TOXICOLOGY

POINTS OF CONTACT
Seabees have no organic Industrial Hygiene (IH) support. In all cases, such support must be requested from Naval Hospitals and/or Fleet support assets. Force Service Support Groups (FSSG) have IHs assigned and are a resource when supporting Marine Corps operations. IH support is generally not a problem in forward deployed sites, but remote and DFT sites require some advance notice (and funding) to get an IH on site in a timely fashion.

If for some reason, these sources are unavailable, or unable to meet your needs, contact the nearest Environmental Preventive Medicine Unit (EPMU).

- EPMU-2 Norfolk, VA
- EPMU-5 San Diego, CA
- EPMU-6 Pearl Harbor, HI
- EPMU-7 Naples, IT

GENERAL
For those not familiar with some of the terms used in IH and Occupational medicine, the following discussion will introduce some of those terms, and provide a general overview of most of the chemical hazards that may be encountered in naval operations.

TOXICOLOGIC EVALUATION
The toxicity of a substance not only depends on the substance itself, but also upon the dose and the duration of exposure. Simultaneous and consecutive exposure to more than one chemical may result in additive, synergistic, or potentiated effects. Likewise, chemical antagonism, functional antagonism, competitive antagonism, and noncompetitive antagonism may be factors to consider. Toxicologic evaluation involves several concepts which must be defined. Risk denotes the probability (expected frequency) that a chemical will produce undesirable effects under specified conditions. NEL (no effect level) is the maximum dose that has not induced any sign of toxicity in the most susceptible species of animals tested and using the most sensitive indicator of toxicity (not applied to carcinogens). There is no threshold defined for carcinogens because cancer cells can be induced by a single change in the cellular genetic material and they are self-replicating.

The dose-response relationship is graphically displayed by plotting the frequency of an event vs. the dose on a log scale, which results in a sigmoid-shaped curve. The portion of this curve between 16-84% response is nearly linear and represents one standard deviation each direction from the mean. The LD$_{50}$ is also utilized to classify the toxicity of substances, as demonstrated in the following:
<table>
<thead>
<tr>
<th>Category</th>
<th>LD&lt;sub&gt;50&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supertoxic</td>
<td>5 mg/kg</td>
</tr>
<tr>
<td>Extremely toxic</td>
<td>5-50 mg/kg</td>
</tr>
<tr>
<td>Highly toxic</td>
<td>50-500 mg/kg</td>
</tr>
<tr>
<td>Moderately toxic</td>
<td>0.5-5 g/kg</td>
</tr>
<tr>
<td>Slightly toxic</td>
<td>5-15 g/kg</td>
</tr>
<tr>
<td>Practically non-toxic</td>
<td>15 g/kg</td>
</tr>
</tbody>
</table>

Duration and frequency of exposure are also important parameters:

Acute exposure = an exposure of 24 hours. Subacute exposure = repeated exposure over one month. Subchronic exposure = exposure occurring over 1-3 months. Chronic exposure = over 3 months.

Toxic substances may be excreted as the parent chemicals, as metabolites, or as conjugates. Generally, when xenobiotic metabolism results in more polar chemicals, they are more readily excreted by the kidneys. However, in some cases, the metabolite is more toxic (termed bioactivation).

Conjugation reactions are of several types, including glucuronide formation, sulfate conjugation, methylation, acetylation, amino acid conjugation, and glutathione conjugation. Glucuronide formation is the most common and important.

Adipose tissue presents a storage depot for lipid-soluble substances, which are often released slowly over longer periods of time.

**Major Routes of Exposure**
Inhalation is the most important in industry. Ingestion is most important in civilian exposure, least important in industry. Percutaneous is rare and seldom serious unless one is exposed to significant concentrations of insecticides or chemical warfare agents.

**Types of Hazardous Substance Exposure Controls**
- **Substitution.** This implies using a less hazardous material, however, the substituted material seldom works either as well or as cheaply. Substitution is the best type of control.
- **Engineering controls.** This involves placing a permanent barrier between man and the hazard. It can be simple or it can be very expensive. Engineering controls are the next best type of control.
- **Personal protective devices.** These are self-donned temporary barriers. They often work well, however, a sizeable number of workers simply cannot be relied upon to use the devices.
• **Administrative controls.** This entails setting limits, or educating those who may be exposed. Although important, it is the most difficult of the controls to enforce and should not be relied upon routinely.

