SUBMARINER'S ADVOCACY GROUP

Submariners Helping Submariners

Synopsis of Discoveries & Our Responsibilities

The **Submariners' Advocacy Group** (SAG) is a Non-Profit Organization, 501(c)(3) that has been established by a group of 17 US Navy Submarine Force Veterans. We are very proud of our service in the Silent Service and maintain our commitment to honoring, serving, and protecting our fellow Submariners.

Each one of us is innately aware of the responsibilities we undertook when we were assigned to our first US Navy submarine and completed our qualifications in submarines. We fully understood and continue to understand that our Dolphins, the Submarine Warfare Insignia (both Enlisted and Officer), display our knowledge and experience as a specialist in submarines. Further, our Dolphins exhibit our ability to protect the lives of our shipmates, while assigned to an operational submarine, and fellow Submariners, in our lives after our time in the Navy.

Submariners are an exclusive group of individuals who have been bonded together by our very unique experiences associated with extended duty while submerged in the most unforgiving environment on Earth. Each Submariner is fully cognizant that his/her life is dependent on the knowledge and expertise of our qualified shipmates. Further, we are aware of the trust placed in us by these same shipmates to protect their lives. This often carries over into our lives in the civilian community. Yes, Submariners tend to trust no one more than other Submariners.

Submariners are often referred to as "the Elite of the Fleet." Our standards are higher, in education, expectations, and performance. All submarine commands and the crews themselves enforce these higher standards. Additionally, we are trained and expected to ask questions about anything and sometimes everything. When we observe or discover something that doesn't seem right we will ask questions, often a lot of questions. We will dig for the answers. If that something is a problem or an issue, then we will search to identify the problem so that we can present a solution, a valid solution, one that will "fix" the problem.

So, it is with this small band of Submariners known as SAG. In our efforts to support our Brothers and Sisters, we began to identify a possible problem. We began to hear stories related to the VA denying submarine veteran claims. The VA has made statements similar to "there has not been a large enough study to look into this," or "the available studies were too small or didn't cover an adequate amount of time," or the dreaded "you don't have that problem." It is even worse when a Submariner's disability claim is denied because the VA simply does not recognize it as being caused by submarine duty.

Yes, we began to ask questions and research to discover the problem or problems. Our initial discoveries have only led to more questions and revealed a problem larger than ever imagined.

The Initial Studies and Research Reports

In March, the VA announced that it was extending VA benefits to all veterans who were exposed to toxins and other hazards during their military service. (See VA Press Release of March 4, 2024.) This sparked some questions that led to an Internet search on "submarine atmosphere contaminants." The search results guided us to the discovery of several reports that have caught the attention of several submarine veterans.

The primary reports discovered are:

1. **Proceedings of the SUBMARINE ATMOSPHERE CONTAMINANT WORKSHOP** held NSMRL on Submarine Base, Groton, Connecticut. (Shea et al., 1984)

2. **Submarine Air Quality – Monitoring the Air in Submarines – Health Effects in Divers of Breathing Submarine Air Under Hyperbaric Conditions** by:

   Panel on Monitoring and
   Panel on Hyperbarics and Mixtures
   Subcommittee on Submarine Air Quality
   Committee on Toxicology
   Board on Environmental Studies and Toxicology
   Commission on Life Sciences
   National Research Council

   Published by National Academy Press, Washington, DC (NRC, 1988)
   And,

3. **Emergency and Continuous Exposure Guidance Levels for Selected SubmarineContaminants: Volume 1 (NRC, 2007), Volume 2 (NRC, 2008), and Volume 3 (NRC, 2009)**

   Subcommittee on Emergency and Continuous Exposure Guidance Levels for Selected Submarine Contaminants
   Committee on Toxicology
   Board on Environmental Studies and Toxicology
   Division on Earth and Life Studies
   National Research Council of the National Academies

   Published by National Academy Press, Washington, DC, as noted above.

These reports are quite revealing and expose critical shortcomings in understanding as related to the submarine atmospheric environment.

Proceedings of the SUBMARINE ATMOSPHERE CONTAMINANT WORKSHOP

Submariners from the 1960s, 70s, and 80s all remember how we were introduced to CAMS I (Central Air Monitoring Station) with the assertion that this helped us properly monitor and make sure that the air we breathed was safe. But, the workshop introduced information that dispelled that notion quickly.

