

Modeling of Blood Lead Levels in Astronauts Exposed to Microgravity-Accelerated Bone Loss

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Abstract: Human exposure to lead has been associated with toxicity to multiple organ systems. Studies of International Space Station (ISS) crew members have demonstrated that lead exposure results in a net loss of bone lead levels from periods of microgravity exposures compared to those on Earth. This study used a PBPK model of lead metabolism to evaluate the potential contributions of lead released from bones during long-duration spaceflights to the bone lead levels observed in astronauts. The model predicted that in 2030 (the earliest potential launch date for a long-duration mission), the average blood lead level (PbB) was expected to be 1.5 µg/dL. However, in-flight PbB levels would depend on factors such as pre-launch blood lead levels, the rate of bone loss, and the concentration of lead in water consumed at a rate of 2.8 L/day. A PbW of 9 μg/L was chosen based on published rates reported for average PbWs at the International Space Station (ISS). The model predicts that in 2030 (the earliest potential launch date for a long-duration mission), the average PbB would be 1.5 µg/dL.

Materials and Methods: A recently published PBPK model (Garcia, Tsuji, and Hays, 2003) of the effects on PbB and bone lead concentration was used to evaluate the potential contributions of lead released from bones during long-duration spaceflights to the bone lead levels observed in astronauts. The model predicts that in 2030 (the earliest potential launch date for a long-duration mission), the average PbB would be 1.5 µg/dL.

Results: The model predicts that in 2030 (the earliest potential launch date for a long-duration mission), the average PbB was expected to be 1.5 µg/dL. However, in-flight PbB levels would depend on factors such as pre-launch blood lead levels, the rate of bone loss, and the concentration of lead in water consumed at a rate of 2.8 L/day. A PbW of 9 μg/L was chosen based on published rates reported for average PbWs at the International Space Station (ISS). The model predicts that in 2030 (the earliest potential launch date for a long-duration mission), the average PbB would be 1.5 µg/dL.

Conclusions: The model predicts that in 2030 (the earliest potential launch date for a long-duration mission), the average PbB was expected to be 1.5 µg/dL. However, in-flight PbB levels would depend on factors such as pre-launch blood lead levels, the rate of bone loss, and the concentration of lead in water consumed at a rate of 2.8 L/day. A PbW of 9 μg/L was chosen based on published rates reported for average PbWs at the International Space Station (ISS). The model predicts that in 2030 (the earliest potential launch date for a long-duration mission), the average PbB would be 1.5 µg/dL.

Table I. The effects of PbB at launch, PbW, and rate of bone loss on maximum inflight PbB

<table>
<thead>
<tr>
<th>Scenario</th>
<th>PbB at Launch (μg/dL)</th>
<th>PbW (μg/L)</th>
<th>Rate of Bone Loss (%)</th>
<th>PbB at 1000 Days (μg/dL)</th>
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<tbody>
<tr>
<td>Scenario 1</td>
<td>1.5</td>
<td>9</td>
<td>0.5</td>
<td>1.73</td>
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<tr>
<td>Scenario 2</td>
<td>1.5</td>
<td>9</td>
<td>1.0</td>
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<td>Scenario 3</td>
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<td>6.92</td>
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<td>Scenario 4</td>
<td>1.5</td>
<td>9</td>
<td>3.0</td>
<td>10.32</td>
</tr>
</tbody>
</table>

Note: PbW = Pb in water; PbB = Pb in blood; Pb = lead; μg/dL = micrograms per deciliter; μg/L = micrograms per liter; % = percent; μg Pb/g = micrograms of lead per gram; µg Pb/L = micrograms of lead per liter; SWEGs = Space Station Environmental Guidelines; SWIRG = Space Station Interface Radiation Guidelines; Pb = lead; B = bone; SWEGs = Space Station Environmental Guidelines; SWIRG = Space Station Interface Radiation Guidelines; Pb = lead; B = bone.