### GLOSSARY

**PEL - Permissive Exposure Limit**

The maximum permissible concentration of a toxic substance (averaged over eight hours) to which an employee may be exposed, by directive. A legal limit that takes into account both chronic and acute effects.

**TLV - Threshold Limit Value**

A time weighted average exposure over an eight hour day, five day week, from which no acute ill effects occur. Excursions above the TLV are permitted if properly compensated with appropriate times below the TLV. This is a practical limit developed by industry prior to OSHA which takes into account only acute effects and contains a generous safety factor.

**TLV-C - Threshold Limit Value - Ceiling**

A value not to be exceeded even briefly.

**STEL - Short Term Exposure Limit**

A legal fifteen minute time limited exposure which may not be exceeded.

**OSHA - Occupational Safety and Health Administration**

A Federal Bureau and a political organization empowered to enforce Federal Safety Standards. It was organized in 1970.

**NIOSH - National Institute of Occupational Safety and Health**

Responsible for research, development and publishing of standards. This is a scientific organization.

**ACGIH**

American Conference of Governmental Industrial Hygienists.

**Carcinogenesis**

The ability to induce malignant neoplasm. Harms a single individual. Effects this generation.

**Mutagenesis**

The ability to change genetic material. Harms the succeeding generations.

**Teratogenesis**

The ability to cause birth defects by direct effects on the fetus. Harms the next generation.
Vapor
The gaseous phase of a material which is mostly solid or liquid at room temperature. (eg. gasoline)

Aerosol
A dispersion of particles, either solid or liquid, of microscopic, size in a gaseous medium.

Mist
An aerosol of suspended liquid droplets (eg. fog)

Fume
An aerosol of solid particles (0.1 microns or less) generated from condensation from a gaseous state, usually after volatilization from metals (as a cutting torch on lead).

Smoke
An aerosol of carbon particles (0.1 microns or less) of very small size mixed with droplets of various things.

Dust
An aerosol of solid particles of 0.1 to 5.0 microns (eg. talc).

Toxic
An inherent capacity to produce illness or injury when in physical contact with a living cell. Toxicity does not necessarily imply hazard.

Hazardous
For purposes of discussion, a substance which is toxic, exposure is reasonably likely, and harmful effects are likely.

Threshold Value
The level below which there is no effect. This involves determining exactly when "approaching zero" is replaced by "zero." Very difficult to define, much less determine.

Voids
Voids are "unused" spaces aboard a ship that are closed and not ventilated for months at a time. Rust formation consumes available oxygen. They may be entered safely with a source of supplied air or generated oxygen. An organic vapor mask or a bandanna over the nose and mouth is not adequate.
TOXIC SUBSTANCES IN MILITARY USE

The following are substances that you may encounter while you are practicing operational medicine:

HYDROCARBONS
Hydrocarbons are divided into two general classes, aliphatic and aromatic. Aromatic compounds contain a benzene ring. Aliphatics are everything else. Saturated compounds are "saturated" with hydrogen and contain no carbon to carbon double or triple bonds. Alkenes have double bonds, alkynes have triple bonds. Solvents are composed predominantly of hydrocarbons, thus their importance in many types of military operations. Solvents are substances capable of dissolving another substance (solute) to form a uniformly dispersed mixture (solution). Solvents are either polar or non-polar. Hydrocarbon solvents are generally non-polar.

Exposure to solvents occurs primarily through skin or inhalation of vapors.

The very short chain gases, methane (C1), ethane (C2), propane (C3), and butane (C4), are biologically inert and non-toxic. They may serve as simple asphyxiants as they will not support life. They have no significant narcotic effects as straight chain compounds. The rules change with other than the straight chain isomers. Cyclopropane is an excellent anesthetic, but it is explosive. The C5 through C8 straight chain compounds are powerful narcotics. Above C8 are weak narcotics. Above C18 are solids. These are broad generalizations. Gasoline is C5-C15 with a few aromatics. Cyclic and unsaturated compounds tend to be more narcotic.