The first issue appears on **page 1**, from the "Introduction to Workshop" by Dr. Michael Shea. Dr. Shea stated in the second paragraph:

> Two major concerns were stated in the memo. The first was that **current limits** for 90 day continuous exposure to atmospheric contaminants in the closed submarine environment **<u>were never validated by actual animal or human exposures</u>** and were derived by taking existing industrial limits for 8 hour/day, 40 hour/week exposures and lowering them by some factor to convert to continuous 90-day limits. **This approach was deemed unsatisfactory for several reasons.** 1.) **The factors used to set the limits were <u>arbitrary</u> and in some instances were set because of limitations in atmosphere control equipment.** 2.) The limits **may not be conservative enough for some substances**. 3.) The standards did not address the problems of aerosols in the submarine atmosphere since aerosols can both modify the entry of contaminants and may be contaminants themselves. 4.) The current limits may be too conservative with the results that: unwarranted restrictions may be placed on materials brought aboard for use during patrols; surface ventilation to reduce contaminant levels could reveal the submarine's location; and atmosphere control equipment may be unduly complex and costly. (1984, p. 1) (Emphases added)

This was followed by Mr. Jesse Lieberman stating in "Development of Novel Theshold [*sic*] Limit Values for Submarines," "A point he **made very clear** is that **TLVs are arbitrary** and are not used as an index for toxicity hazard." (Emphases added) Further, "TLVs are really designed to prevent gross over exposers [*sic*] to hazardous materials." (Shea et al, 1984, p. 8)

There was another discussion, "Status of the CAMS II Atmosphere Analyzer" by Dr. Jeffrey Wyatt that begins on page 3. This discussion pointed out the inherent weaknesses in CAMS I and the need for CAMS II.

This workshop either directly or indirectly led to the **Submarine Air Quality** report.

Submarine Air Quality – Monitoring the Air in Submarines – Health Effects in Divers of Breathing Submarine Air Under Hyperbaric Conditions

It must be noted that while this study and report focused strictly on the nature and effect of the submarine atmosphere being introduced to divers as a result of the submarine atmosphere being used to charge their air tanks. While the study was thorough and dealt with a large number of contaminants and byproducts of these contaminants in the target submarine atmosphere (see Appendix A and Table A-1, pages 60 through 65 for a list of possibly 130 chemicals), little to nothing was mentioned about the effects on the submarine crews of breathing these chemicals and gases during normal submarine operations.

However, in "Chapter 5 Conclusions and Recommendations", we find:

> Results of **full analysis of the submarine atmosphere were not available** to the Panel, and apparently **no such analysis has been done in recent years**. Therefore, the Panel was limited in its ability to answer fully the questions put to it. **Without such information, detailed conclusions and recommendations that reflect the current environment cannot be offered**.
>
> > The Panel **recommends that the Navy thoroughly survey various classes of submarines for trace contaminants and particulate matter**. Carefully controlled sampling procedures should be established to collect samples quantitatively with such sorbents as Tenex and have them analyzed in on-shore laboratories. Other techniques should be used for inorganic and small organic substances. **Compounds of concern that have been detected or are**

> **suspected, but for which no concentrations are available, should be measured**. (NRC, 1988, p. 47) (Emphases added)

Emergency and Continuous Exposure Guidance Levels for Selected SubmarineContaminants: Volume 1 (NRC, 2007), Volume 2 (NRC, 2008), and Volume 3 (NRC, 2009)

These three volumes have become the most telling and the source of primary concern for those of us at the **Submariner's Advocacy Group**.

This study was undertaken and funded by the DoD as a follow-up to the **Submariner Air Quality** cited above (See the below citation). The issues of concern begin to appear in the Summary found at the beginning of each volume. The following citations are from Volume 1, but they are repeated and emphasized in Volumes 2 and 3. (Note: all emphases have been added.)

