Technical Bulletin - #310704
Occupational Safety & Health

Fuels & Solvents Exposure

Dermal and respiratory exposure to hazardous chemicals in the workplace is an important occupational hygiene issue and a growing field of interest to health professionals. Toxicological studies of military-grade fuels have demonstrated exposure to high levels of Jet Propellant Type 8 (JP8) via either dermal contact or inhalation may result in adverse neurologic, immunologic, dermatological, cytotoxic, and genotoxic effects in animals. Similarly, if worker health is impacted by jet fuel, those working with JP8 could be expected to report more illness symptoms than those who do not work with jet fuel.

Within the last few years several studies have been commissioned as a result of an increase in health-related complaints from US military personnel who are exposed to military-grade fuels on a regular basis. Complaints range from dizziness, nausea, headaches, skin irritations and blisters, heart palpitations, forgetfulness, trouble concentrating, difficulty breathing, general weakness, and difficulty gripping objects, among others. Those individuals included in the studies that were classified in the “HI” and “MOD” categories of exposure levels generally reported more symptoms than those in the “LOW” category.

These studies included a battery of test protocols to see what effects, if any, exposure to JP8 throughout the course of their day-to-day assigned duties would have on workers. JP8 exposure was measured both externally in the environment immediately surrounding personnel enrolled in the studies and internally through the use of several body burden measures. The tests included, among others, blood sampling, urine sampling, skin exposure sampling, breath analyses in order to determine what amounts of benzene and naphthalene, (two key components of JP8), might be present after acute (short-term) exposure to JP8.

Discussion

(1) – Dermal Exposure to JP8 – The test consisted of a validated, non-invasive tape-stripping technique to determine JP8 contamination in the skin. This technique removes the upper layers of the stratum corneum (dead skin cell layers) using successive tape stripping with an adhesive tape, which allows for determination of the quantity of JP8 retained in the skin following exposure. Naphthalene was measured as a marker for jet fuel exposure.

Final results indicated a wide range of exposures (5 orders of magnitude) among all of the test groups and demonstrated the effectiveness of the tape-stripping technique as a method for measuring contamination on the skin.

The tests left little doubt that JP8 is able to penetrate the stratum corneum. Further analysis of the test data is aimed at shedding light upon the amount actually absorbed into and through the skin, and what amounts will contribute to the total body dose.

(2) – JP8 in Blood – Each test subject was required to provide pre and post exposure blood specimens for testing. A procedure recommended for summing the nonane, decane, and undecane and dodecane concentrations into a single value representing the JP8 "fingerprint" in blood was used. The range of exposure values between all test subjects in the "HI" exposure category was very large, which indicated a need for further investigation into the specific types of JP8 exposure.

Further study of this method of establishing JP8 body burden is required due to the wide variations observed in the specimens analysed, but blood data is considered a useful indicator for aggregate JP8 exposure because it represents exposures from multiple routes, including dermal and inhalation.

(3) – Total Body Burden of JP8 – Human exposure assessment to volatile organic chemicals (VOCs) is an important subset of the overall requirements for characterizing risk from environmental pollutants. Breath is preferable to blood as a biological medium for VOC exposure because collection is non-invasive, is relatively simple, and does not generate potentially infectious waste. Breath directly reflects the blood VOCs concentration; this is the basis of the police "breathalyser" test for ethanol inebriation where a breath measurement is interpreted as a "blood alcohol" level.

Breath samples were collected from "exposed" test subjects prior to and after the nominal exposure period. Knowledge of the composition of the jet fuel allowed for the analytical system to be calibrated externally to allow for quantitative determination of key constituents of fuel expected to be found in the breath samples. Specifically, these were single-ring aromatic hydrocarbons (benzene, toluene, ethylbenzene, m,p-xylene, o-xylene, 4-

ethyltoluene, 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene, and styrene) and C_4 to C_{12} n-alkanes. (Naphthalene, as a major aromatic component of JP8, is present at about 0.26%).

