TRANSIT

SNAP-27

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Washington, D. C. 20545

Dear Rudy:

I am replying to your January 21, 1971 letter asking for a reply to G. P. Dix's January 6, 1971 questions to you on particle resuspension for the Transit Program.

Very little new experimental resuspension data have been generated since the SNAP-27 Meteorological Working Group report. These results will be discussed together with out additional questions and thoughts on resuspension.

The crux of these new questions is the determination of whether we are only interested in the immediate inhalation hazard or are also interested in the long-term particle migration by saltation and surface creep. These particles may not present an immediate inhalation hazard, but subsequently these larger particles could become the sources for a new inhalation hazard. This long-term surface migration of particles cannot be handled within existing diffusion models unless we also develop a model for describing particle translocation by saltation and surface creep. This new model would require a matching of airborne particle concentrations and concentration profiles at an interface above which conventional diffusion models are applicable.

The following answers are supplied in direct response to the questions which were asked during the review of the Transit Program.

1. Some additional work has been reported on particle resuspension since the November 29, 1968 draft of the SNAP-27 Meteorological Working Group Paper. In Project Schooner, a 31-kt cratering detonation was

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was conducted on December 8, 1968 at the Nevada Test Site.

Several days after the event, W-181 was the predominant radionuclide detected and it served as a unique tracer. The half-life of suspended radioactive particulates was observed to be 38 days. Resuspension factors were between 6×10^{-5} and 10^{-7} m^{-1}. The half-life and resuspension factors are in general agreement with the SNAP-27 paper.

Unanswered questions still remain which we suggest should be answered. Admittedly the half-life is initially between 30-40 days, but what are the half-lives for longer time periods? Half-lives for resuspension are needed for time periods beyond the initial half-life and for time periods for which soil movement is great. If soil movement were great, all activity could be resuspended before the 30 day half-life occurred.

A serious question exists concerning the definition of the resuspension factor as being equal to the airborne concentration divided by the ground concentration. Typically, the airborne concentration has been measured from 3 to 6 feet above the ground surface. Such a definition may be satisfactory if we assume that the resuspension factor is to be applied to inhalation at the test site. For the immediate inhalation problem, field experiments are stated (p. 6, UCRL-72534) to suggest that an inverse relationship exists between the resuspension factor and the level of deposited activity. Since this is true, we really do not know the physics of resuspension. That report suggests that "the mass deposition at high activity areas is sufficiently high to significantly lower the amount of material available for resuspension, or that air levels in low ground activity areas mainly represent suspended material that originated in high ground activity areas far removed from the point of measurement." At first inspection, we tend to agree that the inhalation hazard is due to upstream resuspension. The physics of resuspension from upstream conditions to the local inhalation hazard must be determined.

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Resuspension factors would more correctly model the physics of the resuspension if we were to add the qualification that we were interested only in the immediate inhalation hazard. If we are also interested in the long-term translocation of the source and subsequent resuspension to an inhalation hazard, we must also now define a resuspension factor for particle saltation and surface creep. These are the processes which move greater than 50 to 100 μm diameter particles.

The early work of R. A. Bagnold and W. S. Chepil on soil movement has shown that 90% of the airborne material is within one foot of the surface and that obviously the airborne soil diameter decreases with an increase in height. Consequently the resuspension factor would increase if the airborne concentration were measured closer to the surface. Thus, a resuspension factor for tracer movement by saltation may be several orders of magnitude greater than the 6×10^{-5} to 10^{-7} m^{-1} for the inhalation hazard.

We recommend that data be obtained to determine the saltation resuspension factor. Data are also needed to establish how the tracer is moved--is the tracer resuspended by itself or is the tracer attached to the host soil particle? This attachment would probably be more important for smaller sized particles.

A modeling problem using the resuspension factor exists in evaluating the boundary conditions if any of the tracer moves in either surface creep or in saltation. These cases are not considered in existing particle diffusion models. We will suggest the nature of the problem.

Particles moving in saltation initially acquire sufficient energy to cause the particle to move almost vertically upward. Depending upon the amount of energy imparted, the particles will rise to various heights before the particle motion can be assumed to be described by a Sutton type diffusion model.

The real questions then are firstly, is radioactive particle resuspension by saltation important for long-term tracer translocation, secondly, can particle resuspension be handled within the framework of existing diffusion models, and thirdly and most importantly, do we now need to develop a resuspension model which can be mathematically matched at an interface height which separates upward particle movement by energy from saltation as opposed to particle motion by conventional eddy diffusion.