> **The submarine atmosphere does not appear to be well characterized. In conducting its evaluation, the subcommittee found that few exposure data are available on the Navy's chemicals of concern or other chemicals**. This **subcommittee agrees** with a previous NRC report, *Submarine Air Quality* **and** recommends **again** that "**the Navy thoroughly survey various classes of submarines for trace contaminants and particulate matter**" and that "**monitoring on submarines provide complete analysis of submarine air and data on exposure of personnel to contaminants**." (NRC, 2007, p. 5)

> **The subcommittee did not address exposures to chemical mixtures**. **When** empirical data that characterize mixtures found in submarine air become available, the subcommittee recommends that they be evaluated. **The potential for antagonistic, additive, or synergistic interactions between contaminants in the submarine environment is an area of significant uncertainty that remains largely unexamined and needs to be studied**. (NRC, 2007, p. 7)

> Several of the chemicals that the subcommittee evaluated for this report are sensory irritants. The derivation of quantitative environmental and occupational exposure limits for sensory irritants is fraught with difficulty because measures of the ocular and respiratory tract irritation experienced by human subjects are often considered subjective. The results of controlled human exposures to many sensory irritants typically use descriptors, such as "mild" or "mild to moderate," and the database for sensory irritation thresholds can be highly variable. **Research is needed to quantify the diverse methods and end points used in sensory irritation studies, so that these data can be used in public- and occupational-health risk assessment with greater confidence**. (NRC, 2007, p. 7)

Recommended Survey & Analysis of Submarine Atmospheres

Thus, consistently for at least 24 years, from the Proceedings of the Submarine Atmosphere Contaminant Workshop in 1983 through the NRC's *Submarine Air Quality* report in 1988 and to the NRC's Committee on Toxicology (COT) via the Subcommittee on Emergency and Continuous Exposure Guidance Levels for Selected Submarine Contaminants' three-volume report published between 2007 and 2009, we can identify the following:

- The atmospheres on US Navy submarines have **not** been adequately studied, measured, or monitored.
- The NRC has recommended four times, in 1988, 2007, 2008, and 2009, that thorough surveys be taken of submarine atmospheres from different locations within individual

submarines and from different classes of submarines to provide for a **complete** analysis of US submarine atmospheres.

- Data on personnel exposures be collected.
  And,
- There is a need for the collection of substantial data on the affects and effects of long-term and low-level exposures of submarine crews to obtain information on the health impacts of these exposures.

The *Submarine Air Quality* report in Appendix A and Table A-1 pages 60 through 65, lists **130 chemicals** that could be submarine atmospheric contaminants. (NRC, 1988) The following report by the NRC COT's subcommittee, as directed by the DoD, only focused on **26 individual chemicals or gases**. This is only **20%** of the known or possible contaminants present in the submarine atmospheres.

Why were the surveys recommended by the 1988 report not accomplished by the time of the establishment of the NRC COT subcommittee in 2002? Wouldn't this have provided a better understanding of the submarine atmospheres and allowed for a better determination of what chemicals or gases should have been studied by the subcommittee from 2002 to 2009 and the publication of the final volume of its report? **In the interim, thousands of members of the Navy's submarine-assigned crews continued to be exposed to these chemicals.**

Returning to the **Emergency and Continuous Exposure**… report. This study targeted 26 different chemicals and gases:

Acrolein	Carbon Dioxide	Carbon Monoxide
Formaldehyde	Hydrazine	Methanol
Monoethanolamine	Nitric Oxide	Nitrogen Dioxide
Oxygen	Ammonia	Benzene
Freon 12	Freon 114	Hydrogen
2190 Oil Mist	Ozone	Surface Lead
Toluene	Xylene	Acetaldehyde
Hydrogen Chloride	Hydrogen Sulfide	Propylene Glycol Dinitrate
2,6-di-tert-butyl-4-nitrophenol (DBNP)		

It must be noted that the results of the study for each chemical or gas received a separate and thoroughly referenced chapter in the various volumes of the report. The final section of each chapter is entitled "DATA ADEQUACY AND RESEARCH NEEDS." The highlights of the final section of each chemical or gas follow (Emphases added):

Acrolein	Considerable research should be done to quantify the diverse sensory irritation methods for use in public- and occupational health risk assessment (Dalton 2001). **Thus, the subcommittee concludes that additional studies on the irritant effects of acrolein are needed to better define the exposure guidance levels for the short-term durations**. (NRC, 2007, p. 39)
Carbon Dioxide	The **neurobehavioral studies** on which the 1-h EEGL is based **were conducted no more recently than the 1970s** except for the small studies of Sun et al. (1996) and Yang et al. (1997). More sensitive tests and tests