A wide variation in concentration levels was recorded in one study, ranging from 1 ppbv (part per billion by volume) to as high as 1250 ppbv. Factors contributing to these variances imply that fuel components may be much more variable than originally expected, may be partly attributed to subject behavioural differences or to differences in the assigned tasks at each base tested.

In another study the median concentrations of both **benzene** (a known carcinogen) and **naphthalene** in air among the moderate exposure category was significantly higher than those in the low exposure category. Those test subjects from the high exposure category recorded concentrations **30 – 40 times higher** than the moderate group. Health effects are believed to be more closely related to body burden than to external concentrations and concentrations in breath are thought to more accurately represent body burden.

Breath analysis is a useful indicator for aggregate exposure because it represents both **dermal** and **inhalation** exposure routes. Concentrations of the unchanged parent compound in exhaled air reflect the actual amount of body burden derived from all routes and sources of exposure and account for individual differences in physiology and work practices. Concentrations of naphthalene were higher than concentrations of benzene in air, but lower in breath, demonstrating that the lower volatility and higher blood: air partition coefficient of naphthalene reduced that amount excreted in breath relative to benzene.

The study recommends further investigation be undertaken with respect to those test subjects who recorded the highest exposure levels, in order to see if there are **changes that can be made to their work practices to reduce the amount of their exposure.**

(4) – Biomarkers of Acute Exposure to JP8 – This test protocol investigated the use of urinary benzene, naphthalene, and hydroxynaphthalene as possible biomarkers of acute (short-term) exposure to JP8. Of the hundreds of discrete chemicals in JP8, naphthalene and benzene are important aromatic constituents, which have been suggested as surrogate markers of JP8 exposure.

Naphthalene and benzene have rapid elimination kinetics. Following inhalation, these compounds are absorbed into the blood. Some of the internal doses of these compounds are eliminated unchanged in breath and urine, while the remainder is metabolized to products that are excreted in urine. Spot urine samples collected at the end of the work-shift reflect exposure to benzene and naphthalene within the same day.
Urine samples were collected prior to and at the conclusion of the work shift.

Test results demonstrated a relationship between levels of airborne and urinary benzene and naphthalene, which confirmed a single trend among exposed subjects ("HI") that does not exist among the control group ("LOW"). Measurements of urinary analytes in samples obtained at the end of the work shift were significantly correlated among high-exposed subjects but not among low-exposed subjects.

These results indicate that there is a common source of exposure to benzene and naphthalene during the work-shift among exposed subjects. It is reasonable to conclude that the source of exposure was JP8.

<u>Conclusions</u>

(1) – Based upon the data obtained from the studies listed above, and from questionnaires distributed to jet fuel exposed participants, many strongly believe their job is impacting upon their health.

(2) – The findings of the various studies support the need for improved risk communication regarding jet fuel, improved work practice guidelines, and further research into enhanced **<u>personal protective equipment.</u>**

(3) **–** Test participants routinely exposed to JP8 worked in positions such as Aircraft Fuel Cell Maintenance, Fuels Specialty or Fuels Transportation Shops. All of the studies conducted confirmed that JP8 is entering test subjects bodies through dermal and respiratory means.

<u>Improvements to Work Practices using Best Available Technology</u>

The long-term effects of exposure to JP8, and other VOCs, has yet to be determined but in the meantime the prudent course of action would be to minimize the amount of exposure military personnel are subjected to in as many ways as is possible and practical.

Adsorbents – Leaks and spills of fuels and solvents are typically cleaned up at military bases with ***"<u>ad</u>sorbents"*** such as polypropylene pads and granular mineral products. The mechanism of adsorption relies upon a liquid **"coating the surface"** of a matted fibre or granule, and **"surface area"** is a critical component of these materials' performance.

While **<u>ad</u>**sorbents are generally very quick to pick-up fuels and solvents, because the liquid is simply sitting upon the surface of the material they also tend to re-release an amount of their contents just as quickly, either through simple gravity or in the presence of water. This in turn leads to **<u>secondary contamination</u>** of the environment and perhaps more importantly in light of the information contained above, increases the risk that personnel will also come into direct contact with the spilled fuel.

