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Colonel Howard Killian, Deputy Director
U.S. Army Installation Management Command
Pacific Region
132 Yamanaga Street
Fort Shafter, Hawaii 96858-5520

Dear Colonel Killian:

I have had an opportunity to review the reports released from DU studies at Schofield Barracks and Pohakuloa Training Area. I also spoke with Dr. Lorrin Pang, some members of the Community Advisory Group, and met contractor Dr. Jeff Morrow.

I agree with your statement that you mentioned in a previous communication we had, and that is to let the science speak.

In that light, I am particularly concerned that what is proposed by the U.S. Army for future studies at PTA will fall far short of providing the best information possible at this time, or for that matter, provide any information that can be used to develop a real rather than a speculative risk assessment.

DU is an issue of evolving study results and knowledge. There are some points that are immutable fact. We know that DU is present at Schofield and Pohakuloa. As I recall, the Army does not dispute the point of potential health risk. Therefore, we must take the best information we obtain today and use it to address the concerns about the level of health risks from potential exposure to DU.

The citizens of the Big Island are concerned. This is a natural, often fearful, reaction anytime the word radiation is mentioned in our society. Yet, we live in a world with ubiquitous and unavoidable natural radiation, from cosmic rays to the foodstuffs that provide our sustenance. According to the position of the U.S. EPA, any and all ionizing radiation has the potential of causing cancer. Thus, there has to be a reasoned balance between unavoidable exposure and elective exposure.

The past use of DU on the Big Island places exposure to that type of radioactive material in the “unavoidable exposure” category. This brings forth the question then of how much additional risk does it pose to the people of the Big Island including the military personnel stationed and working at Pohakuloa.

I believe that with adequate study, this question can be answered with reasonable assurance. As I mentioned, I do not believe the currently planned study has the capacity to answer that question. The reason for my belief is that the study design is to measure

total uranium and to show that it is below standards set by World Agencies for regulated exposures. This may present itself as a feel-good approach, but it is unfortunately misleading even with the rudimentary information we have today about the form and occurrence of uranium in the natural environment. In other words, the study as currently planned still leaves the door wide open on determining excess health risks, if any.

The attached commentary contains suggestions on what additional information could be collected to help determine the risk. It is fair to assume that the information about the use of DU is as accurate as it can be. That is, the only use was in the Davy Crockett spotting rounds, no use of penetrating munitions occurred, that is the 20mm or 30 mm rounds from various Gatling configurations, smaller caliber rounds, or larger caliber armor penetrating munitions. It assumes that DU does not remain from any breach of containment if used as ballast or armor reinforcement, or any other possible presentation of DU.

My comments are intended for a reasonably informed individual about DU issues; it is not overpoweringly technical but does use various standard abbreviations, chemical, isotopic, and radiological inferences and acronyms. For example, I use DU for depleted uranium and its various components, and natural uranium or NU for naturally occurring uranium. I am not suggesting that the uranium has a chemical, physical, or radiological difference. However, it is different in form and that is a significant difference for risk assessment. In addition, unless specifically mentioned, I do not separate radioactive decay into the three common particles, alpha, beta, and gamma radiation. Of special note is my use of the term "form" in describing uranium. Unlike the Hawaii Department of Health presentation (November 2007), I use form not to refer to the element uranium (and isotopes) but to describe its occurrence in a matrix – natural, alloy DU, or oxidized DU.

This is a commentary; it is not a formal, peer-reviewed technical report although it may in some instances give the appearance of a peer review for the program. I do not duplicate information that can be found elsewhere and except in unusual or compelling circumstances, I do not provide references. For detail not presented here, I am sure various contractors you have will be able to address and clarify the concepts more fully. However, I am also willing to further explain my commentary for those issues that might be seen as some in a gray area of meaning.