The most common acute effect of hydrocarbons in the workplace is not a loss of consciousness, but instead, a prenarcotic syndrome of mild incoordination and general malaise progressing gradually into more severe symptoms. Many organic solvents have the potential upon acute high level vapor exposure to cause narcosis and death. Disorientation, euphoria, giddiness, confusion, progressing to unconsciousness, paralysis, convulsion, and death from respiratory or cardiovascular arrest are typically observed. In the majority of subjects, recovery from CNS effects is rapid and complete following removal from exposure. One must also remember fire and explosion are common hazards associated with use of solvents. Aspiration of any of these organic fuels can cause chemical pneumonitis. No common organic fuels can be considered pure. All are mixtures defined by certain physical parameters such as specific gravity, boiling point, or viscosity. As a general rule, the more volatile the hydrocarbon, the more toxic and the more hazardous. Usually the se compounds are excreted rapidly, but some have long term effects. Chronic exposure to Benzene may cause leukemia. Benzene more commonly causes bone marrow depression. Carbon disulfide may cause psychosis and peripheral neuropathy of sensory nerves. Vinyl chloride may cause hemangiosarcoma of the liver although polyvinyl chloride is harmless. Aromatic nitro and amino compounds cause production of methemoglobin, which interferes with normal oxygen transport. Solvents are used in dry-cleaning agents, drying compounds, degreasers, and liquid extractions.
**JP4-JP5**

**Chemical nature**

JP4 is 65% kerosene and 35% gasoline. JP5 is kerosene.

**Method of absorption**

Primarily by inhalation, although superficial cutaneous is also common. Ingestion is rare.

**Associated clinical syndrome**

In high concentrations, may cause headache, nausea, confusion, drowsiness, convulsions, coma, and finally death. Skin exposure lends to defatting and dermatitis. Prolonged skin exposure can lead to second degree burns. Ingestion lends to chemical pneumonia.

**Association with USN/USMC**

These are jet engine fuels

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**ETHYLENE GLYCOL**

**Chemical nature**

A low molecular weight alcohol.

**Method of absorption**

Not an inhalation hazard unless heated. Accidental or purposeful ingestion.

**Associated clinical syndrome**

In cases of fatal poisonings, symptoms include those of typical alcoholic intoxication followed by coma, pulmonary edema, and death within 72 hours. In non-fatal cases, acute tubular necrosis with anuria occurs within 24 hours. 100cc may be fatal. Liver alcohol dehydrogenase metabolizes ethylene glycol to oxalic acid, which is the likely cause of the metabolic acidosis and subsequent nephrotoxicity.

**Treatment**

Ethyl alcohol is a better substrate for alcohol dehydrogenase, which accounts for its use as therapy in massive ingestion. The oral loading dose is 0.6 gm of 50% ethanol per kg body weight. Hourly oral maintenance doses of 109 mg of 20% ethanol per kg body weight should be administered, along with rapid initiation of hemodialysis.

**Association with USN/USMC**

Antifreeze, hydraulic fluids, condensers, and heat exchangers.

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**TRIORTHOCRESYL PHOSPHATE - TOCP**

**Chemical nature**

An aromatic ester with three benzene rings.
Method of absorption
   Ingestion. This compound occurs as a contaminant in some other product. It is never produced deliberately.

Associated clinical syndrome
   Basically an ascending paralysis.

Association with USN/USMC
   This was found in small amounts in green hydraulic fluid. Approximately one gallon of this hydraulic fluid would have to be ingested before a toxic dose of TOCP would be absorbed. There has never been a documented case of TOCP toxicity in the Navy. The new hydraulic fluids have no TOCP.

BENZENE
Chemical nature
   The basic unsaturated resonating ring compound. This is the basis of all aromatic compounds.

Method of absorption
   Rapidly absorbed via inhalation of vapor and distributed throughout body, tending to concentrate in tissues with high fat content. Measurement of total urinary phenols gives the most specific indication of exposure.

Associated clinical syndrome
   Acute exposure to high concentrations results in CNS depression with headache, nausea, dizziness, convulsions, coma, and death. Contact with broken skin may result in erythema, blistering, or dry, scaly dermatitis. Benzene is best known for its chronic effects; aplastic anemia, preleukemia, and acute myelocytic and monocytic leukemia.

Association with USN/USMC
   Extensive use as a solvent. May contaminate gasoline, paint remover, degreasers, and kerosene. An extremely valuable compound of mild toxicity except for its ability to cause leukemia. Benzene has also been used in the illegal production of cocaine.

TOLUENE
Chemical nature
   A benzene ring with an attached methyl group.

Method of absorption
   Inhalation - formerly common with glue sniffers.

Associated clinical syndrome
   An irritant to the eyes, respiratory tract, and skin. A CNS toxin which may produce
exhilaration, inebriation, headache, extreme lassitude and in high concentration, collapse, coma, and death. Abuse produces hyperchloremic acidosis, renal tubular acidosis, hypokalemia, and hypophosphatemia.