We interpret saltation and surface creep as an important mode of surface translocation of tracer. This interpretation has some support in the aerial surveys of ground level activity after the Schooner test (pp. 21-23, UCRL-50718). The contour of 5X of background activity showed a downwind migration of up to about 9 miles from the 13th to the 20th day. This translocation could not be attributed to particle movement by true suspension, but could have been caused by removal of inert soil from the base cloud which initially covered the tracer. Nevertheless, saltation + surface creep are believed to be the means of translocation since the 5X contour movement occurred over a broad area.

2. Small (<3 μm diameter) high density (10 g/cc) $^{238}PuO_2$ can definitely be resuspended to attain a level of 1 meter or higher above the ground. A 3 μm particle corresponds to a soil particle of 5 μm diameter of density 2 g/cc. Soil particle concentrations measured at the BNW tower (1959) showed that over 2×10^3 particles/ft^3 were collected at the 400 foot level. Concentrations at ground level were over 5×10^3 ft^{-3}.

The question we propose and cannot answer is: "Do these small particles retain their identity as a tracer or does the tracer attach to the soil particle." If the tracer particles were attached to the host sand particle, the large host particle may never (unless wind speeds are very high) present an immediate inhalation hazard. In this case, the problem of inhalation would arise if the tracer were to subsequently detach from the host sand particle.

3. The resuspension factors for <3 μm diameter and high density (10 g/cc) $^{238}PuO_2$ particles are desired. A direct answer is not known since we do not know if the tracer would retain its identity, or if it would attach to a host soil particle. In addition the resuspension factor would be a function of the surface type as well as airborne loading of soil passing over the contaminated area.

   Consequently, we have to conclude that the plausible estimate of the experimental resuspension factor is still 6×10^{-5} to 10^{-7} m^{-1} or greater. However, Fuquay's model in the SNAP-27 review does predict resuspension factors as high as 0.3 m^{-1} for 1.5 μm diameter particles at a wind speed of 10m/sec.

4. It is anticipated but unproven that charged $^{238}PuO_2$ particles would coagulate faster than uncharged particles with natural dust particles. The electrical forces are present to cause the increased coagulation, but the coagulation would depend upon the relative proximity of particulates.

   The hypothesized mechanisms for increased coagulation is as follows: Radiation from the particle would electrically ionize the surrounding air. If subsequently the particles became oppositely charged, an electrical attraction between particles would increase the coagulation rate.

   This increased coagulation rate is the case of coagulation in a bipolar ion source. The theory for ionic equilibrium has been developed in the literature. However, we are not talking about an equilibrium condition in time, space, and concentration. For these non-equilibrium conditions, a definite possibility exists that coagulation would be enhanced. Indeed, we propose within to determine the importance of this non-equilibrium charge distribution on enhanced coagulation.

5. We cannot predict the post-impact weathering half-life or factor associated with the Pioneer capsule and plutonic molybdenum cermet fuel as opposed to the < 3 μm respirable particles of $^{238}PuO_2$.

We know that initially the half-life is about 30-40 days for deposited radioactivity to weather into a relatively non-erodible state. However, we do not know the long-term time dependency of the half-life as a function of any variable. One variable influencing the half-life is migration into the soil. For Pu, this weathering includes migration down into the soil as far as 13 cm (HASL-235).

As you can see, little is really known about particle resuspension. Consequently, we have tried within the question review to identify additional general problem areas which must be evaluated.

Hazard appraisals to date have used the best estimates so far but these are really inadequate and misleading.