Sincerely,

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Distribution: Sherry Davis, Corey Hardin, Hawaii County Council, Pete Hendricks, J. Morrow, Ph.D., L. Pang, M.D., LTC Richardson, S. Troute

Advisory Commentary of Michael Reimer on PTA Depleted Uranium Studies

Overview

Uranium in the natural environment occurs as an element within a mineral matrix. This is true for the oceanic basalts that comprise the bulk of the volcano building material or even uranium mineralization associated with economically recoverable uranium deposits. This is in contrast with DU used as munitions. There, uranium is in a metallic form commonly alloyed with another metal or as a component derived from that metallic form. Regardless of physical form or chemistry, uranium is radioactive. In addition, uranium is a heavy metal and can cause heavy metal toxicity if ingested in sufficient quantities.

Any analysis of airborne materials that reveals uranium does not necessarily distinguish between metallic or matrix-included uranium. DU used at Pohakuloa is reportedly 92 percent uranium alloyed with 8 percent molybdenum. Other alloy materials of DU munitions not known to have been used in Hawaii included titanium, cobalt, and nickel. Molybdenum as a heavy metal also has associated toxicity.

There is a major difference in potential cellular radiation damage if exposed to metallic uranium (or any particle with high uranium content, such as the 92 percent DU) versus exposure to oceanic basalt dust or aerosols where the uranium content may be 0.1 to 1 part per million (0.00001 to 0.0001 percent). The reason for this is quite intuitive. The more closely packed the uranium is, if embedded in tissue, the greater the likelihood that its radioactive alpha particles can provide multiple transits of the same cell during the cell's lifetime.

Chemical form is also important to consider. DU and its alloys oxidize. Oxidized uranium (commonly valence VI) is more mobile in the environment that reduced uranium (IV). DU oxidizes as seen from the photographs of yellow residues on spotting round assemblies. The rate of oxidation is highly dependent on the local environment in which the metallic alloy is deposited. One estimate from DU in soils indicated a 30 year time span before the DU would be completely oxidized. I find such a time frame incredibly

quick and would need conforming evidence to reinforce its validity. From suspected oxidized fragments found on Oahu, it does appear that the oxidization process may be rapid in a moister environment. The oxidization process of DU has been observed for spotting rounds in Hawaii and while it occurs, it seems to be at a much slower rate of progression as it has been perhaps over 40 years since the munitions were fired on the Big Island.

In effect, there is a mixed scenario regarding the transport and migration of DU, in both metallic and oxidized forms and there is a different health response from both radioactive and heavy metal exposures. Background surveys at Schofield seemed to indicate that surface U radioactivity was less than that found with samples taken from depth. This is not unusual when you consider that weather (leaching) of uranium and other metals can occur from surface materials and it can be redeposited in lower horizons. Migration of oxidized DU could follow the same path but on a more rapid time frame. I point this out so that it may be considered as a mechanism for either form of uranium.

In response to finding DU at Schofield and Pohakuloa, the military performed various scoping surveys and analyses to determine the probable extent of the distribution of the DU munitions. These surveys included soil sampling, plant sampling, controlled burn of vegetation with ash collection and analysis, ground surveys, aerial photographic surveys, and airborne fly-overs with a helicopter fitted with sophisticated radiation detectors, and walk-overs with scintillometers looking for spent rounds that have a rather unique shape.

DU, because of it purity of uranium, is difficult to find using common radioactive detectors. Its primary decay is through alpha particle emission. These alpha particles, have very limited range in air, perhaps 5 cm and even less within any matrix material or soil cover. There are limited emissions of beta and low energy gamma rays from the decay and progeny, again with limited range before all energy is transferred to the surrounding medium. That medium can be any combination of mineral matrix, soil, water, or air. The progeny of uranium decay are also radioactive until the end member is reached (Pb-206 in the case of U-238). Thus the radioactivity of purified U-238 begins to provide greater radioactivity with the in-growth of progeny than that uranium immediately after purification and the progeny can be detected just a few months after

pure uranium is cast. In fact, within about 6 months after purification, the radioactivity increases from about 50 percent that of natural uranium (depending on the extent of U-235 separation) to about 75 percent.

