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RADIATION PORTAL MONITOR PROJECT

Pallet Load of Potash as NORM

Revision 0

ER Siciliano
GA Sandness

January 13, 2011

Pacific Northwest
NATIONAL LABORATORY

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Richland, Washington 99352

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Pallet Load of Potash as NORM

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Name and Title	Approvals	Date
Ron McConn, Modeling and Analysis Subtask Manager	Approved via email	01/06/11
Joel Hoyt, Science and Technology Task Manager	Approved via email	01/13/10
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1 Introduction

To analyze the effects of cargo containing naturally occurring radioactive material (NORM) that could act as a source for crosstalk or masking signals, products were sought that would be commonly shipped in a palletized configuration and contain a large quantity of high-energy gamma emitters. Natural sources of potassium were selected because ^{40}K emits 1460-keV gammas, and these gammas are highly penetrating compared to most gammas emitted by NORM. Two types of ^{40}K-containing products were considered: potash and potassium-chloride-based ice melt. While rock salt is commonly used as ice melt, some users prefer potassium chloride, since it is not as harsh on roadside vegetation. The ice melt can be sold in 20- to 50-lb sacks, which contain essentially pure KCl. Similarly, potash is an important component of fertilizer, and for certain applications it can be sold in bags of essentially pure KCl. We had easy access to data on potash, so this report focuses on pallets of potash in bags as the radiation source for the crosstalk or masking studies. The results should be identical whether ice melt or potash is used as the radiation source.

1.1 Material Elemental Composition

Two fertilizer products were used to obtain an average composition for potash: Agrium Muriate of Potash (0-0-60)[1] and Evergro Muriate of Potash (0-0-62)[2]. In the standard specification for fertilizer, the third number is the percentage of K_2O in the fertilizer. If the fertilizer contains KCl instead of K_2O, this number is an equivalency based on the quantity of K in KCl versus that in K_2O. Pure KCl has a rating of 0-0-62 based on this equivalency. Typical chemical compositions for the two products were decomposed into their elemental atomic components and averaged to give a material composition model for the material. This analysis is summarized in Table 1.1, where the last column gives the final fertilizer material composition for model (e.g., MCNP) applications. (For reference, the vendor's specification sheet listings are included at the end of this document.)

[1] Information obtained from: http://www.agrium.com
[2] Information obtained from: http://www.growercentral.com

Table 1.1. Chemical Composition of Muriate of Potash for MCNP Models

		Agrium				Evergro				Averaged, Normalized
Component	**At Wt**	**wt fraction**	**Elemental wt fraction**	**Normed wt fraction**		**wt fraction**	**Elemental wt fraction**	**Normed wt fraction**		**Elemental wt fraction**
K	39.1020	0.50300	0.50300	0.50558		0.51770	0.51770	0.51787		0.51172
Cl	35.4530	0.47700	0.47700	0.47945		0.47600	0.47600	0.47616		0.47780
Na	22.9898	0.01350	0.01350	0.01357		0.00390	0.00390	0.00390		0.00874
Ca	40.0800	0.00030	0.00030	0.00030		0.00025	0.00025	0.00025		0.00028
Mg	24.3120	0.00030	0.00030	0.00030		0.00011	0.00011	0.00011		0.00021
SO_4		0.00050	N/A	N/A		0.00045	N/A	N/A		N/A
S	32.0640	---	0.00017	0.00017		---	0.00015	0.00015		0.00016
O	15.9994	---	0.00033	0.00051		---	0.00030	0.00092		0.00072
Br	79.9090	0.00010	0.00010	0.00010		0.00056	0.00056	0.00056		0.00033
H_2O		0.00020	N/A	N/A		0.00070	N/A	N/A		N/A
H	1.00797	---	0.00002	0.00002		---	0.00008	0.00008		0.00005
O	15.9994	---	0.00018	see above		---	0.00062	see above		see above
Total:		0.99490	0.99490	1.00000		0.99967	0.99967	1.00000		1.00000

1.2 Pallet-Sized Model of Material

The simplest approach is to model the potash as a uniform, homogeneous block of material representing a full pallet load, rather than trying to model individual bags of potash or individual granules inside bags. Thus a "loose-packed" density is the most appropriate to use for such a model. The vendors' specification sheets (see Section 1.4) showed that the density depended on the type of granules used in the packaging. The coarse grades had a loose density of 0.99 g/cc (62 lb/ft^3), while the fine granules had a loose density of 1.20 g/cc (75 lb/ft^3). To maximize the emissions from this material (and thus provide an upper bound to its crosstalk or masking effects), the lowest density is suggested, since this may give the lowest self-shielding or attenuation to the emitted gammas.

