Good Morning

At the senate hearing in Adelaide I gave a commitment to forward the recommendations form the Oberon Class Occupational Study to the committee, please find 2 files

1. Recommendations

2. DVA Business Line

Please note as far as I know only recommendation 1 has been carried out and it is my view not followed.

Regards

Ray Kemp JP

Discussion

This project appears to be the most wide ranging review of exposures experienced on Oberon class submarines, covering hazards as diverse as noise and psychosocial stress.

Concerns have been expressed about exposures that may lead to long term irreversible health effects, such as cancer and neurological damage, but the focus of this study was on hazards experienced at sea, where mission and operability requirements may have been the dominant considerations. In particular, the hazards faced during dived patrols, including snorting, may be regarded as the most significant, and thus the emphasis in this report, and indeed most previous studies, is in respect of that situation. That is not to say that submariners were not also exposed to hazards during shore duties, for example during loading, storage and maintenance tasks such as painting.

One of the strengths of this study was its use of multiple sources of data. In addition to a review of the military and general scientific literature, the CMVH team, which included two senior occupational hygienists for the bulk of the work, visited the decommissioned HMAS ONSLOW, conducted focus groups in Sydney and Rockingham, spoke with several experienced submariners and triangulated the evidence to arrive at the conclusions and recommendations.

The focus groups were able to provide an insight into the day to day experiences and perceptions about hazards and hazard management in the submarine environment. In many ways, the hazards were seen as “part of the job” and exposures tolerated for the sake of others. In respect of the submarine atmosphere, the captain appeared to be the arbiter of what was tolerable. Individual relief could be found in medications, smoking and alcohol consumption. With few exceptions, personal protective equipment did not appear to be used, and personal hygiene was compromised, through a shortage of water. Formal occupational health and safety thinking did not emerge until the 1980s, but it is unclear whether this had a dramatic impact on exposures.

Apart from any physical, chemical and ergonomic hazards that may exist in the submarine, the fact that a relatively large number of sailors are in a confined environment for extended periods potentially creates a raft of health issues, including psychosocial, ergonomic and communicable disease problems.
On the other hand, submariners are a self selected population and there is a strong supportive (“family”) culture. The issue of being a self selected population needs to be considered when examining standardised morbidity and mortality rates, where a healthy worker effect may be evident. Additionally, due to the prevailing submarine culture, illness is likely to be under-reported.

As part of their training, all submariners are expected to know, or be aware of, the jobs of others. This feature, as well as the intrinsic characteristics of a submarine and its operational demands, tend to exacerbate the usual occupational hygiene uncertainties associated with "peak" versus "averaged" exposures; “extended duration” exposures versus traditional shifts, "breathing zone" versus "fixed location" values, multiple exposure routes and variable disease susceptibilities associated with sleep-wake patterns, diet, exercise and socially-driven habits.

In developing the Oberon submarine exposure profile, reference was made to the available scientific and technical literature. It rapidly became apparent that systematic occupational hygiene and health studies of Oberon class or even diesel electric submarines were rare. Based on US research report titles, much of the literature has a focus on performance, and deals with nuclear submarines. However, to the extent that Australian submarines were not significantly modified from the original UK configuration, it is feasible to generalize from the Canadian and UK literature (where available). Some aspects of the nuclear submarine literature, e.g. psychological and musculoskeletal hazards, may also be applicable.

Most of the previous studies of chemical exposure were monitoring equipment evaluations, rather than personal exposure assessments, and those that were of an investigative nature produced very little air monitoring data. The Canadian studies of the *HMCS Okanagan*, which appeared to be the best available, aimed to gather information about the ambient environment, and only approximated a hygiene survey.

The first point that needs to be made is that there is strong anecdotal evidence that the submariners' exposures were tolerated, or volunteered, rather than regulated. Conditions were highly variable, such that peak exposures at the limit of tolerability were often encountered. Canadian studies of airborne chemical hazards demonstrated high peaks, e.g. of aerosols, but the average values were usually within military guidelines. In some situations where intolerable exposures were encountered, personal respiratory protection was required.

