SELF-REPORTED EXPOSURES AND HEALTH STATUS AMONG WORKERS FROM THE EXXON VALDEZ OIL SPILL CLEANUP

By

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ABSTRACT

Objective. To investigate whether workers on the *Exxon Valdez* oil spill (EVOS) cleanup experience higher prevalence of self reported physical symptoms, which might be attributable to exposures to crude oil and other chemical hazards during their work on the cleanup.

Methods. A cross-sectional telephone interview survey of former *Exxon Valdez* oil spill cleanup workers was conducted using both validated and investigator-derived questions to assess relevant exposures and medical conditions. Potential subjects were located from Alaska Department of Labor records from the cleanup and were interviewed in February 2003. Exposures were categorized on the basis of job tasks conducted during the cleanup and on self-reported exposures to specific oil and chemical hazards encountered.

Results. EVOS workers who conducted jobs with high oil exposure or reported exposure to oil mists, aerosols, or fumes during cleanup work have a greater prevalence of symptoms of chronic airway disease than workers with less exposure. Nonsmokers with high oil exposure have significantly greater prevalence of symptoms of chronic bronchitis than nonsmokers with less oil exposure. High oil exposure was also associated with a greater prevalence of symptoms of neurological impairment, as well as with symptoms of multiple chemical sensitivity. Moderate chemical exposure was also associated with a greater reported prevalence of chronic airway disease and symptoms of multiple chemical sensitivity.

Conclusions. The results indicate that some component of work on the EVOS cleanup may contribute to an excess prevalence of respiratory and neurological conditions reported by EVOS workers. However, there is a great need for further surveillance and detailed studies on workers who participate in marine oil spill cleanup operations, utilizing both exposure data and physical evaluations. Limitations that were present in the operation of the EVOS cleanup are discussed, and recommendations to ensure protection of workers' health in the event of future oil spill cleanup operations are presented.

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I. INTRODUCTION

The *Exxon Valdez* oil spill (EVOS) in March, 1989, was the largest oil spill in the history of the United States (EPA 2003). Immediately following the spill and during the summer months from 1989 to 1992, thousands of skilled laborers, untrained workers and volunteers flooded into the Alaskan coastal cities to assist with the cleanup efforts. The spill was classified as a hazardous waste cleanup operation by the Occupational Safety and Health Administration (OSHA) due to the hazardous chemicals used and toxic compounds present in the oil. It is unclear whether the best controls were used to fully protect worker health, and it is possible that workers on the cleanup may have been overexposed to hazardous chemicals at levels above the NIOSH recommended exposure limit (REL) (Reller 1993) as well as above the OSHA Permissible Exposure Limit (PEL) for several substances. At the time of the cleanup, many workers had complaints of various health problems, such as respiratory irritation, nausea, dizziness and skin rashes (Alaska Oil Spill Health Conference Summary, 1989). Anecdotal reports indicate that chronic health complaints still exist among workers, with symptoms of skin rash, chronic respiratory disease, multiple chemical sensitivity and neurological damage the most commonly reported (Phillips 1999, Murphy 2001). Some workers also claim that they worked without adequate protective equipment and that now they and "hundreds" of other workers are getting sick due to their exposures (Coughlin 1992).

Immediately following the spill and during the past fourteen years, considerable attention has been given to the ecological impacts of the spill on the marine ecosystem and animals of Prince William Sound. Despite extensive research to determine the environmental effects of the spill, no epidemiological studies have been conducted, to date, to assess the health effects on the workers involved with the cleanup. There were several potentially hazardous compounds of concern present during the oil spill cleanup, most notably oil mist containing polycyclic aromatic hydrocarbons (PAHs), volatile organic carbons (VOCs) evaporating from the crude oil, and various chemicals present in the bioremediation and dispersion agents used by workers. A large body of evidence exists regarding adverse health effects due to occupational exposures to these agents. Because of the potentially severe exposures among workers on the EVOS cleanup, reports from many workers of chronic health problems, and the lack of scientific knowledge about long-term health consequences of oil spill cleanup exposures, this study was conducted to assess the self-reported exposures during the cleanup, acute health symptoms during work on the cleanup, and chronic health symptoms among EVOS cleanup workers fourteen years after the spill.

The specific aims of this study are: first, to assess the prevalence of chronic health symptoms among former EVOS cleanup workers and secondly, to determine the specific oil spill cleanup tasks and exposures which are associated with the greatest prevalence of adverse acute and chronic health impacts. My primary hypothesis is that workers who had the highest exposure to crude oil fumes and mist, and oil response technicians (ORTs) who worked on beaches using high pressure hoses to spray the shoreline, will have a higher self-reported prevalence of chronic respiratory illness and neurological impairment than workers who had less oil exposure or were unexposed during cleanup. My secondary hypothesis is that EVOS workers, who experienced high chemical from their cleanup job tasks, and those who report exposure to the chemicals Inipol EAP 22® and Customblen ® used for bioremediation during cleanup, will have a higher prevalence of multiple chemical sensitivity, neurological impairment, anemia and liver disease than unexposed workers.

II. LITERATURE REVIEW

There are two bodies of evidence indicating the possibility of potentially harmful health effects from exposures sustained during oil spill cleanup work. The first is from epidemiological studies, which examine the health effects among residential populations exposed to oil spills and acute health effects among oil spill cleanup workers from spills other than the *Exxon Valdez*. However, the applicability of residential studies to an occupational setting is questionable, and no studies regarding chronic effects several years following exposure among workers could be located. The second body of evidence supporting potential adverse health effects from oil spill cleanup exposures is the wealth of scientific literature on specific chemical hazards present in the individual constituents of crude oil, from toxicological studies of these components or on various occupational exposures where these chemicals are present.

Epidemiological studies of coastal populations exposed following oil spills

Several studies have attempted to determine both acute and long term effects among coastal residents exposed following marine oil spills. Two of these studies, conducted by Campbell *et al.* on populations exposed after the Braer tanker oil spill near Shetland, Scotland, used questionnaires primarily structured to determine participants' perceptions of health following exposure to the spill (1993 and 1994). Residents within 4.5 km of the spill were surveyed and it was found that those living in the greatest exposed areas reported increased frequencies of headaches, throat irritation and itchy eyes than unexposed populations (Campbell *et al.* 1993). A similar study on later effects was conducted 6 months following the spill and 344 of the original 420 subjects were interviewed (Campbell *et al.* 1994). This second study found that significantly more exposed individuals considered their health to be altered following the spill than controls.

Similar results were found in a population-based retrospective cohort study of residents exposed to the Sea Empress Spill near Wales, which found significantly higher self-reports of headaches, sore eyes and sore throats among exposed populations compared to controls after adjusting for several potential confounders, including the belief that the oil spill had affected an individual's health (Lyons *et al.* 1999). These and other studies which focus on the acute health effects of marine oil spills on the residential populations in coastal areas are limited in their applicability as a comparison to the experiences of the EVOS cleanup workers, due to differential intensities and duration of exposures. However, they provide some indication of the nature of acute health complaints among people exposed to oil spills.

Epidemiological studies on oil spill cleanup workers

No studies could be located which have examined chronic effects on oil spill workers,[2] although one study was located which used questionnaires to determine acute health effects. A questionnaire was used to assess exposures, protective measures and acute health effects among workers following the *Nakhodka* spill near Japan. Of the workers involved with the *Nakhodka* spill cleanup, 282 were interviewed by public health nurses to determine whether they suffered physical symptoms after exposure to the oil spill. The average number of days worked on cleanup activities was 4.7 for men and 4.3

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[2] Extensive searches conducted on Medline, Pubmed and various other scientific databases produced no epidemiological studies on long-term effects among oil spill workers. A review article by Park and Holliday on the occupational health aspects of marine oil spill response also concluded that "there seems to be no comprehensive epidemiologic studies on oil-spill cleanup workers." (1999). This may be due to the difficulty of assessing exposures and outcomes due to short-duration of employment and the often transient nature of the employees involved with oil spill cleanups, or simply a lack of interest among the scientific community.

for women. The symptoms reported included low back pain, headaches, and irritation of eyes and throat (Morita *et al.* 1999). Workers were also asked how often they wore PPE, and it was found that gloves were worn by almost 100% of subjects, whereas masks were worn by 87.1% of women and 35.4% of men (Morita *et al.* 1999).

While no other epidemiological studies pertaining to oil spill workers could be located, a particularly relevant risk assessment was conducted on workers who participated in the cleanup of the *Erika* oil spill near France in 1999. It was determined that workers who had bare-handed contact with the oil while cleaning birds had increased risk for developing acute skin irritation and dermatitis, and the potential for developing skin tumors (Baars *et al.* 2002). Workers who were involved with high pressure sprays to clean protective clothing were also at greater risk of general toxicity due to naphthalene and carcinogenicity due to PAHs present in the aerosol-like atmosphere generated (Baars *et al.* 2002). The generalizability or applicability of these studies for the EVOS workers is limited by small sample sizes, short duration of exposures, and arguably less intense exposure with regard to specific chemicals present, such as Inipol EAP 22®, a potentially hazardous product introduced as a bioremediation agent on beaches during the EVOS cleanup. Furthermore, no long-term follow up studies were conducted on these populations.

The chronic effects associated with brief or sustained exposures encountered during the cleanup of oil spills have not been established. However, a review of the scientific and toxicological literature on the individual occupational hazards encountered during a marine oil spill cleanup operation may provide insights with which to guide the generation of hypotheses for estimating the long term effects on workers exposed to these substances. The hazards of greatest concern, the major exposure routes and subsequent potential health impacts associated with each are presented as follows.

Major contaminants and sources present during the EVOS cleanup

Assessing the exposures at the hazardous waste cleanup site of a major oil spill is often difficult, since "crude oil is a complex mixture of organic chemicals" (NIOSH 1991). Although there are little data on inhalation effects from exposure to crude oil as a single entity, there are "literally thousands of papers dealing with the chronic effects of inhalation exposure to specific crude-oil components" (Park and Holliday 1999). The primary hazardous substances of concern present at an oil spill cleanup site are the actual components of crude oil,[3] and the chemicals used for decontamination, bioremediation, and dispersion of the oil. The constituents of crude oil which present the greatest potential hazard are volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs) (Park and Holliday 1999) and hydrogen sulfide (H2S), a naturally-occurring component of crude oil, which is further generated through the biodegradation of oily waste (ATSDR 1999b).

The specific VOCs most commonly present in crude oil are benzene, toluene, ethylbenzene and xylene (Alaska Oil Spill Health Conference Summary 1989). Significant exposure routes for VOCs are inhalation and dermal absorption (ATSDR 1997). Various PAHs in particulate form in oil mist constitute a significant portion of the inhalation and dermal exposures in oil spill cleanup operations. Some of the representative PAHs found in crude oil, tars and combustible products are: anthracene,

[3] Crude oils are complex mixtures that vary greatly depending upon their source but are generally composed primarily of hydrocarbons, including straight, branched and cyclic alkanes. Crude oils also are composed of aromatic components including benzene, alkylbenzenes, napthalenes and PAHs, as well as non-hydrocarbon components, including sulfur-, nitrogen-, oxygen- and metal-containing compounds (ATSDR 1999a).

phenanthrene, benzo(a)pyrene, fluoranthene, benzo(a)anthracene and chrysene (Attias *et al.*, 1995; Sprince, Thorne and Cullen 1994) which all have varying degrees of carcinogenicity, but for which the toxic effects in humans following exposure in oil spill cleanup sites are considered collectively.

Chemicals used during the EVOS cleanup may also have led to significantly harmful exposures. Inipol EAP22® (hereafter referred to as Inipol) was a product used for bioremediation which involves the application of fertilizers and microorganisms to the shoreline to speed up the biodegradation of oil (Alaska Oil Spill Health Conference Summary 1989). Inipol contains 2-butoxyethanol, which if inhaled, may result in "dizziness, headache and respiratory irritation, to unconsciousness and possibly death" (Coughlin 1992). Other chemicals used in decontamination of equipment and PPE, such as the cleaner De-Solv-It®, the "cleaner of choice for the equipment being used in the beach cleanup" (Griesemer, 1989), or agents used in dispersion (to flush the beaches) and bioremediation, such as Corexit® and Customblen®, respectively, may have contributed to significantly hazardous exposures experienced during the EVOS cleanup (Griesemer1989). Finally, workers may have been exposed to diesel exhaust from machinery and carbon monoxide at potentially hazardous levels.

Monitoring for several of these exposures listed above was conducted during the cleanup by Exxon's primary contractor, Med-Tox Associations, Inc. Limited industrial hygiene monitoring information from this company was obtained and is presented in Table 1. The OSHA Permissible Exposure Limit (PEL) levels are also listed for comparison with the range of actual exposures. As indicated in Table 1, the possibility exists for over-exposure of workers to many of the hazardous constituents present during the EVOS cleanup, particularly benzene, oil mist, butoxyethanol, carbon monoxide, and hydrogen sulfide. Since it is possible that many EVOS workers were exposed to these chemicals at levels above the OSHA PEL, the primary exposure routes, the magnitude and duration of the exposures, as well as the possible subsequent harmful health and comfort effects, are considered below.

Job classification and exposures among EVOS cleanup workers

From the time of the spill in March 1989 to the point when cleanup operations ceased in Sept 1992, there were over 11,000 workers employed on the cleanup (Phillips 1999), the majority of whom were Alaskan residents (NIOSH 1991). The intensity of the exposures among EVOS cleanup workers were largely determined by the specific job tasks each individual conducted. Although the exposures also varied within each job task, the nature of jobs conducted is one measure with which to determine an estimate of exposures. Figure 1 describes the distribution of the work force involved with the cleanup in 1989, and the size of the population employed throughout the summer of 1989 is presented in Figure 2. Although not all workers had direct contact with oil or chemical agents used on the cleanup, almost half (44%) of the workers in 1989 were oil spill response technicians (OSRTs or ORTs) who worked on the beaches using high pressure hot water washes to spray oiled shoreline and rocks (Exxon 1989b) (Figures 3, 4 and 5). This process created a mist and aerosol formation from the crude oil which likely contained airborne PAHs (Park and Holliday 1999). Workers on Omni barges who used high pressure hoses to spray steep shorelines were also likely exposed to the aerosolized oil-water mist (Figures 6 and 7).

Other work categories with potentially significantly exposures to hazardous substances were: skimmers who scooped oil from the surface of the water, boom handlers who used large booms to contain the spread of the oil, machine operators, decontamination crews who cleaned boats, clothing, and personal protective equipment (PPE), and the bioremediation application team who applied chemical fertilizers to the beaches, such as Inipol, which were designed to degrade or 'eat' the oil. Those with the greatest potential for continuous exposure to oil mists and PAHs were likely the ORTs who were surrounded by oil mist from the hot water washes, whereas the skimmers and boom operators who worked during the first few weeks of the spill likely had the greatest exposures to VOCs.[4]

It is more complex to assess the exposures of the decontamination and bioremediation crews, since they were exposed to many different chemicals such as De-Solv-It®, Corexit®, Customblen®, Inipol EAP22® and Citriklean ®. These workers may also have experienced significant exposures to oil mists through decontamination of PPE (the decontamination crew) or through working near ORTs on the beaches (the bioremediation crew). Workers who conducted decontamination of PPE in the 1999 *Erika* oil spill cleanup in France were reportedly exposed to a "humid and PAH-rich atmosphere" where exposure measurements indicated 23 ng and 33 ng benzo [a]pyrene equivalents and 620 ng and 680 ng naphthalene per m^3 (Baars, 2002). Assessing exposures based upon jobs becomes further complicated due to the fact that many workers conducted several different tasks throughout the period of their employment on

[4] Although most of the VOCs likely evaporated within the first few days following the spill, the potential for longer sustained exposure is possible in situations where fresh oil is continuously renewed or released to the air, which could occur if a skin were formed on the top of oil or if rough waters stirred new releases (Park and Holliday 1999).

the spill. The workers whose primary task was the collection and treatment of wildlife may have experienced significant VOC exposure if they worked during the first few weeks following the spill, and they also had the potential for exposure to formaldehyde and formalin used to preserve dead animals throughout the duration of the cleanup.[5] These workers may also have experienced significant dermal exposure to oil, as workers with the same job task in the *Erika* oil spill cleanup (bird/ animal cleaners), cleaned birds "bare-handed, using various detergents."(Baars 2002).

Routes of exposure

Among workers involved with an oil spill cleanup, the primary routes of exposure with contaminants of concern are inhalation and dermal routes (Baars 2000, 2002). Although ingestion of food or beverages contaminated with oil is possible, measures taken to prevent this exposure are quite obvious and therefore it is the least likely exposure route. Until the time of the *Exxon Valdez* oil spill in 1989, the primary hazards due to exposure after an oil spill were widely accepted to be inhalation of VOCs from fresh crude oil and skin contact with fresh or weathered crude oil (NIOSH 1991; Park & Holliday 1999). However, contact with oil mists or aerosols, diesel fumes and exhaust, and dermal exposure to various chemical bioremediation and decontamination agents used during oil spill cleanup operations are further exposure routes which must be considered. The media through which workers can be exposed to these hazards are primarily air, water and through direct contact with the substance, such as skin contact with crude oil or with oil-contaminated seawater (Baars 2002). The inhalation and

[5] In addition to exposures present due to the oil and chemicals used during the cleanup, wildlife crews were potentially exposed to "gallons" of formaldehyde and formalin used to preserve tissues from the creatures killed by the spill (Alaska Oil Spill Health Conference Summary 1989, Eric Shortt and Russell Palmer, Alaska Dept of Labor), although this particular exposure was not addressed in the NIOSH HHE or in any other documents located.

dermal exposure routes to each of these hazardous compounds, as well as factors influencing the absorption into the body following exposure are discussed as follows.

Factors determining uptake following exposure

The extent of hydration is one of the most important physiological factors which influences percutaneous absorption of chemicals. The permeability of skin has been shown to increase as much as four-to fivefold following hydration (Eaton and Robertson 1994), and detergents and other surfactants may also alter the dermal absorption of chemicals. PAHs are generally believed to be more readily absorbed via the skin of humans and experimental animals if PAHs are present in a solvent, or in an oily or fatty vehicle (Baars 2002). During the EVOS cleanup, workers were constantly exposed to an oil-water mist, and often worked in wet conditions, since it was a marine oil spill cleanup. Workers on the decontamination crew used detergents to remove oil and chemicals on clothing and PPE, and were therefore likely differentially exposed than other workers.

SPECIFIC EXPOSURES VIA INHALATION

Volatile Organic Compounds (VOCs)

In determining the exposure of workers to VOCs from the crude oil, consideration must first be given to the physical and chemical transformations of these chemicals. There is general agreement in the literature that the volatile components of crude oil evaporate quickly, therefore resulting in minimal exposures to personnel who may not be involved with the cleanup until after most of the vapors have been volatilized. Crude oil undergoes a "weathering" process due to the effects of the ocean and the environment which removes a large proportion of the VOCs through evaporation.[6] The VOCs present in crude oil likely evaporate during the first 10-20 days following an oil spill (Alaska Oil Spill Health Conference Summary 1989). Once in the air, VOCs such as benzene break down in a few days (ATSDR 1997). Therefore, exposures to these components are most significant during the first few days following an oil spill. Although the process of weathering releases the majority of the VOCs from crude oil, it may also concentrate the PAHs in the oil (Rall 1989).

Investigators from the National Institute for Occupational Safety and Health (NIOSH) reported that "almost all of the exposure data prior to NIOSH involvement focused on evaluation of worker exposure to VOCs" (NIOSH 1991). The primary route of exposure to VOCs for the EVOS workers is through inhalation of fumes from the crude oil. One important VOC of concern is benzene, which has established detrimental health effects such as leukemia, anemia and neurological effects. When benzene is inhaled, about half of the amount inhaled is absorbed through the lungs and enters the bloodstream (ATSDR 1997).

No monitoring data could be obtained to quantify the immediate exposures following the spill; however, NIOSH investigators conducted their exposure assessment approximately four months following the spill and concluded that "exposure to the volatile components of the original crude oil was not anticipated to pose a significant hazard, except for confined space tasks or instances when fresh crude had crusted over or been trapped in areas in such a way that evaporation was hampered, and then was

[6] Outdoor wave tank experiments were conducted to attempt to determine the fraction of VOCs that were removed from crude oil through the weathering process. Prudhoe Crude oil was found to release substantial concentrations of aliphatics (methane through n-octane) and aromatics (benzene, toluene, ethylbenzene and xylene) (Alaska Oil Spill Health Conference Summary 1989).

disturbed as part of the cleanup operations" (NIOSH 1991).[7] However, with regard to the exposures experienced immediately following the spill, the NIOSH report stated that "exposures to volatile components of the crude oil at the very beginning of the cleanup operation may have been substantially different" (NIOSH 1991).[8] Other reports indicate consensus that it is difficult to estimate the potential inhalation exposure following an oil spill, due to the general lack of data and the highly varying composition of heavy fuel oils in general, and while exposure to vapor concentrations of toxicological significance is unlikely, higher exposures are possible, particularly if circumstances facilitate aerosol formation, such as through the use of high-pressure hoses (Park and Holliday 1999; IARC 1989).

Crude oil mists, PAHs, and aerosols

The removal of crude oil from the beaches during the EVOS cleanup relied heavily on the use of high pressure hot sea-water washes and steam to blast the oil from the rocks (Exxon 1989a). This process worked through pumping salt water through boilers housed either on shore or on the beach (Lamming 1989b). EVOS workers were surrounded by a pervasive cloud of aerosolized oily sea spray throughout the cleanup, as shown in Figures 3, 4 and 5. The majority of the risk of exposure to this aerosol-like atmosphere was a risk of general toxicity due to naphthalene and a risk of carcinogenicity due to PAHs (Baars 2002). The oil particles contain PAHs of varying concentrations[9]

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[7] The Laborers' International Union of North America also reported that the "tides continually move and redistribute the oil, so that formation of a tar-like skin is less likely. Even if a skin is formed, vapors can be released when the skin is disturbed during cleanup work" (LIUNA 1989).

[8] There were several reported incidents of workers who were overcome by fumes from the oil and became ill. Fourteen workers at Windy Bay were transported to South Peninsula Hospital to be treated for exposure to fumes on May 9, 1989 (Ortega 1989). Other workers later filed lawsuits, claiming that the crude oil fumes made them sick during the earliest stage of the cleanup (Coughlin 1992).

[9] Most of the inhalation exposures of PAHs are through particles or dust rather than vapors of PAHs (ATSDR 1995b). While the composition of the aerosol particles is difficult to determine, it is unlikely that

and carcinogenic properties, but one of the most important to consider is Benzo(a)pyrene (BaP), due to its high carcinogenic potency and its relatively long environmental persistence (Attias *et al.* 1995). Inhalation is a significant route of human exposure to PAHs, and human lung cells are capable of metabolizing PAHs to reactive intermediates, which could result in respiratory tract toxicity (ATSDR 1995b).

Inipol EAP 22® (2-butoxyethanol)

Among the various chemicals used during the cleanup, perhaps the most important to consider with regard to hazardous exposures is the bioremediation agent Inipol. Inipol contains the chemical 2-butoxyethanol, which causes established adverse health effects, such as decreased hemoglobin levels, headaches, nose and eye irritation, vomiting and contact dermatitis (ATSDR 1998). The Material Safety Data Sheet (MSDS) for this product, produced by Exxon in partnership with the French company Elf Aquitaine, lists primary occupational exposure routes as skin contact and inhalation (Exxon 1989b). As is shown in Figures 8 and 9, workers who sprayed Inipol on the beaches often did not wear respirators; therefore, potentially significant inhalation exposures may have occurred. Industrial exposures through vapor inhalation as well as inhalation exposures through the use of household products containing 2-butoxyethanol have been reported (ATSDR 1998).

Hydrogen sulfide (H2S)

Hydrogen sulfide (H2S) is a naturally-occurring component of crude oil and inhalation is the most common route of exposure (ATSDR 1999b). EVOS workers were

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they would contain appreciable amounts of VOCs. The concentration of these aerosols may be approximately 1 mg/m3, and might contain up to about 1% PAHs, which would suggest a possible airborne concentration of 10 ug/m3 in the aerosols. Assuming a worst-case scenario, this could lead to "an intake of about 100 ug carcinogen per day… which "would not be insignificant" (Park and Holliday 1999).

likely exposed from oil fumes and through handling bags of oily waste, since H2S was released by biodegradation of the waste. The main recovery yard, where the oil/water mixture was taken after the tanker ran aground, in order to try to extract and salvage the remaining oil, was a location where there was a great deal of exposure to H2S (Hunninen 2002). According to Katherine Hunninen, an industrial hygienist working on the cleanup in 1989 for Veco, one of the main cleanup contractors, there were large problems with exposure to H2S, and several workers exposed to it experienced severe acute lung damage (Hunninen 2002). Hydrogen sulfide is estimated to remain in the atmosphere for an average of 18 hours (ATSDR 1999b). It is likely that the significant exposures to this compound occurred in the first few days following the spill and in the recovery yard where oil-water mixtures were separated.

DERMAL EXPOSURES

Dermal exposures constituted a significant proportion of hazardous exposures during the EVOS cleanup work, and the assessment of this exposure is quite complex. Dermal exposures "remain a possibility throughout a cleanup" (Park and Holliday 1999). There were several potential opportunities for dermal exposures during the EVOS cleanup; among those working on the beaches, during skimming, washing, boom movements and even during decontamination at the end of the work day (Barnhart 1989). Dr. Scott Barnhardt, of the University of Washington, Occupational Medicine Division, also noted that "not all workers take showers at the end of the work day, and there are no good, existing ways to measure whether the oil has, in fact, been removed from exposed skin"(1989). The potential for dermal exposure to specific hazards present during the EVOS cleanup is discussed below.

Volatile organic compounds (VOCs)

Although the main route of exposure to benzene and other VOCs is through inhalation, exposure through the dermal route is also possible and may actually be a significant contribution to overall exposure during an oil spill cleanup operation (ATSDR 1997; Park and Holliday 1999). Benzene is classified as a "chemical commonly identified as hazardous by dermal exposure" according to the American Conference of Governmental Industrial Hygienists (ACGIH) (Eaton and Robertson 1994). Studies of occupational exposure to benzene suggest that absorption occurs both by inhalation and dermally[10] (ATSDR 1997). Skin irritation has been reported following contact with benzene, and acute exposures have caused second degree burns (ATSDR 1997).

Crude oil mists, PAHs and aerosols

The hands and forearms of many workers were consistently contaminated with weathered crude oil during the EVOS cleanup. During warm weather, oil response technicians (ORTs) involved with directly cleaning the beaches through high pressure hot water washes, were frequently observed taking off the tops of the PVC rain gear (NIOSH 1991) which resulted in greater dermal exposure of oil mist and PAHs. There were shortages of personal protective equipment (PPE), particularly gloves and respirators. Six weeks after the EVOS spill, cleanup worker ORT Lisa Jones testified before a congressional oversight committee that workers were told in their safety training course that they would have respirator masks and cream for their faces to prevent the oil from burning it due to the hoses splashing oil up off the rocks, but, they never received them (Ward 1989). Furthermore, NIOSH found that the "decontamination of PPE was not

[10] Studies on human volunteers indicate that only approximately 0.05% of the dermally-applied dose of *liquid* benzene was absorbed (ATSDR 1997 emphasis added), although the absorption could differ with exposure to benzene vapors.

consistently effective in the prevention of skin contact with the weathered crude oil" (NIOSH 1991).

According to Dr. Eula Bingham, Assistant Secretary of Occupational Safety and Health at the time of the EVOS cleanup, the conditions were very dirty and workers were constantly covered in oil. Before the Laborer's International Union of North America (LIUNA) became involved and worked to ensure better regulatory protection measures, men were seen wiping up oil with paper towels and bare hands (Bingham 2002). In a report prepared by the Laborer's Union, it was noted that "some workers were observed wearing protective clothing that was contaminated with oil over 25-75% of the surface" (LIUNA 1989). Studies on human volunteers and human cadaver skin have found that several PAHs (such as phenathrene, pyrene, fluoranthene, and benzo[a]pyrene) were absorbed through the skin, and many animal studies have also indicated significant dermal absorption of PAHs (ATSDR 1995b).[11]

Inipol EAP 22®

The primary human exposure route for 2-butoxyethanol in Inipol is through dermal contact (ATSDR 1998). Studies on human volunteers found that immersing four fingers on one hand into butoxyethanol was the equivalent dose of being exposed to vapors at the 20 ppm level (Johannson, Boman and Dynesius 1988). Animal studies have indicated that 2-butoxyethanol is absorbed much more readily through the skin under wet conditions which is of particular relevance during a marine oil spill cleanup (Johanson and Fernstrom 1988). The Toxicological Profile for 2-butoxyethanol also noted that

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[11] While no successful personal monitoring of dermal exposure to PAHs was conducted on EVOS workers, the concentration of BaP present in crude oil is typically in the 1.2-2.8 ppm range (Attias *et al.* 1995) and a limit value derived for dermal exposure to PAHs which would result in a $1:10^4$ lifetime excess skin cancer risk is 2ng benzo[a]pyrene (BaP) equivalents per cm^2 skin (Baars 2000).

dermal contact with *vapors* would lead to skin absorption (ATSDR 1998, emphasis added). One EVOS worker who applied Inipol to beaches through a pump attached to his backpack (shown in Figure 8) likely received significant exposure to 2-butoxyethanol when his pack broke through and the chemical ran down his back (Moeller 1989). Other worker complaints of rashes, skin blisters and headaches following work with Inipol also indicate potential overexposure to this chemical.[12] However, at the time of these complaints, there was confusion whether the dermatological irritations were caused by contact with Inipol or with crude oil, which causes similar symptoms (Spence 1989b).

Hydrogen sulfide (H2S)

Animal studies have shown that dermal absorption of H2S can occur, although large surface areas of skin must be exposed; however, no information regarding absorption in humans after dermal exposure was included in the ATSDR Toxicological Profile for H2S (1999b). The amount of H2S found in water would have been minimal, since it evaporates readily (ATSDR 1999b). Therefore, dermal exposures, if present, would most likely have been due to skin contact with vapors of H2S, rather than the presence of this compound in the water.

Exposures via ingestion

Although it is a less significant route of exposure than inhalation or dermal contact, workers could still be exposed to oil and chemicals through inadvertent swallowing while handling food or cigarettes which were contaminated[13] (LIUNA 1989).

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[12] Four out of twenty-one workers complained of these symptoms after being assigned to work on an Inipol-sprayed beach (Spence 1989a). That crew was subsequently laid off by Exxon's contractor, Veco, that same evening, although the contractor denied any connection with the complaints (Ortega 1989).

[13] According to the LIUNA report, "anecdotal reports have claimed that workers eat lunches on the beach, and that wash-up is not performed beforehand." Furthermore, workers may not have been fully aware of the severity of the hazards associated with ingesting even small amounts of oil, as "the Exxon manual and the worker training session do not address this issue." (LIUNA 1989).

Also, particles could be cleared from the respiratory tract and subsequently swallowed, leading to gastrointestinal tract absorption (Herrick and Dement 1994). Petroleum distillates are not readily absorbed from the gastrointestinal tract and do not generally cause significant systemic toxicity when ingested unless inhalation occurs (Baars 2002). Due to the relatively less serious exposures in comparison with inhalation and dermal routes (Attias *et al.* 1995; Park and Holliday 1999), this pathway is not considered to represent significant exposures for the majority of the EVOS workforce.

Magnitude and duration of exposures

It is an immense challenge to attempt to quantify both the specific time intervals and the intensity of exposures among workers employed in the EVOS cleanup. It is difficult to assess each worker's individual exposure since some worked for a few weeks while others remained on the cleanup the entire summer each year. At the time of the Alaska Oil Spill Health Conference in July 1989, there were over 10,000 workers employed for the various contractors; however, over the period of four months since this diverse task force was assembled, the turnover rate had been as high as 30% (Florky, Exxon Corp. 1989). Some workers, who were involved immediately following the spill, experienced significant exposure to VOCs and the most toxic components of the crude oil. In the days immediately following the spill, contaminant boom handlers worked for days at a time in the same oil-soaked clothing, "literally up to their elbows in crude [oil]" (Barinaga 1989). Those workers employed later in the summer of 1989 and subsequent years (1990-92) would have had the potential for exposure to the bioremediation agent Inipol, which Exxon began to apply to the beaches in August of 1989 (Ortega 1989, NOAA 1989). The working conditions were also not the standard 8-hour shifts[14] experienced in most jobs. EVOS workers typically were on the spill cleanup for 12-14 hours a day, seven days a week and some worked months without a break (Reller 1993).

HEALTH AND COMFORT EFFECTS FROM EVOS CLEANUP EXPOSURES

As described above, the EVOS workers experienced potentially harmful inhalation and dermal exposures to both the constituents of crude oil as well as to cleanup chemicals of varying hazard levels. Those workers with preexisting conditions who would have been particularly susceptible to the chemical agents in the oil and products used during the cleanup are summarized in Table 2. The acute health effects from inhalation exposure to oil spills are mostly associated with discomfort and irritation at low airborne concentrations, but more severe central nervous system effects can occur at higher concentrations (Park and Holliday 1999). Reports of acute health effects were common among EVOS workers, especially symptoms of respiratory disease. Of the total workers' compensation claims reported in 1989 from workers on the EVOS cleanup, the primary non-physical injury reported was respiratory system damage (Reller 1993, Bender 1989).[15] While some of these complaints were likely due to bacterial or viral infections due to crowded living conditions and cold environments (NIOSH 1991), the possibility of adverse effects due to oil and chemical exposure must also be explored. Although there are very few studies on the chronic health effects due to exposure to crude oil, there is a wealth of scientific literature on the health effects due to individual

[14] The OSHA permissible exposure limit levels (PEL) and the NIOSH recommended exposure limits (REL) are typically determined based upon exposures for an 8-10 hour work shift.

[15] For the complete data from the Alaska State Workers' Compensation Claim list for the EVOS cleanup workers in 1989, refer to Table 3. It is of interest to note that 7.2% of all claims made in 1989 were for general and ill-defined symptoms which were not classified into one of the injury/illness categories. This group of symptoms made up the largest number of claims following sprains/strains, respiratory system complaints, cuts/lacerations, and contusion/crushing claims.

components of crude oil, and at moderate exposure levels (up to a few hundred ppm), effects from individual oil compounds might serve as an adequate indicator of the overall effects of exposure to crude oil (Park and Holliday 1999). In order to evaluate whether the exposures of the EVOS workers could be responsible for the self-reported acute health problems at the time of the cleanup and rumored current chronic health conditions, the potential adverse health effects associated with the relevant exposures are presented as follows.

Crude oil mist, PAHs and aerosols

There are limited studies on the chronic health effects of exposure to crude oil through inhalation exposure (ATSDR 1999a). However, the International Agency for Research on Cancer (IARC) has concluded that there is sufficient evidence of carcinogenicity from exposure to mineral oil mist (ATSDR 1995b). It is well established that inhalation of oil mist is associated with occupational respiratory tract injury, occupational asthma and lipoid pneumonia[16] (Sprince, Thorne and Cullen 1994; Lancet 1990; Robertson, Weir and Burge 1988). Mineral oils were assigned an IARC classification of Group 1: carcinogenic to humans, and a major health effect for workers exposed to oil mist is accumulation in the lungs (pneumonitis) (OSHA 2003). Other symptoms associated with inhalation exposure to oil mist and PAHs include chronic cough, hemoptysis, chest pain, hoarseness, sore throat, fever, dyspnea and fatigue (Sprince, Thorne and Cullen 1994). It is generally accepted that PAHs present are responsible for the carcinogenic effects following exposure to fuel oils or crude oil[17]

[16] The most commonly reported occupational exposure to inhalation of oil mist has been among metal workers, although few epidemiological studies are available to assess the prevalence rate of workers exposed to mineral or crude oil mists (Sprince, Thorne and Cullen 1994).

[17] (with the exclusion of leukemia attributable to benzene exposure from crude oil)

(Baars 2002). Furthermore, it is thought that the absorption of PAHs across the bronchial lining layer may be facilitated when these compounds are contained in particles such as oil-containing mists and aerosols (Park and Holliday 1999).

Other potential adverse effects due to crude oil exposure include hepatic effects, which were noted in animals following oral administration and in a worker after inhalation exposure to crude oil (ATSDR 1999a). There is also the potential for long-term effects due to inhalation exposure to PAHs contained in oil since several of these are known carcinogens[18] (ATSDR 1995b). Workers with dermal exposure to crude oil or substances containing mixtures of PAHs experienced chronic dermatitis and hyperkeratosis, oil acne, irritation, dryness and photosensitivity (EPA 1988, ATSDR 1999a, Baars 2002). However, specific effects in humans due to dermal contact with individual PAHs, except for Benzo[a]pyrene, which is a "potent experimental skin carcinogen," have not been reported (ATSDR 1995b). IARC concluded that there is limited evidence that working in petroleum refining causes an increased risk of skin cancer and leukemia (ATSDR 1999a), however, exposures during refining may not be particularly comparable to those experienced during a hazardous waste cleanup operation of a crude oil spill. Also, since eye and skin irritation are generally reversible adverse events, the risk for permanent dermal damage is nearly negligible and the risk of developing skin tumors solely attributable to crude oil exposure is likely small (Baars 2002).

