SAFETY NOTE 19
SURFACE CONTAMINATION LIMIT FOR REMOVABLE INORGANIC LEAD

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INTRODUCTION

Due to the extensive use of lead-containing materials at Fermilab, there is a potential for personnel exposure from surfaces that have become contaminated with removable inorganic lead. Such contamination may arise from long-term "weathering," exposure to corrosive chemicals, or the involvement of lead-containing materials in a fire. The primary routes of entry for lead contamination into the body are inhalation from resuspension, and swallowing from contact transfer.

Although there are atmospheric and blood contamination limits for inorganic lead, there are none for removable surface contamination. The OSHA limit for air is 0.05 mg/m3, with a 0.03 mg/m3 action level, and that for blood is 40 μg/dl.

This note contains the derivation of a removable surface contamination limit for inorganic lead. It will be argued that concentrations below 0.05 mg/dm2 should require no special precautions, between 0.05 and 0.50 mg/dm2 precautions should be recommended, and above 0.50 mg/dm2 they should be required.

RESUSPENSION & INHALATION

The airborne concentration of a finely divided solid contaminant (Ca) can be related to its removable surface concentration (Cs) via the resuspension factor (K):

$K = Ca / Cs.$

The resuspension factor depends on the nature of the contaminant, the environment, and the activity taking place. Published values fall into the range of 10-8 to 10-2 m-1 (mean = 10-5 m-1). Seven resuspension factors were also measured during the cleanup from the Fermilab Wide Band Lab Fire (1987) which range from 3x10-5 to 10-3 m-1 (mean = 1.4x10-4 m-1).

Using the above expression, it is a simple matter to calculate the surface concentration that would be required to produce an atmospheric concentration equal to the OSHA action level of 0.03 mg/m3.

CONTACT & SWALLOWING

Normal adult blood is generally reported to contain 10 to 35 μg/dl of lead. However, blood taken from Fermilab firefighters after the fire in PWBL contained 4 to 11 μg/dl, with an average of 6.7 μg/dl. In order to attain the OSHA blood lead limit of 40 μg/dl, the average "Fermilab" concentration would need to increase by approximately 33 μg/dl.

The increase in blood lead concentration at time t can be calculated from the following expression:

$Cb(t) = R * (1 - e^{-a*t}) / (a * V);$

where Cb(t) = the concentration at t (μg/dl),
R = the rate lead is added to blood (μg/day),
a = the clearance rate of lead (day-1), and
V = the volume of blood (dl).

It will be assumed that all the lead from 1 dm2 (= 100 cm2) is swallowed each day. It is known that approximately 10% of swallowed inorganic lead winds up in the blood. Therefore, the rate at which lead is added to blood is given by the following expression.

R = 0.1 * Cs(mg/dm2) * 1000 μg/mg

The half-life for lead in blood is approximately 40 days. Therefore, the clearance rate is 0.014 day-1. A typical human has five liters, or 50 dl of blood. Therefore, the concentration as a function of time is

$Cb(t) = 100 * Cs * (1 - e^{-0.014*t}) / (0.014 * 50).$

Rewriting to solve for surface concentration we have the following expression:

$Cs = 0.23 / (1 - e^{-0.014*t}).$

As above, Cs is in units of mg/dm2 and t is in units of days.

SURFACE CONCENTRATION RELATIONS

Using the relationships derived above, it is possible to estimate the surface concentrations required to reach the atmospheric action level via resuspension, or to reach the lead limit via swallowing. Tabulated below are various surface concentrations and their bases. Also included is a semi-quantitative estimate of the probability (P) that, given the expected variety of activities, a particular concentration will provide adequate protection from exceeding the lead standard at Fermilab. For example, mean resuspension factors were associated with a 50% likelihood. Similarly, it was expected that most uses of lead contaminated materials would result in single ingestions of 1 dm2 of dusts < 50% of the time.

LEAD SURFACE CONTAMINATION LEVELS TO MEET EXPOSURE LIMITS

Cs (mg/dm2)	P(%)	Basis
30,000	< 1	Inhale / minimum published resuspension
30	50	Inhale / mean published resuspension
17	<50	Swallow / one day at 1 dm2 per day
10	<15	Inhale / minimum PWBL fire
2.5	>75	Swallow / one week at 1 dm2 per day
2.1	50	Inhale / mean PWBL fire
0.66	>90	Swallow / one month at 1 dm2 per day
0.32	>90	Swallow / one quarter at 1 dm2 per day
0.30	>85	Inhale / maximum PWBL fire
0.23	>99	Swallow / steady state at 1 dm2 per day
0.030	>99	Inhale / maximum published resuspension

Cs / Removable lead surface concentration.
P / Estimated probability that Cs will prevent standard from being exceeded.

SURFACE CONTAMINATION LIMITS

The data from the preceding table were plotted on log probability paper as shown on the attached page. Using a visual best fit line, the following values of P and Cs result. The geometric mean and standard deviation are 7.0 mg/dm2 and 13, respectively.

SURFACE LEAD CONTAMINATION LEVELS AND PROBABILITY OF NOT EXCEEDING STANDARDS

Cs (mg/dm2)	P(%)	Comment
<0.0001		Background
0.0004		"Clean" lead plate
0.0045	99.99	
0.0049	99.98	Mean wall PWBL pre-dcon
0.016	99.9	
0.020	99.8	Mean floor PWBL post-dcon
0.050	99.4	
0.070	99.0	
0.10	98.4	
0.26	95.0	
0.30	94.0	Mean floor PWBL pre-dcon
0.50	90.0	
1.0	86.0	
7.0	50.0	
10	42.0	
23	26.0	Highest wipe PWBL fire
80	10.0	
100	8.0	
600	1.0	

Based on the above table, as well as the experience with the fire at PWBL, a value of 0.05 mg/dm2 seems reasonable as a removable inorganic lead surface contamination limit. This level is associated with a P of 99.4% (i.e., only 0.6% chance of exceeding standard) and is easily attained with contaminated surfaces through normal washing techinques. Therefore, at levels up to and including 0.05 mg/dm2, no precautions should be required.

During cleanup of the central mess in PWBL, airborne concentrations approximately one-half the action level were attained. Surface concentrations were on the order of 0.5 mg/dm2 and significant precautions were taken to minimize resuspension (e.g., wetting, non-vigorous motions, etc). In the above table this concentration is associated with a P of 90%. It is clear that contamination at this level can be a real problem and contamination control measures should be required.

RECOMMENDATIONS

Precautions may include atmospheric monitoring as well as contamination control measures such as wet methods, body covers, respirators, prohibition of eating, mandatory washing of exposed skin, and proper collection and disposal of contaminated waste. The nature and extent of precautions should be prescribed by the safety organization in authority.

≤ 0.05 mg/dm2	No precautions indicated.
> 0.05 to 0.50 mg/dm2	Precautions recommended.
> 0.50 mg/dm2	Precautions required.