The impact of intermittent peak exposures on chronic disease risk is uncertain, but the recent occupational health literature suggests that it can be important for a range of diseases, for example, respiratory disease. In other words, such exposures may not necessarily result in fully reversible effects. In theory, exposures experienced in service may sensitise the body or result in subclinical health decrements, and be exacerbated in later years.

The actual uptake of substances may be influenced by dermal exposure (and ingestion), and the lack of dermal exposure information is a serious gap in knowledge. Apart from exposure to carbon monoxide, biological monitoring has not been done. Thus it is unclear what was actually absorbed into the body. Given that surface contamination and aerosols were present, nearly all risk assessments based on air sampling are likely to underestimate the true situation. There are also some components of mixtures for which no toxicological data are available.

As there are a variety of hazards to consider, these were taken in turn. In so doing, however, it is important to bear in mind that there are very few data related to shore duties, and that, with few exceptions, the quality of exposure information is poor.

In respect of asbestos exposure, the literature for submarines is sparse, but on the basis of comments made in focus group discussions, visual observations and related literature, it appears that asbestos exposure was low. Engine room crew, especially in the earlier years, may have had elevated exposures, but probably less than those found in surface vessel engine rooms. The CMVH team did not have access to design specifications for the submarine. It was understood that chrysotile was the most likely form of any asbestos used in gloves, blankets, lagging and gaskets.

Carbon monoxide is an insidious toxicant, and is generated during diesel engine activity and other combustion processes, e.g. smoking. A major air contaminant was cigarette smoke. It is unfortunate that appropriate measures of cigarette smoke exposure were not available or undertaken. However, measurements in submarines under normal conditions suggested moderate and variable exposures mainly depending on smoking and cooking. Torpedo firing may have been a short term source of elevated carbon monoxide exposure. However, the UK mortality experience and the Canadian measurements of carboxyhaemoglobin imply that smoking-related health problems may not be as great as some might imagine. In a Canadian study, carboxyhaeomoglobin values were within limits, even without smoking restriction. On the other hand, the potentially significant exposures to hydrocarbons warrant further study of morbidity

Owing to the confined nature of submarines, very high and potentially lethal concentrations can occur during a fire or a diesel exhaust vent failure. The long term health consequences of non-fatal peak exposures are not fully understood, and there may be lasting effects. However, it seems unlikely that the lower level exposures represent an appreciable risk.

Engine room and galley crew may have somewhat higher exposures than other personnel. Interestingly, carbon monoxide (and carbon dioxide) measurements provide an opportunity to assess the ventilation characteristics of the submarine. Canadian research confirms poor ventilation (>35 min of snorting required to clear the air), with somewhat poorer ventilation in the rear of the boat.

Carbon dioxide has been identified as a significant exposure problem with exposures often exceeding 1%, and there is some human and animal evidence of medium term health effects directly attributable to such elevated carbon dioxide. Depending on the circumstances, e.g. the use of the blackout curtain, the concentrations may not be uniform throughout the boat. Anecdotally, crew were often panting during dives, suggesting high carbon dioxide and diminished oxygen. As quoted in the Canadian study by Severs and Sabiston, "the maintenance of the submarine atmosphere is a judgement call of the submarine Commander, based on his experience and his personal interpretation of the Standard". That said, selection into the submarine service implies tolerance to carbon dioxide and thus the respiratory physiological balance may be unusual in this population.

Benzene exposure has been reported in a number of studies. The air concentrations are low (typically less than 0.1 ppm), and on the basis of a "practical" threshold of 16 ppm-years from Australia data in the petroleum industry, it appears that cases of myloid leukemia are unlikely. This conclusion must be tempered by the lack of knowledge of non-inhalational exposure, especially since benzene is a (minor) component of white spirits used to wash down oily surfaces. It is difficult to assess which members of the crew would have had the greatest benzene exposure, although it is tempting to suggest that engine and machine room operators would have had greater exposure, by virtue of diesel exposure, the use of oily rags etc. The available epidemiological evidence, with a relatively short follow-up, for submariners indicates that the SMR for leukaemia is less than 100, but the extent of the healthy worker effect and influence of medical treatment services is unclear.

