORMAL with natural fluctuations of background. This differs from the graphs around Paducah GDP.”

In these car rides with the Inspector around the two GDPs, SSGR was already able to show citizen activists where to check more closely around Paducah. Although SSGR had nothing to show from the CPM measurements around Portsmouth, other methods with the Inspector would prove successful there...

On foot with the Inspector

A car ride, as just described, is safe enough for people. The main concern is to protect the Inspector from dust, debris, and other contamination. As soon as the citizen-activist investigator ventures out of the car, on foot, near a DOE nuclear facility, personal harm becomes a concern. So part of the purpose of the car ride was to gain some familiarity with the operation of the Inspector and to learn what it can tell you if you are watchful.

The purpose of your first walk with the Inspector is to get an idea of how the readings fluctuate in different the surroundings, depending partly on how you hold the Inspector. You can use this method, later, to help identify materials for sampling.

! CAUTION !

- Review “**Before starting**,” and plan ahead. If in doubt, plan to turn back.
- Always zip the Inspector into a pint freezer bag.

Steps:

1. Zip the Inspector into a snug, pint bag with the white printing facing down (under the Geiger counter window screen). This allows you to read the Inspector display through the plastic bag. If you are right handed, place the Inspector into the bag so the zipper is out of your way, on the left side. If you are left handed, have the bag zipper on the right. You can operate the Inspector switches and buttons through the bag. Replace the bag whenever it has been worn through or might possibly have been contaminated.
2. In what you consider a *natural environment*, familiarize yourself with the Inspector, with “background” radioactivity, and with “normal fluctuations” of Inspector readings.

A note on *background* at Portsmouth: Dark Rain Thom, a Shawnee elder, recounts how her people bought their own Geiger counters after the Atomic Energy Commission announced it intended to build the Portsmouth GDP. They found deposits of radioactive materials that they decided were natural [Geoffrey Sea, personal e-communication, March 22, 2005]. —With your Inspector, check out how natural background radioactivity varies.

3. Watch how the Inspector readings change when you hold the Inspector close to an object or far from it. How different are readings if you hold the Inspector close to the ground or at waist height while you walk? How much do readings rise if you point the detector screen at the sun? How do the readings change when you check different items? What is the CPM background in your house, your garage, your yard?
4. Before setting out afoot, near a nuclear facility, finish reading this Guide; review what you’ve learned; and plan ahead. Review the Operating Instructions for the Inspector, to their end. Refer to the reference books in the “Equipment list,” with a thought to what might be important for your excursion. Review what you’ve read in “Environmental Radioactivity,” and select other readings to become adequately informed.
5. Pause and consider your preparations. If you are not confident, don’t do it. Remember, time is on your side. Take your time, and do it right the first time.
6. For this exercise, you need appropriate clothing, an Inspector, the Inspector Operating Manual, this Guide, a GPS (included in the “Equipment list”), and the bound notebook, and a wristwatch, already mentioned. If there is any likelihood that you might encounter radioactivity approaching four times background, take along spare clothes and shoes to change into and water to wash with. Take some garbage bags for any soiled articles. —If you get that close to contamination on your first outing, you have not planned well!

Steps:

7. Set out walking with the Inspector in CPM mode, with Audio On. Be observant as you walk. Keep the Inspector at a fixed height and orientation. Gain a sense of relationships between frequency of beeps and what is around you.
8. When you encounter something that catches your interest, switch the Inspector to Total/Timer=10 minutes mode. (The Operating Manual that you've brought along tells you how to set the mode.) Compare those CP10M readings with your initial CPM readings of the same thing. Gain a sense of the relationship between readings in these two modes. Differences between CP10M readings of different objects in an area of interest will help you decide later which materials are most attractive for sampling and later analysis.
9. Afterward, be sure you're not contaminated. If in doubt, scan the bagged Inspector over yourself, including the soles of your shoes. As soon as you are back home, put your clothes into the laundry and take a shower to wash off. Then you are ready for a meal.

By trial, you'll discover how much more precise the readings of the Inspector are with Total/Timer=10 minutes, than in the CPM mode. Here is a somewhat technical note for the technically inclined reader:

A somewhat technical note on interpreting CP10Ms

--This takes up where the somewhat technical note on Page 11 left off. Please glance back to that for orientation.

In Total mode, the Inspector accumulates counts over the selected time for totaling. As the Inspector accumulates counts, it displays the running total. At the end of the accumulation, the Inspector *beeps* and the total remains fixed.

Table 2. How much random variation contributes to CP10Ms. [TRAC]

displayed CP10M:	180	320	500	720	980	1280	1620
random variation [CP10M]:	13.4	17.9	22.4	26.8	31.3	35.8	40.2
<i>variation as % of display:</i>	<i>7.4</i>	<i>5.6</i>	<i>4.5</i>	<i>3.7</i>	<i>3.2</i>	<i>2.8</i>	<i>2.5</i>

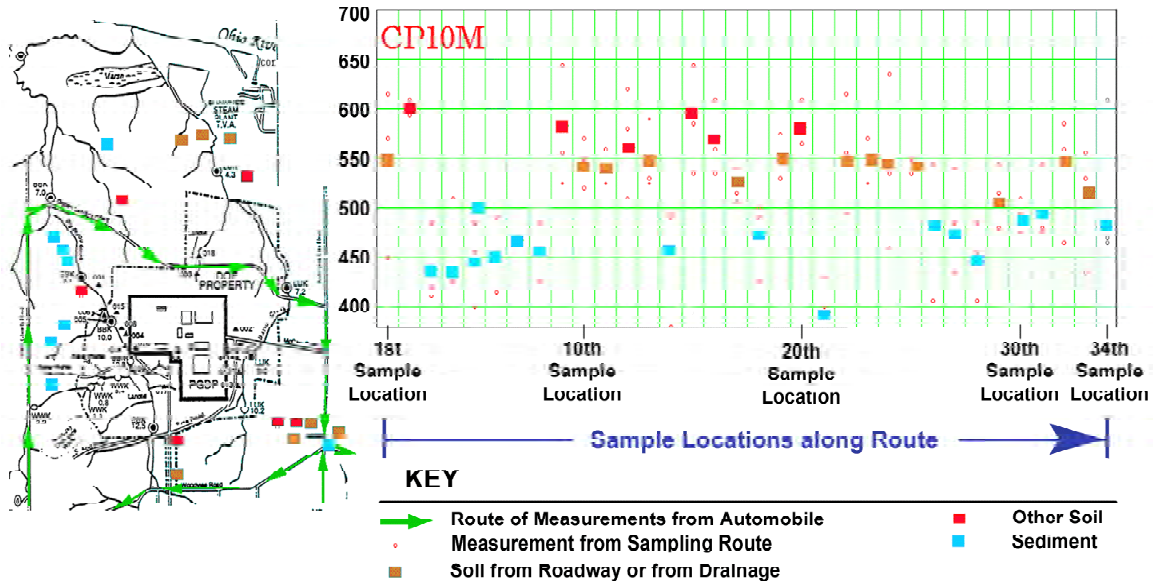
--As with the previous, somewhat technical note, notice how the percentage of variation diminishes with increasing CP10Ms.

--Notice that these CP10Ms are exactly ten times the CPMs in the previous, somewhat technical note. Compare the "variation as % of display" here with the previous, corresponding values.

