Diving For Science 2009
Proceeding of the
American Academy of Underwater Sciences
28th Scientific Symposium

Neal W. Pollock
Editor

Atlanta, GA
March 13-14, 2009

In: Pollock NW, ed. Diving for Science 2009.
Proceedings of the American Academy of Underwater Sciences 28th Symposium.Dauphin Island, AL: AAUS; 2009.

Diver Exposure Scenario for the Portland Harbor Risk Assessment

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Abstract

Recreational, public safety and commercial diving occur in contaminated harbors. Much of this diving continues to be undertaken without adequate protective gear thereby exposing the diver to a variety of chemicals and possible health risks. The Portland Harbor Superfund site is a stretch of the Willamette River located north of Portland, Oregon. Diving practices have been observed at the Superfund site that may lead to or exacerbate exposure from contaminants in water and sediment for recreational, public safety, and commercial divers and dive tenders. These practices include the use of wetsuits, use of recreational regulators, use of hardhats not mated directly to the drysuit, lack of proper decontamination, and use of materials not suitable to decontamination. The Human Health Risk Assessment that is being done for the Portland Harbor Superfund site will include a quantification of the possible risks for divers who use wetsuits or drysuits where the hardhat is not mated directly to the drysuit. For the wetsuit exposure, dermal exposure to contaminants in surface water and sediment is assumed to occur over the entire body. For the drysuit with neck dam, dermal exposure is assumed to occur to the head, neck and hands. For both wetsuit and drysuit use, inadvertent ingestion of contaminated sediments and surface water is also being evaluated. The results of the diver risk assessment will be used to educate the dive community of possible negative health outcomes when appropriate, required equipment and decontamination are lacking. The intent of this paper is to give an overview of polluted water diving procedures and equipment that are available to protect the diver and discuss the lack of adherence to these by some divers in Portland Harbor. The risk assessment methods and exposure assumptions that will be used to quantitatively evaluate the potential risks from diving when appropriate personal protective equipment and decontamination are lacking will also be discussed. Future efforts will be targeted at using this quantitative exposure and risk evaluation to reduce polluted water and sediment diver exposures in Portland Harbor.

Keywords: polluted water diving, risk assessment of diver exposure, Portland Harbor cleanup

Introduction

The potential health risks for persons who dive in the Portland Harbor Superfund site will be evaluated as a part of the Portland Harbor Remedial Investigation (RI). This paper summarizes the agreement reached for the diver evaluation by EPA and its partners, including the Oregon Department of Environmental Quality, and the potentially responsible parties for the contamination found within the site. In the Portland Harbor Superfund site, an approximately 11 mile stretch located at the lower end of the Willamette River and north of Portland, Oregon, diving is done by several groups of people including: the public for recreation and gathering of biota for consumption; the sheriff's office for investigations and emergency activities; and, commercial divers for a variety of purposes, including marine construction, underwater inspections, routine operation and maintenance, and activities related to environmental work. In addition, both government and contracted scientific diving work is taking place for various types of sample collection. The majority of divers are expected to be commercial divers or government or contract divers diving under the Occupational Safety and Health Administration (OSHA) scientific diving exemption (OSHA CFR 1910 Subpart T). As Portland Harbor is an active harbor, commercial and scientific diving is anticipated to continue into the future, and in an intensive fashion to support the investigation and cleanup of the site over the next several decades.