If the DU was obtained from reprocessed fuel rods, the possibility of other isotopes is real and they could include significant radiation emitters even in trace quantities. While one might be tempted to state factually that the radiation of DU is less than natural uranium, it is the total radiation of the spotter round that should be addressed.

The paper "Depleted Uranium, Natural Uranium and Other Naturally Occurring Radioactive Elements in Hawaiian Environments" by Dr. Kenneth Rubin, of at University of Hawaii (May 30, 2008) is an excellent overview paper covering many details of uranium in the natural environment. It is unfortunate that the copy I read did not contain references.

Analysis

Uranium can be analyzed chemically and the surveys used ICP-MS that could even provide isotopic analyses. DU typically contains the naturally occurring isotopes, U-238, U-235, and U-234. If processed from spent fuel rods, it may also contain U-232, U-233, and U-236, and nano-traces of other isotopes, as well. Typically, the presence of U-236 is an indicator of fuel rod processing. The energy of the alpha particle release is also indicative of the particular isotopes. Those energies can be resolved using alpha spectrometry.

All analytical measurements have detection limits. That is, they have a limiting number (concentration) below which the element of interest cannot be detected. The methods used in the scoping surveys probably provide the lowest possible detection limit available by analytical instrumentation today. For example, if enough of the sample is available, ICP-MS can measure one part of the element of interest in 1,000,000,000,000,000 parts of the other material; that is 1 part in a million billion. An advantage of the ICP-MS is that it can measure isotopes of some elements, if enough material of the element of interest is present.

Alpha spectrometry is another analytical means of detecting uranium isotopes and was used for some sample analysis at Schofield. It is capable of measuring the alpha decay of individual atoms and the energy released is often characteristic of the isotope! Some care must be used in selecting a calibrating isotope for this system so as to not interfere with the energy of the particle of interest.

This is, of course, high praise for the potential of the analytical capability but if not used properly in a well designed program, the analytical results can be incorrect or misleading.

For example, if the analytical results are close to the minimum detection level of the instrument, there is great uncertainty in the precision of the results. In other words, the standard deviation of the analysis can be so great that the uncertainty (often shown as a plus or minus number indicating a range of the result or expressed as standard deviation) pushes the analysis into a region less than the minimum detection level.

A note is in order here. There is another limit commonly used, identified as the reporting limit or RL. It is typically higher than the minimum detection level (MDL), often by an order of magnitude, just to avoid the great uncertainty that accompanies analyses close to the MDL. I would have to carefully check Figure 3.1 on the Final Report of the ICM-MS results for total suspended air filters to see if the RL is properly placed.

Analysis on the edge of the detection limit is particularly bothersome when attempting to use the uranium isotope ratios from ICP-MS analyses to determine if they are representative of natural or depleted uranium.

Typically, U-235 and U-234 are lower in DU than in natural uranium. U-236 does not occur in natural uranium. An isotopic analysis of uranium and comparison of ratios of isotopes can reveal whether or not it is likely to be natural or depleted uranium. In addition, the presence of U-236 is nearly confirmatory that DU is present. Thus, the analysis of uranium isotopes presents many internal controls for determining the possible existence of depleted uranium. In short, we know depleted uranium is there. The question to be resolved is if it has an airborne mobility vector.

From typical analytical results reported so far especially from the Schofield studies, the total uranium concentrations are going to be between the MDL and the RL. Isotopic analysis if performed may not present any useful (resolvable) information.

Next Sampling Phase

As I understand, the design of the continuing program to monitor airborne particulates, I believe the results are going to be inconclusive whether DU has mobility through an airborne vector. I believe only ICP-MS is going to be used for the analyses of particulates on the air filters.

Minimal modifications could enhance the monitoring to provide results that have a better chance of revealing if DU is transported in the air. I shall outline them here with a brief explanation as to why they should be incorporated into the study.