--Notice how much lower the random variation, as a percentage of the display, is in this Total mode, in comparison to the CPM mode, Table 1. The CP10M results are a factor of $\sqrt{(10 \text{ minutes}/0.5 \text{ minute})} = 4.5$ times as precise as the CPM results. Are you beginning to get a little sense of the effect of the underlying square-root law?

The disadvantage of using the Inspector in its Total mode is that it takes more time to get results than in the CPM mode: 20 times as long. As a concerned citizen-activist, you have the motivation and the *time* to obtain precise and accurate results. Only concerned citizen-activists are willing to take long enough to make this work.

...Back at Paducah, SSGR began to follow up the abnormal CPM results, shown in Fig. 5, with closer checks of what had been observed in the two drive arounds. See Fig. 7.



--“CP10M” means counts per 10 minutes, with the Inspector in Total mode and Total/Timer set to 10 minutes.

Fig. 7. CP10Ms around Paducah GDP. The route map is shown by green arrows on the map at the left. [Modified from SSGR]

For each type of sample medium in Fig. 7, the range of CP10M values show significant variations. That is a main result of SSGR’s work around Paducah GDP: **Variations in radioactivity invite specific, detailed follow-up analysis.** Sergey pointed to tomatoes as a sample medium warranting citizen-activist study.

During such follow-up study, as described in the next sections of this Guide, the citizen-activist investigator should keep her or his eyes wide open: Why is this Inspector reading what it is? Is there an important, radioactive pathway it is flagging? What is the reading telling me? Is it worth following up? How can I follow up to gain a better understanding? What else should I be looking at?

Sample selection

After you have practiced with the Inspector, in CPM and CP10M (Total/Timer=10 minutes) mode, as described in the previous sections of this Guide, you might be prepared to select samples for collection and then analysis.

Experience is the key to selecting samples that will yield interesting results from your analyses with the Inspector. Experience is gained through practice. The purpose of the first samples you select is to begin to gain experience in sample selection, in order to select samples that have a reasonable chance of yielding positive results. When you begin, one sample in 50 might lead to positive results. After years of practice, one sample in three might provide interesting analytical results.

Everything that has been described in the previous sections, applies here, but more so. Check to be sure you understand what is involved. Plan to follow these instructions and the instructions in the Inspector operating manual.

Take heed of what instructors of somewhat hazardous sports, like scuba diving and rock climbing call the “200-hour effect.” The good student, having acquired about 200 hours of successful experience, becomes confident and bold. The fatality rate jumps.

Apply the rock climber’s creed to your monitoring of radioactivity around your neighboring nuclear facility: *There are old rock climbers and there are bold rock climbers, but there are no old, bold rock climbers.* Remember that years will pass before any harm radioactivity does to your body will be revealed. Work on the safe side. As a citizen-activist, *time* is on *your* side; treat time respectfully.

Prepare even more carefully than for setting out on foot. Anticipate what you might identify to sample, and get appropriate sampling equipment and Ziploc® bags for the samples. --By now, you should know enough to take responsibility and initiative. If you honestly do not know enough, are unsure, or are uncomfortable collecting samples; then back up and take your time, rather than rushing ahead.

This section describes sample *selection*, not sampling and analysis. Having carefully identified one or more samples to collect, you will be naturally tempted to collect them, of course. But restrain yourself for now. Read the rest of this Guide, and be sure you have everything prepared for sample processing before you collect your first sample.

As soon as you have collected a sample, its radiological clock begins to *run*. In order to obtain very useful results, you must make some arrangements beforehand. This section, “Sample Selection,” is presented before the section, “Sample Collection,” to encourage you to prepare in advance. --Teach yourself to do it right, instead of letting your enthusiasm lead you into bad practices that you will have to unlearn.

! CAUTION !

- Review “**Before starting.**”
- Beware of the “200 hour effect.”
- Sampling is time-sensitive. Read ahead; plan ahead; and prepare for samples.
- Evaluate the nature of a sample you have selected: Have you selected the sample because it might be hazardous? Are you sampling foodstuff to confirm it is radiologically safe? Have you selected a sample because of an anecdote or someone’s curiosity? --Treat your selected sample according to its nature.

Steps:

1. Identify your particular purpose for sampling: **WHY** are you collecting *this* particular sample, and **WHAT** is it? Is it potentially hazardous and so of concern as an indicator or a problem? Are you or is someone else merely curious? Do you consider this sample to be potentially poisonous to be warned against or to be healthy food to be validated informally by an analysis?
2. Identify radioactive pathways that carry radioactivity from a source, like the GDPs, into their surrounding environment. General pathways are transportation of radioactive materials, animal track-off, the air (–wind, rain, snow–), surface water, groundwater, and uptake by vegetation. Refer to “Environmental Radioactivity,” in the “Equipment list.” Review what you learned from “A car ride with the Inspector.” Maybe take another car ride.
3. Visit locations that might be on pathways that would carry radioactivity that you seek to sample for your purpose, identified in Step 1. For example, if you want to investigate fallout from airborne releases, go to areas that are generally downwind of the radioactive source. Compare what you see with published information, with DOE reports, with anecdotes of site workers, and with concerns of site neighbors.
4. Revisit potential sampling locations. Keep your eyes open for materials (*-media-*) that might be attractive for sampling, and check out your access to it.
5. Identify alternative sample media in candidate sampling locations. TRAC recommends a focus on vegetation samples, as did SSGR; see Fig. 8.



Fig. 8. Identifying (and collecting) vegetation samples from around the GDPs in 2003. [SSGR]

TRAC recommends against sampling water in bulk, soil, or sediment. These media are either difficult for the citizen-activist to prepare or usually yield uninteresting and discouraging results. To analyze a water sample by the methods of this Guide, a sample of 10 to 40 liters would have first to be reduced to dryness. Soils and sediments contain substantial, naturally occurring radionuclides in the uranium and thorium decay chains, in addition to natural potassium-40. There are usually too many radioactive components in such samples for you to reliably sort them out by the methods of this Guide. Leave these more difficult and less productive sample materials (“media”) to professional scientists.

Aerosols and dust (fallout) are somewhat difficult and potentially hazardous media to sample. But they are also important if your purpose involves radioactive fallout.

! CAUTION !

- Dust poses an inhalation hazard, even if it is not contaminated with radioactive fallout.
- Handle dusty materials outside.
- Use a dust mask, as appropriate.
- Avoid putting the dust into the air where it might be breathed or contaminate hands or clothing.
- Take a shower and wash your clothes immediately after working with dusty materials.

Sergey Pashenko is expert at sampling and analyzing aerosols in air and (fallout) dust particles. See Fig. 9 for one SSGR arrangement for sampling air and dust.



Fig. 9. On the left, a Russian air filter on a funnel, hooked to a Russian car vac on the right. See the Equipment list for possible U.S. equals. [SSGR]



Dust samples can be collected from used air filters from cars, from vacuum cleaner dust bags, and from home furnaces; see Fig. 10 on the next page. To collect dust from a filter, take the filter to a well ventilated location. Place the dust side of the filter downward, in a plastic trash bag. Tamp the filter to remove the dust into the bag, being careful not to put the dust into the air. Slowly and carefully pour or slide the dust from the trash bag into a freezer bag.