Methods

Divers are expected to be exposed to contaminants in both sediment and water in the Portland Harbor Superfund site. Contaminants include metals, pesticides, polycyclic aromatic hydrocarbons (PAHs), volatile and semi-volatile organics (VOCs/SVOCs), polychlorinated biphenyls (PCBs), and polychlorinated dibenzodioxins, and dibenzofurans. In addition, frequent sewer overflows contribute high bacteria counts during rain events (USEPA 1998). Though there are methods to limit diver exposure to these contaminants which have been widely published and available since 1985, these methods are not always employed. These methods include: keeping the diver completely dry through use of a drysuit, utilization of drygloves, ensuring materials including the drysuit are constructed of an easily decontaminated material such as vulcanized rubber (EPA, 1985), use of a full face mask that seats on a dryhood or preferably a hardhat that mates directly to the drysuit (USEPA 1985; Barsky 1999), appropriate training, and thorough decontamination such as a potable water post-dive rinse (USEPA 2001). For example, inappropriate drysuit material (neoprene) and wet gloves are being used at a site in Portland Harbor (Figure 1). A neoprene drysuit cannot be decontaminated and can spread contaminants onto the boat and potentially to the next dive operation. The reason for prevalent use of wetsuits in Portland Harbor is twofold: higher cost of drysuits versus wetsuits and river temperature. The Willamette River is Clean Water Act 303d listed (Clean Water Act § 303(d) List of Impaired Waters: http://yosemite.epa.gov/R10/WATER.NSF/TMDLs/CWA+303d+List/) as a temperature impacted area with the Lower Willamette reaching average temperatures of over 70°F in the summer months. EPA's experience is that most contractors on the Willamette River are still using or initially propose use of wetsuits. As an example, both EPA's contractor for oversight of a manufactured gas plant (MGP) site and a diver working at the MGP site noted that other divers at the site "definitely were not suited up or following the rigid health and safety requirements" and were wearing gear that "one would use for recreational diving in the tropics" (Davoli 2008, personal communication). Wet gloves are used (Figure 2), which the divers may have deemed necessary due to impingement hazards that may compromise dry gloves. Wet gloves used in polluted water cannot be decontaminated and should be disposed of after dive operations and/or specially managed to not expose tenders and divers on this or the next dive operation. Wet gloves also potentially introduce dermal exposure to the diver during the dive. A better course might be to put nitrile or rubber gardening-type gloves over the drygloves to offer some chaffing protection, and then dispose of all the gloves after the dives. Another example of commercial dive exposure in the river is a solo diver for hire who makes himself available to find lost items, such as car keys, in marinas throughout Portland Harbor, utilizing a wetsuit and recreational regulator to "dig around in the muck" using scuba or freediving to find lost items (Oregon Public Broadcasting 2008).

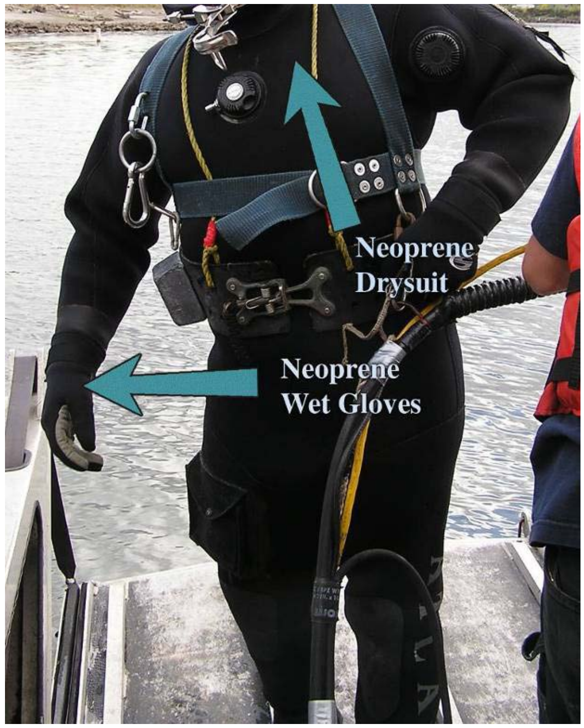

Figure 1. A diver exiting the water at a Portland Harbor Superfund cleanup site.

Figure 2. A diver exiting the water at a Portland Harbor Superfund Cleanup site.

As a part of the human health risk assessment required for the Portland Harbor Superfund site, the potential risk to divers from sediment and water will be assessed. US EPA's Superfund guidance recommends that exposure be evaluated for the "reasonable maximum exposure" (RME) as well as for an average exposure (*i.e.,* central tendency [CTE]) (USEPA, 1989; 1992). For the diver scenario for the Portland Harbor risk assessment, exposure is assumed to occur in four ways: dermal exposure (absorption through the skin) from water, dermal exposure from sediment, inadvertent ingestion of water and inadvertent ingestion of sediment.