	specifically designed to evaluate the skills required for high technology equipment use and onboard decision making might be available. It is important to validate the Sun et al. (1996) and Yang et al. (1997) findings, **because they suggest significantly lower acceptable concentrations than do previous studies**. Also, **subchronic studies should be repeated to evaluate more sensitive end points and should include complete lung function tests with diffusing capacity as well as neurobehavioral tests**. (NRC, 2007, p. 62)
Carbon Monoxide	**Although the literature on the effects of CO exposures in humans and animals is extensive, a number of data gaps remain. The conflicting results of studies on the neurobehavioral and cardiovascular effects of low-level CO exposures are of <u>concern for submariners</u>**. There is **<u>little experimental or epidemiologic information</u>** available on the potential for increased health risks in smokers exposed to CO. Subchronic and chronic low-level exposure studies and long-term follow-up studies in submariners, including those who smoke, are needed to reduce uncertainty in the derivation of the 90-day CEGL. (NRC, 2007, p. 94)
Formaldehyde	Formaldehyde has a relatively robust data set for developing health protective exposure levels that includes controlled human studies, occupational and nonoccupational studies, and animal studies. **Uncertainties for setting exposure levels include the short-term nature of controlled human studies** (less than 24 h) and the apparent variation and subjectiveness in individual reporting and rating of irritation associated with formaldehyde. The variation is not related to the typical sensitivities of such subgroups as asthmatic individuals. Because the available evidence indicates that adaptation occurs with time, the lack of longer-term studies is not considered to be a serious data limitation for setting EEGLs. **Continued research and publication on the low-dose carcinogenicity of formaldehyde will help support the confidence of the CEGL <u>for protecting submariners</u> from the effects of longer-term exposures to formaldehyde**. (NRC, 2007, p. 131)
Hydrazine	Sufficient data were available for deriving the submarine guidance levels for hydrazine. However, **<u>fundamental</u> mechanistic studies of hydrazine tumorigenesis in the rat nasal epithelium recommended by Latendresse et al. (1995) have not been conducted**. Although similarities to formaldehyde carcinogenesis have been noted in this profile, such as the association with pronounced necrosis and regenerative hyperplasia, *the subcommittee concludes that data are needed to determine the relationship between overt cytotoxicity induced in rodent respiratory tract tissues and carcinogenic response*. **Data are also needed to elucidate the contribution of the genotoxic activity of hydrazine at doses and exposures that elicit a significant carcinogenic response, given the overt tissue damage observed at those doses. <u>These data would improve the confidence</u> of the 90-day CEGL value and its protectiveness for longer-term exposures to hydrazine**. (NRC, 2007, p. 161)
Methanol	The data available on methanol toxicity were deemed sufficient to derive EEGL and CEGL values. The subcommittee in part relied on the subchronic inhalation studies in monkeys performed by NEDO. The subcommittee recognizes that there were some weaknesses in those studies. The report produced by NEDO (1986) is often fragmentary and lacks full descriptions of the raw data from the experiments. Moreover, some of the histologic descriptions in that report are incomplete and

	inadequately documented. Other studies were available to support the validity of the NEDO studies. When considered collectively, the relevant studies provided an adequate database for the subcommittee's deliberations. (NRC, 2007, p. 189)
Monoethanolamine (Amine)	**There is a paucity of data available for determining the effects of MEA following inhalation exposure**. The available studies are considered incomplete because little information is provided about histologic, hematologic, and enzymatic changes that might be produced systemically or in the nasal turbinates following repeated or long-term exposure to MEA. **None of the inhalation studies provide** a no-effect level useful for direct extrapolation to human exposure conditions. Although MEA does not appear to be genotoxic, no data on carcinogenicity are available for review. Additional short-term studies would be helpful for developing 1- and 24-h exposure limits with greater confidence, **because there is insufficient resolution within the available data set to support the development of different values for those time points**. Well-designed continuous 90-day and lifetime studies would provide information for developing 90-day exposure limits and for determining the carcinogenic potential of MEA. (NRC, 2007, p. 206)
Nitric Oxide	Sufficient data are available to develop 1-h exposure limits. Additional nonlethal exposure data would assist in deriving 24-h exposure limits, **because the present recommendations primarily rely on limited data in respiratory-compromised patients who might be less sensitive to NO than normal humans. There are no supporting long-term studies on NO available to determine 90-day exposure limits or to determine the carcinogenicity of NO. Thus, well-designed, continuous 90-day and lifetime studies would provide needed information to develop 90-day exposure limits and to determine the carcinogenic potential of NO**. (NRC, 2007, pp 218-219)
Nitrogen Dioxide	Sufficient data were available, having a fairly high degree of confidence, to develop 1-h and 24-h exposure limits for NO_2. The 90-day exposure limit was based on long-term exposures in nonhuman primates, which could result in conservative values. **Thus, continuous subchronic and chronic exposure data are needed to improve the subcommittee's confidence in the 90-day exposure limit determined**. (NRC, 2007, p. 240)
Oxygen	**Additional studies are needed to evaluate the appropriateness of the 90-day CEGL. The subcommittee could not find any studies examining the effect of subchronic exposure to mild hypoxia on mood state or cognitive performance**. The subcommittee suggests the Navy perform prospective studies to evaluate submariners for complaints of headaches, fatigue, and other symptoms that might be associated with the mild hypoxic environment often encountered on board submarines. (NRC, 2007, pp 271-272)
Ammonia	Quantitative exposure data are available on humans—including asthmatics, smokers, elderly people, and children—and laboratory animals, including such susceptible species as mice and rats. **Most human studies suitable for quantitative assessment used short-term exposure** (up to 2 h; one study incorporated exposure of 4 h and 6 h), **which necessitate assumptions regarding the concentration-dependent nature of the toxic response to ammonia**. **Controlled human exposure studies for extended exposure (especially 24-h continuous and**