Fig. 10. A filter from a furnace in a home near Portsmouth GDP.
[Modified from SSGR]



An example of potentially hazardous dust in filters: TRAC's laboratory is located close to Hood Canal in western Washington state. Aerosols from breaking waves off the estuary contain enough natural lead-212 from the natural thorium decay chain that TRAC double filters laboratory air. TRAC handles old air filters carefully, as *environmental waste*. (The half-life of 212Pb is only 11 hours.)

See the SSGR REPORT for ways to filter-sample snow and other media.

Steps:

6. Identify particular samples as candidates. Match the possibilities to what exists and you have access to. Prioritize the possibilities, for your purposes, in consideration of the pathways you have identified.
7. Visit the most promising sample sites, identified in your car and on-foot inspections. With your Inspector in the CP10M (Total/Timer=10 minutes) mode, compare readings from different candidate sample media and from different samples of one kind taken from different locations; see Fig. 11. This comparison will help you decide which materials to sample.

Fig. 11. SSGR checking a sample of leaves. --The Inspector should be bagged to protect it from contamination. [SSGR]



8. Document what you are doing, and how and why. See “field/lab book” in the “Equipment list.”
9. Select a sample to collect. Your decision depends on how you weight the selection considerations that have been listed. For now, expect all of your samples to yield negative results and to best serve as a learning experience, providing more practice.

Sample collection

This section describes carrying out the plan of the previous section. Have all your equipment (including “scales,” “oven,” and” Nfoils jig”) ready. Read ahead for what you’ll need and check the “Equipment list” for items to purchase or build.

! CAUTION !

- Review all the instructions; be sure you understand them.
- Focus on the main radiation hazards: inhalation, ingestion, and track off: If it might be hazardous, treat it as hazardous, from the outset.
- Evaluate the nature of a selected sample, as already cautioned. —Treat it accordingly.

Steps:

1. Plan. Decide how you will collect the sample: Pick it? Clip it? Dig it? Decide how you will get the sample into the freezer bag: Should it be rinsed off in a stream at the sampling location? Have the equipment you need ready.
2. Document what you are doing. Date and time, location, sampling conditions, sample identification (such as year month day.time, for example: “5 4 16.18”).
3. Collect the sample into a labeled freezer bag. Label each sample bag with a Sharpie® fine point, permanent marker, so it cannot be confused. Establish the chain of process and chain of possession. Weigh the sample, while sampling or afterward, to be sure you will have enough dried material for counting in your Nfoils jig. See Fig. 12 for an example. As a rule of thumb, assume that drying will reduce sample weight by a factor of 10.

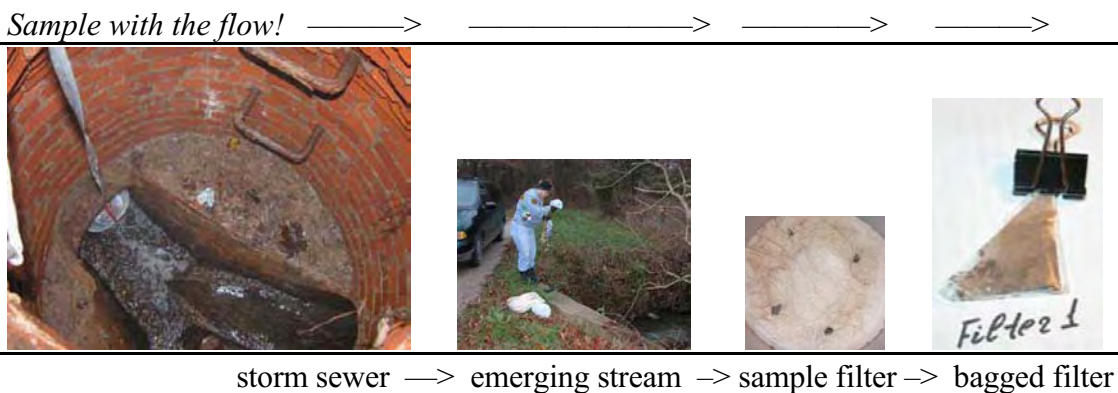


Fig. 12. Collecting a crucial sample of filtered effluent water from the Portsmouth GPD. [Modified from SSGR]

As soon as the sample is bagged, radon decay products begin to grow-in. Some of the decay products have short half-lives, which will allow you to quantify them with the Inspector. So time is of the essence, as soon as you have collected a sample.

Sample preparation

By the time you submit a sample to long-counts with the Inspector, under very controlled conditions, you must have made ready the preparation process. Else the work may have to be repeated.

Continue to document your observations and activities, throughout this process.

Plan to keep each sample in its sealed bag for no more than a couple hours between the time of collection and drying in foilware in a toaster oven. (See the “Equipment list.”)

! CAUTION !

- Review and be clear on all previous steps and considerations.
- Focus on the main radiation hazards of this step: inhalation, ingestion, and contamination of processing equipment. If it might be hazardous, treat it as hazardous, from the outset. **Never burn or ash samples!**
- Place drying oven in well ventilated, unoccupied location, such as a garage or outbuilding.
- Sample preparation is time sensitive: Read ahead and plan ahead. Prepare to count prepared samples.

As soon as feasible, get the sample out of its collection bag and into a drying oven, Fig. 13 (-see the “Equipment list”-). The drying oven should have adequate ventilation or should be protected out of doors.



Fig. 13. A mock “sample” divided into ten parts, in a drying oven. Place the sample in disposable foilware, instead of the tray shown in this oven manufacturer’s photo. [Black and Decker]

Four reasons to prepare samples by drying them:

1. Eliminate water that blocks detection of radioactivity.
2. Concentrate the sample by drying, so readings are more accurate. (In this case, bigger numbers are better).
3. Dry the sample so radioactivity can be reported on an inter-comparable, dry-weight basis.
4. Wet samples rot; dry samples do not.

Steps:

1. Place one sample at a time in disposable foilware into a drying oven that has been dedicated to preparation of samples for radiological analysis.

! CAUTION !

- Be sure the foilware does not touch either heating element.

2. Dry each sample for 24 hours at <200°F (95°C). --Above 212°F (100°C) samples will begin to drive off hydrocarbons, disturbing the logged weight of the dried sample. Use a meat thermometer (–see the “Equipment list”–) to verify the oven’s set temperature.
3. Allow oven to cool before removing the sample.
4. After drying for 24 hours, the sample should be crisp. If you are not sure it is thoroughly dry, weigh it and then dry it a few more hours. When dry, sample weight won’t decrease with more drying.
5. Homogenize the dried sample to conform to a standard weight and size for counting in your Nfoils jig.

Many dried samples of vegetation can be crushed by hand in a heavy duty Ziploc® freezer bag. Grass is too fibrous to be crushed effectively. A food blender (-such as Osterizer-) allows homogenization and compaction of such samples. Try to avoid collecting samples that will require blending after they are dry. When you must blend a dried sample, dedicate a blender to radiological sample preparation, make arrangements as with dust in filter samples, in the previous section of this Guide.