Two scenarios have been selected for the RME based upon diving practices in Portland Harbor. For the first RME scenario, referred to as the wetsuit RME, a diver is assumed to be a commercial diver wearing a wetsuit without a full face mask and wearing wet gloves or no gloves. Therefore, dermal exposure to water and sediment is assumed to occur over the entire body. For the second RME scenario, referred to as the drysuit neck dam scenario, a diver is assumed to be a commercial diver who wears a drysuit and hardhat attached through a neck dam rather than having a helmet mated to the drysuit. This diver is also expected to be wearing wet gloves. For this diver, dermal exposure to water and sediment is assumed to occur to the head, neck and hands. For both RME scenarios, inadvertent ingestion of water and inadvertent ingestion of sediment are assumed to be the same since both diver scenarios assume face exposure, wet gloves, and inadvertent exposure in the water and on the boat. Inadvertent exposure to sediment on the boat can occur as a result of the absence of or lack of attention to thorough decontamination (*e.g.,* donning and removing diving suits that have not been decontaminated and/or handling gear which cannot be decontaminated such as a neoprene drysuit or wetsuit and eating food with contaminated hands).

An average exposure scenario will also be included assuming use of a wetsuit without a full face mask and wearing wet gloves or no gloves. For the CTE scenario, the exposure routes are the same as that for the corresponding wetsuit RME scenario but the exposure values have been reduced for some exposure parameters.

To evaluate the potential exposure and health risks for a diver, information is needed on the level of contaminants in the media (*i.e.,* sediment and water) that that diver is being exposed to as well as information on the diver's behavior (*e.g.,* type of equipment worn, frequency and duration of diving, years spent diving, and amount of inadvertent sediment and water ingestion) and the diver's characteristics (*e.g.,* body weight, surface area of the body).

For the Portland Harbor risk evaluation for divers, data collected as a part of the Superfund site Remedial Investigation (RI; http://yosemite.epa.gov/R10/CLEANUP.NSF/ph/Technical+Documents) and other studies are available to provide information on sediment and water contaminant levels that a diver might be exposed to. In the risk evaluation method described below, the information on diver behavior and characteristics is from a variety of sources.

Most of the equations, exposure assumptions, and/or calculation of exposure values are consistent with EPA's Risk Assessment Guidance for Superfund, Part A (USEPA 1989) and/or Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual Supplemental Guidance "Standard Default Exposure Factors," Interim Final (OSWER Directive 9285.6-03, March 25, 1991; OSWER 1991). However, others as noted below are based upon other EPA guidance, were calculated using Portland Harbor site-specific information, or were based on Best Profession Judgment (BPJ).

SEDIMENT EXPOSURE
Sediment Ingestion

For sediment ingestion by divers, the general equation for soil ingestion from EPA's Risk Assessment Guidance for Superfund (USEPA 1989) is used but chemical concentration in soil is replaced with the chemical concentration in sediment.

$$\text{Daily Intake } (mg \cdot kg^{-1} \cdot day^{-1}) = \frac{EPC \cdot SIR \cdot EF \cdot ED \cdot CF}{BW \cdot AT}$$

where:

Daily Intake- milligrams of a contaminant in sediment (dry weight) ingested per kilogram body weight per day ($mg \cdot kg^{-1} \cdot day^{-1}$)
RME - Reasonable maximum exposure
CTE - Central tendency exposure
EPC - Exposure Point Concentration, chemical concentration in sediment ($mg \cdot kg^{-1}$ dry weight)
SIR - Sediment Ingestion Rate ($mg \cdot day^{-1}$); [both RMEs (use of a wetsuit or a drysuit with neck dam) 50 $mg \cdot day^{-1}$; CTE = 25 $mg \cdot day^{-1}$]
EF - Exposure Frequency ($days \cdot year^{-1}$) [both RMEs= 5 $days \cdot year^{-1}$; CTE = 2 $days \cdot year^{-1}$]
ED - Exposure Duration (years) [both RMEs=25 years; CTE=9 years]
CF - Conversion Factor ($kg \cdot mg^{-1}$) [10^{-6}]
BW - Body Weight (kg) [both RMEs /CTE = 70]
AT - Averaging Time (days) – [Cancer RMEs/CTE=25,550 days; Non-cancer RMEs=9,125 days and Non-cancer CTE=3,285 days].