Recommendations

Alpha spectrometry. Alpha spectrometry should be applied to all the samples collected. The alpha spectrometry is an important component to the overall comprehension of the sample makeup. It should detect U-234, U-235, and U-236. It could reveal U-236 if present that would be a clear indicator of depleted uranium and the sample should be counted long enough to detect any Po and Ra, progeny of U that could help distinguish between DU and naturally occurring U. I understand from Dr. Morrow when we met on March 3, 2009, that alpha spectrometry is not part of the future studies. I believe at least some minimal number of samples should be designated for alpha spectrometry. The reason is that it might be able to detect the presence of isotopes characterizing DU. This may require extended sampling time or greater pumping speeds. Alpha spectrometry was performed at Schofield and should be continued at PTA. A total uranium analysis will not distinguish DU from NU.

ICP-MS. ICP-MS should be continued and additional elements included. In fact, there may be a suite of elements included that come as an analytical packet for a minimal fixed cost. Mo should definitely be included in the analysis. There is very little in

Hawaiian basalts and larger quantities may be an indicator of DU. Additional analyses would be Ni, Co, and Ti. Ti, a later alloy of DU munitions might have a fairly high background in Hawaii as it occurs in the percent range in some Hawaiian basalts. Phosphorous may indicate the use of fertilizer in the case where high uranium values are seen. Although ideally every sample should have a full analysis, I believe for at least 25 percent of the samples, a full suite of commonly run ICP-MS analyses should be made.

The partial digestion analysis of a standing dust sample from Waiki`i ranch is interesting in that it strains the analytical detection limits and vaguely hints at the possibility of DU in airborne dust. We have no information on the quantity of the sample, counting times, particulate size distribution or calibration and standards. It is reasonable to suspect however that a rather large quantity of sample was available for this ICP-MS analysis to include U-236 detection.

Duplicate, background, standards, and blank samples. I recommend that duplicate field samples be collected at certain times, even if this means running two filters in parallel. The issue of standards, blanks, backgrounds, and replicates was poorly covered in the scoping reports. Some indication of reasonable measurement error range should be obtained and reported. The samples should be given to the laboratory unidentified as to whether they are special category samples. Typically, these samples represent 10 percent of all samples. Blanks are self explanatory; standards are those made by the lab to calibrate the equipment and those prepared by the party submitting the samples. For background, see Sampling Frequency, below.

Particle observation. I recommend that some of the filters be photographed using an electron microscope to observe the particles that have been collected. Such photographs may indicate the nature of the particulate matter, if it is amorphous or crystalline, organic (pollen) or inorganic. It would also be worthwhile to get some idea of the particle size distribution from a range of 10 nanometers to 100 micrometers. For some samples, I recommend that an analysis be made of post-filter collections. There are multiple ways of obtaining this information, including post-filter large surface area collectors, that the contractor can recommend.

Sampling frequency. I believe the sampling of aerosols is scheduled for pumping 24 hours, once a week. I would recommend that the sampling occur every 6 days or more frequently to obtain coverage for days of the week when different scheduled activities may occur. I also would like to see sampling stations set up around the island. *I understand from Dr. Morrow that such sampling has already occurred as part of other, non-military sponsored monitoring, and some information from those collections will be included in this study. In addition, the present sampling program is following a random day, US EPA protocol.

There should be some samples that are included as background. These could be upwind samples. There are several air sampling programs in effect on the Island, from government to university studies. These monitor air quality for a number of reasons, including particulates and elements related to volcanic emissions and VOG. I would suggest exploring the feasibility of including air sampling for uranium as part of these ongoing operations and to have several stations operating for several years in the quest for airborne DU. A collection and comparison of data from these other monitoring stations and their ongoing analyses would be a good addition to discussion in a final report. This possibility of cooperation has been mentioned in various reports and I encourage it as part of this survey. For example, I highly recommend discussions and data exchange (past, present and future) with researchers at the Mauna Loa observatory. They have been measuring particulates and radioactivity as part of many different programs over the years.

Training. Personnel who traverse PTA should be given training in the appearance of spotter rounds and potential fragments. If seen, they should be noted and reported for recovery. I have seen that this training is included in the license application to the NRC.