Chronic exposure to diesel vapour was a feature of the Oberon class submarine. Marine diesel is a complex mixture with greater than 10% polycyclic aromatic hydrocarbons. There are multiple exposure pathways, and whereas inhalational exposure may be experienced by all crew, engine room crew are exposed to localised fuel aerosol, leaks etc. Anecdotally, diesel was a contaminant of water and was an undesirable characteristic of submariners returning home. Air sampling data for diesel components are difficult to interpret, as volatile organic compounds arise from a number of sources, e.g. cleaning agents. In an Australian review by Gan and Mazurek, it was reported that concentrations of greater than 50 ppm were common in Oberon class submarines. Cancer and neurotoxic risks were calculated, although the International Agency for Research on Cancer has concluded that there is inadequate evidence for human carcinogenicity. The lack of biological monitoring data and the complexity of the exposure pathways, make risk assessment problematic. Nevertheless, there is some evidence that solvent exposed workers may experience long term neurological changes (e.g. "painters syndrome", and visual disturbance), and that certain types of PAH exposure may lead to photosensitivity. Some submariners reported that, on returning home, bed sheets would be stained from skin contact. This is a disturbing remark and suggests that skin is a reservoir for the semi-volatile compounds, and that skin permeation studies should be conducted for diesel exposed submariners.

Diesel exhaust particulate exposure has been linked with cancer, and it is clear that submariners were exposed during snorting. There are some technical difficulties in measurement, and the best available metric (i.e. elemental carbon) has not been sufficiently used to be able to evaluate risk. Once again, engine room crew would be the ones most likely exposed.

There is anecdotal evidence of occasionally significant hydrogen sulphide concentrations, as evidenced by high short term detector tube results and visible sulphide deposition. The most obvious source is sewage, e.g. associated with the break-up of the surface crust in the bilge tanks, but the marine diesel may have had an appreciable sulphur content. Like carbon monoxide it is unclear whether there are long term health consequences for these variable exposures. It is uncertain as to whether any particular members of the crew had greater exposures. It was reported that a crew member, if asked, would volunteer to enter a bilge tank.

Generic aerosol exposures have been studied. In a Canadian study, respirable particle concentrations were found to be highest in the engine room. It would be expected that cooking, frying and smoking could also generate significant aerosol. Peaks may arise from re-entrainment of diesel exhaust (“getting your own back”) and a number of other scenarios. It is difficult to interpret the health significance of unspecified aerosol exposure, and future studies should attempt particulate speciation.

Relatively low levels of other air contaminants have been reported. Arsine, stibine ozone, ammonia or nitrous compounds were not detectable in Canadian studies. Mercury was present in small amounts, but values for sonar operators slightly exceeded the guideline of 50 micrograms per cubic metre. Freon-12, associated with refrigeration units, ranged up to 32 ppm, which is well below the guideline of 500 ppm. Hydrogen, chlorine, hydrogen chloride and hydrogen fluoride have been monitored during battery charging. Only a small amount of hydrogen was detected in the battery compartment. These monitoring data would suggest low exposures, but anecdotally, sea water contact with the battery could generate chlorine, and fires could result in phosgene, hydrogen cyanide, chlorine and hydrogen chloride on an irregular basis. Sulphuric acid aerosol was also mentioned as a hazard in the battery compartment.

Finally, a range of cleaning agents, propellants, hydraulic fluids, degreasers, release agents, paints and pesticides were said to be found on the boat or used during maintenance (whilst docked). Epoxy paints, Otto fuel, Brasso, Silvo, White Spirits, turpentine, carbon tetrachloride, Ardrox, Gamlen and Turcosol were mentioned. Without access to an inventory of materials brought on to the submarine, product identification and composition cannot be determined. Day to day cleaning activities using hydrocarbons may result in personal exposure over and above background levels. Of great concern is the reported usage of carbon tetrachloride for cleaning circuits. This substance is known to cause liver damage, and it is tempting to suggest that elevated rates of cirrhosis of the liver among submariners were partly due to the historical use of chlorinated hydrocarbon solvents.