6. See the “Equipment list” for “scales” and “Nfoils jig.” Place the dried sample into a Ziploc® snack bag (about 2 grams, weigh the bag before and after adding the sample) for counting in your *Nfoils jig*. Weigh the sample. Target 9 grams for the gross weight. Subtract the Snack bag weight and record the dry sample weight. See Figs. 14 and 15.

Fig. 14. Dried moss sample in a freezer bag. It weighs too much and has to be split and repackaged into a Snack bag before counting. [TRAC]

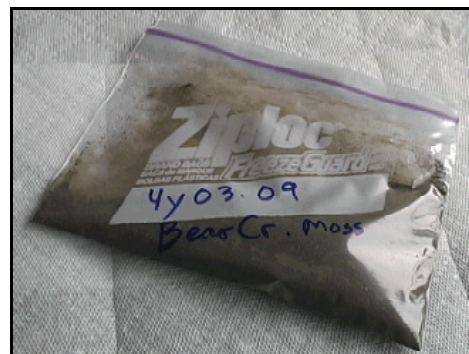




Fig. 15. Dried berry sample, split to 7 g in snack bag, ready for counting. [TRAC]

Steps:

7. Adjust the *sample geometry*, as needed. Sample geometry is sample weight, sample volume, and sample shape. In order to obtain consistent results, your sample counting geometry must be the same for each sample you count in the Nfoils jig. If the dry sample is more dense than the standard density you select, you can lighten your sample up by adding Safeway cosmetic puffs, or some other light weight filler. How you get each sample into a standard geometry depends on the particular sample and on the details of the sample space in your Nfoils jig, described in the next section. Calculate the wet/dry weight ratio for your sample, and record that for your future reference.
8. Label the sample bag with identification and other reference information, as shown in Figs. 14 and 15. A Sharpie® fine point, permanent marker does the job well enough.

Ingrowth and decay with the Inspector

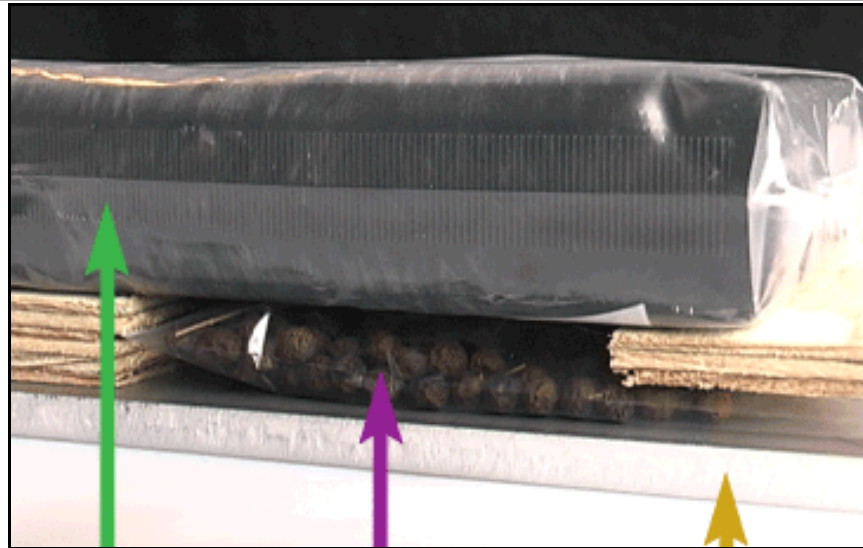
In this transition, the keys to success shift from being sensible and applying good sense to consistent attention to details. As the citizen-activist moves from introductory to advanced material, the form of this Guide shifts from instruction to guidance. This section is a transition from hands-on, observational methods in the field to analytical methods in the home-laboratory.

You need the Nfoils jig ready to begin counting, as soon as the sample has cooled enough to take from the oven, and has been bagged and weighed. The Nfoils jig is a do-it-yourself construction; see the “Equipment list.”

Steps:

1. Set the Inspector to Total/Timer=3 hours.
2. Place the Ziploc® snack-bagged sample into the bottom of the Nfoils jig, below the Inspector in its pint freezer bag. The layout is shown in Fig. 16, on the next page.

Fig. 16. Mock-up of Nfoils jig counting arrangement. Inspector in a pint freezer bag. 7.0 g dried sample in 2.1 g snack bag. [TRAC]



bagged Inspector

bagged sample of berries

aluminum table

Steps:

3. Count the sample (3 hours), and record the result, along with the date and time.
4. Wait one day.
5. At the same time of day and in the same location, under the same conditions, count again for 3 hours. Record the result.
6. Compare this result to the prior result. If the second value is much more than the first result, there has been radioactive in-growth in the sample. If the second result is much less than the first result, there has been radioactive decay in the sample.
7. Based on the comparison of Step 6, decide if either in-growth or decay are of enough interest to repeat this counting process, with one day elapsing between counts. –Your decision depends on the purposes served by your analysis of this sample, on your estimate of the relative quality and value of this sample, on the magnitude of the increase or decrease in Total/Timer= 3 hours counts, on other uses of your equipment and your time, and on your other considerations.

In 2003, SSGR did not have time at Paducah and Portsmouth to follow this procedure. Instead, samples were placed immediately into a jig and counted for Total/Timer=10 minutes. Then Russian aluminum foils (-which may be more or less comparable to American aluminum foils-) were added, and SSGR recounted the sample.

Serendipity favored SSGR. After Sergey had counted the water/foam filter sample of Fig. 12, at CP10M with 8 or 9 foils, his counting was interrupted for a lecture for the community around the Portsmouth GDP. He was unable to resume counting until a day later. The result is shown in Fig. 17.

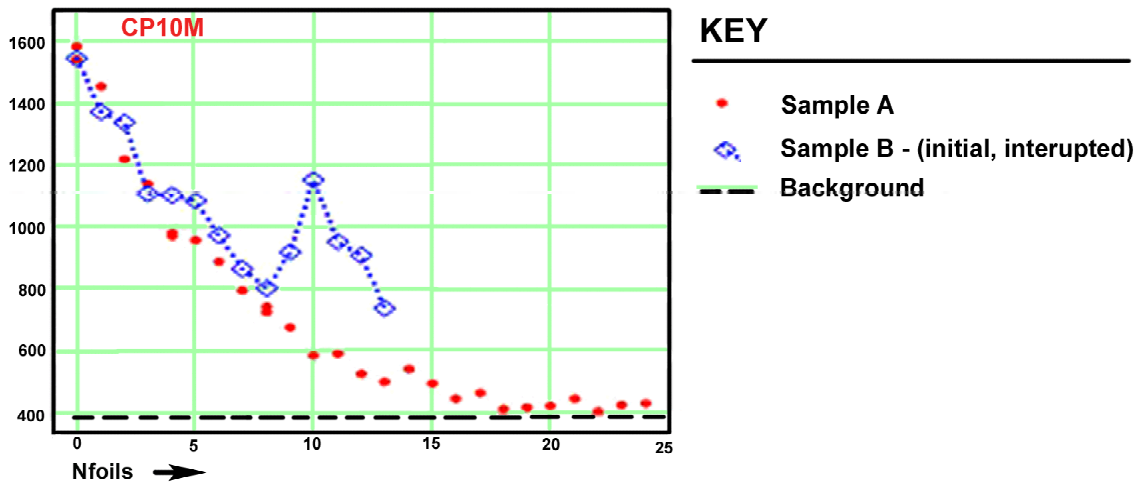


Fig. 17. In-growth revealed by interrupted counting of filtered water/foam sample. [modified from SSGR]

The spike at Nfoils=10 showed that ingrowth had occurred in the sample. Sergey commented,

“This result was the first indication for me in [the] expedition around Portsmouth that we have emanation (release) of radon (daughter products) if the sample is closed [a] long time. [Personal e-communication, 26 March 2005].”