[18] The International Agency for Research on Cancer (IARC) has determined that benz[a]Anthracene and Benzo[a]pyrene, both found in crude oil, are probable human carcinogens (ATSDR 1995b).

Volatile Organic Compounds (VOCs)

Inhalation of VOCs, while a rather insignificant exposure after the first few days following an oil spill, causes significant health consequences, most notably leukemia from exposure to benzene (Sprince, Thorne and Cullen 1994; ATSDR 1997). Respiratory effects, such as nasal irritation, mucous membrane irritation, sore throat, laryngitis, bronchitis and pulmonary edema have been reported in humans after acute exposure to benzene vapors (ATSDR 1997). Hematological effects such as leucopenia, anemia and thrombocytopenia were reported following significantly large exposures (Midzenski, McDiarmid and Rothman 1992). Chronic periods of exposure also indicate hematological effects such as aplastic anemia[19] or leukemia, as well as immunological effects such as decreased levels of immunoglobulins (ATSDR 1997). Neurological effects such as drowsiness, dizziness, headaches, tremors, and loss of consciousness have been reported following inhalation exposures to VOCs (ATSDR 1997). Skin irritation has also been observed following dermal contact with benzene vapors (ATSDR 1997).

Inipol EAP 22® (2-butoxyethanol)

There were several anecdotal accounts of EVOS workers who experienced acute health effects such as headaches, skin blisters, nausea and rash due to exposure to the bioremediation agent Inipol which contains 2-butoxyethanol (Peninsula Clarion 1989, Ortega 1989). Other potential health effects from exposure to 2-butoxyethanol include eye, nose and throat irritation, coughing, runny nose and nausea (ATSDR 1998). Since many of these symptoms are common health complaints, it may be difficult to ascertain the effects of Inipol among workers and to use these effects as indicators of exposure. Hemolysis has been observed in animal studies, which may be indicator of potential

[19] Aplastic anemia can also progress to acute mylogenous leukemia (ATSDR 1997).

adverse hemolytic effects in humans. The long-term health effects associated with this chemical have not been thoroughly studied in humans, although no studies have thus far indicated an association between 2-butoxyethanol and cancer in humans or animals (ATSDR 1998).

Hydrogen Sulfide (H2S)[20]

Inhalation of hydrogen sulfide (H2S) may cause this compound may cause fatigue, loss of appetite, headaches, irritability, eye irritation, nasal irritation, memory loss and dizziness (ATSDR 1999b). Other respiratory symptoms associated with acute H2S exposure include noncarcinogenic pulmonary edema, sore throat, cough and dyspnea (Parra *et al.* 1991). H2S in fuel oils may cause eye irritation, nervousness, nausea, headaches and insomnia (Baars 2002). Exposure to H2S at levels between 50 and 500 ppm primarily causes respiratory irritation (Park and Holliday 1999) and among those exposed to H2S in occupational studies, respiratory symptoms persisted for several weeks to several months or longer following exposure (ATSDR 1999b). Nausea, vomiting, convulsions, neurobehavioral changes and tremors were also reported among those with acute H2S poisoning (ATSDR 1999b).

Non-specific health effects from oil/chemical exposure (Multiple Chemical Sensitivity)

In addition to specific, established health effects which may result from exposure to the various hazards above, the possibility exists that non-specific exposures to a variety of chemical stressors could lead to the more subtle symptoms characteristic of multiple chemical sensitivity (MCS). Multiple chemical sensitivities syndrome (MCS) is generally described as "an acquired disorder characterized by recurrent symptoms to

[20] Methyl mercaptan, a gas also often present in crude oil, causes acute health effects similar to those caused by H2S: it can cause death by respiratory paralysis and also depresses the heme-synthesizing enzymes (Park and Holliday 1999).

multiple organ systems. These symptoms occur in response to demonstrable exposure to chemically unrelated compounds at doses far below those known to cause harmful effects in the general population. No single widely accepted test of physiologic function has been shown to correlate with symptoms" (Cullen 1987). Affected individuals report an acute hypersensitivity to low levels of chemicals found in everyday substances such as household cleaning agents, pesticides, fresh paint, new carpeting, synthetic building materials, newsprint, perfume and numerous other petrochemical-based products (Davidoff *et al.* 2000). Other substances which also cause reported discomfort among those with MCS include nailpolish, gasoline, detergent aisles in the grocery store, new automobile interiors, and insect repellents (Nawab *et al.* 2000). This condition is a relatively new health concern which is emerging in public health research as more attention is drawn to recent reports of symptoms of MCS among Persian Gulf War Veterans exposed to a variety of chemicals while in the Middle East, including smoke from oil-well fires (Schwartz *et al.* 1997) and to related disorders, such as sick building syndrome.

Common symptoms among individuals with MCS include headache, memory loss, forgetfulness, joint aches, trouble thinking, back pain, muscle aches and nausea (Black *et al.* 2000). Others also report chronic congestion, sore throat, shortness of breath, gastrointestinal problems such as indigestion and bloating, and overwhelming fatigue (Mooser 1987). While some individuals with MCS experience only mild symptoms, others have reported that their hypersensitivities have caused them such severe morbidity that they are unable to work or have severely modified their lifestyles in order to control their symptoms (Cullen 1987).

There have been several proposed causes of MCS but no definitive explanations for this condition. The primary widely-accepted hypothesis is that it may be induced by exposure to chemicals or solvents, although no established thresholds or specific etiologic agents have been identified. Affected individuals have reported intolerance and hypersensitivity to chemicals after various occupational exposures, exposures to "tight" or "sick" buildings, organophosphate exposures, and solvent exposures (Cone 1987; Gyntelberg 1986). It was only recently acknowledged by the scientific community as a disease, and many still do not recognize it in "mainstream medicine" (Black *et al.* 2000). Some physicians believe that the hypersensitivity to chemicals associated with MCS is imaginary or attributable to the patient's misinterpretation or physician's misdiagnosis of a psychiatric disorder such as major depressive or phobia (Davidoff and Fogarty 1994). Skeptics of MCS often suggest that it is not a valid syndrome on its own apart from depression and similar psychiatric diagnoses (Black *et al.* 1990; Terr 1993.) Yet, other physicians believe that both environmental and personality factors work together in the etiology of MCS (Rest 1992).

Since MCS is potentially caused by a broad array of chemical stressors, and since several anecdotal reports from EVOS workers indicate that many experience symptoms similar to those reported by sufferers of MCS, this condition was considered as a potentially relevant health outcome in this study.

III. STATEMENT OF PURPOSE

As described above, there were many potentially hazardous chemicals present during the EVOS cleanup. The variety of exposure routes, in addition to the apparent inadequacy of personal protective equipment could have resulted in potentially serious exposures among cleanup workers. It is well established in the scientific literature that many of these hazards can lead to both acute and long term health affects. The purpose of this study was to examine the job-exposure categories on the EVOS cleanup which were likely to be associated with an increased prevalence of self-reported adverse acute and chronic health effects. The relationship between self-reported exposures to oil and chemical agents and health outcomes was also explored. Due to the limited epidemiologic data on the health of oil spill cleanup workers, a broad health assessment approach was used in this investigation. Based on a review of the existing epidemiological and toxicological literature, as well as anecdotal reports from workers, the primary medical conditions evaluated were symptoms of respiratory disease, neurological impairment, cognitive dysfunction, and multiple chemical sensitivity. A variety of additional medical outcomes were also assessed, including cancers, anemia, dermatologic conditions or irritation, kidney disease and liver disease. It was hypothesized that those workers who performed jobs with the greatest potential for oil and/or chemical exposure would be more likely to report a greater prevalence of these medical conditions than those who were less exposed.

IV. METHODS

Study design

I conducted a cross-sectional study of workers who had participated in the *Exxon Valdez* oil spill (EVOS) cleanup. Data were gathered with regard to retrospective exposures[21] as well as retrospective and current health status.

Selection of study population

The subject population from which participants were recruited was workers who participated in the EVOS cleanup 1989, 1990 or 1991. Throughout these years, more than 11,000 workers were involved with the cleanup operation, either through direct physical labor or through administrative and clerical tasks. In order to reduce selection bias, and to obtain a representative sample of workers, participants were randomly selected from public records obtained from the Alaska State Department of Labor files. Workers were selected if they were listed as employees of the major EVOS cleanup contractors, namely: Veco, Exxon, Norcon, Martech and Chugach/NANA/Marriot or if the claim was filed from the town of Valdez in 1989. The final selection criterion was that participants must be alive at the time of the interview and complete the telephone interview themselves.

Locating strategies

Contact information for a total of 1785 potential study participants was obtained through several methods. A search of public labor records including workers' compensation claims for 1989-1991 yielded potential participants who were employed by

[21] No specific data could be obtained for each individual worker's exposures; therefore the proxy measure for exposure utilized in this study was classification based upon job task and direct exposure-based questions in the interview. Available exposure data are also summarized in Table 1 but may not be representative of the exposures sustained by study participants.

either Exxon or one of the primary cleanup contractors (N=1473). Motznik Computer Services, Inc., a professional locating service in Anchorage, AK, conducted the search for telephone numbers from an Alaskan public information access system database for those individuals from this list for whom no contact information was provided.[22] Due to the time lapse since this list was originally compiled (14 years), many numbers were not valid or individuals could not be located, and therefore, other strategies were also utilized to identify a greater number of potential participants.

Interviewers asked individuals contacted during the first round of interviews to provide telephone numbers for referrals of co-workers from the EVOS cleanup, which yielded 57 potential participants. A final source of potential study subjects was obtained from community contact personnel in Anchorage, Valdez and Cordova who had maintained private lists of EVOS workers (N=255). A total of 4394 phone calls were made to attempt to contact individuals from these three sources. Five attempts were made to contact each potential participant before exclusion.[23] Of the 1785 potential participants called, approximately 22% were ineligible (i.e. did not meet screening requirements, did not participate in the cleanup, wrong individuals) and 31% were not valid numbers (number disconnected, business or fax) (Table 4). Among those contacted and who met enrollment criteria to be eligible for participation in the study, 169 (40.7%) completed the telephone interview in January and February 2003 (Table 5). Among those who completed the interview, 56.2% were from the workers' compensation and labor records list, while 43.2% of completes were from referrals and other sources. The

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[22] Telephone numbers were provided by the Alaska State Department of Labor for the majority of workers from their files.

[23] Craciun Research Services began with 10 attempts to contact workers, but had very low completion rates for attempts 6-10 and thus reduced the number of attempts to 5 for the remainder of the study.

source of each participant was noted in the data collection (coded as workers' compensation, referral or other) and this was controlled for as a potentially confounding variable in the multivariate analysis to reduce the effect of bias within the study population.

Survey instrument development

The study instrument was developed by the investigator to assess exposures at the time of the cleanup, acute health problems during cleanup work, and current health status. In order to enhance the generalizability and validity of the instrument, standardized questions were used whenever possible.[24] The survey also consisted of investigator-derived questions, which were general modifications of previously-applied questions utilized in either the Persian Gulf War Study (Schwartz *et al.* 1997) or in the Amchitka Workers Medical Surveillance Program (Weber 2002) but which were abbreviated in order to fit the time constraints of the telephone interview and the specific outcomes of interest. Particular focus was given to specific medical concerns and exposures based upon interviews and reports with former EVOS cleanup workers available through several media sources and to biologically plausible outcomes as a result of oil and chemical exposure.

EXPOSURE ASSESSMENT

Two measures of exposure were used in this study. Worker exposures were first categorized according to the job tasks conducted during the cleanup. A secondary measure to assess exposures was the use of questions which directly inquired about specific hazardous substances or situations encountered during cleanup work.

[24] Several questions, specifically measures for assessing multiple chemical sensitivity, respiratory impairment, cognitive dysfunction and general health symptomology, were modeled after the questionnaire used by Schwartz *et al.* on their study of Persian Gulf War veterans (1997).

Job or task definition

Two different questions were used to categorize the job task that each study participant conducted. Workers were asked to separately describe the first job to which they were assigned during the cleanup and the job which they conducted for the longest period of time. Participant answers to these two questions were coded by the interviewer into one of fourteen job categories, such as: "Used hydraulic hoses and/or wands to spray oiled rocks/beaches," "Worked on the bioremediation application (Inipol) crew," or "Worked on a housing boat or barge, such as a cook or medic." The complete list of coded job tasks is available in the attached survey instrument (Appendix A). Although workers may have conducted more than one job, gathering data on the first exposure experienced would reduce the influence of healthy worker effect[25] while gathering information on the job task conducted for the longest duration would provide another measure of exposure which would be less susceptible to recall bias. The two job categories were analyzed separately, as discussed under *data analysis.*

Exposure categories

For the purpose of analysis, each of the fourteen job categories was separately condensed into four oil exposure categories (no exposure, low, medium and high) and three chemical exposure categories (no exposure, moderate and high). For each group of exposure categories, workers were classified separately according to the first job task they reported, and the job task they conducted for the greatest duration while employed on the cleanup (presented as "first job" and "longest job" in all tables and analyses).

[25] i.e. the effect of being assigned to another cleanup position due to an adverse health reaction or susceptibility to the first assignment

All jobs were first classified according to their potential for oil exposure, which was defined as exposure to crude oil, oil vapors or fumes, and aerosolized oil mist through either inhalation or dermal contact. Those considered at the greatest risk of exposure to oil vapors and mist were oil spill response technicians (OSRTs or ORTs) who worked on the beaches using high pressure hot water washes to spray oil off shoreline rocks, workers on Omni barges who used similar high-pressure hoses to spray steep shorelines, boom operators and skimmers who worked from small boats in the oiled water, and the decontamination crew who used pressurized water to clean oiled boats and personal protective equipment (PPE). Workers considered to have experienced moderate oil exposure are those who operated cranes or other machinery, waste handlers and wildlife rescue crew. Those placed in the low oil exposure category were workers from the bioremediation application crew, those who worked in housing boats or barges, workers who transported supplies or collected trash from small boats on the beaches, and those who worked on the beaches but whose job task did not likely involve direct oil contact.[26] Finally, those workers assumed to have no oil exposure during their work on the cleanup are those who worked in towns or warehouses, such as clerical or administrative positions, or as welders, electricians, and other similar positions.[27]

Three chemical exposure categories were determined in a manner similar to the oil exposure categories- on the basis of probable exposures encountered while performing specific cleanup jobs. Those jobs presumed to have the greatest potential for exposure to hazardous chemicals are: the bioremediation workers who applied Inipol EAP22 ® to the

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[26] Several examples of these jobs classified into this category are given in Table 6. Refer to Tables 10 and 11 for the classification method of job-exposure categories.

[27] See Table 6 for those jobs classified as unexposed to oil and chemicals.

beaches from hoses attached to personal backpacks,[28] workers involved with the removal and disposal of trash who likely experienced significant hydrogen sulfide (H2S) exposure, those who deployed booms to contain the oil in the early days following the spill and those who worked to skim oil from the water's surface or conducted oil recovery at sea, all of whom had probable exposure to VOCs, wildlife recovery and treatment workers, who likely had formaldehyde and formalin exposure, and the decontamination crew, who worked with a variety of detergents, surfactants and potentially harmful chemicals. Those classified as having "moderate" chemical exposure were workers on large Omni barges who sprayed oiled shoreline, workers in housing boats or barges, including cooks and medical staff, workers who transported supplies to and from small boats on the beach, those who operated cranes or other equipment, and oil spill response technicians (OSRTs) who used hydraulic hoses to spray oiled beaches. Workers whose primary position during the cleanup was either in town, a warehouse or administrative roles, in addition to those who worked on beaches but were not as severely or directly exposed to chemicals were considered collectively in the "no-to-low" chemical exposure category.

Questionnaire assessment of exposures to specific substances during cleanup

Information on self-reported exposures was also gathered by asking respondents about individual exposures encountered during the cleanup, through questions about specific scenarios, such as "Did you inhale oil vapors or water-oil mist?" and "Did you work around/near burning trash or oil?" and questions about specific materials, such as "Did you work with Inipol?" and "Did you work with Corexit?"[29] Workers were also

[28] See Figures 8 and 9.
[29] For the complete list of these exposure-related questions refer to the survey instrument in Appendix A.

asked if they felt ill at the time of each specific exposure in order to determine the onset of symptoms immediately following exposure to a particular substance. The prevalence of specific self-reported exposure variables was compared among the oil and chemical exposure categories to evaluate a measure of exposures among these classes. These variables were also used for independent analyses to assess the difference in the prevalence of health effects between exposed and unexposed workers.

Exposure measurements

Although no direct personal data could be obtained, a statistical summary of the range of exposures measured for several hazardous compounds of concern during the EVOS cleanup by Exxon's primary industrial hygiene monitoring contractor, Med-Tox Associates, Inc., are presented in Table 1. These numbers are presented only for reference and to demonstrate a potential inhalation over-exposure of cleanup workers above the OSHA PEL for benzene, butoxyethanol, oil mist and hydrogen sulfide. No data were available for individual workers who participated in this study and it is not known whether the average or extreme air monitoring measures best represent the exposures of workers in this study sample.

DEFINITION OF HEALTH OUTCOMES

Acute symptoms experienced during cleanup work

As a measure to determine the cleanup jobs and exposures which were associated with a greater prevalence of acute health symptoms during oil spill cleanup work, respondents were asked several questions about their health and how they felt when they were working on the cleanup. Questions were phrased "Did you ever experience the following symptoms at any time during your work on the spill?" and for each symptom, respondents were also asked "About how often did you experience this?" Acute health symptoms of interest include: dry, scratchy/sore throat, a lot of phlegm or mucous and/or a persistent cough, dizziness, itchy skin or blisters, headaches, nausea or vomiting, low back pain or muscle pain, and trembling or numbness in extremities. The reported prevalence of these acute symptoms among the oil exposure categories, chemical exposure categories and the self-reported oil and chemical exposure variables was determined; however, only chronic conditions were included in the final multivariable analyses, as these were the outcomes of greatest concern and which have the most significant implications for the basis of future research.

Chronic symptoms

For questions regarding chronic symptoms of airway disease, neurological impairment and cognitive dysfunction, short time periods were used in order to obtain more precise answers and to reduce potential recall bias. Respondents were asked whether they had experienced the criteria symptoms within the past year for symptoms of chronic airway disease, symptoms of neurological impairment, multiple chemical sensitivity, and dermatologic conditions. Symptoms of cognitive dysfunction were evaluated within the past month. For all health outcomes, respondents were asked the year when they first began experiencing the symptom or were first diagnosed with the specific condition. Only those conditions which were first experienced or diagnosed during or following the first year of employment on the EVOS cleanup (1989 for the majority of respondents) were considered in the analyses.[30]

[30] To minimize bias, the year of diagnosis or the onset of each symptom was asked rather than questions of the nature "Did you first experienced this symptom before or after your work on the cleanup?"

As a method to reduce bias and to validate several of the health outcomes which tend to be reported with a relatively greater degree of subjectivity, participants were asked "have you ever seen a physician for this condition/disease?" and several questions were phrased "have you ever been diagnosed by a doctor as having (condition/disease)?" For symptoms of airway disease, cognitive dysfunction and neurological impairment, seeking medical attention for these conditions was analyzed as a separate variable but was not included in the composite score to avoid the introduction of bias by access to health care or insurance coverage among study participants. Physician visits and lifestyle modifications were used as a proxy measure for severity of symptoms of MCS, due to the typically subjective nature of health complaints among those who claim to be afflicted with this condition, with the assumption that those who believe their symptoms are sufficiently troublesome to warrant seeking medical attention would have a greater degree of severity than those who experienced mild discomfort.

Respiratory symptoms

Symptoms of chronic airway disease were assessed using several questions, such as "In the past year, did you have chronic sinus problems and/or ear infections?" and "Did you have sleep apnea?" For the purpose of analysis, these questions were then collapsed into a composite variable, called "Symptoms of chronic airway disease" where participants were coded as positive if they answered "yes" to at least one of the six individual respiratory symptom questions. Symptoms of chronic bronchitis were analyzed separately from this composite respiratory variable and were evaluated by asking participants if they have had a cough and produced a lot of phlegm/mucous for more than 3 months in a row during the past year. To evaluate asthma, respondents were asked if they have ever been told by a doctor that they have asthma. As with all study variables, the year of diagnosis was asked and coded as before, during or after start of employment on the cleanup.

Neurological impairment

In order to determine symptoms of neurological impairment, respondents were asked questions of the nature, "During the past year, have you had tremors or shaking?" and similar questions regarding symptoms such as seizures or convulsions, faintness, lightheadedness or dizziness, and numbness or tingling in parts of the body. These four questions were then collapsed into a composite variable, "Symptoms of neurological impairment." A minimum of one and maximum of four positive responses in the individual neurological questions was coded as a "yes" for this composite variable. Physician visits for treatment of neurological symptoms were also assessed but analyzed separately from this composite variable.

Symptoms of Cognitive Dysfunction

Symptoms of chronic cognitive dysfunction were assessed using a series of questions regarding symptoms experienced in the past month. Respondents were asked whether they have had problems with amnesia or severe memory loss, difficulty thinking clearly or concentrating, trouble with their speech, and general confusion or feelings of disorientation. As a method of validating their symptoms and to assess a measure of severity, they were asked whether they have visited a physician for treatment for any of these conditions. Respondents were considered to have symptoms of chronic cognitive dysfunction if they reported a minimum of one of these four conditions which first began during or after their time of employment on the EVOS cleanup.

Multiple Chemical Sensitivity (MCS)

The criteria for the outcome of "symptoms of multiple chemical sensitivity" were developed based on accepted criteria from standardized instruments and medical literature on this relatively controversial disorder but with modifications for the time constraints of this survey. A three-tiered question was used to assess these symptoms. First, subjects were asked if they felt physically ill, with symptoms including nausea, headaches, difficulty breathing, and dizziness around substances such as gasoline, hair spray, paint, household cleaners, perfumes, cigarette smoke, vehicle exhaust, pesticides, soaps, newspapers or other chemicals. If they reported feeling ill around any of these substances, respondents were then asked whether they had seen a physician for any of their symptoms and also whether they have changed their lifestyle because of these reactions. A composite score was calculated using these questions on a scale of one to three, with three equal to a positive response to all three questions, and a one equal to a positive response to only the first question (0= no symptoms, 1= reaction to various chemicals, 2 or 3= reaction to chemicals and sought medical attention for this reaction and/or altered lifestyle in order to cope with this condition). For the purpose of analysis, those with a MCS composite score of 0 or 1 were considered collectively, and those with a score of 2-3 were considered as exhibiting symptoms of MCS. As with other questions on the survey, respondents were also asked when they first began experiencing these symptoms in order to determine whether the onset preceded their work on the EVOS cleanup.

Cancers

The cancers of interest in this study were ones which were most likely biologically plausible as a result of exposure to oil and chemicals present during the cleanup. Participants were asked if they have ever been diagnosed with leukemia, multiple myeloma, Hodgkin's Disease, lymphoma, lung cancer, liver cancer, any other type of cancer, and non-malignant tumors, including sinus polyps. Respondents were also asked the year of diagnosis for each cancer or tumor, and only those first diagnosed during or after employment on the cleanup were included in the analysis.

Other general health conditions

To assess other various general health conditions, participants were asked separate questions of the nature "Have you ever been diagnosed by a physician with: kidney disease/poisoning from solvents/ hepatitis/liver infection)?" Dermatitis was assessed through inquiring about a persistent skin rash or sores during the past year. Respondents were asked if they have been diagnosed with anemia, had frequent nosebleeds within the past year, and if they have any other blood conditions. Finally, an open-ended response question was given at the end of the survey, for participants to state any final comments or concerns regarding their health, cleanup conditions or overall opinions about the oil spill. A summary of some notable responses to this question is presented in Appendix D.

Potentially confounding variables

In the multivariable analysis, I identified potentially confounding variables on theoretical grounds, and controlled for them by including each in the full model. The potentially confounding variables included in the analysis were: smoking, alcohol consumption, age, gender, ethnicity, previous or current employment in another field of the oil/petroleum industry, and previous or current employment involving exposure(s) to hazardous chemicals. Smokers were defined as anyone who ever smoked cigarettes for at least six months or longer. To determine alcohol consumption, participants were asked "how many alcoholic drinks do you have a week?" with a drink defined as one glass of wine or beer or one shot of liquor. Since the oil industry is a significant employer among Alaskans, participants were asked whether they currently or previously worked in the oil industry, in addition to their work on the EVOS cleanup. Similarly, workers were asked whether they frequently worked with hazardous chemicals in order to assess other potentially relevant and harmful exposures which could influence health outcomes.

As a method to reduce potential bias, workers were asked whether they believe the oil spill has affected their health, and this variable was also included in the analysis as a potential confounder. The use of a respirator throughout cleanup work was a potentially confounding variable which would likely reduce exposures, and this measure was assessed through two questions. First, respondents were asked if they were provided with a respirator by their employer, and secondly, if they received a respirator, they were asked how often they wore it, with possible answers of *almost always* (80-100% of the time), *frequently* (40-80% of the time), *infrequently* (10-40% of the time) or *never*.

Pilot study

The survey instrument was pilot tested in a sample of individuals randomly selected from the workers' compensation database. The pilot study was conducted by three different interviewers under the direct monitoring of the supervisory staff. Information from the pilot study was used to refine and finalize the interview.

Individuals selected for the pilot study (N=10) were excluded from participation and analysis in the final study.

Administration of survey

Participants were contacted by telephone from Craciun Research Services, Inc., in Anchorage, AK. A random sampling procedure was utilized to select numbers from the list of potential participants. Subjects were read an information statement about the study, including information regarding the potential risks and benefits of participation.[31] Using the Computer Assisted Telephone Interview system, (CATI, V7), Craciun conducted telephone interviews in January and February 2003, approximately 14 years after the beginning of the Exxon Valdez oil spill cleanup. Five attempts to contact each potential respondent were made before exclusion. The interview was administered in approximately seven minutes (range 6-11) and following completion of the interview, participants were given a telephone number of an Anchorage-based nonprofit organization which they could call to request a summary of the completed study results and receive referral information for medical or other social support services.

Data analysis

The analysis was structured to examine the primary and additional medical symptoms in three exposure groups: 1) four oil exposure categories, 2) three chemical exposure categories, and 3) several specific self-reported exposure categories. Categorization into each of the oil and chemical exposure strata was conducted separately by first and longest job task conducted. I used logistic regression to conduct bivariable and multivariable analyses to determine the association between selected chronic health

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[31] Permission was obtained by the Human Investigations Committee at Yale University School of Medicine to obtain oral consent rather than a signed form, as risk to participants was considered to be less than minimal. An abbreviated version of the consent form shown in Appendix B was read to study participants.

outcomes and the oil, chemical and self-reported exposure categories, utilizing a separate model for each set of analyses. Those health outcomes for which significant amounts of data were missing were not tested in the multivariable analysis.[32] The significance of each variable was assessed using the Wald χ^2 test, unless insufficient data prohibited the accurate use of this test, in which case two-tailed Fisher's Exact Tests were used to determine the association, which was noted in all presentation of results. Prior to the study, a two-tailed α value of .05 was established for statistical significance, and 95% confidence intervals (CIs) were calculated for all prevalence odds ratios (ORs) presented. All statistical analyses were performed using Statistical Applications Software (SAS) Version 8.2 for Windows (SAS Institute Inc, Cary, NC).

All potentially confounding variables were included all in the main effects model simultaneously. A backward stepwise selection process was utilized to eliminate the non-significant variables. The following potential confounders were not significant and therefore were not included in the final model: previous or current employment in another branch of the oil industry, a medical disability which currently prohibits employment, the use of a respirator during the EVOS cleanup, and current or previous employment with hazardous chemicals. The linear trend test was used to determine that age and alcohol consumption should be modeled as semi-continuous rather than categorical variables in the model. Each final multivariable model was controlled for age, race/ethnicity, sex, smoking status, the belief that personal health had been affected

[32] Due to missing data, multivariable analyses were not conducted on dermatologic symptoms, blood systems/conditions (frequent nosebleeds and anemia), or for individual, specific symptoms of airway disease, with the exception of bronchitis. The reported prevalence of these conditions among oil and chemical exposure categories as well as among self-reported oil and chemical exposure variables are presented in Tables 24 -27. Small prevalence rates of kidney disease, hepatitis and cancers within the study sample prevented adequate analyses of these health outcomes and they were therefore not included in the bivariable or multivariable tests with exposure variables, however, a brief summary of these particular conditions reported is included in Appendix C.

by working on the oil spill cleanup, and the original source list which produced the respondent's name (workers compensation, referral or other). For respiratory symptoms, alcohol was not included in the model since it was not significant, but it was controlled for in the model of neurological impairment, cognitive dysfunction and multiple chemical sensitivity.

I constructed an additional model to test two-way interactions between smoking and alcohol consumption, and race and alcohol consumption. I compared the full model to this model containing all the main effects and the two-way interaction terms. The likelihood ratio test showed that these interaction terms were not significant and therefore they were not included in the final model.

The self-reported exposure variables were divided into two classes for the purpose of analyses: oil exposure variables and chemical exposure variables. The oil exposure variables are as follows: oil on skin or in the eyes, inhalation of oil mist or fumes/vapors, inhalation of diesel or generator exhaust, inhalation of smoke from burning oil or trash, consumption of food or beverages exposed to oil and/or chemicals, and being overcome (felt ill or passed out) by gases or fumes from oil at least once during cleanup work. The self-reported chemical variables were classified by working with the following specific products: Inipol, Customblen, Simple Green, Corexit, De-Solv-It, and Citriklean. All oil and chemical exposure variables were separately entered into two models, along with potential confounders. Backward selection was then used to eliminate insignificant variables. In the final multivariable model, each self-reported oil exposure variable was adjusted for the remaining self-reported oil exposure variables and for age, sex, race/ethnicity, belief that personal health was affected by the oil spill, smoking status, alcohol consumption and source list of the participant's name. Similarly, each self-reported chemical exposure variable was adjusted for the remaining self-reported chemical exposure variables and for the same potential confounders.

V. RESULTS

Characteristics of the study population

The characteristics of the study population are summarized in Table 7. Consistent with the demographics of the Alaskan population and work force, the majority of study participants were Caucasian males (*Caucasian:*75.7%, n=128, *males:* 72.8%, n=123). The second largest ethnic group represented in the study population was Alaskan Natives (14.2%, n=24) followed by American Indians (3.0%, n=5). The mean age of participants at the time of the survey was 50 (± 9 years). Nearly all workers surveyed participated in the cleanup in 1989, the year the oil spill occurred, during which the greatest numbers were employed on the cleanup. Only a small percent (3.0%, n=5) were not employed on the cleanup in 1989 but worked either in 1990 or 1991 or both years. There was a large degree of variability in the number of months employed on the cleanup (5.8 ± 7 months), and therefore the number of months worked was not used in analyses with health outcomes.

Data on the frequency of potentially confounding variables among the study population are presented in Table 8. Nearly 60% (n=101) of the workers surveyed regularly drink one or no alcoholic beverages each week, and similar numbers are current or former smokers (61.5%, n=104). More than one third of the workers sampled believe their health has been affected by working on the oil spill (36.7%, n=62). Fifty-six percent (n=95) of the respondents were from the original workers' compensation database, whereas the remaining participants were drawn from referrals and other community-based sources. Potentially confounding sources of hazardous exposure, including additional work within the oil industry were reported by 37.3 % (n=63) of all workers surveyed, and 23% (n=39) currently work with hazardous chemicals or in hazardous waste disposal. 14.2% (n=24) of workers claim to have a medical disability which currently prevents them from working.

A sample of several notable responses to the open-ended response question asked at the end of the interview regarding health, cleanup conditions or overall opinions about the oil spill is presented in Appendix D. Responses ranged from individuals who believed that they are sick due to cleanup exposures and know of sick co-workers from the cleanup, to other individuals who think the cleanup was a safe operation with little hazardous exposures or subsequent negative health effects.

Distribution of study sample among job tasks and exposure categories

The distribution of study participants among the thirteen job categories is presented in Table 9, separated by the first and longest jobs worked. The largest percent of workers surveyed worked in town, administrative, clerical or other similar positions (*first job*: 17.7%, n=30; *longest job:* 16.6%, n=28). The second largest group represented was workers who handled booms to contain the oil and/or were skimmers who scooped oil from the water (*first job* 13.6%, n=23; *longest job* 13.0%, n=22). Very few workers claimed that their first or longest job was on the bioremediation application team (*first and longest job* 1.2%, n=2), and few claimed to have worked on the decontamination crew (*first job:* 1.2%, n=2; *longest job:* 2.4%, n=4).

The job-exposure classification system for the four oil exposure categories and three chemical exposures categories, and the distribution of workers into these exposure categories are presented in Tables 10 and 11. More than one third of the sample population was classified with high oil exposure category (*first job* 33.7%, n=57; *longest* *job* 37.3%, n=63). For the chemical exposure categories, those in the highest exposure category were the largest group among the first job worked (41.4%, n=70) whereas those in the moderate chemical exposure category were the largest proportion determined by the longest job worked (40.2%, n=68).

Distribution of self-reported oil and chemical exposures

Among all cleanup workers

The overall frequency of self-reported exposure variables among all cleanup workers and the proportion of those who felt ill following each exposure are presented in Table 12. The majority of workers in the study sample reported that they inhaled oil mist or vapors during their work on the EVOS cleanup (76.3%, n=129), and among those workers, nearly half claimed that they subsequently felt ill (46.5%, n=60). Approximately half of the study sample also reported exposure to oil on their skin or in their eyes during the cleanup (47.3%, n=80) or worked with Simple Green (51.5%, n=87), but 41.2% of those dermally exposed to oil claimed to have felt ill, whereas 13.8% who worked with Simple Green felt ill following their exposure to this product. Among the 18 workers who reported exposure to Inipol, one third felt ill at the time of exposure.

Within job-defined oil exposure categories

Table 13 presents the distribution of self-reported exposure variables among workers in the job-defined oil exposure categories, separated by first and longest jobs worked. Among the workers in the four oil exposure categories, those in the high oil exposure category were more likely to report exposure to oil on their skin or in their eyes during cleanup (*first job* 60.7%, n=34, p=.032; *longest job* 57.1%, n=36, p=.113) and inhalation of oil mist or vapors (*first job* 92.6%, n=50, p<.001; *longest job* 90.2%, n=55, p<.001) than workers in the lower oil exposure categories. Consumption of food or beverages exposed to oil or chemicals during EVOS cleanup work was reported with increasing intensity of oil exposure levels (*first job* 7.7% among 'no oil exposure' to 31.4% among 'high oil exposure'; *longest job* 11.5% to 27.6% from 'no' to 'high'). Workers in the "low" oil exposure category reported significantly greater inhalation exposure to diesel exhaust or generators than other workers (*first job* 70.3%, n=26, p=.043; *longest job* 72.1%, n=31, p=.013) while those in the "high" oil exposure category also reported a large frequency of exposure to diesel or generator exhaust (*first job* 67.3%, *longest job* 64.5%).

Fewer workers recalled specific chemical-related exposures than oil-related exposures. Therefore, there were several missing observations for questions pertaining to specific cleanup products. Among those who answered, workers in the "high" oil exposure category were most likely to report working with Inipol and Citriklean, whereas workers in the "low" oil exposure category reported the greatest use of the chemical Simple Green (Table 12). Exposure to De-Solv-It was distributed evenly among the oil exposure categories, and although very few participants reported working with Customblen, those in the "low" oil exposure category for their first and longest job reported the greatest frequency of use of this chemical (*first job* 14.3%, n=5; *longest job* 10.5%, n=4).

Within job-defined chemical exposure categories

Table 14 contains the distribution of self-reported exposure variables among workers in the chemical exposure categories. Among workers in the job-based chemical exposure categories, those in the "high" exposure category reported the greatest frequency of exposure to oil on their skin or in their eyes (*first job* 58.6%, n=41, p=.046; *longest job* 60.7%, n=37, p=.037). There was also increasing reports of inhalation exposure to oil mists or vapors from the "no-low exposure" to the "high exposure" categories (*first job* 64.1%, n=25 among "no exposure" to 88.2%, n=60, p=.012 among "high exposure"; *longest job* 61.5%, n=24 among "no/low exposure" to 86.4%, n=51, p=.014 among "high exposure"). With regard to specific chemical exposures, workers in the "moderate" chemical exposure category reported the greatest use of Simple Green and De-Solv-It, where workers in the "high" chemical exposure category reported the highest use of Inipol (*first job* 14.3%, n=9; *longest job* 17.5%, n=10). Workers in the high chemical exposure category were also more likely to report exposure to Citriklean than workers in the low or medium categories. All chemical exposure groups reported similar frequencies of exposure to De-Solv-It and Customblen with no statistically significant difference between any two categories.