Exposure Point Concentration (EPC or Chemical Concentration in Sediment) **-** It is expected that divers could dive in any part of the Portland Harbor site and, therefore, be exposed to near-shore contaminated sediment from areas throughout the site. For divers, the Willamette River will be divided into half-mile near-shore segments on each side of the river. The sediment samples in each near-shore segment on each side of the river will be used to estimate exposure point concentrations (EPCs). The arithmetic mean will be used as the EPC for the central tendency exposure (CTE) and the 95% upper confidence limit (UCL) on the arithmetic mean will be used for the EPC for the reasonable maximum exposures (RME) scenario (OSWER, 1989).

Sediment Ingestion Rate (SIR) **-** The sediment ingestion rates chosen for divers are 50 mg/day for both RMEs and 25 $mg \cdot day^{-1}$ for the CTE. The 50 $mg \cdot day^{-1}$ is the value for soil ingestion recommended for commercial/industrial workers (OSWER, 1991). The 25 $mg \cdot day^{-1}$ is one-half of the value recommended for workers and is based upon best professional judgment. The authors, being familiar with diving and overseeing commercial divers within the Portland Harbor site, have suggested that the sediment ingestion rate could be higher for divers for several reasons, including the fact that divers potentially have more direct contact with sediments in the water and that residual contaminant loading on the hands of divers (including those who use wet or dry gloves) may be higher and result in higher exposures when foods are consumed on the boat (D. Davoli, personal communication, 2008). Tasks that are typically undertaken which can accrue substantial diver/sediment interaction could include: hand-core sediment sampling, cap inspection including probing for native material, and anchor installation for silt-curtain dredging controls.

Exposure Duration - The recommended exposure durations for divers are 25 years for the RME (OSWER, 1991) which is EPA's recommended RME default exposure duration assumption for workers and nine years for the CTE (USEPA, 2004). The RME value (on the order of several decades) is a typical duration for a large Superfund site cleanup, and is therefore a reasonable timeframe for longer term Portland Harbor diver exposures.

Averaging time (AT) - The AT corresponding to these exposure durations are 25,550 days for estimating cancer risks for both the RME and CTE; and 9,125 days and 3,285 days for the RME and CTE, respectively, for estimating non-cancer effects(OSWER 1989).

Conversion factor (CF, $mg \cdot kg^{-1}$), and body weight (BW, 70 kg) - The CF is from OSWER (1989) and BW is from OSWER (1991) for workers.

Exposure Frequency (EF) - EF values were derived specifically for divers at Portland Harbor based upon discussions with commercial and EPA divers who work in the Portland Harbor Superfund site. Dive logs were obtained by EPA for a commercial diver who worked for several of the potentially responsible parties at the site in 2005 and 2006. At one site, he dived 74 times on 15 separate days. The number of dives per day ranged from three to eight. The average dive time was 24 minutes with a range from five minutes per dive up to 62 minutes per dive. For the other Portland Harbor sites, the diver dove 80 times on 20 separate days. The number of dives per day ranged from two to six. The average dive time was 25 minutes with a range of six minutes per dive up to 85 minutes per dive.

Discussions that the potentially responsible parties' contractor (D. Davoli, personal communication, 2008) had with dive companies also found that some commercial divers who perform work not related to sampling and analysis and cleanup activities (*e.g.*, diving to repair outfalls, work on ship hulls, underwater inspections) do less dives per day but spend more time (up to four hours) underwater for each dive using surface supplied air. These dive companies also stated that they dive less frequently in Portland Harbor than do those divers who are diving for Superfund cleanup purposes. In addition, Multnomah County Sheriff's Department divers also dive in the Willamette River on a regular basis, including six locations within the Superfund initial study area between 1998 and 2000 (D. Davoli, personal communication, 2009).