Aerosolization. In spite of determined attempts to locate spent spotter rounds, they were largely unsuccessful. Only one round was located at PTA. There could be many reasons for this. One is the difficulty in finding DU via radiometric surveys.

The helicopter over-flights are another example of minimal detection capabilities. The helicopter flew at just feet off the ground but even that small distance is equivalent to the inches of soil cover for attenuating ionizing radiation.

There may have been several hundred to over 2,000 rounds fired. The fact that only one was recovered points out the difficulty of locating the rounds. If a suspicious material is found, that is physically located and recovered, alpha particle detection can be used to determine if it is uranium.

Speculation can present a few additional scenarios besides inadequacies of detection techniques that could provide explanation why more DU rounds are not found. The probable impact area is larger than the area being searched; upon impact (and we do not know the target material), the rounds fragment highly, including partial aerosolization; the rounds have mostly oxidized; the spotter round impact area has been highly impacted by other activities including exploding ordinance or vehicular traffic. It should be pointed out that the oxidized form is highly friable and can be dislodged easily from the host metallic form. It could be carried to deeper horizons by surface precipitation and leaching or aerosolized more readily by mechanical means. I doubt that there is only one mechanism at work making the finding of rounds difficult.

Special sampling events. Anytime there is a special event at the training area, such as road construction or a firepower demonstration, sampling should be done. It is too bad that the helicopter did not include a dust sampling device when it was searching for spotter rounds. Such activities have the capability of placing aerosols and dust into the air and DU may be a part of that release. *I understand from Dr. Morrow that this is planned.

Minimum detection level or limit (MDL). There should be a concerted effort to raise the analytical threshold above the MDL. I recognize the difficulty of this suggestion. If this means collecting a sample for longer than 24 hours or using multiple filters to collect more sample, it should be considered.

As it currently stands, the reported concentrations of material analyzed is about the same as the MDL. This indicates that the concentrations of materials are low and a

conclusion is drawn that because the uranium is low, and below the various exposure limits set by various health organizations, there is no threat from exposure. This is an inadequate approach, convenient, but inadequate.

As argued before, the form of the material is of great importance. If a 10 nanometer diameter of DU is embedded in the lung, it will present a radiation hazard even though it may only register as a small part of total uranium collected on a filter.

Aerosol characterization. These suggestions are made to enhance the characterization of the aerosol sampling program. The addition will impart increased costs but it is needed to say with certainty what any increased health risk might be if DU is present. Aerosols can be created even when a spotter round fragments. This is noted from the dust released when any brittle object is broken. Of course, it is much less than burning an object and changing the form into smoke or ash. I have no information on whether or not the spotter rounds were fired at a target and what that target might be. Simple impact and fragmentation will create aerosols. The extent of this might be seen by measuring the alloy metals (molybdenum) that would be part of the aerosol.

Health risk determination. There are several means by which health risk from exposure to DU can be determined. Various models and worse case scenarios can be used but the primary question is whether people were or are exposed to DU. For this, one hopes to have actual data for input. The difficulty of obtaining this for DU is discussed but I believe some modification to the sampling program, also discussed, can obtain data that can be useful. The selection of risk determination can take many forms; the one used recently by the US EPA for relative risk was particularly understandable by the public. For soldiers and contractors at Pohakuloa, the chance of being exposed to DU is greater than for someone more distant from the site, but the risk is not negligible and the magnitude of that risk will not be determined until data are available from the aerosol monitoring.

For the Big Island, if you are exposed to SO_2, you have an increased health risk. It is likely that most residents in their living locations are exposed to very little SO_2, so

they do have an increased risk, albeit minimal, but an increased risk nonetheless. If it can be measured, it should be reported.

I depart here from my intent of making this a commentary and include some web sites that may be of interest. I mentioned that I feel sample collection must be modified in order to determine if airborne DU is present. Dust-size particles are likely to be localized as they have a high settling velocity, meaning they drop out of the air pretty quickly when the wind that carries them decreases below a certain speed. We know of course that dust can be carried hundreds and even thousands of miles if it is elevated to high enough altitudes but local winds do not appear to have the convective action to carry the dust high to the altitudes needed for long-distance transport. Aerosols, the smaller particles, can be airborne for rather large distances. They are smaller and utilize the buoyancy effect for transport. These are also the particle sizes that are most likely to become inhaled to the deeper regions of the lung.