Use of protective equipment (respirators)

In order to better assess relevant inhalation exposures experienced by cleanup workers, the frequency of those who reportedly received and utilized protective respiratory equipment in each oil and chemical exposure category was determined (Table 15). 11.3% (n= 6) of workers whose first job was in the high oil exposure category and 15.0% (n=9) of participants whose longest job was in this category reported that they received a respirator while working on the cleanup, and wore it either frequently or most of the time. The remaining workers in these categories were either not provided with a respirator by their employer (*first job* 69.8%, n=37; *longest job* 66.7%, n=40) or were provided with a respirator but wore it infrequently (*first and longest jobs* 13.2%, n=7) or never wore it (*first and longest jobs* 5.7%, n=3*)*. Among workers whose first and longest jobs were in the high chemical exposure category, only six received respirators from their employers and wore them consistently (*first* 10.0%; *longest* 10.2%) whereas the majority in these categories were not provided with a respirator from their employer (*first job* 71.6%, n=48*; longest job* 72.2%, n=42*)*. The remaining workers in this category were provided with a respirator, but reportedly wore it infrequently or never wore it.

BIVARIABLE ANALYSIS

Acute symptoms

Among entire study sample

The frequency of acute health symptoms reported by all workers in the study sample is presented in Table 16. Those who claim to have experienced each symptom are further divided by those who occasionally experienced the symptom during cleanup work, and those for whom the condition persisted throughout their duration of employment on the cleanup. The most commonly reported acute health complaint associated with the EVOS cleanup among study participants was low back pain (43.8%, n=74), and among those who reported this condition, half experienced this symptom occasionally, and half experienced persistent back pain throughout the cleanup. Many respondents also reported chronic headaches (40.8%, n=69), dry, scratchy or sore throat (37.3%, n=63) and persistent cough or phlegm (35.5%, n=60) during their employment on the spill. Among the symptoms reported, those that appear to be the most persistent throughout cleanup work, were trembling in extremities (64.0% n=16) and cough or phlegm (55.0% n=33). Although dizziness was reported in approximately one third of the study sample (29.0%, n=49), this symptom was more likely to be experienced occasionally during cleanup (75.5%, n=37) rather than persistently (20.4%, n=10).

Among job-defined oil exposure categories

The distribution of acute health complaints experienced during cleanup work among the job-defined oil exposure categories is presented in Table 17. EVOS workers in the high oil exposure category for their first job reported higher rates of dry, scratchy or sore throat, persistent cough or phlegm, persistent headaches, nausea or vomiting, and trembling in extremities during cleanup than workers in the no, low or medium oil exposure categories. Workers in this category also reported dizziness during cleanup at a significantly greater rate than workers in the other categories (45.3%, n=24, p=.032). Similarly, participants whose longest job task was in the high oil exposure category reported higher rates of dry, scratchy or sore throat, persistent cough or phlegm, persistent headaches, nausea or vomiting, and significantly greater frequencies of dizziness during cleanup work than other oil exposure job categories (42.4%, n=25, p=.042). Low back pain or muscle pain during cleanup work was also reported most frequently among the high oil exposure group compared to the no, low or medium oil exposure categories (*longest job:* 53.4%, n= 31, p=.177).

Among job-defined chemical exposure categories

The distribution of self-reported acute health symptoms experienced during cleanup work among the job-defined chemical exposure categories is presented in Table 18. Among the first job exposure categories, no single group reported a significantly greater proportion of acute illness than any other. However, workers whose first job was in the high chemical exposure category reported a greater frequency of dizziness and trembling in their extremities during work on the cleanup than workers in the no-low and moderate chemical exposure categories (34.3%, n=23, p=.305). Participants in the moderate chemical exposure category were more likely to report the following symptoms: dry, scratchy or sore throat, persistent cough and/or phlegm, rash or skin irritation, headaches, nausea or vomiting and low back pain or muscle pain. Among workers whose longest job was in the high chemical exposure category, symptoms of dizziness, rash or skin irritation and persistent headaches were reported more frequently than among other chemical exposure categories. Symptoms of dry, scratchy or sore throat and dizziness were reported more frequently by workers whose longest job was in the moderate chemical exposure category. Workers in this group also reported a significantly greater frequency of low back or muscle pain than workers in the low or high chemical exposure category (56.1%, n=37, p=.021).

Among specific self-reported oil and chemical exposures

The frequency of reported acute health symptoms among workers who claimed to have experienced specific oil- and chemical-related exposures are summarized in Tables 19 and 20. Within several exposure categories, exposed workers reported significantly higher frequencies of acute health symptoms than unexposed. Workers who reported dermal contact with oil during the cleanup, inhalation exposure to oil mist or vapors, and consumption of food or beverages contaminated with oil or chemicals reported significantly higher frequencies of: dry, scratchy or sore throat, cough and/or phlegm, dizziness, rash or skin irritation, persistent headaches, low back or muscle pain and trembling in extremities than unexposed. Respondents who reported that they were overcome by gases or fumes from oil during cleanup work claimed to have experienced a significantly higher frequency of all acute health outcomes than unexposed. Similarly, workers exposed to diesel exhaust or generators reported significantly greater accounts of all possible acute health symptoms than unexposed, with the exception of persistent cough or phlegm, headaches and nausea or vomiting.

Among self-reported chemical exposure variables

Workers who stated they were exposed to Inipol and Simple Green were significantly more likely to report dry, scratchy or sore throat during cleanup work, persistent cough and/or phlegm, and rash or skin irritation than those who were not exposed to these product (Table 20). Those exposed to Simple Green also reported significantly greater frequencies of low back or muscle pain and trembling in extremities during cleanup. Workers exposed to De-Solv-It and Citriklean were more likely to report rash or skin irritation and persistent headaches. In addition to these health symptoms, workers who used Citriklean were also more likely to report dizziness and low back or muscle pain, whereas those who used De-Solv-It reported greater frequencies of dry, scratchy or sore throat than unexposed.

Due to the subjective nature of these self-reports and the potential for recall bias with regard to both exposures and acute health outcomes during the cleanup, multivariable analyses were not conducted on the relationship between self-reported exposures and acute health symptoms, and therefore adjusted odds ratios for these associations are not presented. However, the crude odds ratios are presented as an indication of the potential risks associated with specific oil and chemical exposures, and acute adverse health impacts during work on the EVOS cleanup (Tables 21 and 22).

Chronic symptoms

Among all workers in study sample

The prevalence of chronic health symptoms among all workers in the study sample is presented in Table 23.[33] A large proportion of respondents reported symptoms of chronic airway disease which began during or following work on the EVOS cleanup (47.9%, n=81), and many also met criteria for symptoms indicative of neurological impairment (39%, n=66). Other chronic symptoms reported by a substantial number of workers were symptoms of chronic bronchitis, cognitive dysfunction and MCS. Very few workers had been diagnosed with cancer, kidney disease, liver disease, or solvent poisoning. 20.7% of workers in the study sample reported chronic dermatological symptoms, and 10.6% reported that they had been diagnosed with anemia.

Among job-defined oil exposure categories

The reported prevalence of chronic conditions among the job-defined oil exposure categories is presented in Table 24.[34] Symptoms of airway disease were reported in the greatest frequency among workers whose first and longest jobs were in the high oil exposure category, although this proportion was not statistically elevated compared to other oil exposure categories (*first job* 55.4%, n=31, p=.218, *longest job* 57.1%, n=36, p=.096). Similarly, workers in the high oil exposure category were more likely to report symptoms of bronchitis and MCS, although these increases were also not statistically significant. Among nonsmokers, 33.3% who experienced high oil exposure during their first job, and 25.9% with high oil exposure during their longest job reported symptoms of chronic bronchitis, compared to no symptoms reported in the no exposure or medium oil

[33] Only symptoms which first began during or after work on the cleanup (1989) were included in these analyses.
[34] The crude odds ratios for these conditions are presented and discussed separately (Tables 28-37)

exposure categories, and 25.0% among those whose first job was in the low exposure category, and 20.0% of those with low oil exposure during their longest job (*first job* p= .005; *longest job*, p=.050, Fisher's Exact Test). This difference in prevalence rates between oil exposure categories was not observed among former or current smokers. Chronic sinus problems and/or ear infections, symptoms of cognitive dysfunction, dermatologic symptoms and anemia were more prevalent among workers whose first job was in the high oil exposure category than those in the no, low or medium oil exposure categories. Symptoms of neurological impairment were reported most frequently among workers in the high oil exposure category, a difference which was statistically elevated for workers whose longest job was in this category (*longest job* 54.8%, n=34, p=.015), and similarly, workers with high oil exposure were most likely to have visited a physician for treatment of their neurological symptoms (*first job* 29.1%, n=16, p=.098; *longest job* 27.4%, n=17, p=.096). A diagnosis of anemia following cleanup work was reported most frequently among workers whose first job was in the high oil exposure category, although this increase was not statistically significant.

Among workers in the job-defined chemical exposure categories

EVOS workers with moderate chemical exposure reported the greatest prevalence of symptoms of airway disease (*first job* 62.1%, n=36, p=.018; *longest job* 60.3%, n=41, p=.006, Table 25). Statistically elevated prevalence levels for symptoms of neurological impairment and physician visits for neurological symptoms were also reported by subjects in these categories. Similarly, those with moderate chemical exposure had the greatest reported frequency for symptoms of MCS, a difference which was statistically significant for the first job worked (*first job* 36.2%, n=21, p=.041), and symptoms of bronchitis, which was significant among the longest job worked (*longest job* 35.3%, n=24, p=.009). Anemia was also reported more frequently among the moderate chemically-exposed group for first and longest positions, although this increase was not statistically significant.

Among self-reported oil exposures

Several self-reported oil exposure variables were associated with increased prevalence of many chronic conditions. Symptoms of airway disease, bronchitis, and chronic sinus problems and/or ear infections were significantly associated with dermal oil exposure, inhalation of oil mist or vapors, diesel or generator exhaust, consumption of food and beverages exposed to oil or chemicals, and being overcome by gases or fumes from oil during cleanup work (Table 26). Respondents who were exposed to diesel or generator exhaust, consumed food or beverages exposed to oil or chemicals, and who were overcome by oil gases or fumes reported greater prevalence of symptoms of cognitive dysfunction and have sought medical attention for these symptoms. Symptoms of MCS were reported more frequently among those exposed in all self-reported oil exposure categories, but at significantly elevated levels for workers who: inhaled oil mist or vapors (30.7%, p=.015), consumed food or beverages exposed to oil or chemicals (53.1%, p<.001) and who were overcome by oil gases or fumes during the cleanup (45.0%, p<.001).

Among self-reported chemical exposures

Fewer self-reported chemical exposure variables were associated with a statistically significant increase in chronic health outcomes than oil exposure variables (Table 27). Interestingly, workers who were not exposed to Customblen reported a significantly greater prevalence of symptoms of cognitive dysfunction (p=.024) and those who were not exposed to Inipol sought greater medical attention for symptoms of neurological impairment than exposed (p=.044). Exposure to Simple Green was associated with statistically significant increases in the prevalence of symptoms of bronchitis (p=.008), persistent hoarseness (p=.024), and symptoms of neurological impairment (p=.024). Symptoms of MCS were associated with exposure to De-Solv-It (p=.038), while symptoms of neurologic impairment were associated with exposure to Citriklean (p=.029). Those exposed to De-Solv It and Citriklean also reported greater prevalence of pneumonia within the past year (p=.035, p=.009, respectively) and have sought medical attention for symptoms of cognitive dysfunction (p=.047, p=.044, respectively).

Crude odds ratios: chronic symptoms

The prevalence of chronic health symptoms among job-defined exposure categories were used to guide the bivariable and multivariable analyses. Symptoms which were not considered major health outcomes due to few responses were excluded from the analyses.[35] The crude and adjusted odds ratios for the major chronic health symptoms and corresponding exposures are shown in Tables 28-37.

Symptoms of chronic airway disease

The crude odds ratios in Table 28 indicate that workers in the low, medium and high oil exposure categories had increased prevalence of chronic airway disease, an

[35] Due to missing data, multivariable analyses were not conducted on dermatologic symptoms, blood systems/conditions (frequent nosebleeds and anemia), or for individual, specific symptoms of airway disease, with the exception of bronchitis. Small prevalence rates of kidney disease, hepatitis and cancers within the study sample prevented adequate analyses of these health outcomes and they were therefore not included in the bivariable or multivariable tests with exposure variables, however, a brief summary of these particular health symptoms is included in Appendix C.

increase which was nearly significant for workers whose first job was in the high exposure category (*crude OR*= 2.48; 95% CI= 0.98,6.25; p= .054) and which was significant for workers whose longest job was in the high oil exposure category (*crude OR*= 3.33; 95% CI= 1.28, 8.70; p= .014). EVOS workers in the moderate and high chemical exposure categories had increased prevalence of chronic airway disease, but this increase was only significant among those in the moderate chemical exposure categories (*first job crude OR*= 3.27; 95% CI=1.40, 7.66; p=.006; *longest job crude OR*= 3.86; 95% CI=1.65, 9.04; p=.002). In the unadjusted model, self-reported oil exposure variables which were associated with symptoms of chronic airway disease were: dermal exposure to oil (*crude OR*= 2.05; 95% CI=1.11, 3.79; p=.022), inhalation exposure to oil mist or fumes (*crude OR*= 4.72; 95% CI=2.01, 11.13; p<.001) exposure to diesel or generator exhaust (*crude OR* 3.04; 95% CI 1.60, 5.82; p<.001), consumption of food or beverages exposed to oil or chemicals (*crude OR* 3.97; 95% CI 1.70, 9.27; p<.001) and being overcome by oil gases or fumes (*crude OR* 3.07; 95% CI 1.48, 6.35; p=.002). No self-reported chemical exposure variables were associated with an increase in symptoms of chronic airway disease, although workers exposed to Simple Green, De-Solv-It and Citriklean had an elevated odds ratio compared to those who were unexposed.

Symptoms of bronchitis

As shown in Table 29, workers in either the low or high oil exposure categories had an elevated prevalence of symptoms of chronic bronchitis, although this increase was not statistically significant. Subjects with moderate chemical exposure reported more symptoms of chronic bronchitis than other workers, an increase which was nearly significant among the first job worked (*crude OR*= 2.68; 95% CI= 0.96, 7.49; p=.060) and which was significant among the longest job worked (*crude OR*= 3.00; 95% CI=1.10, 8.17; p=.032). Similarly, several self-reported oil exposure variables were associated with a significant increase in symptoms of chronic bronchitis: dermal exposure to oil on the skin or in eyes (*crude OR*=2.06; 95% CI=1.00, 4.34; p=.047), inhalation of oil mist or fumes (*crude OR*=4.39; 95% CI=1.27, 15.18; p=.012), inhalation of diesel or generator exhaust (*crude OR*=3.41; 95% CI=1.45, 8.02; p=.003), consumption of food or beverages exposed to oil or chemicals (*crude OR*=2.60; 95% CI=1.11, 6.05; p=.024) and being overcome by oil gases or fumes (*crude OR*=3.95; 95% CI=1.84, 8.49; p<.001). In addition, workers exposed to Simple Green also had an increase prevalence of chronic bronchitis (*crude OR*= 2.80; 95% CI=1.28, 6.13; p=.008).

Symptoms of cognitive dysfunction

Very few associations between job-defined oil or chemical exposure classifications and symptoms of cognitive dysfunction were significant and several odds ratios were less than 1.00 (Table 30). Among self-reported oil exposures, workers who: inhaled diesel or generator exhaust, consumed food or beverages exposed to oil or chemicals, and those who were overcome by gases or fumes from oil all exhibited significantly greater risk for symptoms of cognitive dysfunction than unexposed. Inhalation of oil mist or fumes, dermal oil exposure and exposure to burning oil or trash were all associated with an increase in adverse cognitive effects, but the 95% confidence intervals were not significant. Self-reported exposures to Simple Green, De-Solv-It and Citriklean were associated with increased prevalence in symptoms of cognitive dysfunction, but none of these increases were statistically significant.

Symptoms of neurological impairment

EVOS workers with high oil exposure were significantly more likely to report symptoms of neurological impairment than workers in the medium, low or no oil exposure categories (*first job crude OR*=3.07; 95% CI=1.67, 8.07; p=.023; *longest job crude OR*=3.04; 95% CI=1.16, 7.93; p=.023) (Table 31). Moderate chemical exposure was also significantly associated with an increased prevalence of neurological symptoms (*first job crude OR*=2.73; 95% CI=1.15, 6.49; p=.023; *longest job crude OR*=2.48; 95% CI=1.02, 6.01; p=.045), while high chemical exposure was associated with the significantly greatest risk of neurological symptoms (*longest job crude OR*=2.92; 95% CI=1.18, 7.18; p=.020). Among self-reported exposures, symptoms of neurological impairment were associated with an increased prevalence of exposure to oil mist or fumes (*crude OR*= 4.28; 95% CI=1.67, 10.97; p=.001), diesel or generator exhaust (*crude OR*=2.42; 95% CI=1.25, 4.70; p=.008), consumption of food or beverages exposed to oil or chemicals (*crude OR*=3.68; 95% CI=1.64, 8.30; p=.001), being overcome by oil gases or fumes (*crude OR*=2.63; 95% CI=1.30, 5.32; p=.006), working with Simple Green (*crude OR*= 2.10; 95% CI=1.10, 4.01; p=.024), and working with Citriklean (*crude OR*= 2.07; 95% CI=1.07, 3.98; p=.029).

Symptoms of multiple chemical sensitivity (MCS)

Workers with jobs in the high oil exposure and moderate chemical exposure categories were more likely to report symptoms of MCS, although this increase was only significant for workers whose first job was in each category (*high oil exposure crude OR*=3.68; 95% CI=1.12, 12.10; p=.032; *moderate chemical exposure crude OR*=3.75; 95% CI=1.27, 11.06; p=.017) (Table 32). Symptoms of MCS were associated with self-reported exposure to oil mists or fumes (*crude OR*=3.66; 95% CI=1.21, 11.03; p=.015), consumption of food or beverages exposed to oil or chemicals (*crude OR*=5.72; 95% CI=2.46, 13.31; p<.001), being overcome by oil gases or fumes (*crude OR*=3.55; 95% CI=1.68, 7.50; p<.001) and working with De-Solv-It (*crude OR*=2.21; 95% CI=1.04, 4.69; p=.038). Workers who reported using Simple Green during cleanup work also were more likely to report symptoms of MCS, although this increase was not statistically significant (*crude OR*=2.03; 95% CI=0.97, 4.25,; p=.058).

MULTIVARIABLE ANALYSIS

Full main effects model

To study adjusted associations between exposure risk factors and major chronic health outcomes, I developed a multivariable logistic regression model. In multivariable analyses, several factors had positive associations with chronic health conditions, although the associations were not always statistically significant for both first and longest jobs worked. Tables 28-37 display the statistical comparisons of major chronic health conditions among the oil and chemical exposure categories, stratified by the first job and longest position worked, in addition to specific self-reported oil and chemical exposures. These odds ratios are adjusted for the difference between the groups with respect to age, sex, race/ethnicity, smoking status, belief that personal health had been affected by working on the oil spill cleanup, and original source list of the participant's name. In addition to adjusting for these confounders, each self-reported oil exposure variable was adjusted for the remaining self-reported oil exposure variables and each self-reported chemical exposure variable was adjusted for the remaining self-reported chemical exposure variables.

Symptoms of chronic airway disease

After introducing each of the job-defined oil exposure variables and the potential confounders simultaneously into a logistic regression model, I found that the odds ratios for symptoms of chronic airway disease among workers in the high oil exposure categories remained elevated but were no longer significant (*first job, adjusted OR*= 1.51; 95% CI=0.52, 4.38; p=.447; *longest job, adjusted OR*= 2.99; 95% CI=0.98, 9.08; p=.053) (Table 28). Among workers classified with moderate chemical exposure, an increase in chronic airway symptoms only remained significant for workers whose longest job was in this category (*adjusted OR*= 3.14; 95% CI=1.15, 8.61; p=.026). A self-reported exposure which remained significantly associated with symptoms of chronic airway disease was inhalation of oil mist or vapors (*adjusted OR*= 4.16; 95% CI=1.31, 13.27; p=.016). Self-reported exposures which were associated with chronic airway disease in the unadjusted model but which did not remain statistically elevated in the adjusted model were: dermal exposure to oil (*adjusted OR*= 0.58; 95% CI=0.22, 1.52; p=.267), consumption of food or beverages exposed to oil or chemicals (*adjusted OR*= 1.14; 95% CI=0.31, 4.20; p=.843) or being overcome by oil gases or fumes (*adjusted OR*= 1.19; 95% CI=0.40, 3.47; p=.755). Diesel or generator exhaust was nearly statistically significantly associated with symptoms of chronic airway disease (*adjusted OR*= 2.37; 95% CI=0.97, 5.801 p=0.059) (Table 29). Workers exposed to De-Solv-It exhibited a significant increase in prevalence of chronic airway disease in the adjusted model (*adjusted OR*= 3.88; 95% CI=1.29, 11.67; p=.016) an increase which was not originally significant in the unadjusted model.

Symptoms of bronchitis

Following adjustment for confounders, few associations between job-defined exposures and symptoms of chronic bronchitis remained statistically significant, although several odds ratios remained elevated compared to the reference exposure categories (Table 30). Workers in the high and low oil exposure categories, and moderate chemical exposure categories all reported an increased prevalence of chronic bronchitis which was nonsignificant. Likewise, inhalation exposure to oil mist or fumes continued to be associated with chronic bronchitis, although the strength of this association was much weaker after adjustment for confounders (*adjusted OR*= 1.92; 95% CI=0.36, 10.15; p=.441) (Table 31). A similar decrease in the strength of association with chronic bronchitis was also observed for workers who were overcome by oil gases or fumes (*adjusted OR*= 2.18; 95% CI=0.67, 7.13; p=.198) and those who worked with Simple Green (*adjusted OR*= 3.35; 95% CI= 0.85, 13.17; p=.083). The only self-reported exposure which remained significantly associated with increased symptoms of chronic bronchitis following adjustment for confounders was inhalation of diesel or generator exhaust (*adjusted OR*= 3.57; 95% CI= 1.12, 11.38; p=.031).

Symptoms of cognitive dysfunction

The adjusted odds ratios for symptoms of cognitive dysfunction among job-defined oil exposure categories were all less than one, with a significant association among workers whose longest job was in the low oil exposure category (*adjusted OR*= 0.28; 95% CI=0.08, 0.93; p=.038) (Table 32). No significant associations were observed among job-defined chemical exposure categories, and most odds ratios for these categories were also less than one. Workers who reported exposure to diesel or generator exhaust exhibited significantly greater prevalence of cognitive dysfunction symptoms after adjustment for confounders (*adjusted OR*=6.06; 95% CI=2.06, 17.86; p=.001) (Table 33). Other self-reported exposures which were associated with a non-significant increase in prevalence were consumption of food or beverages exposed to oil or chemicals (*adjusted OR*= 2.38; 95% CI=0.66, 8.54; p=.185) and being overcome by gases or fumes from oil (*adjusted OR*=2.11; 95% CI=0.70, 6.38; p=.187). Among self-reported chemical exposures, only the use of De-Solv-It during cleanup work was significantly associated with an increased risk of chronic cognitive dysfunction (*adjusted OR*= 3.78; 95% CI=1.23, 11.61; p=0.020).

Symptoms of neurological impairment

A job-defined classification of high oil exposure was positively associated with symptoms of neurological impairment which reached statistical significance among those whose longest job was in this category (*first job adjusted OR*= 2.74; 95% CI=0.83, 8.99; p=.098; *longest job adjusted OR*= 3.63; 95% CI=1.05, 12.58; p=.042) (Table 34). No significantly elevated risk was observed among the job-defined chemical exposure categories, although workers whose longest job was in the high chemical exposure category reported the greatest prevalence of neurological symptoms (*adjusted OR*=2.40; 95% CI=0.78, 7.40; p=.127). After adjustment in the multivariable model, the only self-reported exposure variable which remained significantly associated with an increased prevalence of neurological symptoms was inhalation exposure to diesel or generator exhaust (*adjusted OR*=3.86; 95% CI=1.34, 11.13; p=.012) (Table 35). Exposure to Simple Green, De-Solv-It and Citriklean were all associated with non-significant increases in symptoms of neurological impairment.

Symptoms of multiple chemical sensitivity (MCS)

None of the oil or chemical exposure categories remained significantly associated with symptoms of MCS following adjustment for potentially confounding factors, although workers whose first job was in either the high oil or moderate chemical exposure category continued to report the greatest prevalence of these symptoms (*first job, high oil exposure, adjusted OR*=2.17; 95% CI=0.56, 8.38; p=.263; *first job moderate chemical exposure, adjusted OR*=2.10; 95% CI=0.58, 7.56; p=.256) (Table 36). Adjustment for confounders substantially reduced the association between symptoms of MCS and exposure to oil mist or fumes, consumption of food or beverages exposed to oil or chemicals and being overcome by gases or fumes from oil; however, the odds ratios for these exposure variables remained insignificantly elevated compared with unexposed (Table 37). Exposure to De-Solv-It remained strongly associated with higher risk for symptoms of MCS (*adjusted OR*=4.82; 95% C.I.=1.31, 17.72; p=.018).

VI. DISCUSSION

To my knowledge, no previous study has examined the chronic health effects among marine oil spill cleanup workers several years following their initial exposures. This study was designed primarily to investigate whether individuals exposed to oil and chemicals during the cleanup of the Exxon Valdez oil spill (EVOS) suffer any impairment with regard to respiratory symptoms, neurological symptoms, multiple chemical sensitivity (MCS), and other chronic health problems. In this study, I found evidence to support my hypothesis that EVOS cleanup workers who experienced high exposure to crude oil, oil fumes or oil mist reported a higher prevalence of chronic respiratory illness and neurological impairment than workers presumed to have experienced less intense oil exposure or who were unexposed during their work on the cleanup. Some evidence was found to support my secondary hypothesis that workers with high exposure to chemical stressors reported greater prevalence of neurological damage and MCS; however, few workers reported working with the bioremediation agents Inipol EAP22 and Customblen to permit full analysis of any association of health outcomes due to exposures to these products. A summary of the relevant findings and comparisons with scientific literature are presented as follows.

SUMMARY OF MAJOR FINDINGS

Oil exposures

Workers whose longest job was in the high oil exposure category were significantly more likely to report symptoms of chronic airway disease in the unadjusted model (*longest job, crude* OR= 3.33; 95% CI= 1.28, 8.70; p= .014) and this association was nearly significant following adjustment for confounders (*longest job, adjusted OR*=

2.99; 95% CI=0.98, 9.08; p=.053). The effect of oil exposure on symptoms of chronic bronchitis was greater among nonsmokers than smokers. Nonsmokers with high oil exposure reported the greatest prevalence of bronchitis (*first job high oil exposure:*33.3%; *longest job high oil exposure:* 25.9%) compared with no symptoms of chronic bronchitis reported among nonsmokers with either medium or no oil exposure, and 25.0% and 20.0% among those whose first and longest jobs were in the low oil exposure category (*first job* p= .005; *longest job*, p=.050, Fisher's Exact Test). This difference in prevalence rates between oil exposure categories was not observed among former or current smokers. Self-reported exposure to oil mist or vapors was also significantly associated with symptoms of chronic airway disease (*adjusted OR*= 4.16; 95% CI=1.31, 13.27; p=.016).

Workers in the high oil exposure categories were more likely to report symptoms of neurological impairment than workers with less oil exposure (*first job crude OR*=3.07; 95% CI=1.67, 8.07; p=.023; *longest job crude OR*=3.04; 95% CI=1.16, 7.93; p=.023) and in the adjusted model, high oil exposure during the longest job worked remained significantly associated with symptoms of neurological impairment (*longest job adjusted OR*= 3.63; 95% CI=1.05, 12.58; p=.042). Workers who experienced high oil exposure during their first job were significantly more likely to report symptoms of MCS in the unadjusted model (*crude OR*=3.68; 95% CI=1.12, 12.10; p=.032) but this increase was not significant in the multivariable model (*adjusted OR*=2.17; 95% CI=0.56, 8.38; p=.263).

Chemical exposures

Similar to the results among the oil exposure categories, workers with moderate chemical exposure reported a greater prevalence of symptoms of chronic airway disease (*first job crude OR*= 3.27; 95% CI=1.40, 7.66; p=.006; *longest job crude OR*= 3.86; 95% CI=1.65, 9.04; p=.002), which remained significant after adjustment for confounders among workers whose longest job was in this category (*adjusted OR*= 3.14; 95% CI=1.15, 8.61; p=.026). Symptoms of chronic bronchitis were reported more frequently among respondents in the moderate chemical exposure category, an association which was significant in the unadjusted model, (*longest job crude OR*= 3.00; 95% CI=1.10, 8.17; p=.032) but which was no longer significant in the multivariable model (*longest job adjusted OR*= 1.81; 95% CI=0.52, 6.31; p=.354).

High chemical exposure was associated with the significantly greatest prevalence of neurological symptoms among chemical exposure categories in the bivariable model (*longest job crude OR*=2.92; 95% CI=1.18, 7.18; p=.020), but this association did not remain significant following adjustment for confounders (*adjusted OR*=2.40; 95% CI=0.78, 7.40; p=.127). Workers whose first job was in the moderate chemical exposure category reported an increased prevalence of symptoms of MCS (*first job crude OR*=3.75; 95% CI=1.27, 11.06; p=.017), but this association was weaker in the adjusted model (*first job adjusted OR*=2.10; 95% CI=0.58, 7.56; p=.256). Exposures to Inipol and Customblen were not significantly associated with a higher prevalence of any of the major chronic health outcomes assessed in this study; however, this was likely due to low numbers of workers who reported exposure to these chemicals compared with other chemical exposures.[36] There were also insufficient reports of anemia and liver disease in this population, which prevented addressing the latter half of my secondary hypothesis, that workers exposed to Inipol EAP22 and Customblen will have a higher prevalence of multiple chemical sensitivity, anemia and liver disease than workers who were not exposed to these chemical agents.

Other associations

There were also several other notable significant associations between self-reported exposures and chronic health outcomes. Contrary to what I had assumed, there were few positive associations between oil or chemical exposures and symptoms of cognitive dysfunction. The adjusted odds ratios for symptoms of cognitive dysfunction among job-defined oil exposure categories were all less than one, with a statistically significant association among workers whose longest job was in the low oil exposure category (*adjusted OR*= 0.28; 95% CI=0.08, 0.93; p=.038). Exposure to oil on the skin or in the eyes, inhalation of oil mist or fumes, inhalation of diesel or generator exhaust, consumption of food or beverages exposed to oil or chemicals, being overcome by oil gases or fumes, and exposure to Simple Green were all crudely associated with increased symptoms of chronic bronchitis; however, following adjustment for confounders, only the association with exposure to diesel or generator exhaust remained significant (*adjusted OR*= 3.57; 95% CI= 1.12, 11.38; p=.031). Diesel or generator exhaust exposure was also associated with the greatest prevalence of symptoms of cognitive dysfunction (*adjusted OR*=6.06; 95% CI=2.06, 17.86; p=.001) and was the only self-reported exposure which remained significantly associated with symptoms of neurological impairment in the adjusted model (*adjusted OR*=3.86; 95% CI=1.34, 11.13; p=.012).

[36] As shown in Table 12, only 18 workers reported exposure to Inipol and 8 to Customblen.

Several interesting associations were noted among workers exposed to De-Solv-It. Those who reported working with this product were more likely to report symptoms of chronic airway disease (*adjusted OR*= 3.88; 95% CI=1.29, 11.67; p=.016), symptoms of chronic cognitive dysfunction (*adjusted OR*= 3.78; 95% CI=1.23, 11.61; p=0.020) and symptoms of MCS (*adjusted OR*=4.82; 95% C.I.=1.31, 17.72; p=.018) than unexposed. Exposure to De-Solv-It, Simple Green and Citriklean were all associated with non-significant increases in symptoms of neurological impairment after adjusting for confounders.

RELATIONSHIP OF RESULTS TO SCIENTIFIC LITERATURE

Oil (mist) exposure and respiratory symptoms

It is difficult to compare the results of my study with previous findings, since there appear to be no studies which specifically examined the chronic health effects among oil spill cleanup workers, and there are few assessments of chronic effects following exposure to crude-oil aerosols. However, there are many studies on the effects of oil-based mists used in metalworking activities, and oil mists generated from the use of straight or soluble cutting oils may be the closest in properties to mists generated during oil-spill cleanup (Park and Holliday 1999). The finding of increased symptoms of airway disease among EVOS workers with high oil exposures is consistent with higher prevalence of respiratory disease reported previously among workers exposed to mineral oil mist. In one study, mineral oil mist exposed workers had greater prevalence of mucous membrane irritation and dyspnea than unexposed, as assessed through a respiratory symptom questionnaire (Svendsen and Hilt 1997). Furthermore, the population in this particular study was marine engineers, whose environmental working conditions may be more similar to EVOS workers than other industrial or occupational studies on oil mist exposures.

Järvholm *et al.* assessed the prevalence of chronic bronchitis in a cross-sectional study on workers exposed to mineral oils through a method similar to the one I utilized-through a question which asked whether workers experienced a persistent cough for a period of more than three months within the past year (Järvholm *et al.* 1982). Järvholm *et al.* found that non-smoking workers exposed to oil mists had more respiratory symptoms than unexposed controls (14% of exposed nonsmokers vs. 2% of nonsmoking controls).This is similar to my findings among nonsmoking EVOS workers with high oil exposure who reported higher prevalence of bronchitis than unexposed nonsmokers. However, one significant difference which prevents adequate comparisons between these workers and EVOS workers is the length of exposures. Workers in the study by Järvholm *et al.* were exposed to mineral oil mist for an average of 12-17 years, compared with several months of exposure among EVOS workers. Also, the question of whether mineral oil mist is an appropriate substance to use for comparison of exposure to crude oil mist remains to be answered.[37]

Respiratory and neurological symptoms among oil and chemical exposed workers

The finding of increased prevalence of respiratory impairment and chronic neurological symptoms reported among EVOS workers with high oil or medium chemical exposure is moderately supported by studies on occupational exposures to oil or VOCs. A study on workers who cleaned tanks containing heavy fuel oils is likely comparable to the exposures of EVOS workers with regard to total hydrocarbons (HCs),

[37] It should be noted that although crude oil and mineral oil are chemically quite different, the current OSHA PEL of 5mg/m^3 for oil mist was used for crude oil exposure during the EVOS cleanup. (Reller 1989)

benzene, and potentially H2S. In this study, workers from nine tank cleaning companies were interviewed and evaluated by a physician to determine acute intoxication from chemical exposure, reaction time, lung function[38] and heart rate (Lillienberg *et al.* 1992). Several exposed men reported irritated mucous membranes, but no significant differences in reaction time were observed before and after exposure (Lillienberg *et al.* 1992). However, the sample sizes were quite small for each test.[39] A study on benzene exposure among male workers employed in the removal of residual fuel from shipyard tanks found that 80% of these workers had mucous membrane irritation and 67% had dyspnea, and a similar study found that nasal irritation and sore throat were commonly reported following benzene exposure (ATSDR 1997). However, workers in these studies were exposed to very high levels of benzene (33 to 60 ppm) which may be greater than the exposures sustained by the majority of EVOS workers.

Other research has demonstrated an increased risk of neurological symptoms among workers exposed to organic solvents. Commonly reported symptoms following acute benzene exposure at high levels include headaches, nausea, tremors, convulsions and other neurological effects, whereas workers exposed to lower doses of benzene and toluene for a longer time period (2-9 years) had complaints of frequent headaches, fatigue, difficulty sleeping and memory loss, and also exhibited peripheral nervous system effects (ATSDR 1997). A cross-sectional test on residents who lived near an oil processing plant for up to 17 years, and who experienced significant exposures due to heavy contamination, found increased neurophysiological and neurological impairment (Baars 2002). An investigation of footwear manufacturing workers exposed to glues

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[38] As determined by forced vital capacity (FVC) and forced expiratory volume for 1 sec (FEV_1).
[39] A total of 29 men participated in the study and only 7 were given neurological tests.

containing hydrocarbon solvents exhibited a general polyneuropathy and sensory impairment in the extremities (Park and Holliday 1999). A potential mechanism through which these neurotoxic effects may be caused involves the metabolism of hexane in the body to 2,5-hexanedione, the established neurotoxin (MacFarland 1988). A study on painters exposed to organic solvents used a questionnaire to assess neurological symptoms and found that exposed workers had higher prevalence of acute symptoms of neurotoxicity than controls, however, there was no statistically significant evidence of chronic neurotoxic effects (Van Vliet *et al.* 1989).