Association with USN/USMC
    A solvent for parts and coatings and a component of motor and aviation fuels.

CARBON TETRACHLORIDE
Chemical nature
    An absolutely superb solvent and degreaser of metal. Previously used as a fire extinguishing agent.

Method of absorption
    Inhalation, percutaneous.

Associated clinical syndrome
    Chronic exposure causes liver damage with destruction of hepatocytes. It is also a potent liver carcinogen.

Association with USN/USMC
    Very common in the past, but now outlawed. An excellent solvent. A good fire extinguisher (heat and carbon tet form compounds which use up available oxygen forming among other things, phosgene). History of use as a delouser and vermifuge. It is not now used due to severe immediate plus delayed toxicity.

TRICHLOROETHYLENE - TCE
Chemical nature
    A quite volatile halogenated hydrocarbon.

Method of absorption
    Inhalation.

Associated clinical syndrome
    CNS depressant similar to alcohol with symptoms of headache, dizziness, vertigo, tremors, sleepiness, fatigue, and blurred vision; many sudden deaths from ventricular fibrillation from users of this compound. TCE is hepatotoxic and probably a hepatocarcinogen.

Association with USN/USMC
    The principal solvent in vapor degreasing. This was the "safe" substitute for carbon tetrachloride. It is used as a dry-cleaning solvent and metal degreaser in certain shipboard shops with specific venting.
Summary
A liquid which is almost as good a cleaner as carbon tetrachloride, has similar qualitative, but much less quantitative effects. It is safer than carbon tetrachloride, but more dangerous than perchlorethylene and methyl chloroform.

TETRACHLOROETHYLENE
Chemical nature
Another chlorinated hydrocarbon. It is also known as perchloroethylene.

Method of absorption
Inhalation and percutaneous.

Associated clinical syndrome
A narcotic. Also a hepatotoxin and inducer of liver cancer.

Association with USN/USMC
Used only in dry cleaning plants. Of the three, this is safer than trichloroethylene and much safer than carbon tetrachloride. It is more dangerous than methyl chloroform or freon.

FREON
Chemical nature
Trichloro-trifluoro-ethane (many possible isomers).

Method of absorption
Inhalation

Associated clinical syndrome
When inhaled, it is a mild CNS depressant. It will also rapidly defat skin.

Association with USN/USMC
Formerly a very common refrigerant and solvent. Which was quite safe. The major toxic effect occurs with deliberate abuse causing simple hypoxia due to displacement of oxygen in the breathing gas. Freon has largely been replaced because of environmental concerns.

METHYL ETHYL KETONE - MEK
Chemical nature
Much like acetone, but less volatile.

Method of absorption
Rapidly absorbed through the skin, then rapid excretion through expired air.
Associated clinical syndrome
Inhalation may cause narcosis. Skin contact causes marked defatting and a dermatitis.

Association with USN/USMC
Solvents or resins, lacquers, paints, oils, pigments, dyes, and polymers. Very common in shore facilities, not used on ships

METHYL CHLOROFORM
Chemical nature
A carbon with three chlorines and a methyl group

Method of absorption
Inhalation

Associated clinical syndrome
Can cause narcosis, but this is seldom seen. Causes dizziness, incoordination, drowsiness, increased reaction time, unconsciousness, and death.

Association with USN/USMC
Used on ships and ashore as a solvent and degreaser, but only in certain controlled circumstances such as instrument cleaning.

One of the least toxic of the chlorinated solvent chemicals.

CARBON MONOXIDE
Chemical nature
A product of incomplete combustion of carbon compounds.

Method of absorption
Inhalation

Associated clinical syndrome
Well-known competitive hemoglobin binder, also less well known as a direct cellular toxin at the electron-transport level. Causes both anemic and histotoxic hypoxia.

CO HB LEVEL SYMPTOMS

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>headache</td>
</tr>
<tr>
<td>20-30%</td>
<td>nausea, weakness, occasional vomiting</td>
</tr>
<tr>
<td>35-45%</td>
<td>clouding of mental alertness, collapse, coma</td>
</tr>
<tr>
<td>50%</td>
<td>death</td>
</tr>
</tbody>
</table>
Treatment

Hyperbaric oxygen.

Association with USN/USMC

Common in internal combustion engine exhaust and in cigarette smoke. Very small amounts in jet exhaust. A classic killer: ubiquitous, silent, deadly. A colorless, odorless, tasteless gas. It associates 210 times more readily with hemoglobin than oxygen. It has a four hour half-life in air, and a forty minute half-life in oxygen at one standard atmosphere and about half that at sixty feet in the hyperbaric chamber. The treatment of choice is hyperbaric oxygen.