Noting that various statements about radiation risk are attributed to the US EPA, especially their position developed from radon that one ionizing particle intercepting a single cell increases the cancer or mutation risk, I feel it is prudent to use the EPA's risk models. They are pretty well developed and even available on line.

The reason for this approach is that DU has a different form than oxidized DU or natural uranium. It is possible that the aerosol particle is DU, 92 percent uranium (920,000 ppm) rather than basalt with 1 part per million uranium. This potentially has a very different impact from alpha particles with cells in the lung. There are analogies to plutonium risk models and radon risk models. The use of a radon risk model has been independently suggested (Albright and Barbour, 1999). http://www.isis-online.org/publications/rp1.html

The US EPA models and calculator are also available on-line. These were developed for Superfund sites and I would hope these would be considered when developing the health risk determination of DU at PTA. The equivalent of U, Pu, and Rn can be run.

http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/introglos.pdf

http://epa-prgs.ornl.gov/radionuclides

Historical input. There are uncertainties dealing with the DU use at Pohakola. There is still time for contact to be made with individuals who were stationed there at the time of the firing. With luck, one might find a range fire control officer. They may know if there were 200 or 2,000 rounds fired, if the testing was done in confined areas, and even if there were any hardened targets involved. In addition, perhaps a minor ecological health study could be conducted using those stationed soldiers at the time before, during and after firing, could be performed to see if there is a suggestion to conduct a case controlled epidemiological study. I include under this topic the historical data and samples collected previously and available from archives. I learned from Dr. Morrow that these samples are available and predate the recent recognition of DU use on the Big Island.

NRC license application. The license application identifies at least 12 sites in the country that potentially have depleted uranium on site. These are very diverse ecologically and it may enhance the application if each was discussed separately. I make this suggestion in lieu of suggesting that a separate application be filed for each area.

The concept of providing training is sound but training must be an ongoing program for as long or longer than there is DU at these sites. The $1.9 million sought may be insufficient to accomplish and maintain this goal. This training goes along with the commentary I provided in the brief training section above.

I believe the license application should make it perfectly clear that if DU is found, it will be removed. The license application includes a discussion of detecting depleted uranium and talks about the quantity needed to be seen on scintillometer devices. I would restructure this section as it basically states that unless a rather complete spotter round is found lying on the surface, it will not be detected. This comes from the calculation in the application of the amount of DU needed to be detected and the weight of the DU present in a spotter round. Let me provide the example of this. In the application to the NRC for a license to handle, store and dispose of DU at various military facilities, it is stated that a sophisticated radiometric detection system will be assembled and used. It further states that it will be capable of detecting surface fragments 6 cubic centimeters of volume and those buried 2 inches deep that contain 10 cubic

centers volume of DU. As the density of U is 19 g/cm3 and the weight of DU in a spotter round is 190 grams, this highly sophisticated instrument will likely detect nothing. Anything, particularly fragments buried a few inches below the surface avoids detection completely.

Summary

The present method proposed for air monitoring has very little chance of revealing depleted uranium. Several slight modifications to the sampling program are recommended. The major changes are to include alpha spectrometry (U-233, 234, 235, 236, 238, Po, Ra), and additional ICP-MS elements such as typical alloy compounds, Mo, Ti, Co, Ni, Cr, and even Pb. Quantity of samples should be sufficient to move the analysis above the RL level. An attempt to characterize size distribution from millimeter to nanometer should be made on a few samples. Sampling periods should be varied, every six days for example, and include background, duplicate, replicate, and blanks. Ideally, the air monitoring sampling at the perimeter of the training area should be monitored continuously. The sampling program should include special events at PTA such as those that may create a lot of dust and monitoring stations around the Big Island should be set up with monitoring continuing for several years.