Studies on workers exposed to H2S also found similar symptoms of respiratory and neurological impairment. Canadian petrochemical workers exposed to H2S over a five-year period had acute effects of disequilibrium and pulmonary edema, and a follow-up study on this population found seven fatalities which involved the central nervous and respiratory systems (ATSDR 1999b). A retrospective epidemiological study on residents exposed to H2S from naturally-occurring geothermal reservoirs in New Zealand found significant increases in diseases of the nervous system, both in the central nervous system and the peripheral nervous system (Bates *et al.* 1998).[40] An oil-field worker who became unconscious following exposure to H2S had delayed visual reaction times, abnormal balance, slow blink reflex latency, and impaired verbal and visual recall (Kilburn 1993). Workers who had lost consciousness after H2S exposure were re-examined five years later and found to have neurological impairment, with memory and motor function most affected (Tvedt *et al.* 1991).

[40] Levels of H2S in this study were as high as 400 ug/m^3, but the median concentrations of were 20 ug/m^3.

Symptoms of multiple chemical sensitivity (MCS)

My study assessed MCS rather conservatively and the results may not be comparable with previous studies which were able to more thoroughly evaluate the severity of individual symptoms and control for potential confounding influences on this condition, such as negative affectivity or depression. However, the results of this study with regard to MCS are presented briefly and further research is necessary to determine the prevalence of this relatively new and somewhat controversial disorder among EVOS workers and among workers in the petroleum and petrochemical industry. High oil exposure and moderate chemical exposure during the first cleanup job[41] were each weakly associated with increased symptoms of MCS which were not significant following adjustment for confounders. There are difficulties with comparing these results to previous research, since few studies could be located which specifically evaluated the prevalence of MCS among a population with somewhat similar exposures to the EVOS workers. Davidoff *et al.* examined the prevalence of MCS symptoms among tunnel workers exposed to large amounts of benzene underneath an abandoned gasoline station for a period of approximately two months (1998).[42] Thirty workers were interviewed about the degree of sickness that occurred after various environmental exposures and the frequency of their symptoms. It was found that MCS occurred commonly among the men sampled, however, 60.7% of the sample had symptoms of MCS which began before their

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[41] Since only exposures sustained during the first cleanup job were associated with symptoms of MCS, a potential explanatory mechanism could be a one-time sensitization of the individual which then elicits continued immune response following subsequent exposure to various chemical stimuli. However, this mechanism is hypothetical and no evidence to support or refute it was found in a review of the scientific literature, although a proposed theory of total body burden (chemical overload) has been put forth by clinical ecologists to account for MCS as part of an immunological response (Graveling *et al.* 1999).

[42] This population was ideal to study, since they were exposed prior to the time when symptoms of MCS became common health complaints and before a considerable amount of research and publications on this topic had been conducted and therefore would be less subject to potential biases and over-reporting of symptoms (Davidoff *et al.* 1998).

tunnel exposures, and 33.3% of the sample developed such sensitivities or a worsening of pre-existing sensitivities following the tunnel exposure (Davidoff *et al.* 1998).

It is very difficult to determine a causal relationship with exposure among reports of MCS among EVOS workers. The lack of sufficient exposure data in currently published studies on MCS has prevented the determination of an exposure-response relationship with exposures considered to be correlated with MCS, such as chemicals in pesticides (Graveling *et al.* 1999). Some studies have suggested an immunological theory for the cause of MCS (Levin and Byers 1987). A potential mechanism through which crude oil exposure would be consistent with this theory is derived from studies on laboratory animals, which indicate that components of crude oil inhaled as an aerosol can pass through the alveolar membrane and therefore may potentially cause toxic systemic effects throughout the body (Park and Holliday). This may be one potential mechanism through which the multi-organ effects of MCS are caused or through which general toxicity occurs leading people to report symptoms similar to MCS. However, many also refute the evidence that the immune system is involved with the etiology of MCS, and there has been no consistent pattern of immune deficiency or other dysfunction which has been identified among patients with MCS (Graveling *et al.* 1999). Several studies also indicate a possible psychogenic origin of MCS. Although there have been reasonably well-documented associations between MCS and psychological characteristics, such as depression or negative affectivity (Davidoff and Keyl 1996), it is not possible to detect a causal relationship from these.

Diesel exhaust

Diesel exhaust was found to be significantly associated with increased symptoms of respiratory impairment, chronic bronchitis, cognitive dysfunction and neurological damage. While diesel exhaust from machinery was of significant concern during the oil spill cleanup, the hypothesis of my study was designed to test the effect of exposures to oil and chemicals during cleanup work, and the focus was not to determine the extent of health effects due to diesel exposure, since diesel exhaust exposure is not unique to oil spill cleanup operations. There is a wealth of controversial literature surrounding health effects related to diesel exhaust and related particulates; some studies indicate an elevated relative risk of lung cancer[43] whereas others are less conclusive with regard to health effects. Despite widespread controversy over the true relative risk associated with diesel exhaust, it is considered to be a human lung carcinogen due to the available toxicological data (Sprince, Thorne and Cullen 1994).

De-Solv-It ®

The associations shown in this study between De-Solv-It and airway disease, cognitive dysfunction and MCS are not supported by the available literature on this chemical, which may be due to the general safety of this product or lack of studies on its toxicity. There is little information available with regard to health effects associated with this product. The 1989 Material Safety Data Sheet (MSDS) for De-Solv-It lists limonene, petroleum distillate and surfactant as the active ingredients and reports no known health effects other than aggravation of dermatitis in sensitive individuals

[43] Although an increased relative risk (RR) has been detected in several studies, many times this RR was less than 2 and often less than 1.5. Smoking and other confounders also play a significant role in the etiology of lung cancer and may mask the true effects of diesel exposure (Sprince, Thorne and Cullen 1994).

following overexposure (Orange-Sol 1989). A study of human volunteers who were exposed to d-limonene by inhalation found no central nervous system impairment (Falk-Filipsson *et al.* 1993), although a study of the additive toxicity of limonene and 50% oxygen concluded that there were "possible long-term effects of limonene exposure" and that the mechanism of action of limonene on biological systems has yet to be determined (Rolseth *et al.* 2002).

It is possible that the associations between De-Solv-It and health symptoms shown in this study may have occurred due to recall bias or because this product was ubiquitously used during the cleanup that study subjects would be more likely to remember working with it. If any chronic health effects were biologically plausible as a result of exposure to De-Solv-It, dermatologic sensitivity would be most likely, as this product has been described as a "potent allergen" (Teitelbaum 1994) which may also partially contribute to a higher prevalence of respiratory irritation. However, due to the strong associations between oil and chemical exposure and airway disease, it is unlikely that respiratory symptoms would be solely attributable to De-Solv-It exposures. There is no evidence in the literature to support or refute the association between De-Solv-It and MCS found in this study.

EXPLANATIONS FOR FINDINGS

Several explanations may account for the higher prevalence of self-reported chronic medical symptoms among EVOS workers with high oil and chemical exposure than among lesser exposed workers. One explanation is that specific exposures are responsible for the etiology of each medical conditions. For example, inhalation of oil mist may account for the higher prevalence of airway disease or bronchitis, while exposure to chemical stressors such as benzene or H2S could account for the higher prevalence of symptoms of neurological impairment. Another possible explanation is that exposures found to be safe and well-tolerated alone (such as De-Solv-It or Citriklean) may act synergistically with other exposures encountered during cleanup work to cause sensitization and progression towards more severe disease. My results indicate that many EVOS workers exposed to oil mist or fumes, diesel exhaust, De-Solv-It, Citriklean and Simple Green, reported higher prevalence of many health problems. However, whether these exposures act synergistically to cause long-term health effects is unclear. The possibility also exists that the apparently less toxic products used in the greatest amounts during the cleanup (such as De-Solv-It) were most likely to be remembered by workers, rather than potentially more toxic products, (such as Inipol) which were used less frequently.

An alternative and equally plausible explanation for my findings is the effect of differential recall bias, where workers with health problems may "recall" more severe exposures than healthy subjects. In any retrospective epidemiologic study, recall bias is a potential problem, which can be further enhanced by the influence and the ramifications of the heightened media attention given to the EVOS legacy, which may have contributed to the higher prevalence of self-reported medical conditions and exposures. The over-reporting of symptoms would tend to magnify the association between chronic health effects and self-reported exposures, although this effect on the job-defined exposure categories would be less severe than among self-reported exposures.

Many associations between exposure categories and health outcomes were not significant, which could be due to a variety of reasons, but may partially be due to exposure misclassification, particularly among chemical exposures. Dividing workers into categories based upon *a priori* hypotheses about chemical exposures may have limited the ability to detect excess prevalence of some health outcomes, since it is possible that a worker may have low chemical exposure but high oil exposure which would minimize any effect. Also, with regard to specific self-reported chemical exposures, workers likely handled a variety of substances throughout their duration of employment on the cleanup, and may have difficulty recalling specific product names.[44]

Potential misclassification of disease status may also have accounted for some of the study results. Reporting bias may have caused EVOS workers who believed they experienced high exposures to claim a greater prevalence of acute and chronic health symptoms. Since no physical or diagnostic examinations of study participants were conducted, there is no way to validate the health outcomes in this study. Whenever possible, questions were phrased to include physician visits or diagnoses to limit over-reporting. However, physician visits may not always be the best indicator of the severity of a condition, and workers who are ill may not choose to see a doctor.[45] Therefore, workers may be not have received official diagnoses with specific conditions or may not have been tested, even if they have currently experience chronic symptoms. Furthermore, factors such as health insurance coverage or income will tend to introduce bias into this measure since these can influence how often an individual visits his/her physician. The effect of disease misclassification could increase the association between

[44] Many workers did not remember whether they worked with a specific chemical, and there was a high percentage of those who did not answer/did not remember for questions regarding these specific products: (7.1% for Citrisolve, 11.8% for De-Solv-It, 3.5% for Simple Green, 11.24 % for Custombien, and 11.24% for Inipol).

[45] One example of this was evident in a study on tank cleaners exposed to hydrocarbons and VOCs, where ten men who were exposed to petroleum vapors reported irritated mucous membranes when participating in a research study, although none of these men had seen a doctor for their symptoms (Lillienberg *et al.* 1992).

exposure and health effects if only those with high exposures were likely to report more health symptoms. However, since the survey participants were unaware of the job-defined exposure categories, it is likely that if disease misclassification occurred as a result of reporting bias, the associations would have been biased towards the null, since disease misclassification could have occurred in each of the oil and chemical exposure categories.

There exists the possibility of differential selection bias in the study population, since workers willing to participate in the study may have more serious health conditions than those who refused to participate.[46] However, the possibility also exists that those who were too ill to participate were excluded, which would have introduced selection bias towards the null. This investigation may underestimate the true prevalence of several debilitating conditions or diseases among EVOS cleanup workers, as this is a cross-sectional study where the least healthy workers would not be expected to participate.

An alternate explanation to the finding of greater health problems among EVOS workers with high oil or chemical exposure is that an underlying psychiatric condition, such as depression, may lead to a higher prevalence of several medical symptoms or the reporting of such symptoms. This study did not evaluate or control for the effects of depression, although alcoholic substance abuse, often associated with depression, was controlled for as a potentially confounding variable. Previous studies have found that Alaskan residents affected by the spill exhibited excess symptoms of psychological conditions and depression, indicating a significant psychosocial impact of the spill

[46] In a population study to determine the immediate and long-term health effects on the exposed resident population following the Braer oil spill near Shetland, non-responders were more likely to believe that their health was not affected, were not interested in the study or did not think the study was useful (Foster *et al.* 1995).

(Palinkas *et al.* 1993).[47] Although no follow-up studies have been conducted to assess the persistent psychological impacts of the spill on residents or cleanup workers 14 years later, the possibility of potential confounding due to depression from the spill, stemming from the loss of livelihood for fishermen,[48] for example, should be explored and must be considered when interpreting self-reported health information. Also, several verbatim survey responses from survey participants indicate that they believe post-traumatic stress disorder and depression were significant problems among cleanup workers following the spill (Appendix D).

In comparison with other studies, depression was also found to be significantly associated with exposure to solvents/petrochemicals and smoke/combustion products among Persian Gulf War Veterans (Schwartz *et al.* 1997), and residents who were exposed to crude oil following the Sea Empress oil spill in 1996 reported higher anxiety and depression than people living in nearby areas who were unexposed (Lyons *et al.* 1999). Similarly, a follow up study of the Braer oil spill found significantly higher scores for mental distress among the exposed population compared with unexposed, however, this effect was not related to the potential levels of exposures (Campbell *et al.* 1994). There is also some evidence to support the idea that symptoms of MCS may be correlated with depression, negative affectivity or anxiety, and some complaints of individuals with

[47] A community-based study conducted one year after the EVOS found that among residents of 13 Alaska communities, those in the high-exposure group were 3.6 times as likely as unexposed residents to have general anxiety disorder, 2.9 times as likely to have Post Traumatic Stress Disorder (PTSD), and approximately twice as likely to have both a Center for Epidemiologic Studies Depression (CES-D) Scale of 16 and above and a CES-D scale of 18 and above. The study also found that women and Alaska Natives were particularly vulnerable to depressive symptoms after the spill (Palinkas *et al.* 1993).

[48] Immediately following the spill, the Alaska Department of Environmental Conservation (ADEC) canceled the 1989 black cod season in Prince William Sound, banned fishing for Pacific herring and cut short the shrimp season as a result of the spill. It was determined in 1980 that at least 87 per cent of the herring spawning grounds in Prince William Sound were heavily oiled (NOAA 1989). Due to the large number of Alaskans who earn their living fishing, and the large proportion of fishermen who likely participated in the spill cleanup, it is possible that the stress over lost livelihood may have caused significant distress to these individuals.

this disorder may have a psychogenic origin (Graveling *et al.* 1999). Although a causal association has not been established, it would be important to consider the effect of these potential psychological influences when evaluating this condition. It is unlikely that psychological conditions or depression accounted for all of the increased health symptoms observed among EVOS workers with high oil or chemical exposure, however, the possibility needs to be considered that psychological conditions may play a role in either the etiology or the reporting of such conditions.

STUDY STRENGTHS AND LIMITATIONS

This was the first epidemiological study to examine chronic health effects among oil spill cleanup workers 14 years following initial exposures.[49] This research improves upon previous studies which only examined acute health effects, since many health effects related to exposure to crude oil or cleanup chemicals may have substantial latency periods and will not be evident until many years following spill. Such health impacts are also generally the ones of greatest concern, since they may be more debilitating or life-threatening than acute symptoms which are generally of mild discomfort.

The findings of this study must be interpreted in view of several limitations inherent in the study design and data. Most notably, these data were based on self-reports and therefore were subject to potential biases. As with any retrospective study, the influence of recall bias is a considerable limitation. For example, workers with current health problems may be more likely to recall exposures to hazardous chemicals or situations than those who are currently in better health. However, to limit the influence

[49] Extensive reviews of available literature produced no long term epidemiological studies on oil spill cleanup workers and only limited studies on acute health effects. Although detailed studies have been conducted on petroleum industry workers, the exposures experienced by hazardous waste cleanup workers, such as those working on EVOS, may differ greatly from those experienced among workers in an occupational petroleum environment, with regard to the nature, intensity and duration of the exposures

of this, I classified exposures through the objective measures of job tasks and determined the exposure classes before the study began. This may have minimized the effect of this bias, since the selective over-reporting or recall of jobs involving high oil or chemical exposure by workers with health problems seems very unlikely, as respondents were neither informed of the specific associations being studied nor of the job-exposure classification methods. Finally, the use of controls from within the EVOS worker population (workers with no oil/chemical exposure but who were involved with the cleanup) likely reduced the impact of selection and reporting bias which may have resulted had controls been selected from non-EVOS workers.

Reporting bias may also be an issue to consider, since workers who believe they were overexposed to hazards may be more likely to report health symptoms.[50] The social and political ramifications surrounding the EVOS spill may have contributed to the higher prevalence of self-reported medical conditions within this cohort, and the findings must be attributed in light of this limitation. However, participants were asked whether they believe the oil spill has affected their health, a variable which was included in other studies as a method for reducing the effect of reporting bias and to increase validity (Lyons *et al.* 1999) and which I included as a potential confounder in the data analysis. Predictably, a large proportion of participants believed the oil spill had affected their health (36.7%, n=62), and it is possible that those with this belief would tend to over-report symptoms. Adjustment for this factor in the multivariable model may give a more reasonable estimate of risk, and I concluded that after conservative allowances were

[50] Workers who have health symptoms may also tend to over-emphasize work-related exposure and under-emphasize lifestyle habits such as drinking or smoking

made for potential biases, the physical health of workers with greater exposure to oil and chemical stressors remains significantly worse than those with less exposure.

To reduce the effect of reporting bias and to validate health outcomes, several survey questions inquired whether workers were diagnosed by a physician for the specific health outcome of interest or have sought medical attention for particularly subjective conditions. Although the influences of recall and reporting bias are important to consider with regard to study limitations, there is evidence to suggest that many participants did not believe their health was adversely affected by their employment on the spill, as is indicated in several of the verbatim responses to the final open-ended survey question. Several notable comments from this question are listed in Appendix D.

A limitation present in the exposure assessment was the lack of detailed individual exposure information for each study participant, both with regard to the amount and duration of exposure to hazardous substances. The use of individual personal monitoring data would have been a preferential method with which to determine exposures; however, only aggregate exposure information were available for use in this study and these data were not subdivided by job category or date of collection. This average exposure information was presented in Table 1 but represents only a fraction of the EVOS workforce and may not be representative of the workers surveyed in this study, since the utility of average exposure levels in determining individual exposures is questionable. If detailed individual exposure information were available with regard to VOCs and PAHs, it is likely that a dose-response relationship would have strengthened the conclusions found, particularly for symptoms of respiratory disease and neurological impairment.

Due to the lack of specific exposure monitoring data for each specific cleanup job task, considerable assumptions regarding the various exposure scenarios in each job task were made. The classification of exposures based upon job task may have introduced potential exposure misclassification in this study.[51] Furthermore, a worker classified with low oil exposure could have experienced high chemical exposure; therefore, the ability to detect differences between the low, moderate and high exposure classes may have been limited. Also, workers may have conducted more than two jobs during their time on the cleanup, although it is likely that the first and longest jobs conducted would be the best indication of exposures and would be least subject to differential recall bias.

Although misclassification of exposures likely occurred, it is probable that this misclassification was non-differential and would likely bias the results towards the null since there is no indication that any single job task would be more likely to have been misclassified than any other. It is unlikely that recall bias influenced the initial reporting of job tasks conducted, since nearly all workers answered this question without knowledge that it would be used to determine exposure categories. With regard to specific self-reported exposures, low response rates may have reduced the ability to detect correlation with health outcomes and would have likely biased the association towards the null, especially among specific chemical exposures such as Inipol or Customblen.

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[51] An example of potential exposure misclassification which may have occurred is shown in Table 12, where nearly 50% of workers in "no exposure" category reported inhalation of oil mist or vapors. A further example of this is evident when examining the distribution of self-reported exposures among workers in the chemical exposure categories, where some who were presumed to be in the "no-low" exposure category had high prevalence of self-reported chemical exposure. Also, pilots were categorized as unexposed; however, I later obtained anecdotal information of reports from pilots and crews flying over the spill who were exposed to fumes and odors (Alaskan Oil Spill Health Conference Summary, 1989).

There was no significant correlation between the number of months worked on the cleanup and any health outcome assessed in this study, due to large variability in the duration that workers were involved with the cleanup. Therefore, the total time of employment on the cleanup was not included in any analyses and may present a limitation in the detection of a dose-response relationship with regard to specific oil and chemical exposures. However, due to the healthy worker effect, the inclusion of this factor would likely have been a confounder which would have diminished any true association with health outcomes. If duration of employment were to be used in subsequent studies, workers with clerical or administrative positions would have to be excluded, since office workers were employed on the cleanup throughout the year and therefore had the longest duration of employment, but experienced the least exposure to oil and chemicals. Those with active cleanup positions on the beaches only worked during the summer months when the majority of the cleanup was conducted. Furthermore, the length of employment may not be the best method for measuring exposure, since a true dose-response relationship could only be best ascertained through the use of personal monitoring data.

Due to limited time, resources and availability of records, the sample size is relatively small compared to the entire workforce from the cleanup and stronger associations may have been found if this study utilized a larger sample size. The sample of 169 workers surveyed may not be completely representative of the entire population of between 11,000 and 15,000 workers employed throughout the duration of the EVOS cleanup from 1989 to 1992. Furthermore, since the majority of the workers contacted were obtained through record searches of workers compensation claimants, this may further distinguish study participants from the entire oil spill workforce. However, after reviewing the summary of claims from the 1989 database, it appears that a great majority of the complaints were non-specific lacerations, bruises, sprains, other injuries not specifically related to chemical exposure or illnesses (Table 3). This indicates that the Department of Labor database sample may not be as biased as one might assume if all workers had reported systemic or illness complaints which could be directly attributable to chemical exposures sustained during cleanup activities.

Workers from a wide variety of oil spill job tasks were represented in the sample population, from those with the potential for significant oil and chemical exposure, to others who stated that they were never near oil or chemicals. The analysis by the objective means of job task rather than reliance on self-reported exposure data may have limited the effect of reporting and recall bias which would have been present if only self-reported exposure data were used. However, I also included these potentially subjective self-reports to assess the use of specific chemicals among workers and the degree of exposures within each job category, in order to validate the exposure groupings and to provide a secondary method of analysis for comparison to determine health effects.

Due to the limited demographic nature of study participants (mostly Caucasian males), the extrapolation of these study results beyond this particular population is limited. However, this is unlikely to affect the generalizability of the study results to the population of interest, since if another oil spill were to occur near Alaska or most of the northern United States or Canada, it is likely that the population employed in the cleanup would be largely comprised of Caucasian males or a workforce with similar demographic characteristics as the EVOS cleanup workers represented in this study. Therefore, it is advantageous to have a relatively homogenous population in this study in order to better estimate the health effects among workers for whom the findings would be most relevant in future spill situations.

Deceased EVOS workers were not included in the analysis of this study and survivors of these workers were not interviewed. This may be a potential limitation in detecting health effects and mortality due to oil spill exposures, since anecdotal evidence from former workers and family members indicate that many EVOS workers have already passed away, and that diseases such as leukemia, liver disease and other cancers which may be related to oil spill exposures were common causes of death (Philips 1999). A similar limitation is that diseases with long latency periods, such as lung cancer, may not have had sufficient time to develop at the time this study was conducted.

RECOMMENDATIONS FOR FUTURE RESEARCH

Results from this study indicate the need for further epidemiological and basic scientific investigations to study the relationship between oil spill cleanup exposures and health, using objective documentation of both exposures and outcomes. Additional research should be particularly directed towards studying the relationship between high oil exposure and chronic respiratory symptoms, as well as the relationship between high oil and chemical exposure and symptoms of neurological impairment. Future research may also need to specifically address high chemical exposures experienced during cleanup work and symptoms of multiple chemical sensitivity.

It is necessary to conduct an epidemiological study which utilizes specific personal exposure data from EVOS cleanup workers and validated diagnostic methods to determine health outcomes. Associations were shown in this study between adverse health outcomes and exposure categories determined by job tasks. However, if specific monitoring data and physical evaluations were utilized in future studies, more precise associations or dose-response relationships could be determined with regard to specific oil or chemical exposures. This will also provide a more accurate method with which to determine the association with health effects by distinguishing among the most significant exposures.

Diagnostic measures which could be utilized to assess health outcomes include lung function tests, such as forced vital capacity (FVC), forced expiratory volume (FEV_1) and peak expiratory flow to assess changes in lung function among exposed and unexposed nonsmokers.[52] More than half of the workers in my present study were either former or current smokers, but if wide-scale recruitment methods were utilized, future research studies may be able to obtain a larger sample of nonsmokers. Neuropsychological tests are also recommended to more specifically document the degree of neurological impairment.

With regard to specific cleanup chemicals, future studies are also needed to determine chronic health effects resulting from exposures to Inipol EAP22 ® and Customblen ®, which were not reported in great enough frequency to determine an association with health outcomes. This was likely due either to low numbers of workers who recall working with these products or a small number of workers who were actually exposed at the time of the cleanup. However, due to the potentially hazardous health effects which may result from overexposure to chemicals present in these products, it is

[52] These lung function tests were utilized in a study to determine changes in peak expiratory flow rate in schoolchildren living close to the Braer oil spill off the coast of Shetland, Scotland, but no significant difference from the normal peak expiratory flow range was detected among exposed children (Crum 1993). However, these tests may be more useful among an occupational cohort of EVOS workers with significantly greater exposures than the population in the Braer study.

recommended these should be included in future studies on cleanup worker health if these products are to be used in subsequent oil spill cleanup operations. By further studying these potentially significant exposures, recommendations for policy implications could be determined which may lead to improvements in both health monitoring and protection of worker health at oil spill cleanup sites.

In this study, I did not evaluate chronic fatigue, non-Hodgkin's lymphoma, skin cancer and thyroid disease, all of which have been anecdotally reported to be correlated with oil and chemical exposures. I would recommend that future epidemiological studies include these potentially relevant endpoints in their evaluation of health outcomes among oil spill cleanup workers. While evidence exists for an increased risk of skin cancer associated with oil exposure, such as through work in petroleum refineries (ATSDR 1999a), this study did not control for the potential confounding influence of ultraviolet (UV) exposure and did not specifically examine skin cancer as an outcome of interest. It would be noteworthy to include the increased risk of skin cancer in future studies among oil spill cleanup workers, although it would be difficult to determine the extent of contribution from sunlight/UV damage versus the effect, if any, from exposure to crude oil during cleanup work.

Another recommendation for future research would be to conduct a large retrospective cohort study in which former EVOS workers who are deceased are also included. Personal exposure information and interviews with family members or coworkers of the deceased could be used to gather more specific information to determine whether mortality could be related to cleanup work.

In addition to utilizing better monitoring information in future research on oil spill cleanup workers, the use of biomarkers of exposures may be an important area of research to explore. The measurement of DNA adduct formation as well as the induction of sister chromatid exchange in human lymphocytes has been proposed as a biomarker of PAH-exposures for human monitoring programs (ATSDR 1995b). A study on the population exposed following the Braer spill near Shetland, Scotland, utilized DNA monitoring to detect evidence of genotoxic exposure, and although no evidence of greater genotoxicity was observed among the exposed, this study makes several recommendations for the utilization of this technique for oil spill situations.[53] The authors also concluded that due to the nature of the statistical variation for many environmental genotoxic endpoints, such techniques would only be useful if conducted through a large-scale study (Cole *et al.* 1997). Although measurable DNA adducts have been detected in workers exposed to PAHs from exposures in coke ovens and aluminum plants, and among cigarette smokers, (Kriek *et al.* 1998) this method has not been able to accurately distinguish between the exposures which caused the adducts[54] (Sprince, Thorne and Cullen 1994). The use of biomarkers to determine exposure due to PAHs is especially problematic, since many confounding sources of exposure, such as dietary and environmental exposures, can contribute to the total body burden[55] (ATSDR 1995b). Despite these limitations in studying DNA adducts, this may be a potentially useful measure in assessing exposure to oil and PAHs during cleanup work.

[53] Cole *et al.* monitored DNA damage in mononuclear cells by the butanol modification of the 32P-postlabelling method and measured mutations at the hprt locus in T lymphocytes (1997).

[54] Several non-occupational sources of PAHs include cigarette smoke, organic smoke such as bonfires, smoked foods and overcooked meats, all of which could contribute to the presence of PAH-DNA adducts in the body (ATSDR 1995b).

[55] The background exposure of the general [nonsmoking] population for PAHs is approximately 240 ng PAHs per kg body weight per day via the oral exposure route, and about 6.5 ng PAHs per kg bw per day via inhalation, with considerably higher exposures among smokers (Baars 2002).

In any future investigation that proposes to further study EVOS workers and the etiologic basis of their chronic health symptoms, it will be necessary to consider the heightened media attention given to this issue and its potential to influence or bias study subjects. However, the use of objective measures of exposure, disease classification and biomarkers will reduce the influence of such potential biases.

VII. RECOMMENDATIONS FOR FUTURE OIL SPILL CLEANUP OPERATIONS AND SIGNIFICANT LIMITATIONS PRESENT IN THE EVOS CLEANUP

It is obvious by the size and nature of the workforce involved with the EVOS cleanup (more than 11,000 workers in 1989), that at the time of this emergency, Exxon, the State of Alaska and the federal government were not prepared to respond to this disaster. There was an overall lack of personnel and equipment to handle this major oil spill. Workers were recruited from the general population and many had little or no experience handling hazardous waste. Therefore, adequate training to inform these workers of the risks associated with crude oil and cleanup chemicals was essential. However, both sufficient risk communication and proper training were severely lacking during the EVOS cleanup. There were several limitations present in the way the EVOS cleanup was conducted and there are substantial possibilities for improvements in the federal and private response to subsequent oil spills which can be learned from these limitations. There is a great need to need to implement better exposure monitoring techniques and to make data from such monitoring available to regulators and scientists, in order to conduct long-term follow-up studies on workers to benefit scientific knowledge from tragic exposures sustained following national disasters, and also to influence policy decisions with the goal of implementing better methods to ensure protection of worker health in the future. Significant limitations in the EVOS cleanup with regard to the response of federal regulators, insufficient risk communication and training, lack of protective equipment, and the relevance of the occupational exposure limits used are discussed as follows.

Role of federal regulators in monitoring cleanup

Federal investigators from NIOSH attempted to investigate the EVOS working conditions and to examine medical records from workers (both injuries and general medical complaints) at the time of the cleanup. However, they cited "problems of access" (Alaska Oil Spill and Human Health Conference Summary, 1989) and did not succeed in obtaining these records or conducting any thorough investigation of worker health.[56] This lack of follow-up and evaluation of exposure data from EVOS workers prevented the construction of an adequate basis upon which to conduct future epidemiological investigations on oil spill worker health. Had NIOSH obtained the EVOS exposure monitoring data, it is likely that several studies would have been conducted to determine the impact of the oil spill on health, and it is also a possibility that better protective measures may have been implemented both at the time of the cleanup and in future oil spill situations.

If a future epidemiological study were to be conducted on EVOS workers, it would be valuable for the federal government to require that Exxon personal and area monitoring data, along with workers' medical records from the time of the cleanup, be made available to researchers to conduct a thorough epidemiological exposure-based study. Although NIOSH did not exercise its subpoena power with regard to exposure measurements or health information of EVOS workers, investigators from NIOSH conducted their own air monitoring during cleanup. However, initial measurements were taken four months following the spill, when exposures were less likely to be severe than in first month following the release of crude oil and VOCs. This illustrates the necessity

[56] Although NIOSH conducted a health hazard evaluation (HHE) describing potential hazards present during the cleanup, they did not study individual workers' health or obtain monitoring data which could be used to conduct follow-up epidemiological studies.

of federal regulators to be involved with the oversight and monitoring of the cleanup process from the time of the spill, rather than as a follow-up when exposures are anticipated to be less severe and when substantial health impacts may have already occurred.

Furthermore, with regard to the actual monitoring of health impacts by the cleanup contractors involved, Exxon had 13 industrial hygienists working on the spill in 1989 but there were more than 10,000 workers employed during this period in the cleanup (Florky, 1989). Roger Florky of Exxon Corporation said that about 75% of the hygienists' time was spent responding to worker concerns, which he referred to as "basic industrial hygiene fire fighting" (Florky 1989). The ability of industrial hygienists to adequately monitor hazards was "more limited than usual" during cleanup (Hild and Gillen 1989) due to the variety of exposure situations and size of the workforce. In the event of a future oil spill, federal regulators should require and enforce the implementation of a more thorough industrial hygiene monitoring system by the cleanup contractors in order to more accurately track injuries and illnesses sustained during cleanup work, especially those which may be related to chemical exposures.

Risk communication

The issues of risk communication, adequate training, and enforcement of protective equipment in the EVOS cleanup are three key areas which must also be addressed and improved in future oil spill cleanup situations. One significant problem which became evident in researching the exposures and conditions of the EVOS cleanup workers was a general lack of adequate risk communication from the cleanup contractors to the workers. The EVOS workers should have received better training and education about chemical hazards and proper use of protective equipment. Officials from the Alaska Department of Labor and Industrial Hygiene stated in 1989 that, "the safety problems [during the cleanup] have been tremendous" and they cited one example where workers were cleaning oiled boats using an unlabeled cleaner, which was later discovered to be an IARC Class II carcinogen (Short and Palmer 1989). Worker training and perception of risks are important components involved with enforcement of protective equipment and influence general caution taken when handling chemicals or oil during cleanup. Because workers were not adequately informed of the risks involved with the cleanup, they were therefore not as likely to comply with the protective measures and use of protective equipment, which placed them at greater risk of harmful exposures. One EVOS worker said "They told us we could eat that stuff [crude oil] on our pancakes" (Phillips 1999). With regard to the bioremediation agent Inipol, physicians from Exxon may not have adequately conveyed the risk of working with this product, stating that butoxyethanol "is in a lot of compounds on the shelves" sold as cleaning agents (McDowell 1989).

Adequate training

In addition to the lack of thorough risk communication, proper preventive training appeared to be a significant limitation in the way the EVOS cleanup was conducted which may also be responsible for overexposures of workers. In the early weeks after the spill, cleanup personnel received only one hour of training, instead of the OSHA-mandated 40 hours when working with toxic substances such as petroleum (Baringa 1989). As the cleanup progressed, Exxon and government officials agreed on a four-hour basic training course (Alaska Oil Spill Health Conference Summary, Shortt, AK Dept of Labor 1989); however, the focus of this course did not explicitly cover the handling of hazardous substances. Various topics included were earthquake safety, firearms policies, bear/wildlife safety and how to deal with archaeological sites (Alaska Oil Spill Health Conference Summary, Florky, Exxon Corp. 1989). The EVOS worker training program was criticized for lack of hands-on training to prepare workers for hazardous materials cleanup "so that workers would start thinking about what they have to do on the actual job" (Hild and Gillen, 1989). The Laborers' National Health and Safety Union was concerned that workers were not adequately prepared to work with hazardous waste and that they did not fully comprehend the short- and long-term effects of working with crude oil (LIUNA 1989).

Along with adequate training, the utilization of pre-employment physicals and assignment of workers to job tasks according to physical ability and health will help protect workers in future oil spill cleanup operations. The EVOS workers were given little pre-employment physicals or baseline evaluations, and an extreme example of this lack of screening is evident by the employment of susceptible individuals, such as one woman who participated in this survey and stated that she had been 4 months pregnant at the time of the cleanup (Appendix D). The youngest worker who participated in this survey is currently 21 years old, and the oldest worker is currently 79 years old; therefore, they would have been 7 and 65 years old at the time of the cleanup, respectively. The youngest worker's job was to handle oiled trash and the oldest worker set booms to contain the oil, which were two of the job tasks with the greatest potential for oil and chemical exposure. This is just one possible example of the need for improved pre-work screening of workers and the implementation of stricter requirements to determine who should be permitted to be employed around potentially hazardous conditions. Although the spill was arguably an emergency situation, the protection of worker health should still be ensured and basic screening requirements employed to avoid exposures among the most susceptible populations.[57]

Respirator use/ Lack of protective equipment

In determining the intensity of exposures among cleanup workers, the use of personal protective equipment (PPE) and the adequacy of specific PPE in preventing harmful exposures must be considered. Although respirator use and health effects were not correlated in this particular study, it is alarming to note that many workers with the potential for high oil and/or chemical exposure during cleanup work were not provided with a respirator (Table 15). As the work force grew throughout the duration of the cleanup, protective suits were often not available (Baring 1989). The use of PPE, meant to defend workers against inhalation and dermal exposure, was often not enforced or optional (Alaska Oil Spill Health Conference Summary, Gorman, NIOSH 1989). Among workers who were provided with a respirator, the use of this protective equipment was often not enforced and workers were seen removing their respirators during hot weather (NIOSH 1991). In a study by Lillienberg *et al.* on tank cleaners exposed to hydrocarbons and VOCs, interviewers with workers indicated that they usually use their sense of smell to determine whether protective equipment should be used (1992). Better risk communication and enforcement of respirators is essential to protecting workers against significantly harmful inhalation exposures sustained during oil spill cleanup work.[58]

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[57] An abbreviated summary of those individuals with preexisting conditions that would likely be aggravated by exposures to oil or cleanup chemicals are presented in Table 2.

[58] However, it is also important to consider that while the use of PPE must be enforced under conditions of greatest exposure to oil and chemicals, the real world conditions of an oil spill cleanup may make the use of such equipment "inconvenient or even hazardous" and therefore it is important for cleanup contractors and regulators to balance the risk from exposure with the appropriate use of PPE (Park and Holliday 1999).