—Sergey was referring to the jig and the materials it contained blocking the escape of radon-222, so the products of radon decay had begun to grow into the equipment. (222Rn has a half-life of 4 days.)

Maybe there was already a hint, beginning with Nfoils=4 in Fig. 17, that the water/foam Sample B had elevated radioactivity, in comparison to background Sample A.

Unfortunately, the radioactive ingrowth must have occurred not only within Sample B itself, but into the Nfoils above the sample, into the Nfoils jig, and into the Inspector also. Some of the radioactive in-growth shown in Fig. 17 was lead-210. Lead-210 has a half-life of 22 years. So several decades will elapse before the 210Pb contamination has entirely decayed away, and the Inspector returns to true background readings.

SSGR provided citizen activists with two lessons from this demonstration, as follows:

- In its Total mode, the Inspector can detect and identify important radioactivity around DOE facilities.
- Care is needed, or equipment and people might become contaminated.

These lessons would have been all the clearer if the sample had been bagged when SSGR counted it, and if the Inspector had been bagged to protect it. --**Have *two layers of protection between a prepared sample and the Inspector.***

The reason SSGR does not place barrier bags between samples and the Inspector might be described as *expedient*. The rationale for this expediency is explained in the next section of this Guide. Meanwhile, realize that the citizen-activist has an important advantage of *time*. By taking your time, you can obtain much more accurate results without endangering anyone or harming your equipment.

In the example described in this section, the Inspector identified uranium (238U) by ingrowth of products of radioactive decay. This method can also identify lead-212 from the natural thorium decay chain. Lead-212 has a half-life of 11 hours, and decays out of samples. In the GAP and SSGR Russian expedition of 2000, phosphorus-32 was identified in the River Tom. That identification was based partly on measurement of the 14-day half-life of the radioactivity in samples. Identification of 32P was somewhat confounded by co-pollution with strontium-90. Precise, repeated measurements are necessary to sort such complexity out of a sample.

For more information:

“Radioactive Waste of River Tom” at www.radioactivist.org/reports.html

Step:

8. Place the bagged sample into adequately secure storage for at least two weeks, out of reach of children and pets.

After two weeks, the bagged sample will have come close enough to radioactive (“secular”) equilibrium, so more precise measurements to identify its radioactive content can be made. If the sample seems uninteresting, archive it or dispose of it properly, according to its nature.

Nfoils with the Inspector

Here is the most advanced method included in this radiological *package* for the citizen-activist. The Nfoils method described in this section requires day-long counting of a sample in the Nfoils jig, after the two-week storage period of the last step listed, on five different days. If the interest in what is in a sample is greater than this level of resource commitment, the next step might involve radiological analysis by a commercial laboratory, or persuading a regulatory agency to sample and analyze jointly with you.

Note: The battery in the Inspector has a life of one to 12 days, counting samples in an Nfoils jig. Keep track of battery life for counts in this section. Change the battery to prevent loss of data, and then use the partly drained battery in the field.

The Inspector displays counts of radioactive decays. The number of counts displayed (either as CPM or at a total in Total mode) depends on the radioactivity impinging on the Geiger-Mueller tube that is the detector in the Inspector and on the efficiency of that detector in reporting that radioactivity. Variations in detector efficiency for different kinds of radiation are mentioned in Appendix A of the Operating Manual for the Inspector.

The greater the distance between a radioactive source and the Inspector, the lower the Inspector's reading. Readings are lowered by materials intervening between the radioactive source and the detector in the Inspector. The Inspector provides higher readings if there are fewer barriers between a source of radioactivity and the detector. That is the reason International Medcom builds the Inspector with only a thin screen to protect the mica window over the detector. That is the reason SSGR mounts an Inspector under a car, instead of taking readings with the Inspector inside the car; see Fig. 4B. And that is the main reason that SSGR tests samples without bagging either the Inspector or the sample.

The pivotal issue here is: How much is the Inspector's sensitivity to radioactivity reduced by introducing protective barriers to avoid contaminating the detector? Equivalents of barriers are listed in Table 3, on the next page, as centimeters (cm) of air.

Table 3. Barrier equivalents. [TRAC]

Barrier:	Inspector mica window	Ziploc® freezer bag	Reynolds Wrap® aluminum foil (Nfoils=1)	Ziploc® snack bag
air equivalent [cm]:	1.6	5.5	4.1	2.6

(1 cm = 0.39 inch) The density of air is assumed to be 1.1 mg/cm³. This introduces 1.0 cm of air equivalent barrier, in Table 3.

That is, one centimeter of air between a radioactive source and the detector has an equivalence of 1.0 (cm of air). If the distance between a radioactive source and the Inspector is 10 cm (= 4 inches), the barrier equivalence is 10 (cm of air).

The first column in Table 3 shows that the Inspector's mica window already introduces a barrier equivalent to 1.6 cm of air. If the Inspector is zipped safely into a pint Ziploc® freezer bag, a barrier equivalent to 5.5 (cm of air) is introduced.

When the Inspector is mounted under a car, as in Fig. 4B, an air equivalence of only 5.5 cm (2 inches of air) is added. This additional distance between the Inspector and the roadway is a small price to pay in sensitivity, in order to protect the equipment.

What is the cost of protecting the Inspector from contamination from a sample placed in an Nfoils jig? If the Inspector is bagged in a freezer Ziploc® and the sample is bagged in a snack Ziploc®, the added barrier equivalence is 8.1 (cm of air); see Table 3. This is the same barrier equivalence as $N_{\text{foils}}=2$ (two times $N_{\text{foils}}=1$). This means that if both the Inspector and the sample are safely bagged, the Inspector's readings are reduced by a number equal to $N_{\text{foils}}=2$. The readings in Fig. 17 would be about the same, except the number of foils in the barrier ("Nfoils") would be two less. The left hand results with no intervening Nfoils would be about what is graphed at $N_{\text{foils}}=2$. Comparison of the results from Samples A and B, in Fig. 17, shows that the results were not interesting until $N_{\text{foils}}=4$, or higher. That is to say, expediency yielded little or nothing of practical value in this case, while the equipment was probably somewhat contaminated.

Another way of looking at this is to notice that if SSGR had bagged Samples A and B and counted each for 13 minutes instead of 10 minutes, to obtain each graphed value, the results would have been about the same as in Fig. 17.

Most of the difference between the Nfoils graph of one radioactive source and another appears with several sheets of aluminum foil (Nfoils) between the source and the Inspector. In order to distinguish one radioactive source from another, long counts with large numbers of Nfoils between the source and the Inspector are most advantageous.

TRAC recommends Nfoils counts with both the sample and the Inspector bagged, as described above, and the following number of Reynolds Wrap® foil sheets between the bagged sample and the bagged Inspector:

Nfoils = 0, 4, 16, 64, and 256.