CHLOROBROMO METHANE (CBM)

Method of absorption

Inhalation, skin absorption.

Associated clinical syndrome

Pyrolysis resultant compounds are phosgene, HCl, HBr, and CO with their related syndromes. Inhaled phosgene causes a delayed and severe pulmonary edema.

Association with USN/USMC

Aircraft engine fire extinguisher for internal combustion engines.

OTTO FUEL

Chemical nature

1,2 propylene glycol dinitrate; a nitrated ester.

Method of absorption

Inhalation or percutaneous absorption. Product is extremely volatile and TLV's can readily be exceeded.

Associated clinical syndrome

Vascular effects, starting with headache, occur after inhalation. Methemoglobinemia is seen with chronic inhalation exposure. Ingestion can cause circulatory collapse and death.

Association with USN/USMC

This is a torpedo fuel; torpedoes are not only submarine weapons, but can also be dropped from aircraft.

HALON

Chemical nature

A generic term meaning halogenated hydrocarbon. Halon 1301 is in use in the Navy, in
the form of a gas. Generally, those compounds containing fluorine tend to be less toxic, whereas those with bromine or iodine are more toxic than those hydrocarbons containing chlorine.

Method of absorption
Inhalation

Associated clinical syndrome
CNS depressants. Cardiac arrhythmias may result, and the myocardium is sensitized to epinephrine.

Association with USN/USMC
In new ships, halon is utilized to flood spaces to stop fire. Harmless, if breathed for only a few minutes.

HYDRAZINE
Chemical nature
N2H4

Method of absorption
Inhalation, skin contact

Associated clinical syndrome
Inhalation leads to pulmonary edema. Skin contact causes severe burns.

Association with USN/USMC
Primarily used as a missile fuel, it is not likely to be encountered in naval operations except by aviation personnel servicing Air Force aircraft, since the F-16 uses hydrazine as part of their fuel system (as does the space shuttle).

A very toxic and hazardous compound used as a fuel.

ISOCYANATE
Chemical nature
Toluene-2,4-diisocyanate - TDI

Method of absorption
Inhalation of paint vapor and mist.

Associated clinical syndrome
Asthma like syndrome, due to prior sensitization. Repeat exposure of even tiny amounts to a sensitized person can cause symptoms.
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Association with USN/USMC
Polyurethane paints are common in the Navy. It is the standard aircraft paint. Isocyanates are the monomers of polyurethane paint. The cured (polymerized) paint is harmless.

HYDRAULIC FLUID RED (AIRCRAFT)
Chemical nature
Petroleum based and inflammable. Contains traces of TOCP. When burned, liberates phosgene.

Method of absorption
Inhalation; skin contact.

Associated clinical syndrome
Skin contact for prolonged period can cause dermatitis. Phosgene is a war gas causing pneumonitis and severe pulmonary edema.

Association with USN/USMC
In aircraft hydraulic lines. Inhalation of mist possible when line breaks under pressure.
Mild toxicity except when burned. A very minor hazard.

HYDRAULIC FLUID GREEN (SHIPBOARD)
Chemical nature
This is a green synthetic based fluid that does not burn easily. It is also called cellulube.

Method of absorption
Inhalation, skin contact, ingestion.

Associated clinical syndrome
Causes a mild dermatitis on contact. Ingestion is sometimes deadly, more because of the hydrocarbon effects than the TOCP. Approximately one gallon of this fluid would have to be consumed in order to receive a toxic dose of TOCP.

Association with USN/USMC
Deck edge elevators. A large amount of this substance is in the piping of the elevators. TOCP is a contaminant and the new "cellulube" has much less of it. The problem is going away. Sometimes the new cellulube is blue in color, which confuses the issue somewhat. A fairly non-toxic material found shipboard that has received attention far out of proportion to its importance.

PLASTICS
Chemical nature
Burns to CO, HCl, HF, HCN, H₂S, SO₂
Method of absorption

Inhalation

Associated clinical syndrome

This is a black, choking, toxic smoke that quickly incapacitates.

Association with USN/USMC

The interiors of many buildings make use of plastics as part of decoration, partitions and signs. Wiring and furniture also contain much plastics, and are a significant hazard in the event of fire. The same is true of large passenger aircraft fires.