Figure 1 illustrates the contribution of PbB values of 0.5, 1.0, 2.0, and 3.0 percent of total bone minerals per month, and lead in water (PbW) concentrations of 0, 0.5, 1.0, 2.0, or 3.0 percent of total bone minerals per month, and lead in water (PbW) concentrations of 0, 0.5, 1.0, 2.0, or 3.0 percent of total bone minerals per month. The effects on the concentration of lead in bones (PbB) were assessed using a PBPK model of lead metabolism. The model predicts that in 2030 (the earliest potential launch date for a long-duration mission), the average PbB would be 1.5 µg/dL.

Figure 2 illustrates the effects on PbB of various concentrations of lead in drinking water (μg/L): PbW = Pb in water; PbB = Pb in blood; μg Pb/L = micrograms of lead per liter; ΔPbB = increase in PbB; μg Pb/g = micrograms of lead per gram; μg Pb/L = micrograms of lead per liter; % = percent; μg Pb/kg = micrograms of lead per kilogram; Pb = lead; B = bone; SWEGs = Space Station Environmental Guidelines; SWIRG = Space Station Interface Radiation Guidelines; Pb = lead; B = bone.

Note: PbW = Pb in water; PbB = Pb in blood; Pb = lead; B = bone; SWEGs = Space Station Environmental Guidelines; SWIRG = Space Station Interface Radiation Guidelines; Pb = lead; B = bone.

Figure 3 illustrates the contribution of PbB values of 0.5, 1.0, 2.0, and 3.0 percent of total bone minerals per month, and lead in water (PbW) concentrations of 0, 0.5, 1.0, 2.0, or 3.0 percent of total bone minerals per month. The effects on the concentration of lead in bones (PbB) were assessed using a PBPK model of lead metabolism. The model predicts that in 2030 (the earliest potential launch date for a long-duration mission), the average PbB would be 1.5 µg/dL.

Note: PbW = Pb in water; PbB = Pb in blood; Pb = lead; B = bone; SWEGs = Space Station Environmental Guidelines; SWIRG = Space Station Interface Radiation Guidelines; Pb = lead; B = bone.

Figure 4 illustrates the contributions of PbB at launch, PbW, and rate of bone loss on maximum inflight PbB. The effects on the concentration of lead in bones (PbB) were assessed using a PBPK model of lead metabolism. The model predicts that in 2030 (the earliest potential launch date for a long-duration mission), the average PbB was expected to be 1.5 µg/dL. However, in-flight PbB levels would depend on factors such as pre-launch blood lead levels, the rate of bone loss, and the concentration of lead in water consumed at a rate of 2.8 L/day. A PbW of 9 μg/L was chosen based on published rates reported for average PbWs at the International Space Station (ISS). The model predicts that in 2030 (the earliest potential launch date for a long-duration mission), the average PbB would be 1.5 µg/dL.

Note: PbW = Pb in water; PbB = Pb in blood; Pb = lead; B = bone; SWEGs = Space Station Environmental Guidelines; SWIRG = Space Station Interface Radiation Guidelines; Pb = lead; B = bone.

Figure 5 illustrates the contribution of PbB values of 0.5, 1.0, 2.0, and 3.0 percent of total bone minerals per month, and lead in water (PbW) concentrations of 0, 0.5, 1.0, 2.0, or 3.0 percent of total bone minerals per month. The effects on the concentration of lead in bones (PbB) were assessed using a PBPK model of lead metabolism. The model predicts that in 2030 (the earliest potential launch date for a long-duration mission), the average PbB was expected to be 1.5 µg/dL. However, in-flight PbB levels would depend on factors such as pre-launch blood lead levels, the rate of bone loss, and the concentration of lead in water consumed at a rate of 2.8 L/day. A PbW of 9 μg/L was chosen based on published rates reported for average PbWs at the International Space Station (ISS). The model predicts that in 2030 (the earliest potential launch date for a long-duration mission), the average PbB would be 1.5 µg/dL.