Nfoils are easily prepared by folding Reynolds Wrap®. Roll the completed Nfoils packet, of 4, 16, 64, and 256 layers of Reynolds Wrap® flat with a kitchen rolling pin. Trim each packet so it will fit easily into the Nfoils jig, and you can remove it easily. Attach a sticker with the number of foil thicknesses in the Nfoils packet; see Fig. 18 on the next page.



Fig. 18. Nfoils=32. [TRAC]

Place the desired Nfoils packet over the bagged sample, before placing the Inspector in the Nfoils jig. See the desired arrangement from Figs. 16 and 19.



Fig. 19. Placing Nfoils into jig. [Clipped from SSGR]

TRAC recommends Nfoils counts of 23 hours duration, each Total/Timer=**23 hours count beginning about the same time of day**, and counted under the same conditions. Counting one sample five times, by the Nfoils method, will thus take the citizen-activist 5 days.

After completing an Nfoils count, save your Nfoils in a Ziploc® bag. If there is a chance your Nfoils packet has become contaminated, discard and replace it with a new Nfoils packet.

The precision of counts with the Inspector in the Total/Timer=23 hours mode is **1100% better** than the precision of counts in the Total/Timer=10 minutes (CP10M) mode. Citizen activists have a great advantage over professional scientists in the ability of community residents to take the time for very long counts with the Inspector, and so to obtain precise and accurate results.

Analysis and interpretation

The more you know about radioactive decay, the better you can interpret the results of the measurements that are described in this Guide. The reference books in the “Equipment list” are worth reviewing, occasionally, for new insights on what you are learning. Of course, your own experience is most valuable.

When you are surprised, as with the spike at Nfoils=10 in Fig. 17, take some time, and ask yourself, What other test can I do with the Inspector, to confirm or refute my idea of what the cause is?

After Sergey returned from his lecture in Portsmouth, he soon discovered that his Nfoils counts of Sample B had gone amiss with Nfoils=10. He started over. The details are unclear. Sergey omitted Nfoils=10 and =11. The second counts are “Sample B (later)” in Fig. 20.

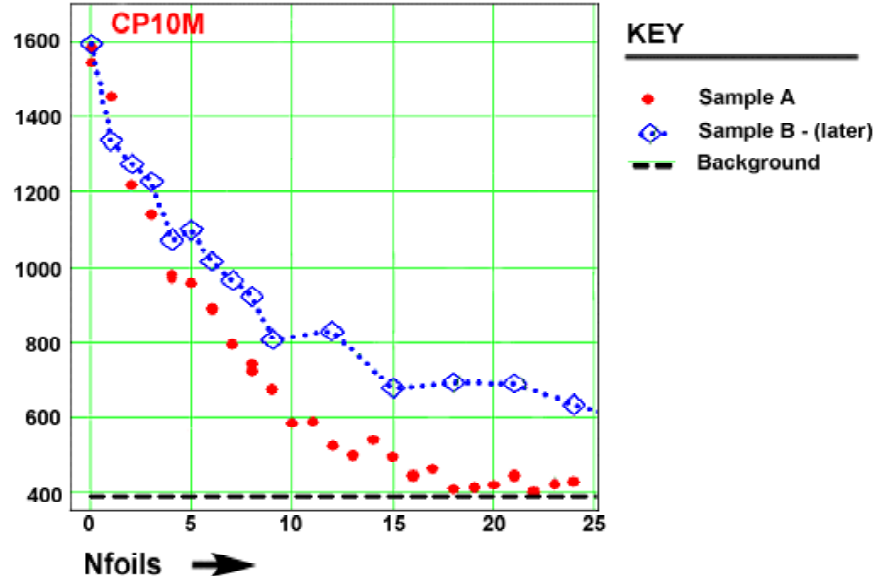


Fig. 20. Sample B, recounted a day later, in comparison to Sample A, as in Fig. 17. [Modified from SSGR]

Sergey is an expert with this method, and he evidently overcame the consequences of contamination with products of radon decay.

Sergey described the difference between the Sample B (later) results and the Sample A results in Fig. 20 this way: “It Is Important. Uranium from underground stream near Portsmouth gaseous diffusion plant [text coloration in original].” Sergey attributed the graph of Sample A to potassium-40 (“40K”).

To understand how Sergey interpreted the results of Fig. 20, it is necessary to appreciate that Sergey has spent years analyzing samples contaminated with uranium,

coming from the chemical combine in Novosibirsk. Furthermore, 40K is a readily available reference source. 0.01% of natural potassium, as found in potassium salts, is 40K.

Sergey’s ready interpretations of his results in Fig. 20 show the importance of building a library of the graphs of different radionuclides, *in the exact arrangement and conditions of all the measurements*. In short, Sergey knew how to interpret his results because he had years of experience with exactly that equipment. He even brought his Nfoils from Russia, rather than using American aluminum foil.

TRAC checked the reasonableness of Sergey’s interpretation of Fig. 20 by setting an Inspector (in a Ziploc® bag) on its back (detector screen facing upward), placing either Nfoils=0 or Nfoils=64 on the screen, and placing a (bagged) 52 g bottle of laboratory reference material on top of the aluminum foil. Each count was with Total/Timer=10 minutes. The results are thus CP10Ms, as with Sergey’s results in Fig. 20. The results are presented as the ratio of counts with Nfoils=64 to the counts with Nfoils=0; See Table 4.

Table 4. A laboratory mock-up of CP10Ms with Nfoils. [TRAC]

	Background	137Cs	ThNat	“ uranium ”	90Sr	40K	99Tc
N(64)/(N0):	0.92	0.59	~0.25	~0.20	0.13	0.08	no detect
Background:	no sample in jig.				90Sr:	strontium-90	
137Cs:	cesium-137				40K :	potassium-40	
ThNat:	natural thorium				99Tc:	technetium-99	
“ uranium ”:	dinosaur bones, containing natural uranium, not in equilibrium						

N(64)/(N0): the number of CP10M counts with Nfoils=64, divided by the number of counts obtained with Nfoils=0, both counts with Total/Timer set the same.

Technical Note 1: The shape of an Nfoils graph, and hence the value of N(64)/N(0), depends on details of your Nfoils measurements. The ratios for your equipment will differ, more or less, depending on the details.

Technical Note 2: A sample density close to 0.25 g/cm³ is convenient for vegetation samples. If your dried sample medium is denser than the consistent standard that you select, you can mix your sample with a light material, like Safeway cosmetic puffs.

Technical Note 3: See the “Equipment list” to obtain natural 40K, as your first reference material. Be more careful with other radioactive reference materials, especially alpha emitters. Read [The Radioactive Boy Scout](#).

Table 4 shows that CP10M counts from 40K are blocked relatively much more by aluminum foils than uranium is blocked. That accords with Sergey’s interpretation.

Notice the “no detect” for 99Tc in Table 4. The Inspector is insensitive to the low-energy beta emissions from technetium-99 decay. Likewise, the Inspector does not detect tritium (3H) or carbon-14. Keep in mind the limitations of the equipment and the methods of this Guide.

! FLASH !