There have been microbiological investigations of submarines, but little in the way of air monitoring. An Australian study involving swipe and air sampling demonstrated low levels of contamination, except when mouldy bags were moved. In other studies, it was found that flora could be related to faecal contamination. *Pseudomonas aeruginosa* was commonly found. A *Mycoplasma pneumoniae* outbreak was reported for a nuclear submarine crew on patrol. Hepatitis and scrotum infections were mentioned in the focus groups. In a recent Swedish study, marker concentrations of fungi and bacteria resembled those found in domestic and work environments. Antibiotics were available on board the submarines, but aspects of their use were not explored further.

Personal hygiene was an issue, due to water rationing. Whilst showering was recommended for certain crew, but this was not always done, perhaps in an attempt to conserve water. Crew went to sleep without changing clothes.
Apart from the confined nature of human occupancy, there seems to be nothing remarkable about the microbiological environment of submarines, and no indication of elevated exposure among any particular subgroup.

The literature search could locate only one report of noise exposure on Oberon class submarines, and this was not representative of normal conditions. Anecdotally, noise was a major issue for those in the engine room, and these crew members were provided with ear muffs and headsets (for some noise reduction and communication purposes). Interference noise was reported for other crew wearing headsets. Data from HMAS COLLINS suggest that noise exposures in the main generator room can approach 110 dB(A) whilst the diesel generators are active. There is evidence that submariners have a higher rate of hearing loss compared with age-matched civilians. Recent guidance on noise management refers to the potential for synergy between noise and chemical exposure, and this may be the case for Oberon class submariners. Carbon monoxide and xylene have been classified as synergistic agents.

No references could be found on radiation hazards pertaining to diesel electric submarines. Nor was it mentioned in the focus groups.

Psychological hazards have not been directly assessed, e.g. via cortisol levels, but it is clear from the focus group information and other data that stress arose during and after deployment. A survey of navy wives, using a mood questionnaire, comparing those whose husbands were away and those port bound, illustrated spouse depression as just one aspect of a complex issue. Compounding the problem is body contamination with diesel. It is likely that psychological "exposures" were not distributed according to rank, but were probably more significant for those married, and with children.

Musculoskeletal hazards arose from assigned tasks, but no exposure data were available locally. Manual handling hazards were described during the submarine visit and during focus group discussions. The hazard of repeatedly rotating high pressure valves in a stooped posture was mentioned on several occasions. It appears that panel operators, and those working in tight spaces have greater exposures. However, a majority of the members of the focus groups reported some back, hip or neck problem.

Atmospheric pressure hazards during dived patrols were commonly reported. Pressure variations led to discomfort, but burst eardrums were not mentioned. All crew would have been affected.

There is little mention of heat stress in the literature, although this would be most apparent in the engine room. In addition, the air conditioning/ventilation system on Oberon class submarines was not suited for tropical climates, and there is anecdotal evidence of heat stress when docked in those ports. The combination of hot and damp skin would have led to heat rashes, and possibly the increased uptake of skin contaminants.

Owing to time constraints and the lack of availability of data, particularly from the UK, an exhaustive literature review could not be conducted. It is possible that musculoskeletal risks, psychological and ergonomic problems have been inadequately addressed. These hazards would be found in all submarines, and not just the Oberon class submarines.

A list of specific data and documents that have been identified as being relevant to this project but were either unavailable or classified (restricted) and therefore unable to be utilised in this report is attached at Annex D. Were these documents to be made available to the CMVH team as unclassified documents, a supplementary report to this report would be able to be provided.

Conclusion

In conclusion, the occupational hygiene literature for Oberon class submarines appears to be sparse. Whilst engine room crew probably experienced a range of significant exposures by virtue of their proximity to the diesel engines, all of the crew were exposed to a cocktail of substances, by multiple routes. A number of factors blur the distinctions, and direct comparison with exposure criteria is problematic.