Based upon this information and using best professional judgment, the recommended exposure frequency that was selected for both RME divers is five days per year and two days per year for the CTE. This exposure frequency assumes that all other diving done by a diver (*i.e.*, diving done the other 360 days/year for the RME and 363 days per year for the CTE) is done outside of Portland Harbor. For the five days (RME) and two days (CTE) per year that a diver is assumed to be exposed at the Portland Harbor site, this exposure occurs at only the one near-shore half-mile segment of the site for which an EPC is being calculated. Cumulative risk for divers who may dive at more than one site in Portland Harbor is not included in these calculations. It is assumed that these assumptions will be protective for commercial divers that are performing routine activities but may underestimate the number of dives done in one or multiple segments for workers conducting hazardous waste operations, including sampling/analysis and cleanup work.

Sediment Dermal

For dermal exposure (absorption of contaminants in sediment through the skin) by divers, the general equation for dermal contact with chemicals in soil from EPA's Risk Assessment Guidance for Superfund (USEPA, 1989) is used but chemical concentration in soil is replaced with the chemical concentration in sediment:

$$\text{Daily Intake } (mg \cdot kg^{-1} \cdot day^{-1}) = \frac{EPC \cdot SA \cdot AF \cdot ABS \cdot EF \cdot ED \cdot CF}{BW \cdot AT}$$

For divers, the recommended EPC, EF, ED, CF, BW, and AT are the same as those described above for sediment ingestion:

EPC - Exposure Point Concentration ($mg \cdot kg^{-1}$) [concentration of a contaminant in each half-mile segment]
EF - Exposure Frequency (Events or $days \cdot year^{-1}$) [both RMEs=5 $days \cdot year^{-1}$; CTE=2 $days \cdot year^{-1}$]
ED - Exposure Duration (years) [RME=25 years; CTE=9 years]
BW - Body Weight (kg) [70 kg]
AT - Averaging Time (days) – [Cancer RMEs/CTE=25,550 days; Non-cancer RMEs=9,125 days and Non-cancer CTE=3,285 days]
CF - Conversion Factor ($kg \cdot mg^{-1}$) [10^{-6}].

For ABS, AF and SA, the following values will be used:

Absorption factors (ABS, dimensionless) – Absorption factors are chemical-specific and are found in Risk Assessment Volume I: Human Health Evaluation Manual (Part D: Supplemental Guidance for Dermal Risk) (USEPA 2004).

Adherence Factors (AF) - Adherence factors (AF, $mg \cdot cm^{-2} \cdot event^{-1}$) are taken from USEPA (2004). For the diver, 0.3 $mg \cdot cm^{-2}$ per event will be used for both of the RMEs and 0.07 $mg \cdot cm^{-2}$ per event will be used for the CTE. These values represent the activity specific surface area weighted soil adherence factors for residential adult gardeners (0.3 $mg \cdot cm^{-2}$ is the 95th percentile and 0.07 $mg \cdot cm^{-2}$ is the geometric mean) and are the same values being used for in-water fishers in the Portland Harbor risk assessment.

Surface Area (SA) - For surface area (SA, cm^2) for the wetsuit RME diver and the wetsuit CTE divers who are assumed to be wearing a wetsuit and to have whole body exposure, the surface area exposed is assumed to be 18,150 cm^2 (average of the mean whole body value for males and females from USEPA Exposure Factors Handbook, EPA, 1997). For the drysuit with neck dam RME exposure, only hands, head and neck are assumed to be exposed. This is equivalent to a surface area of approximately 2,510 cm^2. This is based upon 1,206 cm^2 for the head and 904 cm^2 for hands based on the average of the mean for males and females. A value of 400 cm^2 was a used for the neck based upon 6% of the trunk value (including neck) of 6,600 cm^2 (the average of the 50% value for these body parts for males and females from EPA's Exposure Factors Handbook).