	multiday exposure) <u>are lacking in the database available for study</u>. In addition, **controlled experimental studies of humans are restricted to small numbers of subjects and exhibit incomplete protocols**. **Greater and more objective quantification of such subjective end points as irritation and nuisance is needed; however, evaluations using appropriate psychophysical methods also need to assess cognitive and emotional factors that affect subjective responses** (Dalton 2002). Finally, **there are few contemporary studies of long-term ammonia exposure of laboratory animals; the 90-day studies available for assessment were published in the early 1970s**. Although they are sufficient for the current evaluation, corroborating evidence based on modern analytic and vapor-generation techniques would have been highly useful for application to the 90-day assessment. The results of Verberk (1977; Table 2-2) and Ihrig et al. (2006) indicate that mere knowledge of and exposure experience with the irritant and odor properties of ammonia vapor can effectively reduce human avoidance behavior and increase tolerance to concentrations as great as 140 ppm for exposure as long as 2 h. **That finding has operational significance for naval submarine command and <u>warrants further serious consideration</u> as a training opportunity for submarine crews**. The committee echoes the previous recommendation of the Committee on Submarine Escape Action Levels regarding application of Verberk's (1977) findings to submarine-crew training curricula (NRC 2002) and recommends inclusion of the more recent Ihrig et al. (2006) human-exposure data. (Dalton 2002). (NRC, 2008, p. 57)
Benzene	The Lan et al. (2004) and Shen et al. (2006) studies go a long way toward providing a human dataset that can be used to explore low-level human exposures and chronic clinical outcomes. **The human database on acute exposure to benzene is weak; however, it is unlikely to be improved, given the hazards of substantial benzene exposure**. **Mechanistic information on the metabolites that produce specific effects (bone marrow depression vs leukemia) might allow more specific standard-setting**, but at present the data are considered adequate. **The database on reproductive outcomes is <u>sparse and would benefit from new bioassays</u>**. (NRC, 2008, p. 80)
2,6-di-tert-butyl-4-nitrophenol (DBNP)	**The U.S. Navy is reported to have reduced the DBP in TEP 2190 lubrication oil to less than 10 ppm**. <u>Presumably, the reduction has led to a substantial reduction in the potential exposure of DBNP in the submarine environment</u>. **<u>However, no document substantiating that presumption was made available to the committee</u>**. The animal-toxicity database available for assessment of hazard and risk includes only single or repeat-dose studies, primarily via the oral route, with a small number of end points assessed. The committee considered deriving exposure guidance levels on the basis of noninhalation exposure routes, **but there were insufficient data to support the route-to-route extrapolation**. Furthermore, the overall database available for determining EEGL and CEGL values is small, and many of the data points are conflicting. **Thus, much uncertainty is associated with any attempt to estimate exposure guidance levels for this compound. The committee recommends that, at a minimum, a short-term inhalation study be conducted that looks at a comprehensive set of end points before an EEGL or CEGL value is established**. (NRC, 2008, p. 101)

