# Safety assessment for potential target materials: radioactivity vs. chemical toxicity

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# Hg and Pb are potential high-Z materials for hohlraum fabrication

- Indirect-drive targets for future IFE power plants will require high-Z materials for production of x-rays
- Selection of materials must include many different factors such as target performance, cost, extraction, compatibility, and S&E issues
- Several reasons support the use of Hg and Pb for target fabrication:
  - previous safety work showed that both met radiological criteria
  - economical advantage in using any of these materials instead of the traditional gold-gadolinium cocktail
  - both materials seem to be appropriate for feasible target production
  - recent work on flibe coolant clean-up system presented respective cost-efficient solutions for Hg and Pb
- However, other important aspects that must be addressed before final selection of one particular candidate

# Compatibility with the stainless steel structures needs to be addressed

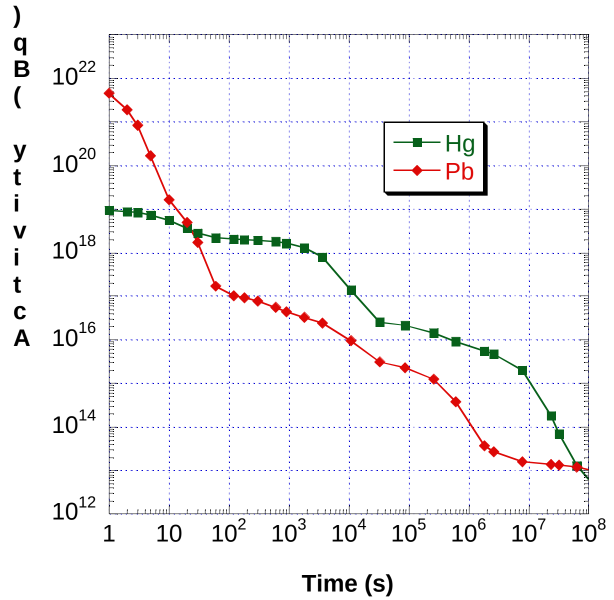
- Use of low carbon SS-304 (SS-304L) has been proposed to prevent corrosion of chamber and piping (creep fatigue tests are needed)
- Highly strained components might be designed to have a shorter lifetime or to support a lower stress
- When comparing corrosion issues there does not seem to be a big advantage of one material over the other
- However, maintenance of structures seems to be more difficult in the case of Pb (expected to precipitate and build up inside pipes)

# Previous work has focused in the radiological safety area

- Previous analysis showed that Hg and Pb meet the criteria for contact dose rate, waste disposal rating and accident dose

- We have re-evaluated the accident dose considering conservative weather conditions

- In order to achieve the 1-rem goal, the release of Hg must be limited to **4.2 kg**
  - from the target fabrication facility perspective, this is ≈ 100% release of a 1-hr supply
  - regarding accidents in the coolant circuit (Hg inventory is 0.17 kg), any release results in insignificant doses to the public




- In the case of Pb, a **20 kg** release would result in 1-rem
  - considering the Pb inventory at the target fabrication facility, this is equivalent to 100% release of a 4.5-hr supply
  - from the primary coolant loop perspective this is ≈ 1% of the total Pb inventory (1740 kg)

# Chemical toxicity issues from the use of Hg and/or Pb have yet to be addressed

- Whereas past work has only looked at radiological consequences of an accident, potential chemical exposure could be a critical issue
- This work is a preliminary assessment trying to compare radiological versus toxicological consequences of Hg and Pb accidental releases
- We have adopted the **TEEL-2** as the criteria at which protective actions will be taken and calculated air concentrations (4.5 m/s windspeed, D stability class at 100 m distance as recommended by DOE Standard 1027)

| Substance | TEEL-0 | TEEL-1 | TEEL-2 | TEEL-3 | NIOSH IDLH |
|---|---|---|---|---|---|
| Elemental Hg and inorg. compounds | 0.025 | 0.025 | 0.1 | 10 | 2 |
| Mercurous oxide | 0.025 | 0.025 | 0.1 | 10 | 2 |
| Mercuric oxide | 0.025 | 0.025 | 0.1 | 10 | 2 |
| Elemental Pb and inorg. compounds | 0.05 | 0.15 | 0.25 | 100 | 100 |
| Lead dioxide | 0.05 | 0.15 | 0.25 | 100 | 100 |
| Lead oxide | 0.05 | 0.05 | 0.05 | 100 | 100 |

Units are mg/m$^3$

# We have performed air dispersion calculations to assess chemical exposures

- We have used the standard dispersion equation backward from the limit concentration at the point of interest to estimate the amount of material released: $C = Q / \pi * \sigma y * \sigma z * u$

- In the case of Hg, a release of **56 mg/s** would reach the value specified by TEEL-2

- For Pb, the smaller value of TEEL-2 would limit the allowed release rate to **28 mg/s**

- We have combined these results with the evaporation model from the ALOHA (Areal Locations of Hazardous Atmospheres) code to determine the radius of the evaporating pool that would match those rates

- We have obtained that the maximum allowed release rates would be reached through evaporation at normal temperature from a **13 m** radius Hg pool and **440 km** radius Pb pool, respectively

# ALOHA was used to analyze the releases from the radiological assessment

- Finally, we used ALOHA to simulate an instantaneous release of 4.2 kg of Hg gas and 20 kg of Pb gas
- Assumptions include 4.5 m/s windspeed, D stability class, 100 meters distance from the release point, as recommended by DOE Standard 1027
- We estimate a peak concentration of Hg of **140 $mg/m^3$** about 3 minutes after the moment of the release
- In the case of lead, the concentration peaks at about **450 $mg/m^3$**
- This values exceed the TEEL-2 limits by several orders of magnitude, however, we are (very) conservatively assuming that all the mass is directly released as a gas

# Conclusions (I)

- From the S&E perspective, one must consider two different kinds of toxicological hazards when deciding on appropriate target materials: **radioactivity** of activated materials and **chemical toxicity**
- Activation results show that both Hg and Pb classify as adequate when analyzing the contact dose rates and waste disposal rating
- Regarding radioactivity releases from accidents at the target fabrication facility, Hg is the most hazardous; however, segregation of the inventory in the plant would make the 1-rem limit goal achievable
- In case of accidents involving the power plant primary coolant loop, Pb seems to pose a greater radiological hazard due to its higher inventory suspended in the coolant flow

# Conclusions (II)

- The chemical assessment shows that due to the similar values of the TEELs, neither material is an obvious candidate
- Release rates of several mg/s would reach the TEEL-2 limit at 100 m for both Hg and Pb assuming that they were released in gaseous form
- The high volatility of Hg presents it as a more hazardous option given its high saturation concentration in air at normal temperatures
- If either material is released at a rate deemed to be acceptable from a radiological point of view, the peak concentrations would exceed the TEEL-2 limits by several orders of magnitude → additional work is needed to assess the acceptability of time-integrated results (TEEL-2 limits are intended for a 15-minute exposure)
- ***For lead and mercury the chemical toxicity seems to be the key issue from the S&E point of view. Further investigation is needed.***