

A CAUTIONARY TALE ABOUT VOLATILE-RICH CARBONACEOUS CHONDRITES.

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Introduction: The parent asteroids of volatile-rich carbonaceous chondrite meteorites, for example Tagish Lake (C2), Murchison (CM), Orgueil (CI), have major components of water, OH-rich clays, as well as a few weight percent complex carbon compounds. These materials have substantial potential for in-situ resource utilization (ISRU) and may be a key resource for future exploration architectures. A number of studies are underway to design and test ISRU approaches, and to develop engineering and chemical simulants for these types of meteorites. However, the carbon compounds in these meteorites are primarily in the form of polycyclic aromatic hydrocarbons (PAHs) [1,2]. PAHs can be considered the residue of incomplete combustion or thermal processing of organic material. They are characterized by multiple ring structures where carbon atoms outnumber hydrogen atoms. While PAHs are common in the environment and can be often found in settings such as barbecue grills, it is useful to remember that many species of PAHs are either toxic or carcinogenic or both. For example the following PAHs have been detected in carbonaceous chondrites and are listed with a brief description of their toxic hazards [1,2,3].

Naphthalene: The active ingredient of moth balls. With inhalation exposure it affects red blood cells creating all the symptoms of hemolytic anemia. Banned in the European Union. Partially banned in California.

Biphenyls: Mildly toxic. Banned in California.

Acenaphthalene: Nonindustrial indoor and outdoor air pollutant. Carcinogenic and produces hemolytic anemia destroying red blood cells. In animals creates lung tumors. Regulated by the Environmental Protection Agency as an air contaminant.

Phenanthrene: Inhalation toxicity, severe skin allergen.

Anthracene: Toxicant, classified as dangerous substance with strict regulations, and decreasing exposure limits.

Fluranthene: EPA high priority as pollutant, highly carcinogenic to most animals.

Pyrene: Carcinogenic with rapid skin absorption. Target organs are liver, blood, and kidney. Highly mutagenic in animals.

Benzofluranthenes: On the list of Special Health Hazard substances due to carcinogenic effects by OSHA, CDC, NIOSH, EPA. Severe risk for human, animal, and environmental toxicity. Produces cancer in lung, liver, skin and has a low exposure limit as a reproductive health hazard.

Conclusions: The effective toxicity risk of PAHs in carbonaceous chondrites will be a function of the species abundance in individual meteorites and will probably be a research topic for future toxicology studies. However, the existence of PAHs in the resource feedstock on asteroids and their toxicity will need to be factored into the design of ISRU extraction hardware, the experimental design of any testing and processing using meteoritic material, and as well as the development of engineering and chemical analogs for asteroidal material.

References: [1] Yabuta H , et al. 2007 *Meteoritics & Planetary Science* 42, 37-48 () [2] Pizzarello S et al. 2001. *Science* 293, 2236-2239. [3] The National Institute for Occupational Safety and Health (NIOSH), cdc.gov/niosh.