In addition to the lack of enforcement of respirators during the cleanup, the actual respirators used may have been inadequate, since the ones distributed were for organic vapors, but did not protect workers against H2S or methylmercaptans, which were released from the recovery yard and the biodegeneration of oil waste (Hunninen 2002). Furthermore, the PPE such as gloves meant to protect dermal contact with oil and chemical agents were often inadequate.[59] According to Dr. Knut Ringen of the Laborer's International Union (LIUNA) and Center to Protect Workers' Rights, one of his main concerns at the time of the cleanup was the permeability of the gloves used. The ones initially used before regulatory improvements were implemented allowed benzene and 2-butoxyethanol to penetrate through (Ringen 2002), which were arguably the two most potentially harmful sources of dermal exposure present. The use of proper gloves is essential in order to prevent dermal absorption of chemicals, since the "use of gloves that serve as an incomplete barrier to chemicals may actually enhance percutaneous absorption by 1) increasing permeability by increased skin hydration and elevated temperatures and 2) increasing the contact time and epidermal concentrations, especially for volatile chemicals that would otherwise evaporate from the surface of the skin"[60] (Eaton and Robertson 1994).

Applicability of occupational exposure limits for oil spill working conditions

In considering recommendations for future oil spill cleanup operations and protection of worker health and safety, it is important to consider the applicability of the

[59] Also, the Exxon cleanup contractors did not provide laundering for personal clothes worn under the PPE, as workers had been told would be done, which would possibly increase the potential for dermal exposure (Gorman 1989).

[60] When the gloves used to protect workers from the 2-butoxyethanol present in Inipol were tested, the breakthrough time of polyvinyl and neoprene gloves was found to be 3 minutes and 45 minutes, respectively (LIUNA 1989).

current occupational exposure limits to the situation faced by oil spill workers. While the OSHA permissible exposure limits (PELs) for hazardous exposures are based on a worker being exposed for 5 days per week, 50 weeks per year for a 40 year working life, oil spill cleanup workers are likely to have more intermittent exposure, such as the EVOS workers who were employed 12-14 hours per day for the period of several months. Whether or not the OSHA limits are acceptable standards in such situations and whether acute exposures to oil mist, benzene, H2S and cleanup chemicals can cause appreciably adverse health effects following short but intense exposures has yet to be decisively established. In addition to oil and chemical exposures sustained while working on the spill cleanup, a significant number of study participants (37.3%, n=63) currently work in the oil industry,[61] and many (23.1%, n=39) reported employment where they work with hazardous chemicals or in hazardous waste disposal. Although oil spill cleanup operations generally employ workers for a short time period, additional hazardous occupational exposures which contribute to a workers' total lifetime exposure must be considered when determining whether higher levels of exposure are acceptable during oil spill cleanup operations if workers are only exposed "for a few months."

While the applicability of the mineral oil mist OSHA PEL to the oil spill worker cleanup situation is important to consider, the adequacy of this PEL for protecting health is also questionable. The current OSHA standard for mineral oil mist exposure is 5 mg/m^3, and NIOSH has concurred with this limit of 5 mg/m^3 for a 10-hour workday, 40-hour work week, and has set a 10mg/m3 Short Term Exposure Limit (STEL) (ATSDR

[61] Including work on an oil tanker, in oil drilling operations, in an oil refining plant, and/or on another oil spill cleanup operation besides EVOS.

1995b).[62] However, occupational studies on workers exposed to oil mist indicate that this level may not be adequate to prevent respiratory irritation or damage.[63] One study on workers exposed to aerosolized hydrocarbon mist in steel mill found that, despite personal samples of respirable oil mist at levels below the OSHA standard of 5mg/m^3, a worker with long-term exposure had respiratory symptoms of reduced lung volumes and evidence of lipoid pneumonia (Cullen *et al.* 1981). Similar to these findings by Cullen *et al.*, another study concluded that exposure to oil mists at median levels less than the regulatory standard of 5mg/m^3 may cause respiratory symptoms, although no impairment in lung function levels or roentgenographic changes were observed (Järvholm *et al* 1982). A study by Svendsen and Hilt found that marine engineers exposed to oil mist in the range of 0.12 to 0.74 mg/m^3 exhibited higher prevalence ratios for cough and wheezing, chronic bronchitis, severe dyspnea and mucous membrane irritation than controls (1997). This presents the possibility that health effects, such as the increased prevalence in bronchitis observed among EVOS workers in this study, are biologically plausible, even at levels below the OSHA standard.[64]

[62] Other countries (Australia, Belgium, Germany, Italy, the Netherlands, Switzerland, Japan, Finland and Sweden) have an established occupational exposure limit for oil mist which ranges from 3 to 5 mg/m^3 (Baars 2002).

[63] Furthermore, there is evidence to suggest that the original criteria used to establish the oil mist exposure limit at 5 mg/m^3 were based upon aesthetic purposes, rather than health endpoints. An early review of oil mist exposures stated that "At atmospheric concentrations less than 5 mg. per cubic meter, there are few complaints [among workers]. Above this figure, oil mist can be seen in the air, and complaints may arise." (Hendricks *et al.* 1961).

[64] When "interpreting the results of exposure measurements, an environment should not be considered to be free from risk when exposure levels do not exceed the limit value. In the case of individual workers in the environment, reported symptoms should not be considered nonwork related solely because measured exposure levels are below a limit. Any interpretation of exposure information should recognize that there is uncertainty associated with both the measurement of exposures and the limit value to which it is compared." Also, the extent of variability of individual reactions to exposures is not known, and a conservative approach may be best to protect workers in the face of this uncertainty. (Herrick and Dement 1994).

It is also relevant to note that the OSHA PEL utilized in the EVOS cleanup for oil mist exposure is the standard for mineral oil, rather than crude oil, which is more hazardous. The American Conference of Governmental Industrial Hygienists published a threshold limit value (TLV) in 1992 for an 8 hour time-weighted average (TWA) for severely refined mineral oil mist of 5 mg/m^3, but for mildly refined mineral oil mist containing benzene-soluble PAHs, they established a TLV of 0.2 mg/m^3 (Sprince, Thorne and Cullen 1994). While the available literature indicate that mineral oil mist is often utilized as the standard for crude oil mist, the increased toxicity of crude oil and the observed adverse health effects following exposure to mineral oil mist below the OSHA standards suggest important political implications for the consideration of both stricter standards for oil mist exposure, as well as more stringent requirements for work with crude oil mist, such as the TLV suggested for exposures to mildly refined mineral oil mist.

Additional monitoring techniques

As a final recommendation for further techniques which may be useful in future studies of oil spill cleanup workers, the use of biomonitoring may provide another valuable measure of exposure in addition to the use of air sampling techniques. For nonvolatile components of crude oil, quantitative measurements of exposures can be difficult to obtain, especially with regard to dermal absorption following exposure (Park and Holliday 1999). Biomonitoring is one potentially useful method with which to assess exposure from oil spill cleanup work. Such improvements in technology provide more advanced methods to determine exposures and monitor for early health effects in order to prevent susceptible workers from sustaining significantly harmful exposures. Some relevant biomarkers which could be utilized as indicators of exposures and effects among oil spill cleanup workers are described as follows.

Polycyclic Aromatic Hydrocarbons (PAHs)

Perhaps one of the most important exposures to measure at an oil spill cleanup site is the exposure to PAHs. PAHs or their metabolites can be measured in urine, blood or body tissues (ATSDR 1995b). The measurement of 1-hydroxy-pyrene is the most commonly used method to determine occupational exposures to PAHs (ATSDR 1995b) and was used in a study of petrochemical workers to determine that dermal exposure, in the absence of PPE, made a significant contribution to the total uptake of PAHs (Park and Holliday 1999). Some studies indicate that 1-hydroxy-pyrene levels in the urine correlate with several compounds present in oil and can be distinguished from those PAHs due to cigarette smoke (Sprince, Thorne and Cullen 1994). Biomarkers of effect from exposure to PAHs and oil mists include the use of pulmonary function tests, which may show "restriction, exercise-induced hypoxemia or hypoxemia at rest" (Sprince, Thorne and Cullen 1994). Bronchoalveolar lavage may also find visible oil droplets on the surface of the fluid and increases in neutrophyls more than lymphocytes (Sprince, Thorne and Cullen 1994); however, this specific process is quite invasive and its utility in large-scale epidemiological studies or in monitoring the exposures of workers is questionable.

Volatile Organic Compounds (VOCs)

Most of the metabolites of benzene leave the body in the urine within 48 hours following exposure (ATSDR 1997). The most commonly-measured metabolite used in the occupational setting to assess benzene exposure is urinary phenol levels (Kok *et al.* 1997). However, it is difficult to correlate these levels with benzene exposure, since urinary phenol can be present in high background levels due to exposure to other aromatic compounds, inhalation of cigarette smoke, ingestion of ethanol and particular vegetables (ATSDR 1997, Kok *et al.* 1997). Other urinary metabolites which have been investigated as biomarkers of benzene exposure include catechol, hydroquinone, muconic acid[65] and S-phenyl-N-acetyl cysteine (PhAC) (Inoue *et al.* 1989, Melikian *et al.* 1993; Jongeneelen *et al.* 1987).

Biomarkers of effect which have been used as indicators of high exposure to VOCs include decreases in erythrocyte and leukocyte counts. Surveillance and early diagnosis of effects due to benzene have also been done through measuring blood counts, including hemoglobin, hematocrit, and differential and platelet counts (ATSDR 1997). Also, cytogenetic tests of bone marrow cells are being explored but have not yet been found to be diagnostic (ATSDR 1997). The use of benzene-metabolite DNA adducts, sister chromatid exchanges, and chromosomal aberrations in bone marrow and peripheral blood lymphocytes is a relatively new area of exploration for the potential use of monitoring exposures (ATSDR 1997).

Hydrogen Sulfide (H2S)

Following acute high exposures to H2S, measurements of blood sulfide can be used to confirm exposure. However, samples must be taken within two hours of exposure. A less invasive procedure involves measuring urinary thiosulfate levels; however, these samples must be obtained within 15 hours following exposure. Although these methods indicate exposure to hydrogen sulfide, further studies are needed to correlate airborne exposure concentrations of H2S with blood and thiosulfate levels

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[65] Muconic acid in the urine was found to be best correlated with environmental benzene exposure concentrations, and urinary hydroquinone levels were the most accurate among phenolic metabolites of benzene (Ong *et al.* 1995).

(ATSDR 1999b). The measurement of decreases in heme synthesis enzymes ALA-S and Haem-S are potential biomarkers of effects due to H2S, although the mechanism associated with this remains under study (Jappinen and Tenhunen 1990). Another method involves the use of neurological indices as biomarkers of effects due to hydrogen sulfide.[66] However, effects are not specific to H2S and could indicate exposure to other neurotoxic substances (ATSDR 1999b).

Inipol EAP 22® (2-butoxyethanol)

Most of the metabolites of 2-butoxyethanol leave the body in the urine within 24-48 hours after exposure (ATSDR 1998); therefore, tests conducted to measure for the presence of these metabolites must be conducted within a short period of time following exposure. Smaller amounts of metabolites leave the body in exhaled air. Metabolites, such as 2-butoxyacetic acid, can be measured in the urine, although these tests may not necessarily indicate the amount of exposure a worker has experienced (ATSDR 1998). Urinanalysis was conducted on EVOS workers from the bioremediation application (Inipol) team,[67] however, the available data do not indicate whether this was conducted to measure for biomarkers of exposure or for health effects due to Inipol (Peninsula Clarion 1989).

Since 2-butoxyethanol breaks down red blood cells in the body, certain tests may be used to determine the extent of red blood cell damage. However, these tests are not necessarily specific for 2-butoxyethanol (ATSDR 1998). Hematotoxic effects are the characteristic biomarker of effect used for 2-butoxyethanol exposure in animals and

[66] Potential biomarkers for neurological effects of H2S include indices of "cortical, hippocampal, brain stem, basal ganglia and diencephalons dysfunction."(ATSDR 1999b).

[67] NIOSH recommends if workers are exposed to 2-butoxyethanol at levels of 5ppm or above, that urine be monitored for the presence of 2-butoxyacetic acid. However, the OSHA PEL is 50ppm (ATSDR 1998).

hematological evaluations could be useful in monitoring the effects of this exposure among workers. One method proposed to measure these effects is a hematology analyzer which is able to detect decreases in red blood cell concentrations (ATSDR 1998).

With new advancements in technology providing improved methods to examine both biomarkers of exposure and effect due to occupational exposures, future oil spill cleanup operations will not be required to be fully reliant on the results of air monitoring tests. The available data do not indicate that biomarkers were used on the EVOS cleanup in any area other than among the Inipol workers, who were occasionally given urine tests. If future oil spill cleanup operations utilized these techniques, they may be able to better determine more accurate measures of exposure which would be particularly useful in oil spill cleanup work, since a significant amount of hazardous exposure at such sites occur through dermal absorption of chemicals which may not be adequately assessed through air monitoring data. This new data could then be used to develop improved regulatory measures for enforcement of PPE and other requirements to more thoroughly protect workers from significantly harmful exposures.

VIII. CONCLUSIONS

In July 1989, while the EVOS cleanup was at its peak, scientists and representatives from regulatory agencies such as NIOSH and OSHA met at the Alaska Oil Spill Health Conference in Seattle to discuss the health impacts of the spill. Dr. Philip Landrigan, of the Mount Sinai School of Medicine, discussed the epidemiology research needs, stating that "we will be in a new millennium before we know whether the spill produced adverse health effects on people." (Alaska Oil Spill Health Conference Summary 1989). He stated that several health effects should be examined, such as immune system impairment, kidney and liver damage, and cancers, and suggested that a formal strategy for an epidemiological study be organized by the state health department. To date, no such study has been conducted, despite continued complaints from EVOS workers of existing health problems.

This study marks the first attempt to assess the chronic health problems among EVOS cleanup workers 14 years following their employment on the spill. My results indicate that there are several significant associations between job-defined and self-reported exposures and health outcomes. These findings suggest that some component of work on the EVOS cleanup may contribute to an excess prevalence of respiratory and neurological conditions reported by EVOS workers. The relationship between several self-reported exposures and chronic health conditions provide evidence that no single exposure is related to the medical conditions among EVOS cleanup workers. The exposures sustained during cleanup work were generally not isolated events, and several health outcomes of interest may be due to a synergistic effect of several exposures.

These findings need to be interpreted in light of several limitations, most notably, this study relied upon self-reported exposure and health outcomes, and was not designed to address cause-and-effect relationships. Rather, this study focused on describing the exposure variables and medical conditions in a sample of EVOS cleanup workers. Despite this limitation, the results indicate the need for further surveillance and detailed studies on workers who participate in marine oil spill cleanup operations, specifically, studies utilizing exposure monitoring data and a clinical diagnosis of health outcomes. Future investigations should focus on the individual and combined effects of potential etiologic factors such as oil exposure, cleanup chemicals and additional occupational exposures which may contribute to the reported adverse health outcomes in this population. Since there have been very few epidemiological studies among oil spill cleanup workers and no studies which examine chronic health effects, it would be beneficial to conduct quantitative epidemiological studies in order to provide a better understanding of the health risks and effects due to working on a marine oil spill cleanup operation.

There are also are several recommendations which can be made regarding the nature with which cleanup operations are conducted in the event of future oil spills. Limitations present in the EVOS cleanup elicit areas where substantial improvements could be made. Potential policy recommendations to ensure the protection of worker health in future oil spill cleanup operations include: increased involvement of federal regulators, thorough risk communication, increased enforcement of protective equipment, improved training and pre-work screening, medical monitoring and follow-up of workers, adequate exposure monitoring, and a thorough consideration of the adequacy and applicability of specific occupational exposure limits. Moreover, local, state and federal officials must ensure that well-coordinated response actions and contingency plans are implemented to prepare to respond to such spills in the future.

With many countries throughout the world involved in petroleum exploration, production and transportation, oil spills are a common occurrence and will likely continue to occur in the future, such as the most recent large spill near the coast of Spain: the 26-year-old Prestige, which cracked in two, releasing approximately 5,000 tonnes of oil (Economist 2002). While many spills are left to natural degradation by the ocean, oil spills which contaminate shorelines and valuable harbors will need human intervention and cleanup measures. Improved knowledge about the diverse and serious hazards associated with exposure to crude oil and chemical agents used during oil spill cleanup operations will ideally lead to enhanced regulatory measures and enforcement aimed at best protecting worker health in the event of future oil spill cleanup situations.

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Table 1: Statistical Summary of Industrial Hygiene Monitoring Conducted by Med-Tox Associates, Inc. for the Exxon Valdez Oil Spill, and Relevant OSHA Permissible Exposure Limits (PEL)

Airborne Substance	Geometric mean (x) ± 95% CI	Range	Sample population (n) *	OSHA PEL**
Benzene	0.069 ± 0.596 ppm	0.0 to 7.8 ppm	1,611	**1 ppm**[a]
Toluene	0.103 ± 0.648 ppm	0.0 to 4.96 ppm	1,611	200 ppm[b]
Ethylbenzene	0.048 ± 0.222 ppm	0.0 to 1.82 ppm	1,611	100 ppm [c]
Xylene	0.140 ± 0.660 ppm	0.0 to 6.74 ppm	1,611	100 ppm [d]
Total Petroleum Hydrocarbons	1.329 ± 7.516 ppm	0.0 to 64.93 ppm	1,611	500 ppm [e]
Oil Mist	0.615 ± 4.0 mg/m^3	0.0 to 20.0 mg/m^3	114	**5 mg/m^3** [f]
Butoxyethanol	1.66 ± 19.2 ppm	0.0 to 99.0 ppm	112	**50 ppm** [g]
Carbon Monoxide	1.19 ± 16.64 ppm	0.0 to 100 ppm	711	**50 ppm** [h]
Hydrogen Sulfide	2.11 ± 30.6 ppm	0.0 to 199 ppm	471	**20 ppm** [i]

* The available data did not indicate whether all samples were area or personal samples or a combination thereof. Also, the sampling methods used and the limit of detection for each were not stated in the source. The OSHA PELs in bold indicate the potential for overexposure based upon the range of the available data.

** All OSHA PEL figures presented here are given for a standard 8 hour workday TWA exposure in air (TWA: Time-Weighted Average Concentration which must not be exceeded during any 8-hour shift of a 40-hour working week). The potential for dermal exposure to the above chemicals exists; however, the available data do not provide information on this exposure route and therefore the relevant dermal exposure limits are not presented.

CI= Confidence Interval

[a] ATSDR 1997.

[b] ATSDR 2000.

[c] ATSDR 1999c.

[d] ATSDR 1995c.

[e] ATSDR 1999a. While the OSHA PEL of 500 ppm is the limit for total petroleum distillates/air contaminants, EPA guidelines break down the limits into further components, including ethylbenzene, cumene, naphthalene, n-hexane and toluene.

[f] http://www.osha-slc.gov/dts/chemicalsampling/data/CH_258700.html. Accessed 2/20/2003.

[g] ATSDR 1998. It was noted that at this PEL, there is also a potential for dermal absorption and that "skin exposure should be prevented through the use of gloves, coveralls, goggles and other appropriate equipment." (ATSDR 1998). 50 ppm= (240 mg/m^3)

[h] http://www.osha.gov Accessed 4/15/03. Federal Regulation for Carbon Monoxide, 29 CFR 1917.24. The limit of 50 ppm applies to atmosphere in a "room, building, vehicle, railcar or any enclosed space" and no information on ambient levels in an outside working environment was available. The ceiling concentration for an enclosed space is 100 ppm.

[i] There is no established PEL for an 8-hour workday for H2S exposure, however, the OSHA PEL-Acceptable Ceiling Concentration for H2S is 20 ppm, and the NIOSH ceiling REL is 10ppm (ATSDR 1999b). The Recommended Exposure Limit is a time-weighted average concentration for up to a 10-hour workday during a 40-hour workweek.

Data Monitoring Source: Exxon Company, 1989d.

Table 2. Pre-existing Medical Conditions That may be Aggravated by Exposure to Crude Oil and Chemicals Present During the Exxon Valdez Oil Spill Cleanup

Exposure to Compound/Product	Pre-Existing Condition
De-Solv-It	Dermatitis
Petroleum hydrocarbons	Dermatitis
Benzene	Liver disease
Petroleum solvents	Dermatitis
Glycol ethers (Inipol EAP22, Corexit)	Blood and/or kidney disease
Simple Green	Severe allergies, asthma, skin conditions with open sores

Sources: MSDS for crude oil (Exxon 1988); MSDS for Inipol (Exxon 1989b); MSDS for Corexit 9527 (Exxon 1992); MSDS for Simple Green (US Dept of Labor 1987); MSDS for De-Solve-It Cleaner, Solvent (Orange-Sol, Inc. 1987).

Table 3. Injury and Illness Data from the Alaska State Worker's Compensation Claim System for Exxon Valdez Oil Spill Cleanup Workers (1989)

Nature of Injury or Illness	Frequency	Percent of total
Amputation/Enuclea	1	0.1%
Burn (Heat)	26	1.5%
Burn (Chemical)	13	0.7%
Concussion	7	0.4%
Infective/Parasitic	49	2.8%
Contusion, Crushing	144	8.1%
Cut, Laceration	150	8.4%
Dermatitis	44	2.5%
Dislocation	20	1.1%
Electric shock	4	0.2%
Fracture	47	2.6%
Exposure to Low Temp	6	0.3%
Hearing Loss/Impairment	4	0.2%
Environmental Heat	4	0.2%
Hernia, Rupture	9	0.5%
Inflammation	36	2.0%
Poisoning	34	1.9%
Pneumoconiosis	1	0.1%
Radiation Effects	8	0.5%
Scratches, Abrasions	61	3.4%
Sprains, Strains	506	28.5%
Hemorrhoids	3	0.2%
Hepatitis	3	0.2%
Multiple Injuries	23	1.3%
Cerebrovascular	5	0.3%
Complications- Media	2	0.1%
Eye Disaster	15	0.8%
Mental Disorders	2	0.1%
Nervous System	19	1.1%
Respiratory System	264	14.9%
Symptoms & Ill-Defined	127	7.2%
No Injury or Illness	20	1.1%
Damage to Prosthetic	11	0.6%
Other Dis/Inj NEC	108	6.1%
TOTAL claims:	1776	100%

Source: NIOSH HHE, 1991; Appendix B, Injury/Illness Data from the Alaska State Workers' Compensation Claim System

Table 4. Summary of Telephone Calls Conducted to Potential Study Sample

Call Details	N (%)
Complete	169 (9.5%)
Refused/sick	246 (13.8%)
Ineligible/did not pass screens†	387 (21.7%)
Called but not spoken to/ could not reach (ans. machine, busy signal, etc) or scheduled callback but not completed	437 (24.5%)
Bad numbers (disconnected number, business, fax)	546 (30.6%)
TOTAL	1785 (100%)*

* Percent may not equal 100% due to rounding

† did not work on cleanup, could not speak English or participate in telephone interview/deaf

Table 5. Potential Exxon Valdez Oil Spill Cleanup Workers Reached and Eligible to Participate in Survey*

	N (%)
Complete	169‡ (40.7%)
Refused/sick	246 (59.3%)
TOTAL	**415** (100%)

*not including those who were scheduled to be called-back; 5 attempts were made to contact each worker before exclusion

‡ Among those who completed the interview, 56.2% were from workers' compensation and labor records list, and 43.2% of completes were from other sources, including referrals or contact personnel in Valdez and Cordova who had maintained private lists of EVOS workers

Table 6. Verbatim Survey Responses Which Were Categorized as Unexposed to Oil or No-Low Exposure to Chemical Stressors Among Survey Participants From the Exxon Valdez Oil Spill Cleanup

Classified as unexposed to oil and chemical stressors	Classified as "on beach" but no/ low exposure to oil/ chemicals
Assembled booms (but did not deploy)	Consulted with people on the beach
Assembled logs to improvise booms	Crew foreman
Communications for the civil air patrol	Hauled & assembled equipment on beach
Consulted with people	Investigating officer and inspector
Delivered groceries	Longshoreman
Drilled holes to connect hoses and pumps	Mechanic doing small boat repair
Drove a forklift	Monitored the cleanup effort, people, etc.
Electrician	On-scene coordinator and commander
Environmental technician	Protected the beach workers from the bears
Hauled equipment	Shoreline impact assessment
Interface with government & volunteers	Shoreline surveys
Leased boat to someone else	Studied the quantity of oil on the beach
Loaded supplies	Studied affects of oil on inter-tidal life
Office support staff	
Phone calls for volunteer work	
Picked up the dirty workers and brought in clean workers	
Pilot/pilot air taxi	
Set up offices	
Talked to the press, oversaw handling of equipment	
Transported sewage	
Welder	

Table 7. Description of the Study Sample (n=169)*

Characteristic	N(%)*
Race	
Non-Hispanic Caucasian	128 (75.7%)
Alaskan Native	24 (14.2%)
American Indian	5 (3.0%)
Non-Hispanic African-American	2 (1.2%)
Asian American	1 (0.6%)
Hispanic, Latino/a	1 (0.6%)
Other, non-specified	2 (1.2%)
Age (years), mean ± SD (n=166)	50 ± 9
Sex	
Male	123 (72.8%)
Female	44 (26.0%)
Year(s) worked on the cleanup§	
1989 only	134 (79.3%)
1989 and 1990	15 (8.9%)
1989, 1990 and 1991	12 (7.1%)
1989 and 1991	3 (1.8%)
1990 only	1 (0.6%)
1990 and 1991	2 (1.2%)
1991 only	2 (1.2%)
Total months worked on the cleanup (mean ± SD)‡	5.8 ± (7.0)

* Numbers may not sum to 169 and percentages may not sum to 100% due to missing data and rounding.
‡ Although active cleanup work on oiled beaches was only conducted during the summer months in each year, some individuals held year-long positions, such as office or administrative workers, and therefore worked the maximum possible 36 months in the 3-year period from 1989-1991.

Table 8. Potentially Confounding Factors among Exxon Valdez Oil Spill Cleanup Workers in Study Sample

Characteristic	N(%)*
Smoking history§	
Ever	104 (61.5)
Never	62 (36.7)
Alcohol consumption†	
0-1	101 (59.8)
2-5	26 (15.4)
6-10	19 (11.2)
11+	18 (10.6)
Work in the oil industry‡	63 (37.3)
Work with hazardous chemicals or in hazardous waste disposal	39 (23.1)
Believe that the oil spill has affected health	62 (36.7)
Currently have a medical disability which prevents from working	24 (14.2)
Source of study participant	
Workers' Compensation Database	95 (56.2)
Community lists and referrals	57 (33.7)
Other source	16 (9.5)
Use of personal protective equipment (respirator)	
Never provided with a respirator by employer*	119 (70.4)
Provided with respirator but wore infrequently	15 (8.9)
Provided with respirator but never wore it	10 (5.9)
Provided with respirator and wore it frequently/almost always	18 (10.6)

§ Ever smoked cigarettes for 6 months or more

† Drinks per week; one drink=one beer, one glass of one or one shot of liquor

‡ Currently work or have ever worked in the oil industry, such as on an oil tanker, in oil drilling operations, in an oil refining plant, and/or on another oil spill cleanup besides EVOS

* Among all cleanup jobs, not among all jobs with the potential for high exposure. Many who were not provided with a respirator were likely not given protective clothing because they did not face potentially hazardous exposures; others may have also been in need of protection but did not receive it, as demonstrated by several respondents' comments listed in Appendix D regarding the overall lack of personal protective equipment. For the distribution of respirator use among oil and chemical exposure categories in the study sample, refer to Table 15.

Table 9. First Job Worked on the Exxon Valdez Oil Spill Cleanup and Job Worked for the Longest Duration (n= 169)

Job Description	**First Job N(%)***	**Longest Job N(%)***
Picked up tarred/oiled trash, debris; handled trash bags/trash	22 (13.0)	15 (8.9)
Used hydraulic hoses and/or wands to spray oiled rocks/beaches	14 (8.3)	17 (10.0)
Handled booms to contain the oil; scooped up oil from water	23 (13.6)	22 (13.0)
Cleaned oil off ships (boat decontamination)	4 (2.4)	5 (3.0)
Ran supplies to or collected trash from small boats on beach	8 (4.7)	11 (6.5)
Operated/ was crew member on large boat, omni or MAXI barge	14 (8.3)	15 (8.9)
Operated cranes or other heavy machinery/equipment	5 (3.0)	5 (3.0)
Worked on housing barge or boat (ex: Cook, Medic on boat)	18 (10.6)	20 (11.8)
Collected dead/alive animals; worked at wildlife treatment center	17 (10.1)	13 (8.0)
Worked on the Bioremediation application crew	2 (1.2)	2 (1.2)
Worked on the Decontamination (DECON) crew	2 (1.2)	4 (2.4)
Worked in town, administration, clerical, warehouse, etc.	30 (17.7)	28 (16.6)
Worked on beach but was not directly exposed to oil or chemicals‡	9 (5.3)	11 (6.5)
Don't know/remember	1 (0.6)	1 (0.6)

*Numbers may not add up to 169 and percents may not add up to 100% due to missing information.
‡ For a list of several representative jobs from this category, refer to Table 6.

Table 10. Classification of Job-Defined Oil Exposure Categories for Workers on the Exxon Valdez Oil Spill Cleanup (n=169).

Exposure Category	Job Task Description	First Job N(%)*	Longest Job N (%)*
None	- Worked in town/clerical/warehouse/other unexposed**	30 (17.7)	28 (16.6)
Low	- Worked on beaches but without direct oil contact** - Worked on housing boat or barge (such as a cook or medic) - Transported supplies or collected trash from small boats on beach - Bioremediation application (Inipol) crew	37 (21.9)	44 (26.0)
Medium	- Picked up oiled/tarred trash, debris, handled trash bags - Operated cranes or other machinery/equipment - Collected alive/dead animals from the water, worked in wildlife treatment center	44 (26.0)	33 (19.5)
High *(Crude oil mist and aerosols, oil fumes)*	- Used hydraulic hoses and/or wands to spray oiled rocks/beaches - Worked on large omni or MAXI barge spraying oil off shoreline - Deployed booms to contain the oil, skimmed oil from water, oil recovery at sea - Cleaned out ships in harbor: boat decontamination - Decontamination of PPE crew	57 (33.7)	63 (37.3)

*percents may not add to 100 due to rounding and numbers may not add to 169 due to missing values
** jobs further described in Table 6

Table 11. **Classification of Job-Defined Chemical Exposure Categories for Workers on the Exxon Valdez Oil Spill Cleanup (n=169)**

Exposure Category	Job Task Description	First Job N(%)*	Longest Job N (%)*
No-Low	- Worked in town/clerical/warehouse/other unexposed** - Worked on beaches but without direct oil or chemical contact**	39 (23.1)	39 (23.1)
Medium	- Worked on housing boat or barge (such as a cook or medic) - Transported supplies or collected trash from small boats on beach - Operated cranes or other machinery/equipment - Used hydraulic hoses and/or wands to spray oiled rocks/beaches - Worked on large omni or MAXI barge spraying oil off shoreline	59 (34.9)	68 (40.2)
High (*chemical*)	- Picked up oiled/tarred trash, debris, handled trash bags (*H2S exposure)* - Deployed booms to contain the oil, skimmed oil from water, oil recovery at sea (*VOC exposure)* - Collected alive/dead animals from the water, worked in wildlife treatment center *(formaldehyde and formalin exposure)* - Cleaned out ships in harbor: boat decontamination (*Inipol, detergents and other chemical exposure)* - Bioremediation application crew (*Inipol and Customblen)* - Decontamination (DECON) crew (*Inipol, detergents and other chemicals)*	70 (41.4)	61 (36.1)

*percents may not add to 100 due to rounding and numbers may not add to 169 due to missing values
** jobs further described in Table 6

Table 12. Self-Reported Exposures Encountered During Cleanup Among all Study Participants from the Exxon Valdez Oil Spill (n=169) and Those Who Felt Ill at the Time of Each Exposure

Exposure Variable	No/ Never N (%)*	Yes/ Ever N (%)*	Felt Ill N (%)†
Oil on skin or in eyes	88 (52.1)	80 (47.3)	33 (41.2)
Inhaled oil mist or vapors	37 (21.9)	129 (76.3)	60 (46.5)
Inhaled exhaust from diesel or generators	69 (40.8)	97 (57.4)	40 (41.2)
Worked with or near burning oil or trash	134 (80.0)	33 (19.5)	15 (45.5)
Ate food or drink exposed to oil or chemicals	122 (72.2)	33 (19.5)	9 (27.3)
Worked with Inipol ®	132 (78.1)	18 (10.6)	6 (33.3)
Worked with Corexit ®	N/A‡	N/A	N/A
Worked with Customblen ®	141 (83.4)	8 (4.7)	N/A+
Worked with Simple Green ®	76 (45.0)	87 (51.5)	12 (13.8)
Worked with De-Solv-It ®	95 (56.2)	54 (31.9)	12 (22.2)
Worked with Citriklean ®	92 (54.4)	65 (38.5)	12 (18.5)

* Numbers may not sum to 169 or percents to 100 due to missing values

† Percent of workers who felt ill at time of exposure among workers who experienced specific exposure

‡No one reported working with this product or could not remember

+ No one reported feeling ill when working with Customblen

Table 13. Distribution of Self-Reported Exposures of Exxon Valdez Oil Spill Cleanup Workers, among Job-Defined Oil Exposure Categories

OIL EXPOSURE CATEGORIES

Exposure Variable	*First Job* None N (%)‡	Low N (%)‡	Med N (%)‡	High N (%)‡	P*	*Longest Job* None N (%)‡	Low N (%)‡	Med N (%)‡	High N (%)‡	P*
Oil on skin or in eyes	13 (43.3)	11 (29.7)	21 (47.7)	34 (60.7)	**.032**	12 (42.8)	15 (34.1)	17 (51.5)	36 (57.1)	.113
Inhaled oil mist or vapors	16 (53.3)	26 (70.3)	36 (81.8)	50 (92.6)	**<.001**	14 (50.0)	33 (75.0)	27 (81.8)	55 (90.2)	**<.001**
Inhaled exhaust from diesel or generators	14 (46.7)	26 (70.3)	20 (46.5)	37 (67.3)	**.043**	11 (39.3)	31 (72.1)	15 (45.4)	40 (64.5)	**.013**
Worked with or near burning oil or trash	9 (30.0)	8 (21.6)	4 (9.1)	12 (21.8)	.148	8 (28.6)	10 (22.7)	3 (9.1)	12 (19.3)	.262
Consumed food or beverages exposed to oil or chemicals	2 (7.7)	7 (18.9)	8 (20.0)	16 (31.4)	.107	3 (11.5)	7 (17.1)	7 (23.3)	16 (27.6)	.340
Worked with Inipol	3 (10.7)	5 (14.7)	3 (7.1)	7 (15.2)	.636**	3 (11.5)	5 (12.8)	2 (6.4)	8 (14.8)	.753**
Worked with Customblen	1 (3.8)	5 (14.3)	1 (2.6)	1 (2.0)	.091**	0	4 (10.5)	1 (3.3)	3 (5.4)	.380**
Worked with Simple Green	11 (37.9)	24 (64.8)	21 (48.8)	31 (58.5)	.130	9 (33.3)	28 (65.1)	15 (45.4)	35 (58.3)	**.043**
Worked with De-Solv It	12 (44.4)	14 (38.9)	11 (28.2)	17 (36.2)	.575	9 (36.0)	18 (45.0)	8 (27.6)	19 (34.5)	.505
Worked with Citriklean	7 (25.0)	12 (33.3)	18 (46.1)	28 (52.8)	.064	5 (19.2)	17 (41.5)	13 (43.3)	30 (50.0)	.067

‡ Percents calculated from the number in each exposure category and not from total N (169).
*P-value calculated by Wald χ^2 except when noted; p-values in bold are statistically significant ($p<.05$)
**P-value calculated by 2-tailed Fisher's Exact Test

Table 14. Distribution of Self-Reported Exposures of Exxon Valdez Oil Spill Cleanup Workers among Job-Defined Chemical Exposure Categories

	CHEMICAL EXPOSURE CATEGORIES							
	First Job				*Longest Job*			
Exposure Variable	**No-Low** N (%)‡	**Moderate** N (%)‡	**High** N (%)‡	**P***	**No-Low** N (%)‡	**Moderate** N (%)‡	**High** N (%)‡	**P***
Oil on skin or in eyes	15 (38.5)	23 (39.7)	41 (58.6)	**.046**	15 (38.5)	28 (41.2)	37 (60.7)	**.037**
Inhaled oil mist or vapors	25 (64.1)	43 (74.1)	60 (88.2)	**.012**	24 (61.5)	54 (79.4)	51 (86.4)	**.014**
Inhaled exhaust from diesel or generators	20 (51.3)	43 (75.4)	34 (49.3)	**.007**	20 (51.3)	48 (72.7)	29 (47.5)	**.009**
Worked with or near burning oil or trash	10 (25.6)	14 (24.1)	9 (13.0)	.174	11 (28.2)	15 (22.1)	7 (11.7)	.108
Consumed food or beverages exposed to oil or chemicals	2 (5.7)	15 (27.3)	16 (25.0)	**.034**	4 (11.1)	12 (19.3)	17 (29.8)	.089
Worked with Inipol	4 (10.8)	5 (10.0)	9 (14.3)	.810**	4 (11.1)	4 (7.0)	10 (17.5)	.237**
Worked with Customblen	3 (8.8)	2 (3.6)	3 (5.0)	.582**	2 (6.1)	2 (3.3)	4 (7.3)	.645**
Worked with Simple Green	18 (47.4)	32 (56.1)	37 (55.2)	.670	18 (47.4)	37 (56.1)	32 (54.2)	.684
Worked with De-Solv-It	14 (40.0)	24 (42.9)	16 (27.6)	.206	13 (38.2)	24 (38.7)	17 (32.1)	.733
Worked with Citriklean	10 (27.8)	25 (43.9)	30 (47.6)	.143	9 (25.0)	28 (44.4)	28 (48.3)	.068

‡ Percents calculated from the number in each exposure category and not from total N (169).
*P-value calculated by Wald χ^2 except when noted; p-values in bold are statistically significant ($p<.05$)
**P-value calculated by 2-tailed Fisher's Exact Test

Table 15. **Respirator Distribution and Use by Exxon Valdez Oil Spill Cleanup Workers among Job-Defined Oil and Chemical Exposure Categories**

Oil/chemical exposure category	Provided with respirator and wore it almost always/ frequently N (%)*	Not provided with a respirator by employer N (%)*	Provided with respirator but wore it infrequently N (%)*	Provided with respirator but never/very rarely wore N (%)*
OIL EXPOSURE				
First job				
No exposure	4 (13.3)	24 (80.0)	2 (6.7)	N/A
Low exposure	3 (8.6)	23 (64.7)	5 (14.3)	4 (11.3)
Medium exposure	4 (9.3)	35 (81.4)	1 (2.3)	3 (7.0)
High exposure	6 (11.3)	37 (69.8)	7 (13.2)	3 (5.7)
Longest job				
No exposure	3 (10.7)	22 (78.6)	2 (7.1)	1 (3.6)
Low exposure	3 (7.1)	29 (69.0)	5 (11.9)	5 (11.9)
Medium exposure	3 (9.4)	28 (87.5)	1 (3.1)	N/A
High exposure	9 (15.0)	40 (66.7)	7 (13.2)	3 (5.7)
CHEMICAL EXPOSURE				
First job				
No-Low exposure	6 (16.2)	29 (78.4)	2 (5.4)	N/A
Moderate exposure	5 (8.8)	42 (72.9)	7 (12.3)	3 (5.3)
High exposure	6 (10.0)	48 (71.6)	6 (9.0)	7 (10.4)
Longest job				
No-Low exposure	4 (10.8)	29 (78.4)	2 (5.4)	2 (5.4)
Moderate exposure	8 (12.1)	48 (72.7)	6 (9.1)	4 (6.1)
High exposure	6 (10.2)	42 (72.2)	7 (11.9)	4 (6.8)

*Percents given are calculated from the total N in each exposure category and not the total sample population, and may not add up to 100% due to rounding.