WATER EXPOSURE
Water Ingestion

For inadvertent surface water ingestion by divers, a modification of the general equation for inadvertent surface water ingestion of chemicals in surface water while swimming is used (OSWER, 1989):

$$\text{Daily Intake } (mg \cdot kg^{-1} \cdot day^{-1}) = \frac{EPC \cdot WIR \cdot t_{ev} \cdot EF \cdot ED \cdot CF}{BW \cdot AT}$$

For EF, ED, BW, and AT, the values for divers are the same as those recommended for diver exposure to sediments:

EF - Exposure Frequency (Events or dives·year^{-1}) [both RMEs=5 days·y^{-1}; CTE=2 days·y^{-1}]
ED - Exposure Duration (years) [RME=25 years; CTE=9 years]
BW - Body Weight (kg) [70 kg]
AT - Averaging Time (days) – [Cancer RMEs/CTE=25,550 days; Non-cancer RMEs=9,125 days and Non-cancer CTE=3,285 days]
CF – Conversion Factor is 10^{-3} L·mL^{-1}.

For the EPC, t_{ev}, and WIR, the following values are recommended:

Exposure Point Concentration (mg·L^{-1}) – It is assumed that commercial divers can be exposed to surface water throughout in the Portland Harbor site. Therefore, for divers, all of the surface water data collected for the RI in the PH site will be used in calculating the surface water EPC for divers including single point data as well as near bottom and near surface data collected at specific industrial sites, cross river transect data, and vertically integrated data collected in quiescent areas.

For the transect samples, multiple sample events were collected both spatially and temporally. Therefore a method was developed to generate a relatively consistent set of transect data integrating results over the width and depth of the Willamette River in the site. These data will be used to calculate the arithmetic mean EPA for the central tendency exposure (CTE) and the 95% upper confidence limit (UCL) on the arithmetic mean (when possible) for the EPC for the RME scenario. The single point water data and integrated samples collected in quiescent areas are to be used as individual EPCs; while the near bottom and near surface samples will be averaged and used as the EPC for divers.

WIR - Water Ingestion Rate (mL·h^{-1}) - For the water ingestion rate, the value of 50 mL·h^{-1} is used for both the CTE and RME. This is the values recommended in USEPA (1989) as water ingestion rate for swimmers and was deemed appropriate for divers based upon discussions with EPA divers.

t_{ev} – Event Duration (h·event^{-1} or dives) - For developing values for event duration, the dive logs discussed previously from a commercial diver who works for the responsible parties were used as well as information collected by the potentially responsible parties' contractor who interviewed diving companies. From the early-action cleanup dive logs from the MGP site, the average dive time was 24 minutes with a range of five minutes per dive up to 62 minutes per dive. For the dive logs from the other Portland Harbor sites, the average dive time was 25 minutes with a range from six minutes per dive up to 85 minutes per dive. This information on minutes per dive was used with previously discussed information on the number of dives per day (see discussion under Exposure Frequency in Sediment Ingestion section) to estimate the hours per dive. The range of time spent in the water in a day is, therefore, from 50 minutes (two dives at 25 minutes per dive) to 3.2 hours (eight dives at 24 minutes per dive). The potentially responsible parties' contractors found that a diver can spend four hours in the water in one day using supplied air. Based upon these data, the recommended values for the event duration (for each day) are two hours per dive for the CTE (approximate mid-range of 50 minutes and 3.2 hours) and four hours per dive for both of the RMEs (information from the potentially responsible parties' surveys).

Water Dermal

For dermal exposure (absorption of contaminants in water through the skin) by divers, a modification of the general equation for dermal contact with chemicals in water from USEPA (2004) was used:

$$\text{Daily Intake } (mg \cdot kg^{-1} \cdot day^{-1}) = \frac{DA \cdot SA \cdot EF \cdot ED}{BW \cdot AT}$$

For all of the exposure parameters, except DA (the absorbed dose per event in $mg \cdot cm^{-2}$ per event (*i.e.*, per day), the values EF, ED, BW, AT and SA for divers are the same as those recommended for dermal exposure to sediment :