As this guide was going to press in April 2005, Vina Colley of Portsmouth/Piketon Residents for Environmental Safety and Security (PRESS) reported that USEC had dispatched scientists, on November 19, 2003, to sample foam from the drainage ditch south of the Portsmouth GDP property, near Wakefield Mound Road/Sargents Lane, just west of Big Run Road. Representatives of the Ohio Environmental Protection Agency's Southeast District Office observed USEC collecting two foam samples, the day after a news conference, held by PRESS, where Sergey had stated that the beta radiation of the foam sample he had collected was "at least 100 times higher than normal background levels." USEC submitted its two foam samples to laboratory analysis for *gross beta* radiation, to check Sergey's conclusions (that were based on Figs. 17 and 20).

Over a year later, on February 24, 2005, DOE's Portsmouth/Paducah Project Office published USEC's analytical results [W.E. Murphie, Document PPPO-01-277-05]. USEC/DOE's results for their two follow-up foam samples were

USEC/DOE Sample One:	1,010. pCi/L
USEC/DOE Sample Two:	300. "

By way of reference for gross beta in water:

Clinch River water at Oak Ridge site (TN):	~2. pCi/L
Columbia River water at Hanford site (WA):	~1. "
Ambient Water Quality Standard screening level:	50. "

USEC/DOE reported gross beta results for Sample One and Sample two in unusual units of pCi/mL (picocuries per milliliter). The numerical values for these unusual units were 1.01 and 0.3 pCi/mL, respectively. These numerical values are typical of background gross beta values of about one pCi/L as seen from the Clinch River water and Columbia River water values for gross beta, above.

Considering the Clinch River and Columbia River water samples as a tentative background level of gross beta in foam on surface waters, then the USEC/DOE foam sample results confirm Sergey's conclusion of beta activity at least 100 times higher than normal background levels.

DOE says that no 99Tc was detected in the two analyzed samples. This result accords with the information in Table 4, that 99Tc is not detectable by the Nfoils method. So 99Tc could not have accounted for Sergey's positive results.

DOE has not yet provided analyses of gross beta in foam samples collected from *background* locations. The Nfoils method described in this Guide will allow citizen-activists to determine whether the origin of the high gross beta in foam from this location is the Portsmouth GDP and to better characterize its radioactive constituents.

At the present time, the only available identification of the main contributor of radioactivity in this foam is Sergey's uranium result.

With more experiments along the lines of those already described, the citizen-activist can use this equipment and these methods to quantify the amounts of uranium and 40K in Sample B. With enough attention to details, enough experimentation, and enough patience and replications, several radionuclides could be confidently analyzed with the Inspector, in a sample from around a DOE nuclear facility, like the GDPs at Paducah and Portsmouth.

Results of 2003 SSGR survey

1. SSGR showed how inexpensive equipment can be used by citizen-activists around DOE nuclear facilities, like the GDPs at Paducah and Portsmouth, to identify radioactivity in the environment. If citizen-activists *take advantage of time*, the quality of their results is limited only by their ingenuity and attention to details.
2. Riding around the GDPs, SSGR mounted an Inspector conveniently on top of a car, instead of underneath. Even with consequentially low sensitivity, SSGR documented an area of relatively high radioactivity around the Paducah GDP, for future investigations by citizen-activists, using methods described in this Guide. Likewise, SSGR's "Normal" results around the Portsmouth GDP, should be followed up by more precise measurements.
3. SSGR's tight expedition schedule interrupted Nfoils measurements. Nonetheless, in a sample of radioactive foam from stream water flowing from the Portsmouth GDP, SSGR measured beta radiation counts "at least 100 times higher than normal background levels [in foam]." This was a new pathway of radioactivity that government agencies had not told the GDP's neighbors about. USEC sampled the foam and confirmed SSGR's high beta readings.
4. In very limited time, SSGR identified a main constituent of the radioactive foam from Portsmouth GDP to be uranium. A year and a half later, as this Guide goes to press, DOE and government regulators have not yet matched SSGR's results by identifying the radionuclides in the radioactive foam. Using the methods explained in this Guide and taking advantage of time, citizen-activists can further explore this disturbing lead.

On beyond the Inspector

A specific purpose of this Guide is to provide guidance sufficient for citizen-activists around the Paducah and Portsmouth GDPs to follow-up the results of the SSGR study. The first follow-ups might determine the nature and cause of the relatively high radioactivity around the Paducah GDP, and the origin and cause of the uranium in foam/water screened from an underground stream near the Portsmouth GDP

Citizen-activists can apply some of methods described in this Guide, with more or less modification, to answer other environmental questions and to address other concerns around DOE nuclear facilities.

Citizens have expressed concerns for toxic contaminants like TCE, nickel carbonyl, and fluoride around Portsmouth GDP. Likewise, there are non-radiological contaminants of concern around Paducah and other DOE sites.

Inexpensive equipment is available nowadays to test for particular or general contaminants of concern, often at very low levels. Such inexpensive equipment and the methods described in this Guide invite concerned citizen-activists to develop and apply methods that will gain ownership of environmental facts that are important for their lives.

Equipment list

This list is intended as an aid to getting started. This list is not complete. Shipping and handling charges are not included. Prices may change, along with availability. The end user must determine suitability for a particular application. Check with the manufacturer.

Geiger counter: *Inspector*, Nuclear Radiation Monitor. International Medcom, 7497 Kennedy Rd., Sebastopol, CA 95472. 707.823.0336. www.medcom.com. \$560.
Cable to laptop and software for laptop: \$75.



laptop computer: If you don't have one, borrow one, and install the software for the Inspector cable connection, above.

mounting bracket for Inspector: Drive the car you will use for surveys up onto adequate ramps. Examine the undercarriage, close to the passenger doors. Look for solid fixtures to which you could mount the Inspector, out of line of debris thrown by the tires, away from hot exhaust components, high enough to be protected from obstacles in the roadway, out of the way of vital equipment. Determine a good way to mount the Inspector at a good location. If you expect to do CPM surveys frequently, put some thought to making a mounting bracket that you can easily snap the Inspector into from the side, as in Fig. 4A, without having to raise the car. You might clean the attachment area and epoxy the bracket to the undercarriage. TRAC suggests you find a location farther from the muffler than

shown in Fig. 4B. For a one-time excursion, rubber bands might suffice as a mounting bracket, with foam between the bagged Inspector and what you rubber band it to. Be sure to secure the cable connecting the Inspector to the laptop.

field/lab book: Essential for documentation.



No. 311 “Level Notebook” from J.L. Darling Corp, order from www.riteintherain.com, Pack of 12, \$37. Purchase several Sharpie® ultra-fine point, black permanent markers, from your stationery store, to write on the waterproof paper in the level book. Keep your level books secure as documentation.

wrist watch: to log times of measurements, and so on.

Nfoils jig: Construct a box to hold the Inspector (in a Ziploc® freezer bag) over Nfoils, with a bottom opening for the sample in a Ziploc® snack bag. A quarter-inch, 6-7/8” by 4-1/4” aluminum sheet provides a half-inch clearance around the Inspector, for a wooden frame. The aluminum table can be purchased from www.onlinemetals.com aluminum sheet type 2024T3, cut to dimension, for \$4. Fig. 16 is a mock-up (with no jig side) showing the desired geometry of the jig. Fig. 19 shows a jig frame, without the aluminum table. The jig can either be routed out of plywood or be cut from dimension lumber and glued together. Jig construction is a do-it-yourself, shop project. After the jig is cut out, paint it to seal it.