Table 16. Self-reported Acute Health Symptoms among Entire Study Sample of Exxon Valdez Oil Spill Cleanup Workers and Frequency of Symptoms

Symptom (Total N, excluding missing values)	**Percent reporting symptom** N (%)†	**Occasionally experienced symptom** N (%)‡	**Symptom persistent during cleanup** N (%)‡
Dry, scratchy or sore throat (N=162)	63 (37.3)	43 (68.2)	16 (25.4)
Persistent cough and or phlegm (N=162)	60 (35.5)	26 (43.3)	33 (55.0)
Dizziness (N=163)	49 (29.0)	37 (75.5)	10 (20.4)
Rash or skin irritation (N=166)	35 (20.7)	19 (54.3)	16 (45.7)
Persistent headaches (N=166)	69 (40.8)	45 (65.2)	24 (34.8)
Nausea or vomiting (N=165)	40 (23.7)	26 (65.0)	14 (35.0)
Low back pain or muscle pain (N=163)	74 (43.8)	37 (50.0)	36 (48.6)
Trembling in extremities (N=166)	25 (14.8)	9 (36.0)	16 (64.0)

†Percent calculated among all subjects who answered question (N in column 1)
‡ Percent calculated among those with symptom (N in column 2) and may not add up to 100% due to rounding and missing values

Table 17. Self-reported Acute Health Symptoms Experienced During Work on the Exxon Valdez Oil Spill Cleanup among Job-Defined Oil Exposure Categories

	OIL EXPOSURE CATEGORIES									
	First Job					*Longest Job*				
Acute Health Condition	**None** N (%)‡	**Low** N (%)‡	**Med** N (%)‡	**High** N (%)‡	**P***	**None** N (%)‡	**Low** N (%)‡	**Med** N (%)‡	**High** N (%)‡	**P***
Dry, scratchy or sore throat	11 (39.3)	14 (38.9)	13 (30.2)	24 (44.4)	.561	10 (37.0)	14 (32.6)	9 (29.0)	30 (49.2)	.191
Persistent cough/ phlegm	8 (27.6)	13 (37.1)	12 (28.6)	27 (49.1)	.121	8 (29.6)	11 (26.8)	12 (36.4)	29 (47.5)	.147
Dizziness	6 (20.0)	8 (21.6)	11 (26.2)	24 (45.3)	**.032**	6 (21.4)	8 (18.2)	10 (31.2)	25 (42.4)	**.042**
Rash or skin irritation	4 (13.3)	10 (27.0)	8 (18.6)	13 (23.6)	.526	3 (10.7)	10 (22.7)	7 (21.2)	15 (24.6)	.506
Persistent headaches	8 (26.7)	14 (40.0)	18 (40.9)	28 (50.0)	.219	9 (32.1)	17 (39.5)	13 (39.4)	30 (48.4)	.503
Nausea or vomiting	4 (13.3)	9 (24.3)	12 (27.9)	14 (25.9)	.502	5 (17.9)	10 (23.3)	9 (28.1)	16 (25.8)	.804
Low back pain or muscle pain	11 (36.7)	15 (40.5)	24 (54.5)	24 (47.1)	.422	8 (28.6)	21 (47.7)	14 (42.4)	31 (53.4)	.177
Trembling in extremities	4 (13.3)	3 (8.1)	7 (15.9)	11 (20.4)	.446	4 (14.8)	4 (9.1)	7 (21.2)	10 (16.1)	.508**

‡ Percents calculated from the number in each exposure category and not from total N (169).
*P-value calculated by Wald χ^2 test except when noted; p-values in bold are statistically significant ($p<.05$)
**P-value calculated by 2-tailed Fisher's Exact Test

Table 18. Self-reported Acute Health Symptoms Experienced During Work on the Exxon Valdez Oil Spill Cleanup among Job-Defined Chemical Exposure Categories

	CHEMICAL EXPOSURE CATEGORIES							
	First Job				*Longest Job*			
Acute Health Condition	**No-Low** N (%)‡	**Moderate** N (%)‡	**High** N (%)‡	**P***	**No-Low** N (%)‡	**Moderate** N (%)‡	**High** N (%)‡	**P***
Dry, scratchy or sore throat	13 (36.1)	25 (43.9)	24 (35.3)	.585	12 (32.4)	27 (41.5)	24 (40.0)	.647
Persistent cough and or phlegm	10 (27.8)	24 (41.4)	26 (38.8)	.392	9 (25.0)	25 (37.9)	26 (43.3)	.194
Dizziness	8 (20.5)	18 (32.1)	23 (34.3)	.305	7 (17.9)	24 (36.9)	18 (30.5)	.123
Rash or skin irritation	5 (12.8)	14 (24.6)	16 (23.2)	.335	3 (7.7)	16 (24.2)	16 (26.2)	.062
Persistent headaches	11 (28.9)	26 (45.6)	31 (44.3)	.213	11 (28.2)	30 (44.8)	28 (46.7)	.150
Nausea or vomiting	5 (12.8)	16 (28.6)	18 (26.1)	.174	5 (12.8)	20 (30.3)	15 (25.0)	.128
Low back pain or muscle pain	13 (33.3)	28 (50.0)	33 (49.2)	.206	11 (28.2)	37 (56.1)	26 (44.8)	**.021**
Trembling in extremities	5 (12.8)	9 (15.8)	11 (15.9)	.897	5 (13.2)	9 (13.4)	11 (18.0)	.716

‡ Percents calculated from the number in each exposure category and not from total N (169).
*P-value calculated by Wald χ^2 test except when noted; p-values in bold are considered statistically significant ($p<.05$)
**P-value calculated by 2-tailed Fisher's Exact Test

Table 19. Acute Health Symptoms Reported by Exxon Valdez Oil Spill Cleanup Workers, among Self-Reported Oil Exposures Variables

SELF-REPORTED OIL EXPOSURE VARIABLES

Acute Health Condition	Oil on skin or in eyes			Inhaled oil mist or vapors			Diesel exhaust or generator			Burning oil or trash			Food or drink exposed to oil or chemicals			Overcome by gases or fumes from oil		
	% unexp	% exp	P*	% unexp	% exp	P*	% unexp	% exp	P*	% unexp	% exp	P*	% unexp	% exp	P*	% unexp	% exp	P*
Dry, scratchy or sore throat	30.2	48.7	**.016**	18.9	45.5	**.004**	23.5	50.0	<.001	36.6	50.0	.176	29.7	69.7	<.001	30.6	63.4	<.001
Persistent cough / phlegm	27.1	48.0	**.006**	10.8	45.5	<.001	28.8	42.5	.076	35.7	43.7	.397	23.7	75.0	<.001	28.1	63.4	<.001
Dizziness	19.8	41.6	**.002**	11.1	36.0	**.004**	20.6	37.2	**.023**	26.4	45.4	**.033**	20.7	61.3	<.001	15.7	71.4	<.001
Rash or skin irritation	13.6	29.5	**.012**	2.7	26.8	**.002**	7.2	30.5	<.001	21.2	21.2	1.0	16.4	41.9	**.002**	15.4	37.2	**.003**
Persistent headaches	31.8	52.6	**.007**	18.9	48.8	**.001**	37.3	43.3	.443	42.4	39.4	.752	33.3	72.7	<.001	31.1	70.4	<.001
Nausea or vomiting	21.6	27.3	.395	13.5	27.8	.076	21.7	24.5	.684	24.4	24.2	.982	20.0	37.5	**.039**	15.4	50.0	<.001
Low back pain or muscle pain	33.3	59.2	<.001	25.0	51.6	**.005**	25.4	58.9	<.001	45.0	46.9	.852	41.7	58.1	.102	35.8	72.1	<.001
Trembling in extremities	7.9	23.1	**.007**	0.0	19.7	**.003**	7.3	19.8	**.026**	15.9	12.1	.587	5.0	45.4	<.001	9.9	30.9	<.001

*P- values calculated by Wald χ^2 test except when noted; p-values in bold are considered statistically significant ($p<.05$)
**P-values calculated by 2-tailed Fisher's Exact Test
%= percent of unexposed (unexp) that reported symptom and percent of exposed (exp) that reported symptom

Table 20. Acute Health Symptoms Reported by Exxon Valdez Oil Spill Cleanup Workers, among Self-Reported Chemical Exposure Variables

SELF-REPORTED CHEMICAL EXPOSURE VARIABLES

Acute Health Condition	Inipol			Customblen			Simple Green			De-Solv It			Citriklean		
	% unexp	% exp	P*	% unexp	%exp	P*	% unexp	% exp	P*	% unexp	% exp	P*	% unexp	% exp	P*
Dry, scratchy or sore throat	33.6	61.1	**.024**	37.2	37.5	1.0**	27.8	47.2	**.009**	29.8	58.0	**.001**	36.7	41.9	.512
Persistent cough/ phlegm	31.8	64.7	**.008**	35.0	50.0	.458**	26.7	44.0	**.022**	30.1	46.1	.053	30.7	43.1	.114
Dizziness	26.4	33.3	.575**	29.2	25.0	1.0**	24.7	32.9	.253	26.1	28.3	.772	20.2	35.9	**.030**
Rash or skin irritation	15.1	55.6	**<.001****	19.3	37.5	.204**	11.8	28.2	**.010**	11.6	37.7	**<.001**	14.1	31.3	**.010**
Persistent headaches	39.2	55.6	.187	40.3	25.0	.480**	34.7	45.3	.168	32.3	50.0	**.033**	33.0	50.0	**033**
Nausea or vomiting	23.1	27.8	.767**	23.7	25.0	1.0**	17.3	28.2	.103	20.0	28.8	.224	21.8	25.4	.596
Low back pain or muscle pain	43.0	50.0	.573	46.0	37.5	.728**	34.2	54.6	**.010**	43.5	45.3	.833	32.9	60.0	**<.001**
Trembling in extremities	14.4	16.7	.730**	14.9	0.0	.601**	6.6	21.2	**.008**	9.5	17.0	.180	10.9	17.2	.255

*P- values calculated by Wald χ^2 test except when noted; p-values in bold are considered statistically significant ($p<.05$)
**P-values calculated by 2-tailed Fisher's Exact Test
%= percent of unexposed (unexp) that reported symptom and percent of exposed (exp) that reported symptom

Table 21. **Crude (unadjusted) Odds Ratios for Acute Health Symptoms Reported by Exxon Valdez Oil Spill Cleanup Workers among Self-Reported Oil Exposure Variables**

SELF-REPORTED OIL EXPOSURE VARIABLES

Acute Health Condition	**Oil on skin or in eyes** Prevalence OR 95% C.I.	**Inhaled oil mist or vapors** Prevalence OR 95% C.I.	**Diesel exhaust or generator** Prevalence OR 95% C.I.	**Burning oil or trash** Prevalence OR 95% C.I.	**Food or drink exposed to oil or chemicals** Prevalence OR 95% C.I.	**Overcome by gases or fumes from oil** Prevalence OR 95% C.I.
Dry, scratchy or sore throat	2.19 * (1.15, 4.17)	3.58* (1.46, 8.77)	3.25* (1.62, 6.50)	1.73 (0.78, 3.84)	5.45* (2.35, 12.64)	3.93* (1.87, 8.28)
Persistent cough/ phlegm	2.49* (1.29, 4.80)	6.89* (2.30, 20.6)	1.83 (.936, 3.59)	1.40 (.640, 3.08)	9.63* (3.90, 23.8)	4.43* (2.10, 9.40)
Dizziness	2.89* (1.44, 5.80)	4.5* (1.50, 13.5)	2.29* (1.11, 4.71)	2.33* (1.06, 5.13)	6.02* (2.58, 14.03)	13.42* (5.85, 30.8)
Rash or skin irritation	2.65* (1.21, 5.77)	13.2* (1.74, 99.7)	5.62* (2.05, 15.4)	1.0 (.39, 2.54)	3.68* (1.56, 8.70)	3.24* (1.47, 7.13)
Persistent headaches	2.37* (1.26, 4.46)	4.09* (1.67, 9.99)	1.28 (0.68, 2.43)	0.88 (0.40, 1.92)	5.33* (2.27, 12.5)	5.27* (2.48, 11.2)
Nausea or vomiting	1.36 (0.67, 2.78)	2.46 (0.89, 6.82)	1.17 (0.56, 2.44)	0.99 (0.41, 2.41)	2.40* (1.03, 5.58)	5.47* (2.51, 11.5)
Low back pain or muscle pain	2.90* (1.52, 5.50)	3.20* (1.39, 7.34)	4.22* (2.13, 8.38)	1.08 (0.50, 2.34)	1.94 (0.87, 4.32)	4.63* (2.15, 9.93)
Trembling in extremities	3.47* (1.36, 8.84)	‡	3.11* (1.10, 8.80)	0.73 (0.23, 2.29)	15.83** (5.43, 46.1)	4.18* (1.73, 10.1)

OR= odds ratio; represents prevalence of condition in exposed vs. unexposed
CI= confidence interval
* $P < 0.05$ (Wald χ^2 test)
** $P < 0.05$ (2-Tailed Fisher's Exact Test)
‡ Could not calculate OR due to missing values

Table 22. Crude (unadjusted) Odds Ratios for Acute Health Symptoms Reported by Exxon Valdez Oil Spill Cleanup Workers among Self-Reported Chemical Exposure Variables

	SELF-REPORTED CHEMICAL EXPOSURE VARIABLES				
	Inipol	**Customblen**	**Simple Green**	**De-Solv It**	**Citriklean**
Acute Health Condition	Prevalence OR 95% C.I.	Prevalence OR 95% C.I.	Prevalence OR 95% C.I.	Prevalence OR 95% C.I.	Prevalence OR 95% C.I.
Dry, scratchy or sore throat	3.11* (1.12, 8.58)	1.01 (.232, 4.41)	2.42* (1.24, 4.73)	3.25 (1.59, 6.65)	1.25 (0.64, 2.42)
Persistent cough/ phlegm	3.93* (1.36, 11.4)	1.85 (0.44, 7.74)	2.16* (1.11, 4.23)	1.99 (0.99, 4.02)	1.71 (0.88, 3.33)
Dizziness	1.40 (0.49, 4.01)	0.81 (0.16, 4.18)	1.50 (0.75, 3.02)	1.12 (0.52, 2.48)	2.21* (1.07, 4.58)
Rash or skin irritation	7.0** (2.46, 19.9)	2.51 (0.56, 11.2)	2.93* (1.26, 6.79)	4.63* (2.00, 10.7)	2.76* (1.25, 6.08)
Persistent headaches	1.94 (0.72, 5.23)	0.49 (0.10, 2.54)	1.56 (0.83, 2.96)	2.10* (1.05, 4.18)	2.03* (1.05, 3.92)
Nausea or vomiting	1.28 (0.42, 3.89)	1.07 (0.21, 5.56)	1.88 (0.88, 4.02)	1.62 (0.74, 5.35)	1.22 (0.58, 2.60)
Low back pain or muscle pain	1.33 (0.49, 3.56)	0.70 (0.16, 3.07)	2.32* (1.22, 4.40)	1.08 (0.54, 2.12)	3.05* (1.57, 5.94)
Trembling in extremities	1.19 (0.31, 4.50)	‡	3.81* (1.34, 10.8)	1.95 (0.72, 5.27)	1.70 (0.68, 4.28)

OR= odds ratio; represents prevalence of condition in exposed vs. unexposed
CI= confidence interval;
* $P < 0.05$ (Wald χ^2 test) ** $P < 0.05$ (2-Tailed Fisher's Exact Test)
‡ *Could not calculate OR due to missing values*

Table 23. Chronic Health Symptoms among all Workers in Study Sample Who First Experienced Symptoms or Were Diagnosed During or Following the Exxon Valdez Oil Spill Cleanup (1989 or after)

Health Outcome	N (%)
Chronic symptoms:	
Symptoms of airway disease	81 (47.9)
Symptoms of chronic bronchitis	39 (23.1)
Symptoms of cognitive dysfunction	61 (36.1)
Symptoms of MCS	43 (25.4)
Symptoms of neurological impairment	66 (39.0)
Cancers‡	
Leukemia	1 (0.59)
Lymphoma	1 (0.59)
Hodgkin's Disease	1 (0.59)
Other cancers†	10 (5.9)
Benign tumors (including sinus polyps)	11 (6.51)
Kidney disease	4 (2.37)
Liver disease, including hepatitis	6 (3.55)
Diagnosed with solvent poisoning	1 (0.59)
Dermatologic symptoms	35 (20.7)
Anemia	18 (10.6)

† A list of other cancers reported in the study sample is given in Appendix C.
‡ No one in the sample reported lung cancer, liver cancer, or multiple myeloma

Table 24. Chronic Health Symptoms First Experienced During or After Work on the Exxon Valdez Oil Spill Cleanup, among Workers in Job-Defined Oil Exposure Categories

OIL EXPOSURE CATEGORIES

Condition/ Symptoms	*First Job* None N (%)‡	*First Job* Low N (%)‡	*First Job* Med N (%)‡	*First Job* High N (%)‡	*First Job* P*	*Longest Job* None N (%)‡	*Longest Job* Low N (%)‡	*Longest Job* Med N (%)‡	*Longest Job* High N (%)‡	*Longest Job* P*
Symptoms of Airway Disease (at least one listed below)	10 (33.3)	20 (54.0)	20 (45.4)	31 (55.4)	.218	8 (28.6)	21 (47.7)	16 (48.5)	36 (57.1)	.096
Sleep Apnea or Narcolepsy	2 (6.9)	5 (14.3)	2 (4.6)	6 (12.8)	.430**	2 (7.4)	5 (12.5)	1 (3.1)	7 (12.5)	.467**
Pneumonia	4 (13.8)	5 (13.9)	4 (9.1)	5 (8.9)	.798**	2 (7.4)	5 (11.4)	4 (12.1)	7 (11.3)	.955**
Other lung conditions	1 (3.5)	1 (3.0)	6 (14.3)	9 (17.0)	.107**	1 (3.7)	2 (5.1)	5 (15.1)	9 (15.5)	.217**
Chronic sinus problems and/or ear infections	3 (11.1)	7 (20.6)	14 (32.6)	18 (34.0)	.103	4 (15.4)	9 (21.9)	11 (34.4)	18 (30.5)	.310
Diagnosed with asthma	1 (3.4)	2 (5.6)	2 (4.6)	4 (7.5)	.933**	1 (3.4)	2 (4.6)	2 (6.1)	4 (7.0)	.966
Persistent hoarseness	2 (6.9)	7 (19.4)	2 (4.5)	8 (14.8)	.143**	1 (3.8)	5 (11.4)	2 (6.1)	11 (18.0)	.206**
Symptoms of Bronchitis	4 (13.3)	10 (27.0)	7 (15.9)	18 (32.1)	.125	4 (14.3)	12 (27.3)	5 (15.1)	18 (28.6)	.275
Among nonsmokers	0 (0.0)	3 (25.0)	0 (0.0)	6 (33.3)	.005**	0 (0.0)	2 (20.0)	0 (0.0)	7 (25.9)	.050**
Among former and current smokers	4 (22.2)	7 (28.0)	7 (28.0)	12 (33.3)	.850**	4 (22.2)	10 (29.4)	5 (27.8)	11 (32.3)	.933**

(Table continued on following page)

Table 24 (continued). Chronic Health Symptoms First Experienced During or After Work on the Exxon Valdez Oil Spill Cleanup, Among Workers in Job-Defined Oil Exposure Categories

	First Job					*Longest Job*				
Condition/ Symptoms	**None** N (%)‡	**Low** N (%)‡	**Med** N (%)‡	**High** N (%)‡	**P***	**None** N (%)‡	**Low** N (%)‡	**Med** N (%)‡	**High** N (%)‡	**P***
Symptoms of Cognitive Dysfunction	11 (36.7)	11 (29.7)	14 (31.8)	25 (44.6)	.432	13 (46.4)	12 (27.3)	12 (36.4)	24 (38.1)	.410
Have visited physician for treatment of cognitive dysfunction symptoms	7 (23.3)	3 (8.6)	5 (11.9)	11 (20.0)	.283	6 (21.4)	4 (9.5)	5 (16.1)	11 (17.7)	.558
Symptoms of Neurological Impairment	8 (26.7)	14 (37.8)	15 (34.1)	29 (52.7)	.084	8 (28.6)	12 (27.3)	12 (36.4)	34 (54.8)	**.015**
Have visited physician for treatment of symptoms of neurological impairment	3 (10.0)	6 (16.2)	6 (13.6)	16 (29.1)	.098	2 (7.1)	6 (13.6)	6 (18.2)	17 (27.4)	.096
Symptoms of MCS	4 (13.8)	9 (24.3)	10 (22.7)	20 (37.0)	.115	6 (21.4)	9 (20.9)	9 (27.3)	19 (31.1)	.627
Dermatologic symptoms	5 (17.2)	6 (16.2)	9 (20.4)	15 (27.8)	.527	6 (22.2)	7 (15.9)	8 (24.2)	14 (22.9)	.789
Blood symptoms/ conditions Frequent nosebleeds	3 (10.0)	1 (2.7)	3 (6.8)	1 (1.8)	.305**	3 (10.7)	2 (4.5)	2 (6.1)	1 (1.6)	.260**
Anemia	3 (10.0)	3 (8.6)	4 (9.4)	8 (15.4)	.809	3 (10.7)	4 (10.0)	5 (15.1)	6 (10.0)	.880

‡ N and percents are calculated among those within each exposure category and do not represent percent of total workers
* P-value calculated by Wald χ^2 Test unless otherwise noted; p-values in bold are considered statistically significant ($p<.05$)
** P-value calculated by 2-Tailed Fisher's Exact Test

Table 25. Chronic Health Symptoms First Experienced During or After Work on the Exxon Valdez Oil Spill Cleanup, among Workers in Job-Defined Chemical Exposure Categories

	CHEMICAL EXPOSURE CATEGORIES							
	First Job				*Longest Job*			
Condition/ Symptoms	**No-Low N (%)‡**	**Moderate N (%)‡**	**High N (%)‡**	**P***	**No-Low N (%)‡**	**Moderate N (%)‡**	**High N (%)‡**	**P***
Symptoms of Airway Disease (at least one listed below)	13 (33.3)	36 (62.1)	32 (45.7)	**.018**	11 (28.2)	41 (60.3)	29 (47.5)	**.006**
Sleep Apnea or Narcolepsy	2 (5.3)	9 (16.7)	4 (6.1)	.085**	2 (5.4)	7 (11.5)	6 (10.5)	.593
Pneumonia	4 (10.5)	7 (12.3)	7 (10.0)	.916	2 (5.3)	10 (14.7)	6 (10.0)	.314
Other lung conditions	2 (5.4)	3 (5.9)	12 (17.7)	.059	3 (7.9)	5 (8.2)	9 (15.5)	.350
Chronic sinus problems and/or ear infections	3 (8.3)	21 (39.6)	18 (26.5)	**.005**	5 (13.5)	21 (33.9)	16 (27.1)	.085
Symptoms of Bronchitis	6 (15.4)	19 (32.8)	14 (20.0)	.096	6 (15.4)	24 (35.3)	9 (14.7)	**.009**
Diagnosed with asthma	1 (2.6)	3 (5.6)	5 (7.2)	.693**	1 (2.6)	4 (6.3)	4 (6.8)	.752**
Persistent hoarseness	3 (7.9)	8 (14.3)	8 (11.6)	.638	1 (2.7)	11 (16.4)	7 (11.7)	.112
Symptoms of Cognitive Dysfunction	13 (33.3)	23 (39.7)	25 (35.7)	.804	14 (35.9)	24 (35.3)	23 (37.7)	.957
Have visited physician for cognitive dysfunction symptoms	7 (17.9)	10 (18.2)	9 (13.2)	.708	6 (15.4)	11 (16.9)	9 (15.2)	.962
Symptoms of Neurological Impairment	11 (28.2)	30 (51.7)	25 (36.2)	**.050**	9 (23.1)	29 (42.6)	28 (46.7)	**.050**
Have visited physician for treatment of symptoms of neurological impairment	4 (10.3)	17 (29.3)	10 (14.5)	**.031**	2 (5.1)	18 (26.5)	11 (18.3)	**.024**
Symptoms of MCS	5 (13.2)	21 (36.2)	17 (25.0)	**.041**	6 (15.8)	22 (32.3)	15 (25.4)	.175
Dermatologic symptoms	6 (15.8)	13 (22.8)	16 (23.2)	.634	7 (18.4)	14 (20.9)	14 (23.3)	.842
Blood symptoms/ conditions								
Frequent nosebleeds	3 (7.7)	1 (1.7)	4 (5.8)	.372**	3 (7.7)	3 (4.5)	2 (3.3)	.589**
Anemia	3 (7.9)	9 (16.1)	6 (9.1)	.360	3 (8.1)	8 (12.5)	7 (11.7)	.787

‡ N and percents are calculated among those within each exposure category and do not represent percent of total workers

* P-value calculated by Wald $\chi 2$ Test unless otherwise noted; p-values in bold are considered statistically significant ($p<.05$)

** P-value calculated by 2-Tailed Fisher's Exact Test

Table 26. Chronic Health Symptoms First Experienced During or After Work on the Exxon Valdez Oil Spill Cleanup, among Self-Reported Oil Exposure Variables

SELF-REPORTED OIL EXPOSURE VARIABLES

Symptoms/ Condition	Oil on skin or in eyes			Inhaled oil mist or vapors			Diesel exhaust or generator			Burning oil or trash			Food or drink exposed to oil or chemicals			Overcome by gases or fumes from oil		
	% unexp	% exp	P*	% unexp	% exp	P*	% unexp	% exp	P*	% unexp	% expo	P*	% unexp	% exp	P*	% unexp	% exp	P*
Symptoms of Airway Disease (at least one below)	39.8	57.5	**.022**	21.6	56.6	**<.001**	31.9	58.8	**<.001**	47.8	51.5	.699	40.2	72.7	**<.001**	41.1	68.2	**.002**
Sleep Apnea or Narcolepsy	9.8	9.6	.972	8.1	10.2	1.00**	9.1	10.2	.814	7.9	17.2	.159**	7.0	20.7	**.038****	8.6	12.8	.531**
Pneumonia	6.9	15.2	.086	8.3	11.7	.766**	5.8	13.7	.102	9.8	15.1	.362**	9.9	15.1	.365**	8.0	15.9	.257**
Other lung conditions	7.3	14.7	.139	0.0	14.2	**.018**	7.2	13.6	.212	10.3	13.3	.744**	7.8	17.9	.148**	9.3	15.4	.371**
Chronic sinus problems and/or ear infections	19.3	34.7	**.029**	11.8	30.9	**.026**	14.9	34.9	**.005**	26.9	25.0	.834	18.6	45.4	**.002**	22.0	40.0	**.026**
Symptoms of Bronchitis	17.0	30.0	**.047**	8.1	27.9	**.012**	11.6	30.9	**.003**	22.4	27.3	.552	18.0	36.4	**.024**	16.1	43.2	**<.001**
Diagnosed with asthma	5.8	5.3	1.00**	2.7	6.6	.686**	5.9	5.5	1.00**	6.1	3.4	1.00**	5.1	6.1	1.00**	5.8	4.9	1.00**
Persistent hoarseness	9.3	14.1	.337	2.8	14.3	.077**	7.3	13.8	.195	10.7	15.6	.537**	6.6	28.1	**.002****	8.2	20.9	**.048**
Symptoms of Cognitive Dysfunction	30.7	42.5	.112	24.3	39.5	.090	26.1	43.3	**.022**	35.1	42.4	.432	25.4	63.6	**<.001**	29.8	54.5	**.003**
Have visited physician for treatment of cognitive dysfunction symptoms	12.8	19.5	.244	8.3	18.4	.148	8.8	20.4	**.045**	14.7	21.2	.364	9.3	30.3	**.004****	9.1	35.7	<.001

(Table continued on following page)

Table 26 (continued). Chronic Health Symptoms First Experienced During or After Work on the Exxon Valdez Oil Spill Cleanup, among Self-Reported Oil Exposure Categories

Symptoms/ Condition	Oil on skin or in eyes			Inhaled oil mist or vapors			Diesel exhaust or generator			Burning oil or trash			Food or drink exposed to oil or chemicals			Overcome by gases or fumes from oil		
	% unexp	% exp	p*	% unexp	% exp	p*	% unexp	% exp	p*	% unexp	% exp	p*	% unexp	% exp	p*	% unexp	% exp	p*
Symptoms of Neurological Impairment‡	35.6	43.7	.284	16.2	45.3	**.001**	27.5	47.9	**.008**	36.8	48.5	.220	31.1	62.5	**.001**	33.3	56.8	**.006**
Have visited physician for treatment of symptoms of neurological impairment	19.5	17.5	.735	10.8	21.1	.158	11.6	24.0	**.050**	18.0	21.2	.676	17.2	21.9	.543	14.6	29.5	**.029**
Symptoms of MCS	20.4	32.5	.079	10.8	30.7	**.015**	19.4	30.2	.121	24.8	31.2	.456	16.5	53.1	**<.001**	19.0	45.4	**<.001**
Dermatologic Symptoms	16.3	26.6	.106	13.5	23.8	.180	15.9	25.5	.141	22.6	16.1	.431	18.2	32.2	.086	18.8	27.9	.212
Blood symptoms/ conditions Frequent nosebleeds	3.4	6.3	.480**	0.0	6.3	.200**	1.4	7.4	.140**	4.5	6.1	.661**	3.3	6.2	.606**	4.1	7.0	.428**
Anemia	10.6	11.8	.801	10.7	10.7	1.0**	10.3	12.0	.742	10.8	9.7	1.0**	10.2	20.0	.206**	10.7	12.5	.775**

%= percent of unexposed (unexp) that reported symptom and percent of exposed (exp) that reported symptom
‡ Percents are calculated among those within each exposure category and do not represent percent of total workers
* P-value calculated by Wald $\chi2$ Test unless otherwise noted; p-values in bold are considered statistically significant ($p<.05$)
** P-value calculated by 2-Tailed Fisher's Exact Test

Table 27. **Chronic Health Symptoms First Experienced During or After Work on the Exxon Valdez Oil Spill Cleanup, among Self-Reported Chemical Exposure Variables**

CHEMICAL EXPOSURE VARIABLES

Condition/ Symptoms	Inipol			Customblen			Simple Green			De-Solv It			Citriklean		
	% unexp	% exp	P*	% unexp	% exp	P*	% unexp	% exp	P*	% unexp	% exp	P*	% unexp	% exp	P*
Symptoms of Airway Disease (at least one listed below)	48.5	33.3	.229	48.9	37.5	.720**	40.8	54.0	.092	42.1	57.4	.072	42.4	55.4	.108
Sleep Apnea or Narcolepsy	9.8	6.2	1.00**	10.8	12.5	1.00**	8.4	11.4	.589	6.7	18.4	**.038**	7.2	14.7	.144
Pneumonia	11.4	6.2	1.00**	10.7	14.3	.562	6.6	15.3	.080	9.6	17.3	**.035**	5.5	18.7	**.009**
Other lung conditions	11.3	11.8	1.00**	12.2	0.0	1.00**	10.9	11.2	.954	10.0	10.4	1.00**	9.3	12.9	.486
Chronic sinus problems and/or ear infections	30.3	17.6	.564**	9.6	12.5	.448**	27.1	25.0	.763	9.6	32.6	.220	23.0	31.1	.267
Symptoms of Bronchitis	23.5	22.2	1.00**	23.4	12.5	.683**	14.4	32.2	**.008**	9.6	29.6	.135	18.5	27.7	.172
Diagnosed with asthma	30.3	0.0	.596**	9.6	12.5	.414**	4.1	7.2	.503**	9.6	10.0	.128**	3.4	9.5	.167
Persistent hoarseness	30.3	17.6	.440**	9.6	28.6	.207**	5.3	16.7	**.024**	9.6	15.7	.275	12.1	11.3	.880
Symptoms of Cognitive Dysfunction	37.1	33.3	.754	40.4	0.0	**.024****	35.5	39.1	.640	32.6	42.6	.224	34.8	40.0	.505
Have visited physician for treatment of cognitive dysfunction symptoms	14.8	22.2	.487**	30.3	0.0	.604**	15.1	17.6	.663	10.7	23.1	**.047**	11.2	23.4	**.044**

(Table continued on following page)

Table 27 (continued). Chronic Health Symptoms First Experienced During or After Work on the Exxon Valdez Oil Spill Cleanup, among Self-Reported Chemical Exposure Categories

Symptoms/ Condition	Inipol			Customblen			Simple Green			De-Solv It			Citriklean		
	%unexp	% exp	P*	% unexp	% exp	P*	% unexp	% exp	P*	% unexp	% exp	P*	% unexp	% exp	P*
Symptoms of Neurological Impairment	40.1	35.3	.700	41.1	42.9	1.00**	30.3	47.7	**.024**	35.7	47.2	.175	32.6	50.0	**.029**
Have visited physician for treatment of symptoms of neurological impairment	22.0	0.0	**.044****	19.9	28.6	.630**	19.6	17.4	.707	16.8	22.6	.388	14.1	25.0	.086
Symptoms of MCS	26.1	17.6	.563**	27.1	12.5	.681**	18.6	31.8	.058	20.2	35.8	**.038**	19.0	31.2	.110
Dermatologic Symptoms	22.9	11.8	.367**	23.0	14.3	1.0**	21.3	22.1	.907	19.1	26.9	.277	19.7	23.8	.526
Blood symptoms/ conditions Frequent nosebleeds	3.8	11.8	.183**	5.0	0.0	1.0**	2.6	7.1	.283	2.1	7.7	.186	3.3	3.2	1.0**
Anemia	11.6	12.5	1.0**	11.6	28.6	.210**	13.3	9.9	.500	11.7	9.8	.728	7.7	16.9	.081

%= percent of unexposed (unexp) that reported symptom and percent of exposed (exp) that reported symptom
‡ Percents are calculated among those within each exposure category and do not represent percent of total workers
* P-value calculated by Wald χ^2 Test unless otherwise noted; p-values in bold are considered statistically significant ($p<.05$)
** P-value calculated by 2-Tailed Fisher's Exact Test

Table 28. Crude and Adjusted Odds Ratios (OR) for *Symptoms of Chronic Airway Disease* among Exxon Valdez Oil Spill Cleanup Workers, by Job-Defined Oil and Chemical Exposure Categories

Exposure Variable	N†	%†	Crude OR	95% CI	P*	Adjusted OR‡	95% CI	P*
First job oil exposure categories								
No exposure	10	33.3	Ref	-				
Low exposure	20	54.0	2.35	(0.87, 6.38)	.093	1.65	(0.54, 5.07)	.381
Medium exposure	20	45.4	1.67	(0.64, 4.37)	.300	0.84	(0.27, 2.62)	.763
High exposure	31	55.4	2.48	(0.98, 6.25)	.054	1.51	(0.52, 4.38)	.447
Longest job oil exposure categories								
No exposure	8	28.6	Ref					
Low exposure	21	47.7	2.28	(0.83, 6.27)	.110	1.95	(0.62, 6.13)	.250
Medium exposure	16	48.5	2.35	(0.81, 6.84)	.116	1.41	(0.40, 4.93)	.593
High exposure	36	57.1	3.33	(1.28, 8.70)	**.014**	2.99	(0.98, 9.08)	.053
First job chemical exposure categories								
No-low exposure	13	33.3	Ref					
Moderate exposure	36	62.1	3.27	(1.40, 7.66)	**.006**	1.96	(0.74, 5.21)	.178
High exposure	32	45.7	1.68	(0.74, 3.80)	.210	0.93	(0.35, 2.46)	.890
Longest job chemical exposure categories								
No-low exposure	11	28.2	Ref					
Moderate exposure	41	60.3	3.86	(1.65, 9.04)	**.002**	3.14	(1.15, 8.61)	**.026**
High exposure	29	47.5	2.31	(0.98, 5.45)	.057	1.69	(0.60, 4.75)	.318

Note: OR= odds ratio; CI=confidence interval; Ref= Reference

† N and percents are calculated from the subjects in each exposure category reporting the health outcome of interest and therefore will not add up to 100%

* P-value calculated by Wald $\chi 2$ Test unless otherwise noted; p-values in bold are considered statistically significant ($p<.05$)

** P-value calculated by 2-Tailed Fisher's Exact Test

‡ Adjusted for age, race/ethnicity, sex, belief that personal health was affected by working on the oil spill cleanup, smoking status, and source list of the participant's name.