Freon 12	**Although several studies of various species are available, including controlled studies in a small number of human subjects, most of them are not recent (that is, within the last 20 years), and in many cases the full nature of effects and study methods could not be evaluated, because of limitations in reporting or because the studies were unpublished or otherwise not readily available for review**. **Information on the effects of chronic inhalation exposure, carcinogenicity, or male reproductive or immune system effects is generally <u>less adequate</u>**. The available evidence, however, indicates that Freon 12 is rapidly absorbed and eliminated with little metabolism and that neither cancer nor most other toxic effects would be expected at the proposed EEGLs and CEGL. Additional studies to define the nature of effects at 1,000-10,000 ppm and the effects of chronic exposure would increase confidence in that prediction. Evidence from the literature also indicates that mixtures of chlorofluorocarbons may result in a lower effect level than predicted from the effect levels of individual chlorofluorocarbons alone. **Thus, if mixtures of chlorofluorocarbons could be present in submarines, effect levels for the mixtures should be evaluated**. (NRC, 2008, p. 124)
Freon 114	Most of the studies in the database on Freon 114 were conducted before 1975 and the publication of standardized protocols and good-laboratory-practice guidelines for the assessment of potentially toxic substances. Therefore, **they evaluated few toxicity end points, and effects on many organ systems and functions were not assessed**. The **database on Freon 114 includes few repeat-dose animal studies and no comprehensive long-term or continuous-exposure animal studies**. In contrast with the database on some other CFCs, few data are available on human exposure to Freon 114. **<u>It is recommended that inhalation studies designed to specifically address a broad array of organ systems under the continuous-exposure conditions typical in the submarine environment be conducted</u>**. (NRC, 2008, p. 147)
Hydrogen	Control of submarine air concentration of hydrogen is required to eliminate the explosive threat posed by this gas. Enacting suitable control measures essentially eliminates concern about adverse health effects associated with acute or chronic exposure to hydrogen at concentrations associated with an explosive hazard. **However, the present discussion presumes that hydrogen is biologically inert and acts as a simple asphyxiant. <u>No acute-exposure or repeated-exposure studies of hydrogen are available</u>. Likewise, pharmacokinetic and metabolic information on hydrogen is <u>unavailable</u>** (Wong 1994). (NRC, 2008, p. 155)
2190 Oil Mist	**The committee recommends analysis of the oil mist to which the submariners are exposed. That mist oil should then be evaluated in animals for potential adverse health effects**. If the Navy does not agree with the approach taken by the committee to estimate exposure guidance levels in this profile, acute and 90-day animal studies should be conducted with 2190 TEP. The committee recommends that used 2190 TEP (used in the same manner as in a submarine) be characterized to determine the aromatic components present. (NRC, 2008, pp 180-181)
Ozone	**There is a lack of data on personal exposure of submariners to ozone and other oxidant gases. The committee suggests that the Navy consider conducting exposure studies designed to determine the**

	personal exposure of submariners to ozone during their short- and long-term tours of duty. (NRC, 2008, p. 204)
Surface Lead	**No data were available to the committee on the physical nature, chemical identity, routes of exposure, or bioavailability of the surface lead materials of concern**. **To carry out submarine-specific lead health-risk analyses, data concerning generation, location, dispersion, and extent of onboard lead contamination, including the lead concentration in submarine drinking water, must be available**. Available methods for site-specific human health risk assessment for lead-containing dust require rigorous estimates of the quantity of dust ingested daily. In the present circumstance, it appears unlikely that published estimates of lead house-dust exposure (Clark et al. 1995; Wang et al. 1995) could be applied with confidence to a submarine. **No data concerning inhalation exposure to lead onboard a submarine were available**. Submarine air is one source that could contribute to a submariner’s blood lead concentration (Snee 1981). It is well known that factors other than air lead influence blood lead concentration (Bishop and Hill 1983). **No data concerning urinary lead or blood lead concentrations of submariners were available to the committee**. Thus, it is not clear whether significant exposure of the crew to lead occurs. Individual blood lead concentration is generally correlated with the duration of exposure and how much time has passed since termination of exposure (O’Flaherty et al. 1982). At the outset, however, it must be recognized that individual submariner blood lead concentrations reflect not only the combined occupational and residential lead exposures as a result of active duty but environmental lead exposures while the submariners are not engaged in submarine operations (O’Flaherty 1993). Lead-exposed people who have higher rates of hand-to-mouth behavior often have higher lead intake; individual hand-to-mouth lead exposure patterns can result in higher blood lead concentrations in those people than in people who do not eat or smoke in the same lead-containing environment. It is important to establish whether submariner blood lead concentrations differ from those of civilian adults and active military personnel not engaged in submarine operations who live in the United States. **One potential avenue that the committee highly recommends and that could assist in the definition of submarine-associated lead exposure is determination of crew urinary lead or blood lead concentrations before submarine deployment followed by identical measurements on completion of typical tours of duty**. If individual submariners with increased blood lead concentrations are identified, identification of the lead sources during deployment or as a result of on-shore activity (such as pottery and hobbies) is necessary. (NRC, 2008, pp 223-224)
Toluene	Because toluene is a common solvent, its effects on humans have been extensively studied. Numerous controlled human-exposure studies assess end points meeting the EEGL definition. Animal neurotoxicity studies are extensive, and supporting animal data were in reasonable agreement with values based on human studies. Toluene is fatal to humans only after exposure to extremely high concentrations (greater than 10,000 ppm), and deaths most often occur in cases of solvent abuse. The anesthetic effects and metabolism of toluene are well documented and characterized. Although specific sensitive populations are not identified,