GPS: Garmin Geko 201. www.garmin.com. \$150.



Use the default map datum: WGS 84. Set the Position Format to decimal degrees (0.00001 resolution). Operate in Normal Mode (with WAAS function On).

Ziploc® bags: pint freezer, quart freezer, gallon freezer, snack.

drying oven: Black and Decker Toast-R-Oven, Model 350,

www.blackanddeckerappliances.com. \$45.

- Place sample in foilware from your grocery store. Set Toast-R-Oven to BAKE at 200°F (95°C). Place Good Cook™, non-digital meat thermometer in oven to check temperature.

- You can wash and re-use the foilware. Replace it, as appropriate.

- If you absolutely cannot obtain an adequate analytical resolution for a dried vegetation sample, it is feasible to double counts by collecting twice the sample material. Then the sample can be *charred*, after it has been dried in the oven and weighed. To char a sample, place the oven under a roof, out of doors, and set the oven to 480°F (250°C), checked with an oven thermometer. Weigh the charred sample and compare to the dry weight. **Never prepare samples at temperature above 480 °F, because radionuclides might be released into the air.**

scales: Field, for wet samples: 200 g capacity (1 g accuracy), Accu-weigh tubular spring scale, Model T-2C, from Nicetoys® at



www.nicetoys.com/yamatotubularmechanicalscale.html, \$40.

Laboratory, for dried samples: Cole-Parmer sells a 30 g capacity (1/4 g readability) spring scale, catalog number C-11610-04, for \$65. Minimum order is \$100. So make a shopping list before ordering from www.coleparmer.com. For example, see “filters,” below.

filters and lab ware: For a low budget, try Melitta® No. 6 coffee filters, and funnels made from 2-liter diet soda bottles. For more professional and sometimes more effective filtration, check out the Cole-Parmer catalog, at www.coleparmer.com. The minimum order is \$100.

vacuum to collect dust samples: For example, rechargeable “Bug Vac” with AC adapter, catalog number CJ-50521 from Clever Gear®, www.clevergear.com, 800.829.2685.

calibration reference: (natural) potassium chloride, laboratory grade crystal, CAS# 7447-40-7, from Science Stuff®, 500 grams, order from www.sciencestuff.com/prod/Chem-Rgnts/C2299, \$14. Calculated activity [TRAC]: 441 pCi/g = 16.34 Bq/g. To obtain accurate results, the density and weight of this 40K reference material must be **matched to the consistent density and weight of all the samples you analyze in your Nfoils jig**. You can suspend the potassium chloride crystals in a matrix of Safeway cosmetic puffs to lower the density to the consistent value you have selected for your analyses.

Nfoil: Reynolds Wrap® aluminum foil, from market. Weighs about 4.5 mg/cm².

reference books:

- Operating Manual, for Inspector Nuclear Radiation Monitor, International Medcom (1996), included with Inspector: Worth more than one careful read, to the end.
- Environmental Radioactivity from Natural, Industrial, and Military Sources (4th ed.), M. Eisenbud and T. Gesell (1997), Academic Press, www.amazon.com, \$105. This is the *bible* of its subject.
- The Radioactive Boy Scout, K. Silverstein (2004), Random House, New York, www.amazon.com, \$23. —“a real-life adventure with the narrative energy of a first-rate thriller.” This book provides a different perspective, an alternative history of the atomic age, some warnings about dangers that await the radiologically adventurous, and potentially useful information for the careful, do-it-yourself activist.
- Nuclides and Isotopes, Chart of the Nuclides (booklet, 16th ed.), Lockheed Martin (2002), Knolls Atomic Power Laboratory, www.chartofthenuclides.com, e-mail: nuclides.chart@lmco.com, \$25. This is a technical resource that will allow you to answer advanced analytical questions.

Credits

Nfoils method. The USSR Ministry for Medium Machine Building (in Minatom) originally developed the “fine-screens” method in the 1960s. SSGR has developed and modified this method, especially for use with the Inspector, after GAP provided Sergey and other groups in Russia with Inspectors in 2000. For this citizen’s Guide, TRAC has attempted to Americanize SSGR’s fine-screen method, dubbing it the “Nfoils method” to avoid concerns that this Americanization is not truly the same method.

Equipment for SSGR’s studies, including the Inspector, and international travel for SSGR for this study: The Government Accountability Project (GAP), www.whistleblower.org

Hosting and help at Paducah:

Corinne Whitehead, Director, Coalition for Health Concern, corinne@vci.net
Regional Association of Concerned Environmentalists
Harold Carter
Virginia Carter
Mark Donham
Svetlanna Goman
PCC Greens
Kristi Hanson
Joe W. Nanney

David Nickell
Alford Puckett
Vivian Puckett
Jim Rose
Nita Rose
Norma Stephenson
Ernest R. Whitehead

Hosting and help at Portsmouth/Piketon

Vina Colley, President, Portsmouth/Piketon Residents for Environmental Safety and Security (PRESS), vcolley@earthlink.net

Mr. and Mrs. Blanton
Terry Bloomfield and family
Johnnie Colley
Pat Crabtree
Allan Franz

Jordan Franz
Trease Hall and family
Linda Howell
Silas Howell
Mr. and Mrs. Don Stone

Glossary

background	a location or specimen unaffected by the subject contamination; the natural level of radioactivity in an area or in a kind of material.
beta	a high speed electron emitted from an atomic nucleus undergoing a radioactive decay.
count	to obtain a readout of radioactivity on the Inspector, either at a location or of a specimen in front of its detector window.
counts	readout of the Inspector, in any one of its operating modes, either in a particular location or with a specimen.
CPM	running average readout of the Inspector: twice the total counts over the immediately preceding 30 seconds, updated every 3 seconds.
CP10M	final readout of the Inspector after 10 minutes, with Total/Timer = 10 minutes.
half-life	a property of a radioactive material: the time in which the radioactivity of the material decreases to half its initial level.
Inspector	a consumer market, Geiger counter made by International Medcom.
media	plural of <i>medium</i> ; kinds of material that can be sampled, such as apples, grass, dust, or water foam.
Nfoils	a method of counting samples with the Inspector, with different numbers of layers of aluminum foil between the sample and the detector; a jig in which these counts are obtained.
Nfoils=	the number of layers of specified aluminum foil between a sample and the Inspector's detector.
N(number)=	counts read by the Inspector, with Nfoils = "(number)".
pathway	a route along which a contaminant travels, involving a medium (such as air, surface water, groundwater, or vegetation, or human bodies), and a motion (such as flow, uptake by plant roots, ingestion, or walking).
radioactive	a property of a material; having an atomic nucleus that is unstable and changes form after some overage (half-life) time; accompanied by emission of alpha or beta particles, or electromagnetic radiation (such as x-rays or gamma rays).
radionuclide	a radioactive isotope.
readout	the number of counts displayed by the Inspector.
SSGR report	"SSGR REPORT: Initial Investigation of Radiation in the Vicinity of the Paducah and Portsmouth Gaseous Diffusion Plants," draft sections of report, mostly by S. Pashenko, mostly as a series captioned "English_Content buclata var," produced between November 2003 and April 2005, compiled by and available from ISAR, providing the basic story of this Guide.