Table 29. Crude and Adjusted Odds Ratios (OR) for *Symptoms of Chronic Airway Disease*, among Exxon Valdez Oil Spill Cleanup Workers, by Self-Reported Oil and Chemical Exposures

Exposure Variable	N†	%†	Crude OR	95% CI	P*	Adjusted OR‡	95% CI	P*
Self-reported oil exposures								
Oil on skin or in eyes	46	57.5	2.05	(1.11, 3.79)	**.022**	0.58	(0.22, 1.52)	.267
Inhaled oil mist or vapors	73	56.6	4.72	(2.01,11.13)	**<.001**	4.16	(1.31,13.27)	**.016**
Diesel exhaust or generator	57	58.8	3.04	(1.60, 5.82)	**<.001**	2.37	(0.97, 5.80)	.059
Burning oil or trash	17	51.5	1.16	(.542, 2.49)	.699	0.47	(0.14, 1.51)	.202
Consumed food or beverages exposed to oil or chemicals	24	72.7	3.97	(1.70, 9.27)	**<.001**	1.14	(0.31, 4.20)	.843
Overcome by oil gases or fumes	30	68.2	3.07	(1.48, 6.35)	**.002**	1.19	(0.40, 3.47)	.755
Self-reported chemical exposures								
Inipol	6	33.3	0.53	(0.19, 1.50)	.227	0.17	(0.02, 1.13)	.067
Customblen	3	37.5	0.63	(0.14, 2.72)	.720**	1.85	(0.09, 36.40)	.686
Simple Green	47	54.0	1.71	(0.92, 3.18)	.092	1.31	(0.43, 3.99)	.637
De-Solv It	31	57.4	1.85	(0.94, 3.64)	.072	3.88	(1.29, 11.67)	**.016**
Citriklean	36	55.4	1.69	(0.89, 3.20)	.108	0.72	(0.24, 2.17)	.564

Note: OR= odds ratio; CI=confidence interval; Ref= Reference

† N and percents are calculated from the subjects in each exposure category reporting the health outcome of interest and therefore will not add up to 100%

* P-value calculated by Wald $\chi2$ Test unless otherwise noted; p-values in bold are considered statistically significant ($p<.05$)

** P-value calculated by 2-Tailed Fisher's Exact Test

‡ Adjusted for age, race/ethnicity, sex, belief that personal health was affected by working on the oil spill cleanup, smoking status, and original source list of the participant's name. Each self-reported oil exposure variable was also adjusted for the remaining self-reported oil exposure variables, and each self-reported chemical exposure variable was also adjusted for the remaining chemical exposure variables.

Table 30. Crude and Adjusted Odds Ratios (OR) for *Symptoms of Chronic Bronchitis* among Exxon Valdez Oil Spill Cleanup Workers, by Job-Defined Oil and Chemical Exposure Categories

Exposure Variable	N†	%†	Crude OR	95% CI	P*	Adjusted OR	95% CI	P*
First job oil exposure categories								
No exposure	4	13.3	Ref					
Low exposure	10	27.0	2.41	(0.67, 8.64)	.178	1.77	(0.40, 7.72)	.449
Medium exposure	7	15.9	1.23	(0.33, 4.63)	.760	0.51	(0.10, 2.48)	.404
High exposure	18	32.1	3.08	(0.93, 10.12)	.065	1.63	(0.40, 6.59)	.494
Longest job oil exposure categories								
No exposure	4	14.3	Ref					
Low exposure	12	27.3	2.25	(0.64, 7.85)	.203	2.04	(0.46, 8.97)	.347
Medium exposure	5	15.1	1.07	(0.26, 4.45)	.924	0.65	(0.12, 3.48)	.617
High exposure	18	28.6	2.40	(0.73, 7.90)	.150	1.73	(0.41, 7.33)	.456
First job chemical exposure categories								
No-low exposure	6	15.4	Ref					
Moderate exposure	19	32.8	2.68	(0.96, 7.49)	.060	1.23	(0.36, 4.20)	.743
High exposure	14	20.0	1.37	(0.48, 3.92)	.552	0.53	(0.15, 1.92)	.336
Longest job chemical exposure categories								
No-low exposure	6	15.4	Ref					
Moderate exposure	24	35.3	3.00	(1.10, 8.17)	**.032**	1.81	(0.52, 6.31)	.354
High exposure	9	14.7	0.95	(0.32, 2.92)	.931	0.46	(0.11, 1.89)	.283

Note: OR= odds ratio; CI=confidence interval; Ref= Reference

† N and percents are calculated from the subjects in each exposure category reporting the health outcome of interest and therefore will not add up to 100%

* P-value calculated by Wald $\chi 2$ Test unless otherwise noted; p-values in bold are considered statistically significant (p<.05)

** P-value calculated by 2-Tailed Fisher's Exact Test

‡ Adjusted for age, race/ethnicity, sex, belief that personal health was affected by working on the oil spill cleanup, smoking status, and original source list of the participant's name.

Table 31. Crude and Adjusted Odds Ratios (OR) for *Symptoms of Chronic Bronchitis*, among Exxon Valdez Oil Spill Cleanup Workers, by Self-Reported Oil and Chemical Exposures

Exposure Variable	N†	%†	Crude OR	95% CI	P*	Adjusted OR	95% CI	P*
Self-reported oil exposures								
Oil on skin or in eyes	24	30.0	2.06	(1.00, 4.34)	**.047**	0.54	(0.16, 1.83)	.319
Inhaled oil mist or vapors	36	27.9	4.39	(1.27, 15.18)	**.012**	1.92	(0.36, 10.15)	.441
Diesel or generator exhaust	30	30.9	3.41	(1.45, 8.02)	**.003**	3.57	(1.12, 11.38)	**.031**
Burning oil or trash	9	27.3	1.30	(0.55, 3.09)	.552	0.89	(0.25, 3.23)	.864
Consumed food or beverages exposed to oil or chemicals	12	36.4	2.60	(1.11, 6.05)	**.024**	0.72	(0.18, 2.82)	.639
Overcome by oil gases or fumes	19	43.2	3.95	(1.84, 8.49)	**<.001**	2.18	(0.67, 7.13)	.198
Self-reported chemical exposures								
Inipol	4	22.2	0.93	(0.28, 3.03)	1.00**	0.18	(0.02, 1.55)	.119
Customblen	1	12.5	0.47	(0.05, 3.94)	.623**	0.09	(0.002, 3.60)	.200
Simple Green	28	32.2	2.80	(1.28, 6.13)	**.008**	3.35	(0.85, 13.17)	.083
De-Solv-It	16	29.6	1.80	(0.83, 3.92)	.135	2.59	(0.68, 9.78)	.161
Citriklean	18	27.7	1.70	(0.79, 3.60)	.172	0.98	(0.29, 3.35)	.979

Note: OR= odds ratio; CI=confidence interval; Ref= Reference

† N and percents are calculated from the subjects in each exposure category reporting the health outcome of interest and therefore will not add up to 100%

* P-value calculated by Wald $\chi 2$ Test unless otherwise noted; p-values in bold are considered statistically significant (p<.05)

** P-value calculated by 2-Tailed Fisher's Exact Test

‡ Adjusted for age, race/ethnicity, sex, belief that personal health was affected by working on the oil spill cleanup, smoking status, and original source list of the participant's name. Each self-reported oil exposure variable was also adjusted for the remaining self-reported oil exposure variables, and each self-reported chemical exposure variable was also adjusted for the remaining chemical exposure variables.

Table 32. Crude and Adjusted Odds Ratios (OR) for *Symptoms of Cognitive Dysfunction* among Exxon Valdez Oil Spill Cleanup Workers, by Job-Defined Oil and Chemical Exposure Categories

Exposure Variable	N†	%†	Crude OR	95% CI	P*	Adjusted OR	95% CI	P*
First job oil exposure categories								
No exposure	11	36.7	Ref					
Low exposure	11	29.7	0.73	(0.26, 2.03)	.584	0.33	(0.09, 1.15)	.082
Medium exposure	14	31.8	0.81	(0.30, 2.14)	.665	0.35	(0.10, 1.14)	.081
High exposure	25	44.6	1.39	(0.56, 3.46)	.475	0.82	(0.27, 2.48)	.721
Longest job oil exposure categories								
No exposure	13	46.4	Ref					
Low exposure	12	27.3	0.43	(0.16, 1.17)	.099	0.28	(0.08, 0.93)	**.038**
Medium exposure	12	36.4	0.66	(0.24, 1.84)	.427	0.32	(0.09, 1.08)	.065
High exposure	24	38.1	0.71	(0.29, 1.75)	.456	0.35	(0.11, 1.07)	.066
First job chemical exposure categories								
No-low exposure	13	33.3	Ref					
Moderate exposure	23	39.7	1.31	(0.56, 3.07)	.528	0.77	(0.27, 2.21)	.633
High exposure	25	35.7	1.11	(0.49, 2.54)	.803	0.68	(0.25, 1.89)	.465
Longest job chemical exposure categories								
No-low exposure	14	35.9	Ref					
Moderate exposure	24	35.3	0.97	(0.43, 2.22)	.950	0.51	(0.18, 1.44)	.204
High exposure	23	37.7	1.08	(0.47, 2.49)	.855	0.52	(0.18, 1.47)	.216

Note: OR= odds ratio; CI=confidence interval; Ref= Reference

† N and percents are calculated from the subjects in each exposure category reporting the health outcome of interest and therefore will not add up to 100%

* P-value calculated by Wald $\chi 2$ Test unless otherwise noted; p-values in bold are considered statistically significant ($p<.05$)

** P-value calculated by 2-Tailed Fisher's Exact Test

‡ Adjusted for age, race/ethnicity, sex, alcohol consumption, belief that personal health was affected by working on the oil spill cleanup, smoking status, and original source list of the participant's name.

Table 33. Crude and Adjusted Odds Ratios (OR) for *Symptoms of Cognitive Dysfunction*, among Exxon Valdez Oil Spill Cleanup Workers, by Self-Reported Oil and Chemical Exposures

Exposure Variable	N†	%†	Crude OR	95% CI	P*	Adjusted OR	95% CI	P*
Self-reported oil exposures								
Oil on skin or in eyes	34	42.5	1.67	(0.89, 3.15)	.112	1.51	(0.50, 4.49)	.462
Inhaled oil mist or vapors	51	39.5	2.03	(0.89, 4.66)	.090	0.49	(0.13, 7.80)	.280
Diesel or generator exhaust	42	43.3	2.16	(1.11, 4.23)	**.023**	6.06	(2.06, 17.86)	**.001**
Burning oil or trash	14	42.4	1.36	(0.63, 2.96)	.432	1.16	(0.34, 3.90)	.815
Consumed food or beverages exposed to oil or chemicals	21	63.6	5.14	(2.27, 11.64)	**<.001**	2.38	(0.66, 8.54)	.185
Overcome by oil gases or fumes	24	54.5	2.82	(1.39, 5.72)	**.003**	2.11	(0.70, 6.38)	.187
Self-reported chemical exposures								
Inipol	6	33.3	0.85	(0.30, 2.40)	.754	1.21	(0.22, 6.68)	.825
Simple Green	34	39.1	1.16	(0.61, 2.20)	.640	0.76	(0.25, 2.35)	.638
De-Solv It	23	42.6	1.53	(0.77, 3.05)	.224	3.78	(1.23, 11.61)	**.020**
Citriklean	26	40.0	1.25	(0.65, 2.41)	.505	0.54	(0.18, 1.63)	.274

Note: OR= odds ratio; CI=confidence interval; Ref= Reference

† N and percents are calculated from the subjects in each exposure category reporting the health outcome of interest and therefore will not add up to 100%

* P-value calculated by Wald $\chi 2$ Test unless otherwise noted; p-values in bold are considered statistically significant ($p<.05$)

** P-value calculated by 2-Tailed Fisher's Exact Test

‡ Adjusted for age, race/ethnicity, sex, alcohol consumption, belief that personal health was affected by working on the oil spill cleanup, smoking status, and original source list of the participant's name. Each self-reported oil exposure variable was also adjusted for the remaining self-reported oil exposure variables, and each self-reported chemical exposure variable was also adjusted for the remaining chemical exposure variables.

Table 34. Crude and Adjusted Odds Ratios (OR) for *Symptoms of Neurological Impairment* among Exxon Valdez Oil Spill Cleanup Workers, by Job-Defined Oil and Chemical Exposure Categories

Exposure Variable	N†	%†	Crude OR	95% CI	P*	Adjusted OR	95% CI	P*
First job oil exposure categories								
No exposure	8	26.7	Ref					
Low exposure	14	37.8	1.67	(0.59, 4.77)	.335	0.77	(0.22, 2.77)	.693
Medium exposure	15	34.1	1.42	(0.51, 3.95)	.500	0.74	(0.20, 2.69)	.650
High exposure	29	52.7	3.07	(1.67, 8.07)	**.023**	2.74	(0.83, 8.99)	.098
Longest job oil exposure categories								
No exposure	8	28.6	Ref					
Low exposure	12	27.3	0.94	(0.33, 2.69)	.904	0.62	(0.17, 2.21)	.460
Medium exposure	12	36.4	1.43	(0.48, 4.22)	.519	0.99	(0.25, 3.96)	.991
High exposure	34	54.8	3.04	(1.16, 7.93)	**.023**	3.63	(1.05, 12.58)	**.042**
First job chemical exposure categories								
No-low exposure	11	28.2	Ref					
Moderate exposure	30	51.7	2.73	(1.15, 6.49)	**.023**	1.72	(0.59, 5.05)	.320
High exposure	25	36.2	1.45	(0.62, 3.39)	.397	1.02	(0.35, 2.99)	.965
Longest job chemical exposure categories								
No-low exposure	9	23.1	Ref					
Moderate exposure	29	42.6	2.48	(1.02, 6.01)	**.045**	1.64	(0.54, 4.96)	.381
High exposure	28	46.7	2.92	(1.18, 7.18)	**.020**	2.40	(0.78, 7.40)	.127

Note: OR= odds ratio; CI=confidence interval; Ref= Reference

† N and percents are calculated from the subjects in each exposure category reporting the health outcome of interest and therefore will not add up to 100%

* P-value calculated by Wald $\chi 2$ Test unless otherwise noted; p-values in bold are considered statistically significant ($p<.05$)

** P-value calculated by 2-Tailed Fisher's Exact Test

‡ Adjusted for age, race/ethnicity, sex, alcohol consumption, belief that personal health was affected by working on the oil spill cleanup, smoking status, and original source list of the participant's name.

Table 35. Crude and Adjusted Odds Ratios (OR) for *Symptoms of Neurological Impairment*, among Exxon Valdez Oil Spill Cleanup Workers, by Self-Reported Oil and Chemical Exposures

Exposure Variable	N†	%†	Crude OR	95% CI	P*	Adjusted OR	95% CI	P*
Self-reported oil exposures								
Oil on skin or in eyes	35	43.7	1.40	(0.75, 2.62)	.284	0.63	(0.21, 1.88)	.409
Inhaled oil mist or vapors	58	45.3	4.28	(1.67, 10.97)	**.001**	3.03	(0.79, 11.71)	.107
Diesel or generator exhaust	46	47.9	2.42	(1.25, 4.70)	**.008**	3.86	(1.34, 11.13)	**.012**
Burning oil or trash	16	48.5	1.61	(0.75, 3.48)	.220	0.98	(0.28, 3.46)	.976
Consumed food or beverages exposed to oil or chemicals	20	62.5	3.68	(1.64, 8.30)	**.001**	1.29	(0.33, 5.01)	.708
Overcome by oil gases or fumes	25	56.8	2.63	(1.30, 5.32)	**.006**	0.79	(0.24, 2.58)	.692
Self-reported chemical exposures								
Inipol	6	35.3	0.81	(0.28, 3.33)	.700	0.96	(0.16, 5.66)	.965
Customblen	3	42.9	1.07	(0.23, 4.98)	1.00**	0.80	(0.07, 9.05)	.856
Simple Green	41	47.7	2.10	(1.10, 4.01)	**.024**	1.30	(0.41, 4.09)	.649
De-Solv-It	25	47.2	1.60	(0.81, 3.17)	.175	2.22	(0.72, 6.84)	.163
Citriklean	32	50.0	2.07	(1.07, 3.98)	**.029**	1.31	(0.44, 3.85)	.626

Note: OR= odds ratio; CI=confidence interval; Ref= Reference

† N and percents are calculated from the subjects in each exposure category reporting the health outcome of interest and therefore will not add up to 100%

* P-value calculated by Wald $\chi 2$ Test unless otherwise noted; p-values in bold are considered statistically significant ($p<.05$)

** P-value calculated by 2-Tailed Fisher's Exact Test

‡ Adjusted for age, race/ethnicity, sex, alcohol consumption, belief that personal health was affected by working on the oil spill cleanup, smoking status, and original source list of the participant's name. Each self-reported oil exposure variable was also adjusted for the remaining self-reported oil exposure variables, and each self-reported chemical exposure variable was also adjusted for the remaining chemical exposure variables.

Table 36. Crude and Adjusted Odds Ratios (OR) for *Symptoms of Multiple Chemical Sensitivity*, among Exxon Valdez Oil Spill Cleanup Workers, by Job-Defined Oil and Chemical Exposure Categories

Exposure Variable	N†	%†	Crude OR	95% CI	P*	Adjusted OR	95% CI	P*
First job oil exposure categories								
No exposure	4	13.8	Ref					
Low exposure	29	24.3	2.01	(0.55, 7.34)	.291	1.16	(0.26, 5.12)	.844
Medium exposure	10	22.7	1.84	(0.52, 6.54)	.347	0.74	(0.17, 3.23)	.688
High exposure	20	37.0	3.68	(1.12, 12.10)	**.032**	2.17	(0.56, 8.38)	.263
Longest job oil exposure categories								
No exposure	6	21.4	Ref					
Low exposure	9	20.9	0.97	(0.30, 3.12)	.960	0.62	(0.16, 2.47)	.500
Medium exposure	9	27.3	1.37	(0.42, 4.49)	.598	0.61	(0.15, 2.53)	.498
High exposure	19	31.1	1.66	(0.58, 4.75)	.346	0.81	(0.42, 1.57)	.743
First job chemical exposure categories								
No-low exposure	5	13.2	Ref					
Moderate exposure	21	36.2	3.75	(1.27, 11.06)	**.017**	2.10	(0.58, 7.56)	.256
High exposure	17	25.0	2.20	(0.74, 6.54)	.156	1.10	(0.30, 4.06)	.883
Longest job chemical exposure categories								
No-low exposure	6	15.8	Ref					
Moderate exposure	22	32.3	2.55	(0.93, 7.00)	.069	1.23	(0.37, 4.10)	.741
High exposure	15	25.4	1.82	(0.64, 5.20)	.265	0.78	(0.21, 2.83)	.704

Note: OR= odds ratio; CI=confidence interval; Ref= Reference

† N and percents are calculated from the subjects in each exposure category reporting the health outcome of interest and therefore will not add up to 100%

* P-value calculated by Wald $\chi 2$ Test unless otherwise noted; p-values in bold are considered statistically significant (p<.05)

** P-value calculated by 2-Tailed Fisher's Exact Test

‡ Adjusted for age, race/ethnicity, sex, alcohol consumption, belief that personal health was affected by working on the oil spill cleanup, smoking status, and original source list of the participant's name.

Table 37. Crude and Adjusted Odds Ratios (OR) for *Symptoms of Multiple Chemical Sensitivity*, among Exxon Valdez Oil Spill Cleanup Workers, by Self-Reported Oil and Chemical Exposures

Exposure Variable	N†	%†	Crude OR	95% CI	P*	Adjusted OR	95% CI	P*
Self-reported oil exposures								
Oil on skin or in eyes	25	32.5	1.87	(0.92, 3.78)	.079	0.73	(0.23, 2.36)	.605
Inhaled oil mist or vapors	39	30.7	3.66	(1.21, 11.03)	**.015**	2.32	(0.51, 10.61)	.279
Diesel or generator exhaust	29	30.2	1.80	(0.85, 3.79)	.121	1.56	(0.59, 4.43)	.405
Burning oil or trash	10	31.2	1.38	(0.59, 3.21)	.456	1.48	(0.44, 4.97)	.521
Consumed food or beverages exposed to oil or chemicals	17	53.1	5.72	(2.46, 13.31)	**<.001**	1.24	(0.35, 4.42)	.734
Overcome by oil gases or fumes	20	45.4	3.55	(1.68, 7.50)	**<.001**	1.47	(0.50, 4.31)	.487
Self-reported chemical exposures								
Inipol	3	17.6	0.60	(0.16, 2.23)	.563**	0.13	(0.01, 1.25)	.078
Customblen	1	12.5	0.38	(0.05, 3.22)	.681**	0.21	(0.01, 5.80)	.357
Simple Green	27	31.8	2.03	(0.97, 4.25)	.058	1.05	(0.29, 3.76)	.937
De-Solv-It	19	35.8	2.21	(1.04, 4.69)	**.038**	4.82	(1.31, 17.72)	**.018**
Citriklean	20	31.2	1.82	(0.87, 3.81)	.110	1.01	(0.30, 3.42)	.988

Note: OR= odds ratio; CI=confidence interval; Ref= Reference

† N and percents are calculated from the subjects in each exposure category reporting the health outcome of interest and therefore will not add up to 100%

* P-value calculated by Wald $\chi 2$ Test unless otherwise noted; p-values in bold are considered statistically significant ($p<.05$)

** P-value calculated by 2-Tailed Fisher's Exact Test

‡ Adjusted for age, race/ethnicity, sex, alcohol consumption, belief that personal health was affected by working on the oil spill cleanup, smoking status, and original source list of the participant's name. Each self-reported oil exposure variable was also adjusted for the remaining self-reported oil exposure variables, and each self-reported chemical exposure variable was also adjusted for the remaining chemical exposure variables.

Figure 1. The Distribution and Functions of the Workforce Involved with the Cleanup in 1989, Excluding Exxon and Crawford Personnel (Carpenter and Dragnich 1991)

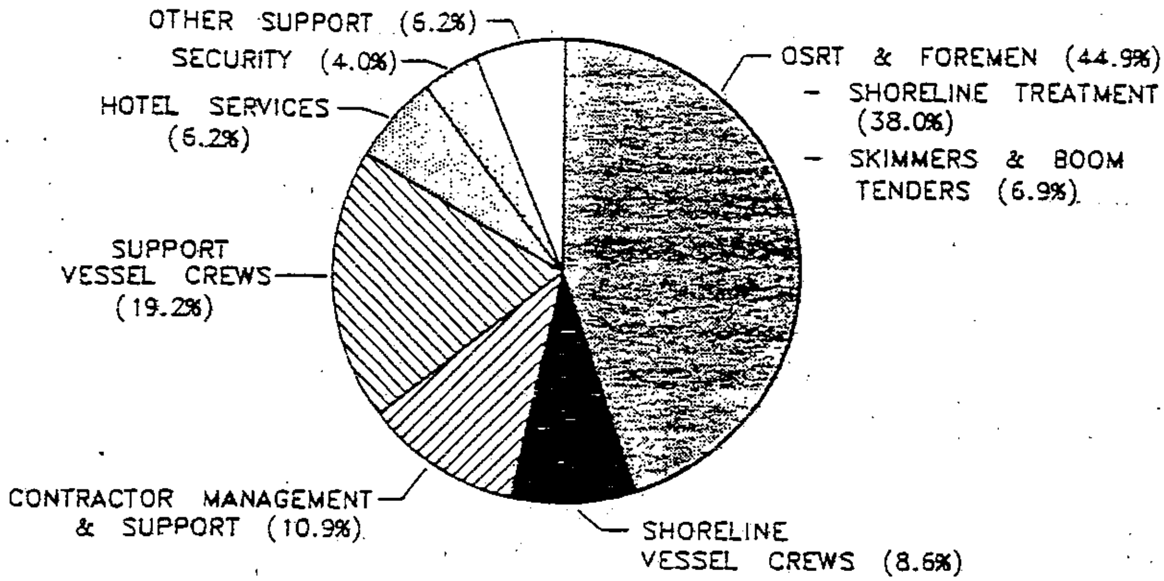


Figure 2. A Summary of the Size of the Population Employed on the Exxon Valdez Oil Spill Cleanup During the Summer of 1989 (Harrison 1991)

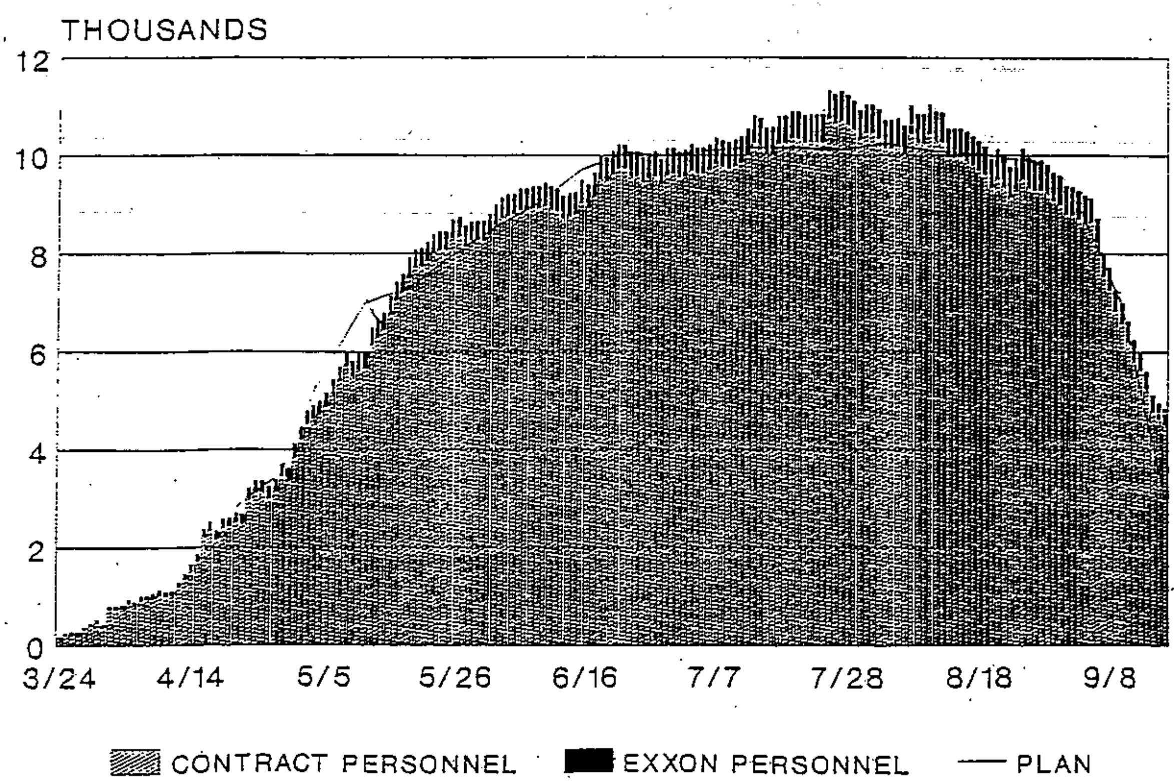


Figure 3. Exxon Valdez Oil Spill Beach Cleanup Workers (Oil Spill Response Technicians) Operating High-pressure Hot Water Hoses to Clean Oil from the Shore
(Photo courtesy of Anchorage Daily News, 1989)

Figure 4. Shoreline Oil Spill Response Technicians Surrounded by a Cloud of Aerosolized Oily Sea Spray (Photo courtesy of Anchorage Daily News, 1989)

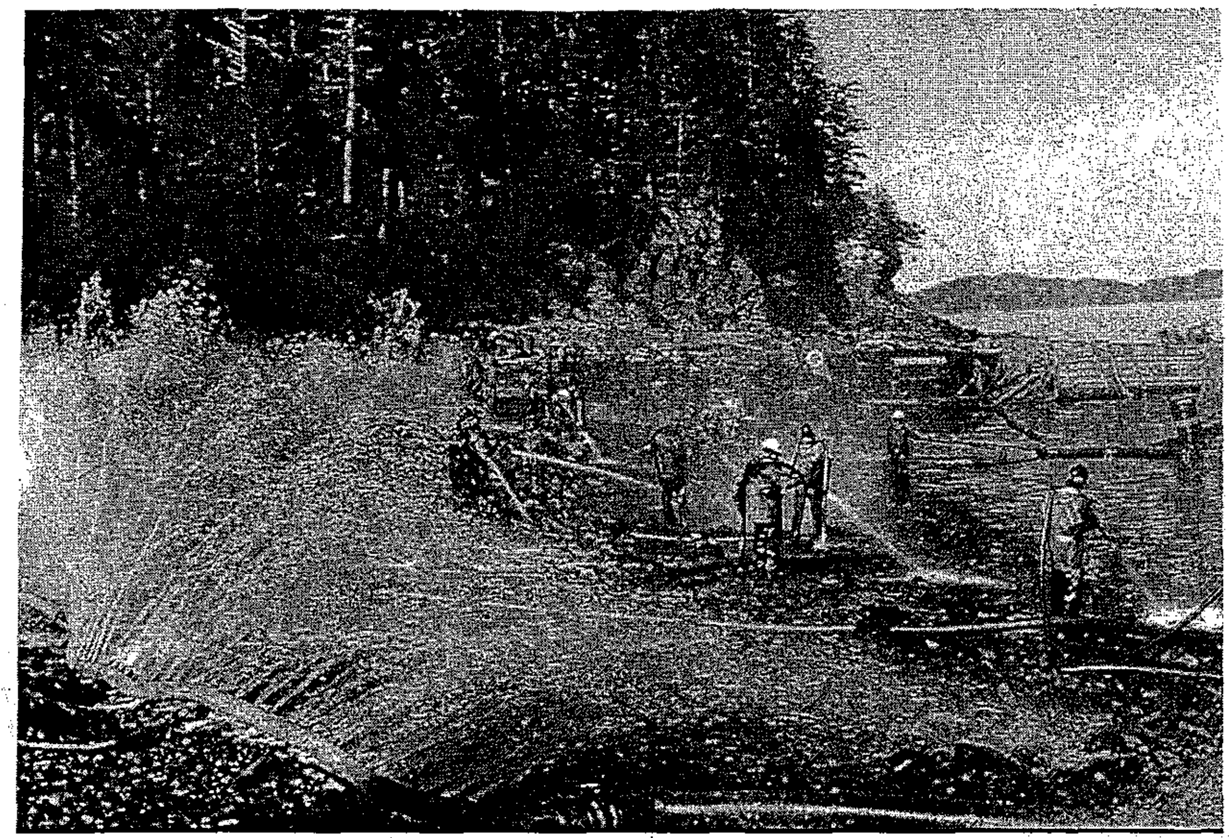


Figure 5. Exxon Valdez Oil Spill Shoreline Cleanup Workers and Small Boat Operators (Photo courtesy of Anchorage Daily News, 1989)

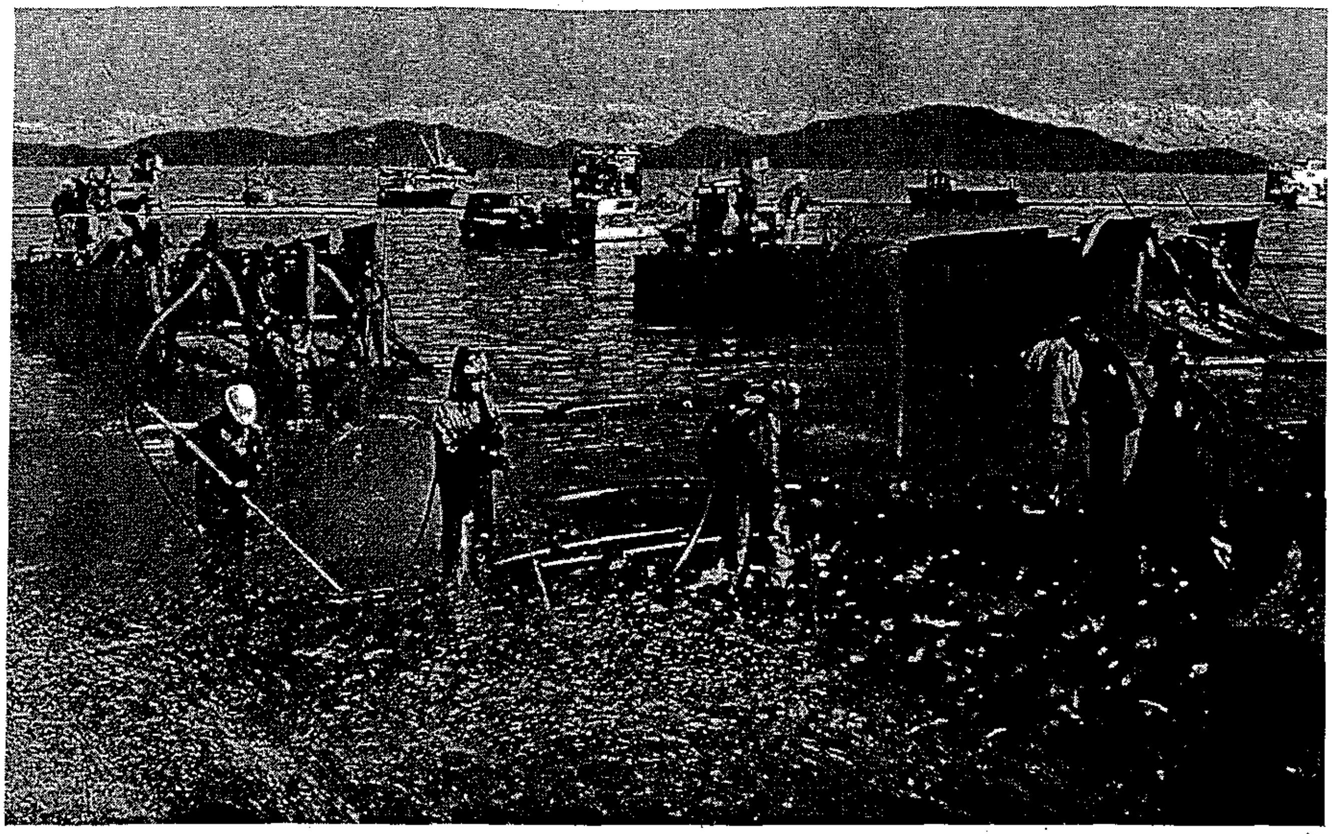


Figure 6. Omni Barge used to Spray Steep Shoreline during the Exxon Valdez Oil Spill Cleanup (Photos courtesy of Anchorage Daily News, 1989)