METHYL ALCOHOL

Chemical nature

CH₃OH

Method of absorption

Ingestion.

Associated clinical syndrome

Disturbances of vision and metabolic acidosis. High exposure results in headache, vertigo, unsteady gait, weakness, nausea, vomiting, inebriation. Optic neuritis, with indistinct vision, changes in color perception, and blindness as common symptoms.

Treatment

Ethyl alcohol, because of its greater affinity for ADH (alcohol dehydrogenase). Drinking methyl alcohol may cause permanent blindness.

Association with USN/USMC

Deicing fluid. Also a solvent in paint, stains, varnishes, cements, dyes, and inks. It is a minor hazard as most people know about the dangers of wood alcohol.

DEICING FLUIDS

Chemical nature

Methyl, ethyl, isopropyl alcohols.

Method of absorption

Deliberate ingestion.

Associated clinical syndrome

Intoxication (drunkenness) with methanol effects.

Association with USN/USMC

Used on aircraft windshields and props.
ORGANOPHOSPHATES
Method of absorption
Inhalation or through intact skin and eyes.

Associated clinical syndrome
Organophosphates inhibit the enzyme cholinesterase and the toxic effects are related to the resulting increase in endogenous acetylcholine at the synaptic sites. Monitoring enzyme activity not only can serve as a measure of acute toxicity, but also can be used to monitor occupational exposure (remove from exposure if enzyme activity decreases 25% from preexposure levels). The time of onset of symptoms after toxic exposure can be very rapid, but rarely longer than a few hours. If the patient is still alive after 24 hours, survival is likely. Recovery, when it occurs, is usually rapid and complete. Early symptoms are pupillary constriction, chest tightness, headache. More severe exposure produces coughing, wheezing, and increased bronchial secretions. Weakness and fatigability lead to twitching and fasciculations and eventual respiratory paralysis. CNS symptoms include anxiety, restlessness and irritability.

Treatment
Atropine 1-2 mg every 15-30 minutes until tachycardia, flushing and dry mouth occur (does not reverse phosphorylation of cholinesterase, but blocks effect of acetylcholine). 2-PAM (Protopam Chloride) will reverse the inhibition of the enzyme if given early enough before aging process occurs (given as 1 gm slowly and repeated in one hour prn). For monitoring workers, both RBC and plasma cholinesterase should be measured. Plasma cholinesterase decreases earlier, and returns more promptly. RBC cholinesterase decreases less readily and has a slower return. Baseline levels are very important because of variability.

PARATHION/MALATHION
Chemical nature
Complex organophosphate

Method of absorption
Ingestion, inhalation.

Associated clinical syndrome
These are the insecticidal equivalent of a war nerve gas. They are cholinesterase inhibitors like the other organophosphates. Parathion is deadly and has caused many times the number of deaths caused by DDT. However, it does not persist in the environment and does not bioconcentrate. These agents tend to persist in the body much longer than weaponized agents resulting in very prolonged treatment periods do.

DDT
Chemical nature
A halogenated hydrocarbon

Method of absorption
    Usually ingestion, by humans. This chemical bioconcentrates.

Associated clinical syndrome
    Hyperesthesia of mouth and face early, followed by paresthesia, tremor, confusion, malaise, headaches, fatigue, and delayed vomiting. Convulsions occur only in severe poisoning.

Association with USN/USMC
    No longer used. EPA canceled its use for all crops in 1972 and all except emergency cases in 1973. Primarily of historical interest.

**BERYLLIUM**

Chemical nature
    A hard, light, easily machined useful metal.

Method of absorption
    Inhalation of the dust

Associated clinical syndrome
    Pulmonary and systemic granulomatous disease requiring exposure over months to years. There is a possible long latent period (suspected cancer inducer). Exertional dyspnea is the most common symptom of chronic disease. Cough, fatigue, weight loss, chest pain, and arthralgia may occur. It is difficult to differentiate from other pulmonary disease.

Treatment
    Cessation of further exposure. Possibly steroids.

Association with USN/USMC
    Brake drums of S3 and F14 are the primary uses, used brakes being the dangerous ones. The aircraft brake shop is usually the locus of the hazard. Modern technology has produced new uses of beryllium in nuclear reactors, electronic equipment, guidance and navigation systems, rocket parts, and heat shields.

**CADMIUM**

Chemical nature
    An elemental metal.