	the mechanism of action of CNS depression is the same in all mammalian species, and the concentration at which this effect occurs after toluene inhalation does not differ greatly among individual humans. **Although empirical data on toluene toxicity in humans and animals are abundant, few experimental dose-response data on human serial exposures are available. This is especially true for long-term human exposures encompassing multiple days or weeks**. Several well-conducted chamber studies have involved human volunteers, but exposure concentrations were limited to concentrations that produce little if any impairment or anesthesia in humans and to exposure durations of less than 12 h. On the basis of existing human studies that describe effects over time and the fact that blood and brain concentrations reach a steady state rapidly, effects observed during the first hours of an exposure are relevant for exposures up to 24 h. **Nevertheless, better characterization could be obtained from studies of a larger range of nonanesthetic concentrations for longer continuous exposure durations**. (NRC, 2008, p.264)
Xylene	The human data for determining 1- and 24-h EEGLs are fairly robust, although many of the studies did not specifically report sensory irritation as an end point or as a symptom. **A study designed to determine the presence and degree of eye and throat irritation for exposure of 1 and 24 h would improve the level of confidence in the EEGL and CEGL values. Epidemiologic investigations of workers exposed to xylene or longer-term controlled exposure studies of xylene at 25-75 ppm would benefit derivation of the 90-day CEGL**. (NRC, 2008, p. 292)
Acetaldehyde	Although data for assessing NOAELs for the different acetaldehyde guidance levels are available, **uncertainties in setting exposure limits for submariners include the relative paucity of studies available for defining the lower limits for eye irritation, the relative effect of ALDH2 polymorphisms in increasing sensitivity to irritation, and the chronic injury at low airborne concentrations of acetaldehyde. More research on carcinogenic mechanisms of inhaled acetaldehyde at low doses is needed to evaluate the potential carcinogenic risk at low concentrations**. (NRC, 2009, p. 39-40)
Hydrogen Chloride	Information in the scientific literature suggests that concentration, not exposure duration, is responsible for irritant effects of chemical irritants. **Well designed inhalation toxicity studies are needed to demonstrate that that observation applies to hydrogen chloride**. Little is known about the acid-base buffering capacity of mucous membranes and tissues of the respiratory tract. **Because hydrogen chloride dissociates rapidly to hydronium ions on contact with tissue surfaces, studies designed to quantitate the acid-buffering capacity of mucosal surfaces and tissues of the nasal cavity may be of value for studying dosimetry and threshold effects of hydrogen chloride**. (NRC, 2009, p. 63)
Hydrogen Fluoride	NRC (2006) identified a number of research needs regarding fluoride toxicology for various health end points. **In particular, nearly all human studies require improved characterization of fluoride exposure, including individual fluoride intake. There are very few subchronic or short-term studies of humans with any route of exposure**. There have been occupational studies and studies of exposures to airborne fluoride from coal combustion in China, but most of the literature on effects in humans comes from ingestion exposures, primarily to fluoride in drinking