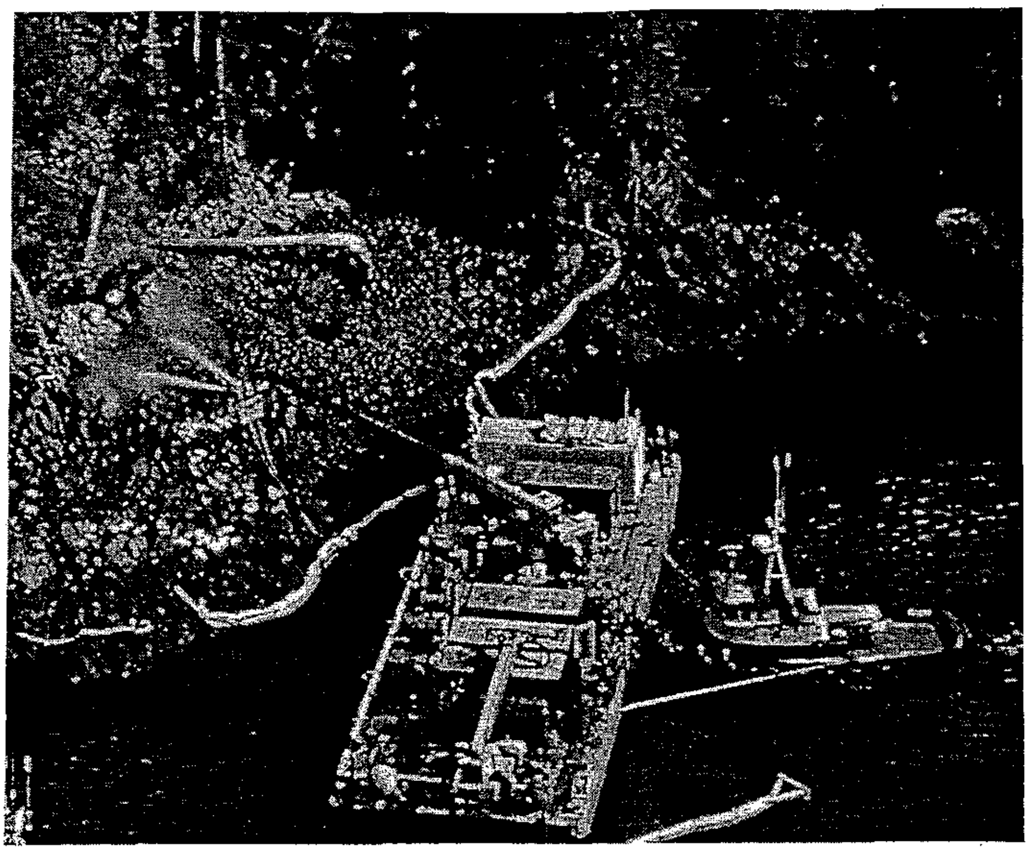
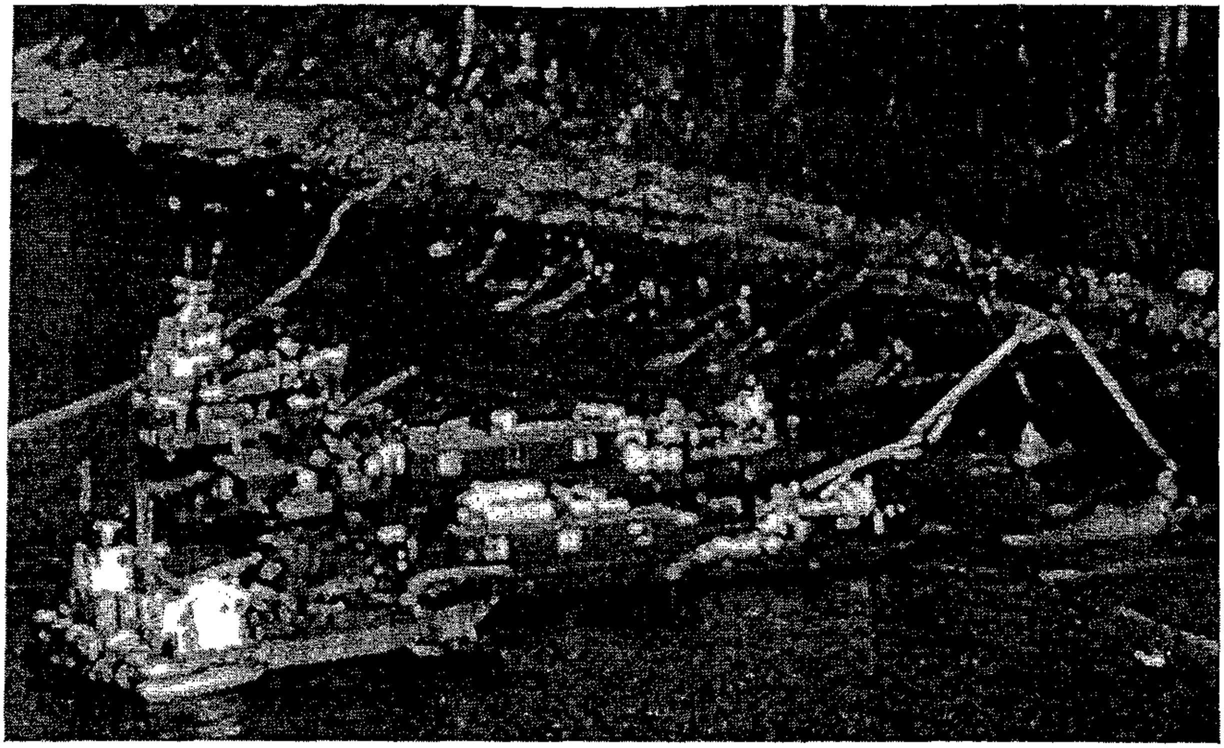


Figure 7. Omni Barges Used to Spray Oiled Shoreline During Exxon Valdez Oil Spill Cleanup. (Photo courtesy of Anchorage Daily News, 1989)



Figures 8 and 9: Bioremediation Application Crew, applying Inipol EAP22 to a Beach Through the Use of a Spray Pump Attached to a Backpack
(Photo courtesy of D. Moeller and Anchorage Daily News 1989)

APPENDIX A: SURVEY INSTRUMENT

Q.1 Hello, my name is ________ and I work for Craciun Research Group, an Alaskan company. We are conducting a research survey for researchers at Yale University, and we want to talk to people who participated in the cleanup of the Exxon Valdez oil spill. Did you help with the cleanup? (INCLUDE MANAGERIAL AND CLERICAL WORKERS AS WELL AS SERVICE CLEANUP POSITIONS)

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS 1, THEN SKIP TO QUESTION 19]

Q.2 Do you know anybody who did work on the cleanup and would be willing to talk with us?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 176]

Q.3 (ENTER NAME: JANE DOE)

____

Q.4 (ENTER PHONE NUMBER: 907-123-4567)

____

Q.5 Do you know anybody else?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 176]

Q.6 (ENTER NAME: JANE DOE)

____

Q.7 (ENTER PHONE NUMBER: 907-123-4567)

____

Q.8 Do you know anybody else?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 176]

Q.9 (ENTER NAME: JANE DOE)

____

Q.10 (ENTER PHONE NUMBER: 907-123-4567)

____

Q.11 Do you know anybody else?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 176]

Q.12 (ENTER NAME: JANE DOE)

Q.13 (ENTER PHONE NUMBER: 907-123-4567)

Q.14 Do you know anybody else?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 176]

Q.15 (ENTER NAME: JANE DOE)

Q.16 (ENTER PHONE NUMBER: 907-123-4567)

Q.17 When we call may we use your name?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 176]

Q.18 (ENTER NAME: JANE DOE)

[IF THE ANSWER TO QUESTION 1 IS NOT 1, THEN SKIP TO QUESTION 176]

Q.19 Would you be willing to answer some questions for this survey? It takes about ten to 15 minutes.

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS 1, THEN SKIP TO QUESTION 37]

Q.20 Do you know anybody who worked on the cleanup and would be willing to talk to us?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 176]

Q.21 (ENTER NAME: JANE DOE)

Q.22 (ENTER PHONE NUMBER: 907-123-4567)

Q.23 Do you know anybody else?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 176]

Q.24 (ENTER NAME: JANE DOE)

____

Q.25 (ENTER PHONE NUMBER: 907-123-4567)

____

Q.26 Do you know anybody else?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 176]

Q.27 (ENTER NAME: JANE DOE)

____

Q.28 (ENTER PHONE NUMBER: 907-123-4567)

____

Q.29 Do you know anybody else?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 176]

Q.30 (ENTER NAME: JANE DOE)

____

Q.31 (ENTER PHONE NUMBER: 907-123-4567)

____

Q.32 Do you know anybody else?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 176]

Q.33 (ENTER NAME: JANE DOE)

____

Q.34 (ENTER PHONE NUMBER: 907-123-4567)

____

Q.35 When we call may we use your name?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 176]

Q.36 (ENTER NAME: JANE DOE)

____

[IF THE ANSWER TO QUESTION 19 IS NOT 1, THEN SKIP TO QUESTION 176]

Q.37 Before we start, I need to tell you that we are conducting these interviews to get a better understanding of the health effects experienced by people who helped with the cleanup of the Exxon Valdez oil spill. I will ask you questions about your work on the cleanup, your health at the time, and your health today. The survey is for scientific research purposes, and is not part of any legal action. The research study is sponsored by Alaska Community Action on Toxins and researchers from Yale University, Medical School, Department of Epidemiology and Public Health. We will keep your identity confidential, so that it will be impossible for anybody to trace your individual survey answers to you. Your participation is totally voluntary and without cost or payment to you. You can stop anytime you want or skip any questions you do not want to answer. Your participation may benefit former and future oil spill cleanup workers by leading to better understanding of health effects associated with working on an oil spill cleanup.

Q.38 What years did you work on the Exxon Valdez oil spill? The spill was in March of 1989.

q 1 1989
q 2 1990
q 3 1991
q 4 None of the above
q 5 Don't Know/Refused

[IF THE ANSWER IS 4, THEN SKIP TO QUESTION 176]

Q.39 How many total months did you work on the cleanup?

Months .. ____

Q.40 What company did you work for?

q 1. Exxon
q 2 Veco
q 3 Chugach/NANA/Marriott
q 4 Price AHTNA
q 5 Martech
q 6 Med-Tox
q 7 Other (NOT LISTED)
q 8 Don't Know/Don't Remember/ Refused

[IF THE ANSWER IS NOT 7, THEN SKIP TO QUESTION 42]

Q.41 Specify for "Other" company

____

Q.42 I am now going to ask you about the jobs you did during the cleanup but I would only like to know about your **FIRST** job you were assigned to and the job you did for the **LONGEST** period of time.

Q.43 What was the very first job you were assigned to?

q 01 Pick up tar/oil trash, debris , handled trash bags, trash
q 02 Used hydrolic hoses and/or wan ds to spray oiled rocks/beach
q 03 Booms to contain the oil and/o r scooped up oil from water
q 04 Cleaning out ship in harbor, such as the Esseons in Seward
q 05 Ran supplies to or collected t rash from small boats on beach
q 06 Operated or was crew member on large boat omni or MAXI barge
q 07 Operated cranes or other machinery/equipment
q 08 Worked on housing barge or boa t (Cook, Medic on boat)
q 09 Collected dead/alive animals/ worked at wildlife treatment
q 10 Worked on the Bioremediation application (BAT) crew
q 11 Worked on the Decontamination (DECON) crew
q 12 Worked in town, administration , clerical, warehouse, etc.
q 13 Other (SPECIFY)
q 14 Don't Know/Refused

[IF THE ANSWER IS NOT 13, THEN SKIP TO QUESTION 45]

Q.44 Specify for "Other" job performed

____

Q.45 What was the job you did the most/ for the longest period of time on cleanup?

q 01 Pick up tar/oil trash, debris , handled trash bags, trash
q 02 Used hydrolic hoses and/or wan ds to spray oiled rocks/beach
q 03 Booms to contain the oil and/o r scooped up oil from water
q 04 Cleaning out ship in harbor, such as the Esseons in Seward
q 05 Ran supplies to or collected t rash from small boats on beach
q 06 Operated or was crew member on large boat omni or MAXI barge
q 07 Operated cranes or other machinery/equipment
q 08 Worked on housing barge or boa t (Cook, Medic on boat)
q 09 Collected dead/alive animals/ worked at wildlife treatment
q 10 Worked on the Bioremediation application (BAT) crew
q 11 Worked on the Decontamination (DECON) crew
q 12 Worked in town, administration , clerical, warehouse, etc.
q 13 Other (SPECIFY)
q 14 Don't Know/Refused

[IF THE ANSWER IS NOT 13, THEN SKIP TO QUESTION 47]

Q.46 Specify for "Other" job performed

____

Q.47 I am now going to ask you about various exposures and how you felt **DURING** the cleanup.

Q.48 Did crude oil stick to your body, face or eyes?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 50]

Q.49 Did you feel sick at that time?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

Q.50 Did you inhale oil vapors or water-oil mist?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 52]

Q.51 Did you feel sick at that time?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

Q.52 Did you breathe in diesel exhaust or fumes or exhaust from heaters or generators?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 54]

Q.53 Did you feel sick at that time?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

Q.54 Did you work around/near burning trash or oil?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 56]

Q.55 Did you feel sick at that time?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

Q.56 Did you eat food or drink beverages exposed to oil or chemicals?

(38)
q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 58]

Q.57 Did you feel sick at that time?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

Q.58 Did you work with Inipol (IN-E-POLE)?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 60]

Q.59 Did you feel sick at that time?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

Q.60 Did you work with Corexit (COR-EX-IT)?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 62]

Q.61 Did you feel sick at that time?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

Q.62 Did you work with Customblen (CUS-TUM-BLEN)?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 64]

Q.63 Did you feel sick at that time?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

Q.64 Did you work with Simple Green?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 66]

Q.65 Did you feel sick at that time?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

Q.66 Did you work with De-Solv-It?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 68]

Q.67 Did you feel sick at that time?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

Q.68 Did you work with Citriklean (SIT-RI-KLEEN)?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 70]

Q.69 Did you feel sick at that time?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

Q.70 During your work on the cleanup, were you provided with a respirator?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 72]

Q.71 How often did you wear your respirator?

q 1 Almost always (80-100% OF THE TIME)
q 2 Frequently (40-80% OF THE TIME)
q 3 Infrequently (10-40% OF THE TIME)
q 4 Never (LESS THEN 10% OF THE TIME)
q 5 Don't Know/Refused

Q.72 Was there any time that you ever stopped working because you felt overwhelmed by GASES or FUMES?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

Q.73 Did you give urine samples?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 75]

Q.74 Was there ever blood in your urine?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

Q.75 Did you ever experience the following symptoms at any time **DURING** your work on the spill?

Q.76 Dry, scratchy, or sore throat

q 1 Yes (Ever)
q 2 No (Never)
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 78]

Q.77 About how often did you experience this?

q 1 Frequently/Persistent (NEVER WENT AWAY)
q 2 Sometimes q 3 Don't Know/Refused

Q.78 A lot of phlegm or mucous in your throat and/or a persistent cough

q 1 Yes (Ever) q 3 Don't Know/Refused
q 2 No (Never)

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 80}

Q.79 About how often did you experience this?

q 1 Frequently/Persistent (NEVER WENT AWAY)
q 2 Sometimes q 3 Don't Know/Refused

Q.80 Dizziness

q 1 Yes (Ever) q 3 Don't Know/Refused
q 2 No (Never)

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 82]

Q.81 About how often did you experience this?

q 1 Frequently/Persistent (NEVER WENT AWAY)
q 2 Sometimes q 3 Don't Know/Refused

Q.82 Itchy skin or blisters

q 1 Yes (Ever) q 3 Don't Know/Refused
q 2 No (Never)

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 84]

Q.83 About how often did you experience this?

q 1 Frequently/Persistent (NEVER WENT AWAY)
q 2 Sometimes q 3 Don't Know/Refused

Q.84 Headaches

q 1 Yes (Ever) q 3 Don't Know/Refused
q 2 No (Never)

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 86]

Q.85 About how often did you experience this?

q 1 Frequently/Persistent (NEVER WENT AWAY)
q 2 Sometimes q 3 Don't Know/Refused

Q.86 Nausea or vomiting

q 1 Yes (Ever) q 3 Don't Know/Refused
q 2 No (Never)

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 88]

Q.87 About how often did you experience this?

q 1 Frequently/Persistent (NEVER WENT AWAY)
q 2 Sometimes q 3 Don't Know/Refused

Q.88 Low back pain or other muscle pain

q 1 Yes (Ever) q 3 Don't Know/Refused
q 2 No (Never)

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 90]

Q.89 About how often did you experience this?

q 1 Frequently/Persistent (NEVER WENT AWAY)
q 2 Sometimes q 3 Don't Know/Refused

Q.90 Trembling or numbness in your legs, arms, hands or feet

q 1 Yes (Ever) q 3 Don't Know/Refused
q 2 No (Never)

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 92]

Q.91 About how often did you experience this?

q 1 Frequently/Persistent (NEVER WENT AWAY)
q 2 Sometimes q 3 Don't Know/Refused

Q.92 Did you file any claims with the Alaska Workers' Compensation Board, the state or federal Department of Labor or any legal suits because of your injuries or illnesses from working on the spill?

q 1 Yes q 3 Don't Know/Refused
q 2 No

Q.93 I am now going to ask you some questions about your medical history.

Q.94 Do you have or did you ever have Leukemia (LUK-EE-MIA)?

q 1 Yes q 3 Don't Know/Refused
q 2 No
[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 96]

Q.95 What year were you diagnosed?

Year .. ________

Q.96 Do you have or did you ever have Multiple Myeloma (MY-LO-MA)?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 98]

Q.97 What year were you diagnosed?

Year .. ________

Q.98 Do you have or did you ever have Hodgkins Disease (HOJ-KINS)?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 100]

Q.99 What year were you diagnosed?

Year .. ________

Q.100 Do you have or did you ever have Lymphoma (cancer of lymph nodes) (LIM-FO-MA)?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 102]

Q.101 What year were you diagnosed?

Year .. ________

Q.102 Do you have or did you ever have Lung cancer?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 104]

Q.103 What year were you diagnosed?

Year .. ________

Q.104 Do you have or did you ever have Liver cancer?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 106]

Q.105 What year were you diagnosed?

Year .. ________

Q.106 Do you have or did you ever have any other kind of cancer?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 109]

Q.107 What kind?

____

Q.108 When were you diagnosed? (ENTER MONTH AND YEAR)

Month ..________ Year ....________

Q.109 Have you had any tumors that are not cancerous such as sinus polyps?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 112]

Q.110 What kind?

____

Q.111 When were you diagnosed? (ENTER MONTH AND YEAR)

Month ________ Year ________

Q.112 Have you ever been diagnosed by a doctor with Kidney disease?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 114]

Q.113 When were you diagnosed? (ENTER MONTH AND YEAR)

Month . ________ Year ....________

Q.114 Have you ever been diagnosed by a doctor with Poisoning from solvents?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 116]

Q.115 When were you diagnosed? (ENTER MONTH AND YEAR)

Month ..________ Year .... ________

Q.116 Have you ever been diagnosed, by a physician, with Hepatitis (Liver Infection)?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 118]

Q.117 When were you diagnosed? (ENTER MONTH AND YEAR)

Month ..________ Year .... ________

Q.118 Now we would like to focus further on your current life and health. Think how you have been feeling **this past year**. During this past year, did you have any of the following medical conditions?

Q.119 Did you have Sleep apnea (AP-NEE-A) or narcolepsy (NAR-CO-LEP-SEE)?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 121]

Q.120 In what year and month did it begin?

Month ..________ Year ....________

Q.121 Did you have Pneumonia (NEW-MOAN-EEA)?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 123]

Q.122 In what year and month did it begin?

Month ..________ Year ....________

Q.123 Did you have any other lung condition?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 125]

Q.124 In what year and month did it begin?

Month ..________ Year ....________

Q.125 Did you have chronic sinus problems and/or chronic ear infections?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 127]

Q.126 In what year and month did it begin?

Month ..________ Year ...________

Q.127 During the past year, have you had a cough and produced a lot of phlegm/mucous for more than 3 months in a row?

q 1 Yes
q 2 No q 3 Don't Know/Don't Remember/ Refused

Q.128 Have you ever been told by a doctor that you have asthma?

q 1 Yes
q 2 No q 3 Don't Know/Don't Remember/ Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 130]

Q.129 What year were you diagnosed?

Year ..________

Q.130 During the past month, have you had persistent or recurring problems with Amnesia or problems with your memory?

q 1 Yes q 3 Don't Know/Refused
q 2 No
[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 132]

Q.131 When did you first experience this?

Month ..________ Year ....________

Q.132 During the past month, have you had problems thinking clearly and/or concentrating?

q 1 Yes q 3 Don't Know/Refused
q 2 No
[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 134]

Q.133 When did you first experience this?

Month ..________ Year ....________

Q.134 During the past month, have you been making slips of the tongue when speaking?

q 1 Yes q 3 Don't Know/Refused
q 2 No

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 136]

Q.135 When did you first experience this?

Month ..________ Year ....________

Q.136 During the past month, have you had problems with feeling confused or disoriented in place or time? (Feeling confused about where you are, who is around, or not knowing what day it is.)

q 1 Yes q 3 Don't Know/Refused
q 2 No
[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 138]

Q.137 When did you first experience this?

Month ________ Year ________

Q.138 Have you ever seen a physician for any of these conditions?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

Q.139 During the past year, did you start feeling sick (headache, nausea, difficulty breathing, dizziness etc.) when you smell or are around substances like gasoline, hair spray, paint, household cleaners, perfumes, soaps, cigarette smoke, vehicle exhaust, pesticides, newspapers or other chemicals?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 143]

Q.140 In what year did this first begin?

Year ________

Q.141 Have you seen a physician for any of the symptoms?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

Q.142 Have you changed your lifestyle because of these problems?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

Q.143 Now I am going to read a list of symptoms. During the past year, have you had any of these problems?

Q.144 Skin redness, rash or open sores

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 146]

Q.145 When did you **FIRST** start experiencing these symptoms?

Year ________

Q.146 Persistent hoarseness

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 148]

Q.147 When did you **FIRST** start experiencing these symptoms?

Year ________

Q.148 Tremors or shaking

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 150]

Q.149 When did you **FIRST** start experiencing these symptoms?

Year ________

Q.150 Seizures or convulsions

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 152]

Q.151 When did you **FIRST** start experiencing these symptoms?

Year ________

Q.152 Faintness, lightheadedness or dizziness

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 154]

Q.153 When did you **FIRST** start experiencing these symptoms?

Year ________

Q.154 Numbness or tingling in parts of your body

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 156]

Q.155 When did you **FIRST** start experiencing these symptoms?

Year ________

Q.156 Frequent nosebleeds

q 1 Yes
q 2 No
q 3 Don't Know/Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 158]

Q.157 When did you **FIRST** start experiencing these symptoms?

Year ________

Q.158 Have you seen a physician for any of these conditions?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

Q.159 Have you had Anemia (A-NEE-MEE-A)?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 161]

Q.160 When were you first diagnosed with this condition?

Month ________ Year ________

Q.161 Have you had any other blood conditions?

q 1 Yes
q 2 No
q 3 Don't Know/Don't Remember/ Refused

[IF THE ANSWER IS NOT 1, THEN SKIP TO QUESTION 164]

Q.162 When were you first diagnosed with this condition?

Month ________ Year ________

Q.163 What type?

____

Q.164 How many alcoholic drinks do you have a week? (IF ASKED: One drink of alcohol counts as one beer, one glass of wine or one shot of hard alcohol)

q 1 0-1
q 2 2-5
q 3 6-10
q 4 11 or more
q 5 Don't Know/Refused

Q.165 Have you ever smoked cigarettes (ever= 6 or more months)?

q 1 Yes (Ever)
q 2 No (Never)
q 3 Don't Know/Refused

Q.166 Besides working on the spill, do you or did you work in the oil industry, such as an oil tanker, in oil drilling operations, in an oil refining plant and/or on another oil spill besides the Exxon Valdez oil spill?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

Q.167 Do you often work with hazardous chemicals or in hazardous waste disposal?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

Q.168 Do you have a medical disability that currently keeps you from working?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

Q.169 Do you believe working on the oil spill has affected your health?

q 1 Yes
q 2 No
q 3 Don't Know/Refused

Q.170 What is your age?
Age ____

Q.171 Gender (INTERVIEWER RECORD)

q 1 Male
q 2 Female

Q.172 What is your ethnic heritage?

q 01 Hispanic, Latino, Spanish
q 02 Caucasian
q 03 African American
q 04 Asian American
q 05 Pacific Islander/Hawaiian
q 06 Alaskan Native
q 07 American Indian
q 08 Other (PROBE FIRST)
q 09 Don't Know/Refused

[IF THE ANSWER IS NOT 8, THEN SKIP TO QUESTION 174]

Q.173 Specify for "Other" ethnic heritage

____

Q.174 Is there anything else you would like to share with us about your work on the oil spill, your health or any friends/coworkers who also helped on the Exxon Valdez oil spill?

____

____

Q.175 I want to give you a phone number now, do you have a pencil? The number is for Alaska Community Action on Toxins which is in Anchorage: (907) 222-7714. You may call Lorraine at this number if you have any questions, or if you want a copy of the results of this survey in June or July of this year.

Q.176 Thank you for your time.

APPENDIX B

INFORMATION FORM FOR PARTICIPATION IN A RESEARCH PROJECT
YALE UNIVERSITY SCHOOL OF MEDICINE
DEPARTMENT OF EPIDEMIOLOGY AND PUBLIC EHALTH

Invitation to Participate and Description of the Research Project entitled:
Exxon Valdez Oil Spill Cleanup Workers Health Survey
Funding Source: This project is funded by a grant through the Alaska Conservation Foundation.

You are invited to participate in the Exxon Valdez Oil Spill (EVOS) Cleanup Worker Health Surveillance Survey. You have been chosen for this study because state Department of Labor records indicate that you were involved with the EVOS cleanup during 1989, 1990 and/or 1991. We request your participation in this survey because at this point, the health effects experienced by former EVOS cleanup workers have not been assessed and are not fully understood. This survey is designed to identify health symptoms experienced by workers which may be associated with substances you may have been exposed to while working on the EVOS cleanup. As part of this program, interviews will be conducted to ask questions about your work history and health symptoms. The goal of this project is to discover risk factors and patterns for diseases related to work on the oil spill cleanup.

This program is sponsored by a grant from the Alaska Conservation Foundation and administered by Alaska Community Action on Toxics (ACAT), Alaska Forum for Environmental Responsibility (AFER) the Alaska Injured Workers Alliance and researchers from Yale University School of Epidemiology and Public Health in New Haven, CT.

In order to decide whether or not you wish to participate in this research survey, you should know enough about its risks and benefits to make an informed judgment. This information form gives you detailed information about the research study which a member of the research team will discuss with you. This discussion should go over all aspects of this research; its purpose, the procedures that will be performed, any risks of the procedures and possible benefits. Once you understand the study, you will be asked if you wish to participate. If so, you will be asked to give verbal consent to an interviewer who contacts you on the telephone. The interviewer will be calling you in approximately two weeks to discuss this information with you and invite you to participate. At that time, please feel free to ask the interviewer any questions you may have about the survey.

DESCRIPTION OF PROCEDURES

After the interviewer contacts you, you will be asked whether you wish to participate in a brief telephone interview. Once you agree to participate, the interviewer will either interview you at that time or schedule an appointment to call you back to conduct the interview. The survey will take about ten to fifteen minutes to complete. This interview will help us determine the agents you may have been exposed to while working on the EVOS cleanup. We will ask you questions about the jobs you performed on the cleanup, how you felt during those jobs, and how your general health is today. After you complete the interview, your results will first be coded to remove any of your personal identification information such as your name and address, and will then be analyzed by researchers at the Yale University School of Epidemiology and Public Health. We will analyze these results to attempt to identify patterns in exposures and illnesses among various job tasks from the EVOS cleanup.

Risks and Inconveniences

The only risk to you for participating in this interview is a breach of confidentiality, or someone outside of the research team finding out that you are participating in this research study. We will take all measures possible to ensure that this doesn't happen. Please refer to the "Confidentiality" section below to review the various steps the research team will take to ensure that any information you give will be kept strictly private and confidential. The time commitment the interview would require is approximately ten to fifteen minutes. Professional interviewers will call you to schedule a convenient time for you to complete the interview. We greatly appreciate your cooperation and time you may be able to give us with this study.

Benefits

By participating in this survey, you may benefit in increased knowledge about the health of workers from the cleanup. Your participation may also benefit future workers by helping to identify trends in exposures and illnesses, and could lead to regulatory improvements which may help better protect workers like you in future oil spills and other hazardous waste cleanup operations. Information from this research could be used to better protect workers like you in the future.

We will provide you with a summarized copy of the results if you wish to receive this information. Furthermore, we will provide you with a list of potential social services and medical resources, should you wish to pursue these services. However, we are not endorsing any particular organization and cannot sponsor these services as part of our study. We are only conducting an interview, but feel that you may benefit from a list of these service providers, should you wish to pursue such assistance on their own. A list of these services can be obtained by contacting Alaska Community Action on Toxics (ACAT) at 1-907-222-7714. You may call ACAT and receive this information even if you do not wish to participate in the interview.

ECONOMIC CONSIDERATIONS

This survey is entirely voluntary and without cost to you. You will not be compensated for your participation. This study is only funded for a limited period of time. We cannot assure that it will continue in the future or that another program will be installed to take its place.

CONFIDENTIALITY

All personal information gathered for this program will be kept strictly private and confidential. Once you complete the telephone interview, your name and personal information will be removed from your survey answers and they will be replaced with a code number. There will be no master list of code numbers and personal identification, so it will be impossible to trace your individual survey answers to you. Your survey answers will be entered by research personnel into a dedicated computer that is password protected and accessible only by Yale researchers who will not release this information to anyone not involved with the study. The list used by the researchers to contact you and conduct the survey will be destroyed . All research files will be stored in a locked file cabinet and will only be accessed for purposes of data analysis. All presentation and publication of results will be conducted without any of your personal information included.

VOLUNTARY PARTICIPATION

You are free to choose not to participate in this survey and if you do become a participant you are free to withdraw from this study at any time during its course. If you choose to participate, you are also free to decline answering any questions you choose. If you do not participate, it will not affect your future relations with ACAT, Alaska Conservation Foundation or Yale University.

SUMMARY

This research study is a survey of former Exxon Valdez oil spill cleanup workers conducted by telephone interviewers. The goal of this study is to assess patterns in health effects experienced by EVOS workers and to compare these effects to various exposures encountered in specific job tasks during the cleanup. If you decide to participate, you will take part in an interview which will take approximately thirty minutes to complete. This interview will ask about your work on the cleanup, your health at the time, and your health today. No personal identification information such as your name or address will be stored with your survey answers, and thorough steps will be taken to protect your confidentiality at all times. Your participation is totally voluntary and without cost or payment to you. We greatly appreciate your time and help if you choose to participate in this project.

QUESTIONS

If you have any questions and would like to discuss this study before making a decision to participate, please call 1-907-222-7714. Please be sure to leave a detailed message that includes the time when you can be called back, in the case no one is available to answer the phone. If you have any questions about your rights as a research study participant, you may contact the Yale Human Investigation Committee at (203) 785-4688.

APPENDIX C

A summary of the health conditions which were not reported in sufficient numbers to permit analyses with exposure variables

Among the entire study population, there were no reported cases of multiple Myeloma, lung cancers or liver cancers. There was one reported case each of: Leukemia, Hodgkin's Disease, lymphoma, and physician diagnosis of poisoning from solvents. Among these responses, there was one single worker who reported all three of the following: Hodgkin's Disease, poisoning from solvents and lymphoma. His first job was working to deploy booms and as a skimmer, and his longest job was in town or a warehouse. The worker with leukemia was a wildlife treatment worker for his first and longest job. The prevalence of kidney disease and hepatitis was evenly distributed among both the oil and chemical exposure categories, as was the prevalence of both benign tumors and other cancers. Other cancers which were present in the population in more than one individual include prostate, kidney, thyroid and skin (n=2 for each cancer type).

There were no significant associations between any exposures or exposure categories and cancers, which is probably due to a very small prevalence of these conditions.

APPENDIX D

Several notable verbatim responses from survey participants to the final survey question: "Is there anything else you would like to share with us about your work on the oil spill, your health or any friends/coworkers who also helped on the Exxon Valdez oil spill?"

"I believe we should have had respiratory masks. There should also have been continuous monitoring of benzene and hydrocarbons."

"When I was there, I just did my job. If they told me something that I wasn't sure about health-wise, I didn't do it."

"The worst health problem at that time was dehydration. We really didn't have enough clean water to drink."

"They didn't tell us about the chemicals. We had blood in our urine. They made us work on the same beach after that."

"There is a lot of people with internal bleeding out on the water. Some of these people took pee tests. They would move them because of danger."

"Sometimes I noticed under my arms…large red bumps from chemicals. I asked around and found that I wasn't the only one. Definitely from chemical use."

"As far as I know, no one has any problems."

"People from the bioremediation crews did a lot of complaining about health problems."

"My exposure to the oil was minimal, due to the work I did was for a short duration."

"I lost my sense of smell but I'm not sure if it was because of the cleanup."

"I was reassigned and the fumes began to bother me."

"The positive thing is better protection for workers."

"I was pregnant four months [during the cleanup]."

"I hated seeing all those critters floating ashore. I hope to get another job like that, only under better circumstances."

"I was only involved for a short time. I was not affected by the chemicals and I do not recall any friends that were sick."

"It was just a job and I enjoyed the job."

"They should have told us from the beginning about the health problems, the right to know."

"I worked my two vessels for $3000 a day each. 7 days a week we left that job, we did all the good that we could do."

"I wish they would tell us what was going on, especially, why did they spray the boats and beaches at night, and they didn't tell us what the chemical was."

"Phlegm and coughing was amongst co-workers. We were exposed to this from using the high pressure that put the mist in the air."

"One guy got burns on his arms from chemicals."

"I didn't actually work on the hands on. I worked the surveys and was not actually exposed to the oil."

"The animals were affected more than the workers"

"I don't believe anyone was exposed to any oil that affected them. We did air monitoring. We wore protective gear."

"I had a rash 2 ½ years after I finished working… on my arms and back."

"I don't personally know anyone who got sick from the oil spill. I consider myself to be in good health."

"I was diagnosed with Reyes syndrome [after the cleanup]"

"I worked at Valdez Marine Terminal prior to the spill. It is of higher risk working in that terminal."

"The shipping company (VECO) was not clear on info or training about our exposure."

"Me and my wife were highly exposed. We were there on the first night and can't think of anyone more exposed. We were right there at the Exxon Valdez."

"I sent memos on a regular basis to the main office requesting respirators and protective gear. It took until the first of July…most complaints were [for] better equipment."

"I thought they did a pretty good job keeping us safe, unless people didn't follow the rules."

"I think they used us as guinea pigs."

"The only thing is that I can't connect anything specifically to the oil spill, health wise."

"Early during the spill we weren't issued safety equipment."

"In the past 5 years, I've had an increased sensitivity to paint fumes."

"Six months after working on the oil spill I developed...non Hodgkins Lymphoma."

"I am little, 4 ft 10 in, and they had no protective clothes that fit me. I was working on the beach in civilian clothes, and oil was soaking into my skin. I had a baby after working on the spill and he was born at 1 lbs, 4 oz, born in the fifth month, with lung disease."

"I believe a lot of us were affected emotionally, post-traumatic syndrome."

"A lot of the people I knew had high stress and depression."

"The cleanup caused more damage than the spill. The people were there to get rich...people used nets to catch clean birds to dip them in the oil to keep their contracts."

"Never got near the oil."

"People who worked on the beaches had complaints similar to the symptoms mentioned in this survey."

"I think there was also psychological impact and stress related health effects."

"The physical problems that others experienced were due to lack of wearing protective gear."

"We just don't know enough about the long-term health."

"Exxon did an excellent job on the cleanup."

"The cleanup was a complete failure... There is still oil there [on the beaches]"

"We didn't get any protective gear."

"Since 1995 my feet have been getting numb (anti-magneuropathy) and I am not sure of that diagnosis."

"I was diagnosed with Fibromyalgia in 1990. My doctor believes that this is a direct effect from the oil spill."

"I was one of the very first hired. I was within 200 feet of the oil spill burn off. Throughout my experience I had a sore throat, coughing all the time. All they gave me was ampicillan, penicillin and other standard meds like that."

"You noticed that some of my co-workers were overcome with fumes when we washed the rocks on the beaches."

"I don't think that we were protected enough. We were put into situations that was totally uncalled for. Lack of decontamination when we got back into the vessel."

"It would have been nice to have been forewarned of possible physical effects."

"Exxon cover up- period."

"I have been diagnosed with a severe under-active thyroid began to affect me during the oil spill cleanup."

"I'm extremely interested in any long-term health effects."