Percutaneous Penetration of Lead: An in-vitro human skin study, the effect of decontamination, and risk analysis of dermal exposure

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This is the amount of lead (as PbO) that is equivalent to the OSHA Permissible Exposure Limit for an 8-hour workday

\[ 50 \, \mu g/m^3 \times 10 \, m^3 = 500 \, \mu g \]
Field Surveys find appreciable Lead (Pb) on hands
Pb mass in hand wipe samples of battery manufacturing workers

µg Pb on hands

Period
1 = before work, 2 = morning break, 3 = before lunch
Pb on the hands of workers at a factory after washing and after eating in a cafeteria.
Firing Arms

- Lead on hands of students at Central Missouri Univ. indoor shooting range

<table>
<thead>
<tr>
<th>Micrograms of Lead on Hands</th>
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</thead>
<tbody>
<tr>
<td>Before</td>
</tr>
<tr>
<td>46</td>
</tr>
<tr>
<td>89</td>
</tr>
<tr>
<td>87</td>
</tr>
<tr>
<td>90</td>
</tr>
<tr>
<td>290</td>
</tr>
<tr>
<td>220</td>
</tr>
<tr>
<td>49</td>
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</table>
If transferred to the mouth, Pb on hands presents additional risk that must be minimized.
Previous Studies Indicate Percutaneous Penetration of Pb

Epicutaneous Application to Rats
Urinary Lead (ng/48 hrs)

Legend
- Control
- Pb powder
- PbO

Exposure Begins

C-C Sun data

Day
The Challenge

Effective and safe Pb removal from skin is necessary to reduce risk of:

1) Hand-to-mouth transfer
2) Percutaneous penetration
3) Take home contamination
A new skin cleanser was developed at NIOSH for removal of Pb and other toxic elements.
Blind participant comparison of the new NIOSH cleanser (A), to two Pb-specialty industrial cleansers (B and C), and Ivory Liquid soap (D)
Where does the Pb that was on the skin go after skin cleansers are used?
Study: In-vitro Human Skin Decontamination Study

- Cleansers: Ivory Liquid & NIOSH Cleanser
- Dosing: 5 mg PbO/cm$^2$ in synthetic sweat, pH=5
- Experiments:
  At 30 minutes post exposure, decontaminate
    #1 No cleanser, just rub with running water
    #2 Ivory Liquid
    #3 NIOSH cleanser solution
    #4, 5 & 6 repeat 1 – 3 using damaged skin
  Measure Pb in skin and in receptor fluid @24 hrs.
Solubility of metal hydroxides/oxides

<table>
<thead>
<tr>
<th>Metal</th>
<th>pH</th>
<th>Dissolution (mol/kg H₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cr(III)</td>
<td>2.4</td>
<td>$10^{-9}$</td>
</tr>
<tr>
<td>Pb(II)</td>
<td>2.4</td>
<td>$10^{-8}$</td>
</tr>
<tr>
<td>Ni(II)</td>
<td>2.4</td>
<td>$10^{-7}$</td>
</tr>
<tr>
<td>Co(II)</td>
<td>2.4</td>
<td>$10^{-6}$</td>
</tr>
</tbody>
</table>

Actual Skin Surface pH

Typical test pH
Office Workers

Forearm pH

MC

Forearm
Affect of Sweating

Skin pH before, at end, and post heavy exercise

Volar Forearm

<table>
<thead>
<tr>
<th>Period</th>
<th>Skin Surface pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>4.0</td>
</tr>
<tr>
<td>End</td>
<td>4.5</td>
</tr>
<tr>
<td>Post</td>
<td>5.0</td>
</tr>
</tbody>
</table>
In-vitro Human Skin Studies

Skin Content

ng Pb/cm²

Intact Skin

Damaged Skin

Water Rinse

Ivory Liq.

N = 8

exp 1

exp 2

exp 3

exp 4

exp 5

exp 6

NIOSH

Ivory Liq.
In-vitro Human Skin Studies

Percutaneous Penetration

ng/cm²

Intact Skin

Damaged Skin

N =

exp 1

exp 2

exp 3

exp 4

exp 5

exp 6

Water Rinse

Ivory Liq.

NIOSH
## Risk Assessment:
**Predicted chronic blood Pb conc.**

<table>
<thead>
<tr>
<th></th>
<th>Hands Only</th>
<th>Hands &amp; Arms</th>
<th>Hands, Arms, Head &amp; Neck</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unwashed Skin</strong></td>
<td>0.7 (0.1-1.4)</td>
<td>2.5 (0.3-5.1)</td>
<td>3.6 (0.4-7.4)</td>
</tr>
<tr>
<td><strong>Ivory Soap Washed Skin</strong></td>
<td>5.4 (3-11)</td>
<td>20 (10-40)</td>
<td>29 (15-58)</td>
</tr>
</tbody>
</table>

Mean (µg/dL) and 25th and 75th percentile values shown in parentheses.
Discussion and Recommendations

- *In vitro* skin penetration protocol designed to mimic *in vivo* exposure, but is not perfect.
  - Skin in prolonged hyperhydrosis state
  - Skin loading was high compared to field results

- Risk analysis included wash data, for intact skin, but:
  - Most people wash repeatedly each day
  - Penetration in damaged skin model much higher and most workers have some skin damage
Conclusions

- 2 studies have previously indicated penetration of skin by Pb particles.
- Effective decontamination of skin is necessary to remove toxic hazard.
- Decontamination by common soap can significantly increase skin penetration.
- Safe and effective removal of Pb from skin is possible with specially designed cleansers.
Acknowledgements

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- Kevin Ashley, CEMB, NIOSH