<u>This provides a potential entry path for fuel through the exposed dermal layer.</u>

In addition, because the liquid is only coating a surface it remains as a "liquid" on adsorbent materials such as polypropylene mats and pads. When liquids with aromatic compounds, such as the benzene and naphthalene found in JP8, are present these materials actually enhance the "rate" at which hazardous vapours are released. This means that concentrations in air rise dramatically when adsorbents are applied to leaks and spills, which in turn increases the amount of hazardous vapour available to be inhaled by responding personnel.

<u>This increases the risk to personnel by optimizing the opportunity for respiratory entry of JP8 vapours.</u>

Absorbents – Imbiber Beads® are reputed to be the ***<u>only</u>*** product currently available that meets ASTM Performance Standards for ***"Absorbents"***, when organic liquids such as fuels and solvents are involved. The US Air Force recognized that Imbiber Beads® are fundamentally different from other sorbent materials as a result of their nine month evaluation of the technology through the Management Equipment Evaluation Program – MEEP.

Referencing Imbiber Beads® performance the MEEP Report states that ***"The ability to capture and contain a free phase liquid is without equal, in most cases".***

Imbiber Beads® differ from other sorbent materials in that instead of simply sitting upon the surface of Imbiber Beads® liquids are absorbed **"into the structure"** of the Imbiber Beads®, which causes them to **"swell"** up to three times their original size. (It is the swelling characteristic that differentiates Imbiber Beads® from materials like polypropylene and "kitty litter").

The "swelling" characteristic provides physical evidence that the liquid has combined with the Imbiber Beads® and is **no longer available as a liquid.** The elimination of the **free liquid**, as referenced by USAF MEEP, eliminates the possibility of secondary contamination as there is no longer any liquid available to leak or drip out of the Imbiber Beads®.
This in turn eliminates the possibility of personnel responding to a leak or spill with Imbiber Beads® being contaminated with JP8 or some other solvent through dermal exposure.

Similarly, the use of Imbiber Beads® to capture and contain fuel and solvent releases drastically **reduces** the **"rate"** at which hazardous vapours are released by eliminating the free liquid phase. The rate of reduction of hazardous vapour release is 500 – 600% less than polypropylene pads or kitty litter. This means that the concentration in air of JP8 vapours at the point where Imbiber Beads® are applied is significantly reduced.

This in turn reduces the risk of vapor contamination through respiratory channels to personnel. In addition, the reduction of fire supporting vapours also makes the area impacted by the fuel or solvent release safer.

The use of absorbents (instead of adsorbents) is a simple, practical, effective and responsible measure, which can and should be implemented immediately in order to reduce the short and potentially long-term adverse health effects of exposure to fuels and solvents on military personnel. Imbiber Beads® represent the **Best Available Technology** for the applications described, and their use represents **Best Management Practices** for **occupational safety and health.**

Note: A portion of the information contained within this Technical Bulletin was excerpted from several studies hosted by Texas Tech University, Institute of Environmental and Human Health, and the US Air

Force, with funding from Strategic Environmental Research Program, which represented the final report of preliminary results of the protocol to assess the health and performance effects of acute exposure to JP8. Additional collaborating institutions for this protocol, referred to as the JP8 Research Team, included University of Cincinnati, Oregon Health Sciences University, University of Texas, University of North Carolina, John Hopkins University, and the US Navy Toxicology Laboratory.

Reference to any of these institutions is not to be construed as an endorsement or acknowledgement of any kind as to the suitability of Imbiber Beads® products for any application. Suitability for any Imbiber Beads® applications described within the text of this Bulletin must be determined by those persons considering their use on a product-to-product basis. Accordingly, any research data referenced within the text of this Technical Bulletin was subject to the interpretation of Imtech America, Inc. and no affiliation between the institutions described above or their research is implied or inferred.

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