The model for the pallet used a standard form factor of 40 in. by 48 in., which is the length and width of a standard pallet in the United States. The Evergro web page stated that their Muriate of Phosphate product is shipped in 25-kg bags, and that a pallet load of 25-kg bags contains 40 bags, which would total 1000 kg. Thus, the model used a volume of 1,007,000 cm^3 for the pallet load, which would correspond to 1000 kg of material at a density of 0.99 g/cm^3. The dimensions of the material are 101.6 cm wide, 121.9 cm long, and 81.3 cm high, which corresponds to 1,007,000 cm^3 of material on a 40-in. by 48-in. pallet. For this simple model, all other container materials, such as cardboard, plywood, or paper bags, are omitted.

1.3 Radiation Source Term for a Pallet of Potash

Using the above composition and mass values, the following elemental properties[3] of ^{40}K can then be used to estimate the total activity of one pallet of fertilizer.

Table 1.2. Isotopic Properties of ^{40}K

Isotope	Natural Abundance	Half-Life	Atomic Mass
^{40}K	0.0117%	1.277×10^9 y	39.96

For the potassium weight fraction of 0.5117 in the model of potash and a weight fraction of 0.000117 for ^{40}K in natural potassium, a mass of 1000 kg of potash would contain 59.9 g of ^{40}K. Dividing this value by the atomic mass gives a total of 1.50 moles or 9.027×10^{23} atoms. Converting the 1.277×10^9 – y half-life into a mean life in seconds, i.e., 5.81×10^{16} seconds, and dividing gives an activity of 1.55×10^7 Bq, or 419 μCi, for this total mass of ^{40}K. ^{40}K emits a gamma with energy of 1460.82 keV with a yield of 0.107 gammas per decay[4]. Thus a full pallet of potash would emit 1.66×10^6 γ/s.

To put the above gamma emission rate for one pallet of fertilizer in perspective, note that the surrogate sources of 14 μCi of ^{133}Ba and 5 μCi of ^{57}Co emit 1.43×10^6 γ/s and 3.00×10^5 γ/s, respectively. Thus, this simple model predicts one pallet of fertilizer NORM should give approximately the same count rate as the ^{133}Ba surrogate. However, the barium source would be more easily shielded because its emitted gammas have low energies (all below ~380 keV) relative to the 1461-keV gammas from the fertilizer.

1.4 Muriate of Potash Data

From Agruim
(http://www.agriumwholesale.com/includes/specsheets/Spec136.pdf)
Standard Grade (same for all other grades, except for densities as noted)
0-0-60
Chemical Analysis

	Typical
Total Potash (wt. %K_20)	60.6
Chloride (wt. %Cl)	47.7
Potassium (wt. %K)	50.3
Sodium (wt. %Na)	1.35
Calcium (wt. %Ca)	0.03
Magnesium (wt. %Mg)	0.03
Bromine (wt. %Br)	0.01
Sulfate (wt. %$S0_4$)	0.05
Total organics (wt. %)	0.20
Total water insoluble (wt. %)	0.4
Moisture (wt. %H_20)	0.02
pH of 10% wt./wt. aqueous solution	9
Product Conditioner (ppm Amine)	150

[3] http://atom.kaeri.re.kr/ton/
[4] http://www.nndc.bnl.gov/nudat2/decaysearchdirect.jsp?nuc=40K

Physical Analysis

Color	Clear to Brick Red
Angle of Repose (Degrees)	31
Bulk Density (kg per m^3/lbs per ft^3)	
Loose	• 1200/75(Standard Grade) • 1090/68(Coarse Grade) • 990/62(Granular Grade)
Tapped	• 1315/82(Standard Grade) • 1270/79(Coarse Grade) • 1185/74(Granular Grade)

From Evergro
(http://www.growercentral.com/UPLOADS/PDFS/0-0-62%20muriate%20of%20potash%20fine%20label.pdf)
Fine 0-0-62
Fine grade MOP is a solution mined, crystallized, high-purity product that is washed, dried and screened. Commercially, it is used in the manufacturing of fertilizers, supplying K_2O. Fine grade MOP is manufactured at Belle Plaine, Saskatchewan. Product analyses are typical as tested at minesite. Handling and transportation may affect the analysis of the delivered product. Revised 04/01

Physical Properties:

	Typical
Bulk Density, loose/packed	
• lb/cu foot	72/79
• kg/cu meter	1153/1265
Angle of Repose (degrees)	27

Chemical Analysis:

Component	**Symbol**	**Typical (%)**
Potassium Oxide Equivalent	K_2O	62.37
Potassium Chloride	KCl	98.72
Potassium	K	51.77
Sodium Chloride	NaCl	1.00
Sodium	Na	0.39
Calcium	Ca	0.025
Magnesium	Mg	0.011
Sulfate	SO_4	0.045
Bromide	Br	0.056
Chloride	Cl	47.60
Water Insoluble	—	0.010
Moisture at 130°C	H_2O	0.070

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