Method of absorption
    Inhalation of fumes. Typically, acetylene cutting of metal plated with cadmium.
TOXICOLOGY

Associated clinical syndrome
Symptom-free period followed in 4-10 hours with dyspnea, cough, chest tightness, chest pain and burning. Metal fume fever is shaking, chills, and myalgia. This can progress to pulmonary edema 24-48 hours after exposure. Chronically, cadmium can cause pulmonary fibrosis, liver and kidney damage, and cancer of the lung and the prostate. This is probably the most harmful of the metal fumes.

Treatment
Remove from exposure; chelation therapy may produce renal damage by increasing the renal concentration of cadmium.

Association with USN/USMC
Electroplating, stabilizer in plastics, component in nickel-cadmium batteries. A common, useful metal with extremely dangerous fumes. Most toxicity is caused by not knowing the Cadmium is there.

CHROMIUM
Chemical nature
A metal with trivalent and hexavalent ions.

Method of absorption
Inhalation of fumes and cutaneously.

Associated clinical syndrome
Cough, wheezing, pain on inspiration, fever, weight loss, and possible chemical pneumonitis. Only the hexavalent form is dangerous and causes both skin ulcers and respiratory ulcers. It may be a carcinogen with a long latent period.

Treatment
Calcium EDTA for skin ulcers

Association with USN/USMC
Chrome plating and as a paint primer (corrosion resistance); a common ion found in rework facilities which causes severe ulcers which are slow to heal.

LEAD
Chemical nature
An easily malleable and very useful heavy metal in industrial settings.

Method of absorption
Inhalation of dust or lead oxide fumes or ingestion. Dust comes from sanding of lead-based paint. Fumes come from gas cutting of metal. Ingestion from any number of
Associated clinical syndrome

Lead poisoning is essentially a chronic disease caused by the gradual accumulation of a significant body burden. One of the most important sites of the toxic action of lead is the inhibition of the heme biosynthetic pathway. Blood lead levels are measured for assessing acute exposure. Accumulation of zinc protoporphyrin (ZPP) is used effectively as a diagnostic test for lead exposure (a measure of the biological effect of lead averaged over a 3-month interval). CNS symptoms include convulsions, delirium, coma, headache, dizziness, sleep disturbances, memory deficit and changes in personality. Progressive renal disease is possible. Some of the most frequent symptoms are GI; including nausea, anorexia, weight loss, epigastric discomfort, dyspepsia, and abdominal cramps (lead colic). The "lead caper": Colic, Arthralgia, Polyneuritis, Encephalopathy, Red blood cell stippling and anemia.

Treatment

Discontinue exposure. Calcium EDTA

Association with USN/USMC

Lead-based paint was in widespread use and sanding of lead paints can cause airborne exposure. Finished lead products are safe in normal use. Heating, grinding, spraying, burning may result in emission of biologically active forms of lead. Consideration of lead exposure is important in the demolition of ships because of lead-based paint.

NICKEL

Chemical nature

An elemental metal of little toxicity as the metal, but with many toxic compounds. Nickel carbonyl - Ni(CO)₄ - has been implicated as a potent carcinogen.

Method of absorption

Inhalation of the compounds (primarily in nickel refinery workers)

Associated clinical syndrome

Gas wielding nickel-plated materials may result in metal fume fever. Ni(CO)₄ produces immediate non-specific symptoms, which soon disappear. Severe respiratory distress develops hours or days after exposure as a result of chemical pneumonitis. Death is usually the result of interstitial pneumonitis. Cancer of the respiratory tract, including nasal cavity, sinus cavities, and lungs may occur.

Association with USN/USMC

Cigarette smoke contains, among other bad things, nickel carbonyl. Chrome and nickel plating is widely practiced in industry, and all chrome plating uses nickel as an underlying bonding layer. It is also a fundamental component of the nickel cadmium (NICAD) battery.
**MERCURY**

**Chemical nature**

An elemental metal liquid at room temperature and fairly nontoxic as the metal. The vapor is toxic and some of the mercury salts and compounds are very hazardous.

**Method of absorption**

Inhalation

**Associated clinical syndrome**

The CNS is generally the target of acute exposure, whereas, the kidney is the target of chronic exposure. Chronic exposure produces the classical triad: erethism, tremor, and gingivitis. Tremor is one of the earliest and most characteristic expressions of Hg toxicity. In the CNS, erethism is described as nervousness, irritability, tendency to resent being observed, timidity, and burst of quick temper of unusual degree for the individual affected. Hg in the urine is a good index of exposure, but not toxicity. Urinary Hg levels remain an important indicator of body burden, particularly when followed over time.

