Toxic Inhalation Exposure Combustion Products CLIFF Peer Review

1. *Strength of evidence presented in CLIFF in modeling the characteristics and mission impact of this medical condition within the spaceflight environment?*

   Score: 3

   Grading Scale:

   4 - Confident

   3 - Somewhat confident

   2 – Neutral

   1 – Somewhat unconfident

   0 – Not confident

2. How confident are you that these data accurately represent the spaceflight environment?	*Tables 1, 2* *Composite Incidence and Level of Confidence*	*Table 3, 4 BC/WC* *Loss of Crew and probability*	*Table 4 - Clinical Phase 1, 2 durations* *Table 5 – CP 2 Loss of Crew*	*Table 4 – RTDC %* *Table 6 – RTDC Loss of Crew*	*Table 4 – Loss of Crew Life %* *Table 7 – Loss of Crew Life, Loss of Crew*	*Table 8 – TI*
Score	*3*	*2*	*3*	*3*	*2*	*3*

Comments and limitations:

1. **General comments.** This CLiFF describes toxic inhalation exposure from the products of combustion during or after a fire that occurs onboard a space vehicle. The toxic inhalation can result in inflammation, thermal damage, hypoxemia and pulmonary irritation. Predicting the incidence of toxic inhalation from fires during spaceflight without knowledge of the exact combustible substances carried on board is difficult. The risk also depends on the engineering safeguards built into the system to mitigate the risk of exposure. This CLiFF excludes toxic inhalation of materials other than those generated by smoke and by respiratory failure as these conditions are covered in other CLiFFs. Toxic dermal exposure is covered in ICL 109. There have been 3 smoke exposures from fires that have been documented in the spacecraft literature. As these occurred on spacecraft that will not be used on exploration missions, the best data comes from the ISS PRA model. While this will be an overestimate given the much larger size of ISS, it is the best approximation that is available. The best case is considered to be an inhalation of combustion products resulting in direct toxic damage to tissue or interference with enzymatic processes, excluding cyanide, responding to supportive treatment. The worst case is an Inhalation of combustion products resulting in direct toxic damage

to tissue or interferes with enzymatic processes, including cyanide, requiring additional treatment. ARDS/Respiratory failure are covered by condition "Respiratory Failure.

2. **Incidence.** There have been several incidents of inhalation of toxic substances due to fires during spaceflight. However, these events happened on older spacecraft. To calculate the incidence, the ISS Fire PRA was used to compute the environmental exposure to the crew from a fire within the spacecraft or habitat. Using this risk assessment, 0.00904 events were predicted per year. Given that the Artemis vehicles/habitats are expected to be fairly small, the probability that each crewmember would be affected was taken as 1.0. It is expected that this will result in a small overestimation of the true incidence given that ISS is a much larger spacecraft than those to be used on Artemis. The incidence of a toxic inhalation due to combustion products is dependent on the materials used during the specific spaceflight and may vary widely from the estimated incidence here. The best case/worst case probabilities used data from a study of residential fires that found that 5.9% of those affected by smoke inhalation required hospitalization. The BC/WC split of 94%/6% was estimated based on this analysis. The clinical phase durations, RTDC and Loss of crew life probabilities are supported by terrestrial evidence, expert opinion, and the BC/WC definitions, and I am in agreement with their calculation. The probability density curve that was derived appears to be a reasonable representation of the data presented.

3. **Clinical phase data**. I am in agreement with the clinical phase 1 duration entered in this CLIFF. This data was compiled by a team of expert clinicians, and I was involved in the discussions leading to the calculation of the clinical phase duration. CP2 was supported by terrestrial evidence.

4. **Task impairment**. The analysis was performed and reviewed by a separate team of expert clinicians. I am aware of the methods that were used but did not directly participate in the discussions.

5. **Dependence on mission phase or duration of mission**. This medical condition is not dependent on mission phase but exposure to toxic combustion products may be greater during certain times such as the performance of scientific experiments or during maintenance/repair of onboard systems.

6. **Limitations**

- The estimated incidence is dependent on the specific materials that will be carried onboard. Current vehicle and habitat designs are still being finalized and tested. Depending on the exact nature of hazardous substances on board and the engineering safeguards built in, the incidence may vary widely from mission to mission.
- Since all smoke-related events occurred on older vehicles (MIR, for example), an updated fire PRA for ISS was used to calculate incidence. Since ISS is a larger vehicle than the Artemis spacecraft/habitats, this is likely to be an overestimation of the true fire risk.
- There is likely to be some overlap with ICL 110 Toxic Inhalation since part of the evidence used in developing the output parameters was from exposure to substances such as NO2 which are covered in ICL 110.
- This medical condition is not dependent on mission phase but exposure to toxic combustion products may be greater during certain times such as the performance of scientific experiments or during maintenance/repair of onboard systems.

Reviewed by:

David C. Hilmers