Very truly yours,

Jim

J. J. Fuquay

JJF:ck

In triplicate

cc: James E. Miller

TABLE VIII

STABILITY FREQUENCY AND WIND SPEED FOR 27 STATIONS
FREQUENCY OF STABILITY CLASS -%

Station	A	B	C	D Neutral 5m/sec	E slightly stable	F Stable	G
Tripoli, Libya	0.8	9.0	17.8	32.6	11.5	15.3	13.0
Angeles, Phillippines	2.3	8.8	14.4	38.1	12.3	19.1	5.0
Fussa, Japan	1.0	8.3	12.9	47.1	5.8	13.6	11.3
Balboa, Canal Zone	2.3	10.8	18.5	21.9	8.7	26.9	10.9
Terceira, Azores	0.1	2.3	9.1	69.5	7.6	7.0	4.4
Thule, Greenland	0.1	6.0	11.8	49.0	14.6	16.2	5.3
Honolulu, Hawaii	0.1	2.3	12.1	60.1	13.8	9.7	1.9
Dhahran, Saudi Arabia	0.8	5.3	16.5	37.5	13.8	15.6	10.5
Berlin, Germany	0.0	3.6	9.6	65.3	10.0	7.9	3.6
[illegible], [illegible]	0.0	2.4	9.0	69.1	5.1	6.3	8.0
New Delhi, India	1.3	9.0	16.7	30.8	10.4	16.9	14.9
[illegible], Pakistan	0.8	6.4	11.6	54.3	11.4	9.9	5.6
Marshall, Liberia	1.0	7.2	14.1	45.1	4.7	23.6	4.2
Natal, Brazil	0.1	2.1	12.6	55.8	18.0	10.9	0.6
Brisbane, Australia	1.5	8.6	16.9	33.8	7.8	18.6	12.8
Bangalore, India	1.2	7.3	11.7	55.5	10.7	9.7	3.8
Leopoldville, Congo	3.0	13.5	13.4	25.9	9.5	21.9	12.8
Dares Salaam, Tanzania	1.0	10.1	20.5	24.4	4.9	14.2	24.8
Edwards AFB, Calif., USA	4.4	11.9	12.9	34.1	11.8	13.6	11.4
Mac Dill AFB, Fla., USA	2.8	8.6	15.0	37.2	12.5	13.6	10.4
Patrick AFB, Fla., USA	1.3	8.9	15.6	42.0	13.5	12.3	6.5
Langley AFB, Va., USA	1.4	7.6	14.9	43.2	9.3	12.9	10.3
Lima, Peru	2.8	7.8	13.3	58.7	6.0	8.0	3.4
Annapolis, Maryland, USA	1.1	7.1	12.4	49.5	11.3	12.4	6.2
Florence, S.C., USA	1.0	7.2	14.5	43.5	13.1	15.3	5.5
Milwaukee, Wisc., USA	0.1	2.6	9.8	65.3	9.9	7.8	4.6
Mather AFB, Calif., USA	3.6	10.8	13.7	37.6	15.1	9.8	9.5
Average	1.3	7.2	13.4	45.3	10.5	13.7	8.2

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TABLE IX

MEAN WIND SPEED - M/SEC, FOR STABILITY CLASS

Station	A	B	C	D	E	F	G
Tripoli, Libya	1.4	2.8	3.9	5.6	3.6	2.1	0.7
Angeles, Philippines	1.3	2.2	2.6	3.5	2.6	1.2	0.8
Fussa, Japan	1.0	1.7	2.3	3.3	3.0	1.4	0.7
Balboa, Canal Zone	0.7	1.9	2.4	3.0	2.8	1.0	0.5
Terceira, Azores	2.0	2.7	3.3	5.7	3.2	1.5	0.6
Thule, Greenland	0.0	0.7	1.4	4.2	3.5	2.0	0.5
Honolulu, Hawaii	1.4	2.7	5.5	6.2	3.6	2.4	1.2
Dhahran, Saudi Arabia	1.1	2.8	5.2	6.4	4.0	2.3	0.6
Berlin, Germany	1.3	2.3	3.2	4.8	3.6	2.3	0.9
Nome, Alaska	0.0	1.6	2.1	5.7	3.8	1.9	0.6
New Delhi, India	1.1	2.2	3.7	4.9	3.2	1.8	0.9
Karachi, Pakistan	0.9	2.2	5.0	7.1	4.0	2.4	1.1
Marshall, Liberia	1.3	1.7	2.2	2.7	2.4	1.0	0.9
Natal, Brazil	2.0	3.6	4.8	4.8	2.7	1.4	1.4
Brisbane, Australia	1.5	2.2	3.0	4.3	2.9	1.2	0.8
Bangalore, India	1.9	2.7	3.8	5.4	2.9	1.9	1.3
Leopoldville, Congo	1.4	2.2	2.1	2.6	2.4	1.2	0.8
Dar es Salaam, Tanzania	0.7	1.6	3.7	5.0	3.1	0.7	0.1
Edwards AFB, USA	0.6	1.4	3.3	6.8	4.1	2.2	0.6
Mac Dill AFB, USA	1.1	2.4	3.5	5.1	3.7	1.8	0.4
Patrick AFB, Fla., USA	1.1	2.7	3.8	5.5	3.7	2.0	0.6
Langley AFB, Va., USA	1.3	2.4	3.0	4.6	3.5	1.6	0.5
Lima, Peru	1.5	2.2	2.0	2.7	3.1	0.9	0.5
Annapolis, Maryland, USA	1.4	2.3	3.1	5.2	4.1	2.1	0.5
Florence, S.C., USA	2.1	2.8	3.7	4.5	3.3	2.3	1.1
Milwaukee, Wisc., USA	1.9	2.9	4.1	5.9	3.7	2.2	0.8
Mather AFB, Calif., USA	0.8	2.0	3.1	5.2	4.1	2.1	0.5
Average	1.2	2.3	3.3	4.8	3.4	2.5	0.7