**Treatment**

Although penicillamine is preferred, dimercaprol (BAL) may be useful. Polythiol resin has been used for the reduction of intestinal absorption of methyl Hg.

**Association with USN/USMC**

Used by dentists. Methyl mercury is another bioconcentrator.

**METAL FUME FEVER**

**Chemical nature**

Caused by the fumes from non-ferrous metal welding.

**Method of absorption**

Inhalation; remember what fumes are.

**Associated clinical syndrome**

Typical of a flu syndrome with fever, chills, and malaise. Usually lasts 6-12 hours but in severe cases can result in severe respiratory embarrassment.

**Association with USN/USMC**

Welding of non-ferrous metals.

**ASBESTOS**

**Chemical nature**

A generic term for naturally occurring fibrous minerals. The fibers are made up of fibrils, some of which are not visible to the optical microscope, but are to the electron microscope.
Method of absorption
Serious toxicity is from inhalation. Some visible fibers break into fibrils in the lung.

Associated clinical syndrome
Three major distinct syndromes: (1) Asbestosis, (2) Lung cancer, and (3) Mesothelioma. Asbestosis is diffuse interstitial fibrosis with a small tight lung. This is due to massive exposure to the airborne fibers. This is the most common disease state associated with exposure. Lung cancer is the most common cause of death, however. This is induced by imbedded fibrils in the lung. Asbestos workers have ten times the lung cancer death rate of non-asbestos workers from lung cancer, all other things being equal. Smokers add a multiplier of eight to this. Mesothelioma was previously extremely rare and has increased to fairly common in asbestos workers. This is what is called a signal neoplasm in preventive medicine.

Association with USN/USMC
Previously ships were full of asbestos, however, new ships have very little. Ripout and breakup of old ships is quite hazardous. A very common mineral fiber. Detailed safety procedures are necessary when working with asbestos. Latency of disease makes cause and effect difficult to measure. See the section on asbestos medical surveillance and hazards training for a more complete discussion.

SILICA
Chemical nature
Common sand, SiO2

Method of absorption
Inhalation of the fume dust. Common with sand blasters and miners.

Associated clinical syndrome
The most common is diffuse interstitial fibrosis due to chronic exposure. Progression of the fibrosis may occur even after removal from exposure. Look for a decrease in vital capacity.

Association with USN/USMC
The fear of silicosis makes sand blasting in the shipyard a difficult and extremely expensive proposition. Therefore, sailors remove old paint with sanders using thousands of man-hours in relatively difficult and dangerous work.

PLUTONIUM
Chemical nature
An artificially produced radioactive solid made by bombarding U238 with neutrons. Plutonium is an alpha emitter.
Method of absorption
   Inhalation of dust is the only significant method.

Associated clinical syndrome
   Concentrates in the bone and liver. Major damage is osteosarcoma.

Treatment
   Chelating agents speed up elimination.

Association with USN/USMC
   Reactors and weapons. Very high public interest - very toxic, very hazardous, very well controlled. Radiologic half-life is 25,000 years. Biologic half-life is 200 years.

DIOXIN / AGENT ORANGE
Chemical nature
   Agent Orange is a 50/50 mixture of 2,4D, and 2,4,5T, which have been in widespread use throughout the U.S. by agriculture for many years. Both are phenoxyaliphatic acids and in their pure forms, are relatively non-toxic. However, 2,4,5 is often contaminated with another compound, dioxin (TCDD: Tetra-chloro-bibenzo-dioxin).

Method of absorption
   Inhalation, ingestion, contacts.

Associated clinical syndrome
   Caused by dioxin toxicity. May be associated with a wide variety of clinical syndromes in those with significant exposure, usually industrial workers. Recent studies have suggested that it is not as toxic as had been thought. Little or no scientific evidence that limited exposure is related to any disease. Major diseases of occupational workers are chloracne, peripheral neuropathy (especially lower extremities), psychological disturbances, neurasthenia, hepatitis, decreased "helper-suppressor" ratio, and cutaneous anergy.

Association with USN/USMC
   A commonly used defoliant during the Viet Nam war. Agent Orange is the common name for a compound that was used extensively during the Southeast Asia conflict. Primarily employed to deny cover and concealment to the enemy, it was used, on occasion, to destroy food crops. Over 200,000 Vets have claimed disability from exposure, although an extensive Air Force/VA study failed to document cause and effect relationships.

REFERENCES

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