However, the exposure profile shown in Tables 4 and 5 illustrate that significant exposures to diesel vapour, other particles, carbon monoxide, carbon dioxide and oxygen (lack of) occurred on the Oberon Class submarine. Additionally, Oberon submariners were significantly exposed to the more traditional types of workplace hazards such as noise, heat, musculoskeletal and psychological hazards. Whilst these types of hazards are not unique to the Oberon submarine the context, of confined spaces and 24 hour exposures, in which the submariners were exposed was unique. In addition, the limited washing facilities and potential for synergistic exposure, e.g. between noise and solvents, need to be acknowledged.

Although it is impossible to re-evaluate most exposures, it may be feasible to undertake biomechanical hazard assessments post hoc, e.g. simulating tasks in the decommissioned submarines to strengthen the level of evidence.

The potentially significant exposures to hydrocarbons warrant further study of morbidity.

Recommendations

The following recommendations are made in the light of the findings:

- The Department of Veterans' Affairs note the Exposure profile in Tables 4 and 5 for consideration as to how it may assist in the compensation process for submariners.

- Defence make available, where possible, documents that have been identified as highly relevant to this project for review. Should this occur, a supplementary document, expanding on the findings of the current report, could then be provided.

- To expand on the findings of this study, a qualified and experienced biomechanist should categorise manual handling, awkward and repetitive tasks on board the Oberon submarine. The most significant of these should be simulated within one of the decommissioned Oberon boats, and biomechanical risk assessments undertaken to strengthen the level of evidence.

- To expand on the findings of this study, tests of skin absorption and skin permeation of diesel could be undertaken and should be considered to add weight to the evidence of risk of diesel exposure.

- Consideration be given to the conduct of a health study of the submariner population to address ex-Oberon submariner concerns and attempt to identify any adverse health outcomes associated with documented exposures. Specific areas of research could include a cancer incidence and mortality study and neurobehavioural testing, using a suite of sensitive indicators of neurological damage. The Defence Deployment Health Surveillance Program is a potential conduit for such a study.

- The Collins Class submarine was not the focus of this study and has not been specifically considered, however, the literature review did reveal that similar hazards may exist on the Collins Class submarines. Systematic occupational hygiene studies, including biological monitoring of hydrocarbon uptake, could be carried out in Collins Class submarines. A gap analysis of what relevant work has already been done and what could be done to expand current knowledge should be undertaken.

Australian Government

Department of Veterans' Affairs

BusinessLine

File/Trim Reference:

NATIONAL MANAGER MILITARY COMPENSATION SERVICE DELIVERY
NATIONAL MANAGER VETERANS' COMPENSATION SERVICE DELIVERY
Directors and Assistant Directors Military Compensation
Directors and Assistant Directors VEA Compensation
Deputy Commissioners

Assessment of Compensation Claims Relating to Service Aboard Oberon Class Submarines

Purpose

The purpose of this BusinessLine is to provide information to delegates administering compensation claims relating to ADF service aboard Oberon Class Submariners under the provisions of the *Safety, Rehabilitation and Compensation Act 1988* (SRCA) and its predecessor legislation and the *Veterans' Entitlements Act 1986* (VEA).

Background

The Centre for Military and Veterans' Health (CMVH) was tasked with creating a hazard exposure profile for Australian Oberon Class submarines that were in service between 1967-2000 (all of which have now been decommissioned).

Beyond the literature review, the CMVH team, which included two senior occupational hygienists, visited the decommissioned HMAS ONSLOW, conducted focus groups in Sydney and Rockingham and spoke with several experienced submariners to develop a hazard exposure profile (which is attached at the end of this Businessline).

From a compensation perspective, there has been anecdotal evidence from personnel who served aboard the Oberon Class submarines of several health conditions they believe to have been caused by their service. In this respect, many submariners highlighted difficulties in having their Department of Veterans' Affairs claims accepted due to the lack of recognition of the hazards experienced during their submarine service. It is therefore hoped that the report will provide better authoritative documentation of the known hazards and will assist in the decision-making processes for future compensation claims.

Tables 4 and 5 in the report detail the exposure profiles and level of evidence of the hazards identified in the project. The legend for each of the tables is as follows:

Legend
*based on proximity to source, task and other factors
Rating: low =low exposure relative to exposure criterion; significant =comparable with or greater than exposure criterion.
Quality of evidence: good =published data under actual conditions; medium =professional judgement in conjunction with focus group information and observation; poor =insufficient, unavailable or presumptive.