	water. Although many health end points (such as effects on bones) require long-term exposure or accumulation of fluoride, **others (such as endocrine effects, low tolerance or hypersensitivity, and asthma) do not**. A critical research need for animal studies would be a 90-day continuous-inhalation bioassay for hydrogen fluoride. **Studies that use multiple 90-day exposures that mimic the exposure of the submarine crew may be needed to examine fully the potential for the induction of asthma. A species appropriate for examination of induction of allergic airway disease and measures of airway function would be critical for such a study**. (NRC, 2009, p. 101-102)
Hydrogen Sulfide	Although there is an extensive literature on the health effects of hydrogen sulfide, questions remain about its possible effects and about concentrations at which effects may occur. **Those questions apply particularly in connection with the end points of neurologic, respiratory, behavioral and developmental effects. At airborne concentrations above 20 ppm, the direct irritation effects of hydrogen sulfide are increasingly apparent. Acute respiratory effects are widely assumed to occur after even brief exposures at concentrations above 200 ppm, and acute neurotoxic responses occur at concentrations above 500 ppm. Questions now exist as to whether longer-term neurotoxic and respiratory or pulmonary deficits may occur after short-term high-concentration exposures. There are also concerns about human health effects in the low-exposure region, especially after chronic low-concentration exposure**. (NRC, 2009, p. 132)
Propylene Glycol Dinitrate (PGDN) primary component of Otto Fuel II	Although there have been short-term human exposure studies and 90-day and chronic animal toxicity studies of PGDN, **the short-term and subchronic effects of PGDN are somewhat uncertain**. The human data are limited to a study in which volunteers were briefly exposed to PGDN vapors (Stewart et al. 1974). The animal data on PGDN are from inhalation studies (Gaworski et al. 1985; Jones et al. 1972; Mattsson et al. 1981) that did not identify NOAELs for hematologic and male reproductive effects. **Acute human PGDN-exposure studies that use more modern imaging techniques for cerebral blood flow and neurologic function are recommended. Depending on the results of the acute human studies, animal inhalation studies to determine NOAELs for neurologic, hematologic, and reproductive effects are recommended**. (NRC, 2009, p. 156)

It must be noted that in 23 out of the 26 chemicals or gases studied, there were recommendations for further research that is directed at the submarine atmosphere. Yet, we have found no additional information in the public domain regarding any further studies having been undertaken.

Result

After reviewing and considering the above information, this group of submarine veterans decided to create SAG. We are committed to protecting and serving our fellow Submariners as a part of our identification as Submariners. This commitment and its accompanying responsibilities are deeply engrained within our psyches.

Submariners' Advocacy Group is incorporated in the State of Missouri and has made application for full IRS and Missouri tax-exempt status.

Our current work includes working on the following:

- Drafting a report on submarine toxic exposures to be used to create legislation similar to the Agent Orange Act that will direct the VA to make a concession regarding submarine duty and acknowledge the toxic exposures of submarine crews. This will lead to the establishment of presumptive medical conditions that are service-connected to submarine duty.
- The database and our associated website for the registry of submarine veterans are in the early stages of development with a target launch date of December 2024.
- Documents, reports, and materials for our electronic library are being collected.
- Initial contacts are being made with potential partners for support.

References

National Research Council. (1988). *Submarine Air quality: Monitoring the air in submarines: Health effects in divers of breathing submarine air under hyperbaric conditions*. Washington, DC: The National Academies Press. https://doi.org/10.17226/19146

National Research Council. (2007). *Emergency and Continuous Exposure Guidance Levels for Selected Submarine Contaminants: Volume 1*. Washington, DC: The National Academies Press. https://doi.org/10.17226/11170.

National Research Council. (2008). *Emergency and Continuous Exposure Guidance Levels for Selected Submarine Contaminants: Volume 2*. Washington, DC: The National Academies Press. https://doi.org/10.17226/12032.

National Research Council. (2009). *Emergency and Continuous Exposure Guidance Levels for Selected Submarine Contaminants: Volume 3*. Washington, DC: The National Academies Press. https://doi.org/10.17226/12741.

Shea, M. L., Milroy, W. C., CAPT, MC, USN, Naval Submarine Medical Research Laboratory, Wands, R. C., Carhart, H., Wyatt, J., Williams, F., Einhorn, L., Nyers, R., Bondi, K., Lieberman, J., Eident, C., Goff, G., Gunter, D. O., Hienzsch, M., Kent, D. G., Knight, D. R., MC, USN, Lory, E., McQuire, E. K., CWO-4., . . . Wyatt, J. (1984). Proceedings of the Submarine Atmosphere Contaminant Workshop. In *Naval Submarine Medical Research Laboratory*. https://apps.dtic.mil/sti/pdfs/ADA145769.pdf