Specified diseases under section 7(1) of the SRCA

Section 7(1) of the SRCA relates to diseases contracted by ADF employees of a kind specified by the Minister in writing. In short, it states that the Commonwealth will be taken to have contributed in a material degree to the contraction of a particular disease if the employee was engaged in employment of that kind, unless the contrary can be established. The declaration under section 7(1) containing each of the occupational diseases (and requisite employment factors) can be found in Appendix 5 of the SRCA.

The profile shown in Tables 4 and 5 illustrate that exposure to certain asphyxiants such as carbon monoxide, hydrogen cyanide and hydrogen sulphide occurred on the Oberon Class submarines (all of which are specified by the Minister under section 7(1)). Additionally, Oberon submariners were significantly exposed to the more traditional types of workplace hazards such as noise, heat, musculoskeletal and psychological hazards. Whilst these types of hazards are not unique to the Oberon submarine, the context (of confined spaces and 24 hour exposures) in which the submariners were exposed was unique.

Assessment of Claims

When considering all future claims relating to service aboard Oberon Class submarines, delegates are now required to have regard to the Tables at the end of this Businessline and also be aware that the provisions contained in section 7(1) of the SRCA may apply in certain circumstances.

MRCA & VEA Claims

While the majority of claims will be assessed under the provisions of the SRCA and its predecessor legislation(s), VEA and MRCA delegates may still benefit from the content of the report and, more specifically, the exposure profiles contained in Tables 4 and 5 (particularly where SoP factors for conditions include any exposures listed in the tables). A full copy of the report will be made available to delegates in the Military Compensation Group staff site on the intranet.

Contact

Any questions regarding the content of this BusinessLine or its implementation should be directed to Michelle Glanville, Director Military Compensation Policy on (02) 6289 6382 or Paul Weber, SRCA Policy Adviser, on (02) 6289 6419.

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Table 4: Exposure Profile and Quality of Evidence

Hazard	**Most exposed crew***	**Rating**	**Quality of Evidence**	**Comments**
Gases (see below)				
Diesel vapour	Engine room crew	significant	medium	
Other hydrocarbons and volatile organic compounds	Engine room crew, electrical maintenance	low	medium	May be peak exposures when cleaning
Metals (e.g. lead, mercury)	Control room, electrical maintenance	low	medium	May be significant for mercury
Asbestos	Engine room crew	low	medium	
Diesel exhaust particulate	Engine room crew	low	medium	
Other particles	Engine room, cook	significant	medium	
Microbes (including bacteria and fungi)	All	low	medium	
Noise	Engine room	significant	medium	
Vibration	Engine room	low	poor	
Heat	Engine room	significant	poor	
Musculoskeletal	All Panel operators	significant significant	poor poor	 Turning valves
Air pressure	All	significant	good	
Psychological	All	significant	medium	
Poor Illumination	Control room		medium	
Non-ionising radiation	Control room, Electrical maintenance	low	poor	
Electricity	Electrical maintenance	low	poor	

Table 5: Exposure Profile (gases) and Quality of Evidence

Gas	Most exposed crew*	Rating	Quality of Evidence	Comments
Carbon Monoxide (CO)	Engine room, torpedo operators	significant	good	Smoking and cooking also relevant
Hydrogen Cyanide (HCN)	No specific crew	low	poor	Only in the event of fire or possibly torpedo firing
Carbon Dioxide ($C0_2$)	All	significant	good	
Oxygen (0_2)	All	significant	good	
Hydrogen Chloride	Electrical maintenance	low	medium	
Phosgene	No specific crew	low	poor	
Chlorine (Cl_2)	Electrical maintenance	low	medium	
Oxides of Nitrogen (NO_x)	Engine room, torpedo operators	low	poor	Only in the event of fire or torpedo firing
Hydrogen Sulphide (H_2S)	All	low	poor	Peaks possible
Hydrogen (H_2)	Electrical crew	low	good	