> EF- Exposure Frequency (Events or dives/year) [both RMEs=5 $days \cdot y^{-1}$; CTE=2 $days \cdot y^{-1}$]
> ED - Exposure Duration (years) [RME=25 years; CTE=9 years]
> BW- Body Weight (kg) [70 kg]
> AT - Averaging Time (days) – [Cancer RMEs/CTE=25,550 days; Non-cancer RMEs=9,125 days and Non-cancer CTE=3,285 days].
> SA - Surface Area (cm^2) - Area of 18,150 cm^2 for the wetsuit RME diver and the wetsuit CTE divers and 2,510 cm^2 for the drysuit with neck dam RME exposure.
>
> Absorbed Dose (DA) - Several values are needed to calculate DA (the absorbed dose per event in $mg \cdot cm^{-2}$ per event [*i.e.*, per day]). These values are the EPC for surface water, t_{ev} (the event duration) and K_p (the dermal permeability coefficient of the contaminant in water in cm/hr). The EPC and t_{ev} are the same as those used above for water ingestion. K_p values are chemical specific and are found in USEPA (2004). There are many uncertainties inherent in the K_p values for certain chemicals (*e.g.*, DDT and PCBs) and these uncertainties will be addressed in the Portland Harbor Human Health Risk Assessment.

As discussed previously, the diver risk assessment being done for the Portland Harbor Superfund site focuses on commercial divers who are performing routine activities within the site. Potential risk to workers conducting hazardous waste operations, including sampling/analysis and cleanup work, should be included in an evaluation of implementation risks in feasibility study. Whether diving under the OSHA commercial diving standards, or OSHA scientific diving exemption, cleanup workers should be working under conditions that are in compliance with OSHA standards (29 CFR 1910.120), as the OSHA scientific diving exemption does not exempt scientific divers from employing personal protective equipment (PPE) and other preventative exposure measures. However, as previously discussed, EPA's experience is that divers in Portland Harbor involved in sampling/analysis do not always dive in compliance with the OSHA standards and/or do not initially propose dive plans in compliance with hazardous waste site operation (HAZWOPER) standards. Typically, items such as basic diver environmental isolation (PPE) and medical monitoring (1910.120 HAZWOPER items) are not proposed in the Health and Safety Plan, and are often only added at the request of EPA. It is a reasonable presumption that contractors doing similar work not under EPA oversight may not be equipping their divers, training their divers, or monitoring their divers for hazardous waste exposure per OSHA 29 CFR 1910.120. As a result, divers conducting hazardous waste operations and not following OSHA standards are likely exposed to risks similar to or greater than those being estimated for non-hazardous waste commercial divers in the Portland Harbor Human Health Risk Assessment (PH HHRA). This is because these divers may spend more time diving in PH and dive in multiple segments of the site that have some of the higher contaminant concentrations.

Discussion

EPA has evaluated and directed the potentially responsible parties to conduct diver exposure assessments for the Portland Harbor Remedial Investigation to ensure that risks of diving at the site for commercial, scientific (commercial or government), public safety, and recreational divers are known and may be used for outreach efforts. Though exposures are qualitatively understood to take place, quantitative evaluation has not been undertaken to date at other Superfund sites, to the authors' knowledge. The equations used for these calculations are derived from existing US EPA guidance. Input parameters are from US EPA Guidance or based on site specific concentration data and EPA staff observations and commercial contractor dive logs. EPA intends to use these results to conduct further outreach with the Portland Harbor diving community to eliminate or mitigate these exposures, and provide this quantitative approach to determining exposure to the larger diving community (*e.g.*, dive safety and rescue organizations). In addition, EPA hopes to solicit feedback on inputs used in this diver scenario for potential application at other Superfund site harbor investigations.

Elimination of exposures may involve boat based sampling techniques rather than diver based techniques, for example. Mitigation measures could involve use of added training, medical monitoring, revisions of commercial and scientific diving safety manuals and dive plans to more clearly acknowledge OSHA 29 CFR 1910.120 requirements in contaminated or possibly contaminated dive areas, and improvements in personal protective equipment. See photo 3 below for an example of personal protective equipment / polluted water dive gear in use by EPA's Region 10 unit. Note that a full face mask is used that sits directly on the dry hood, drygloves, and a suit compatible with decontamination. Outreach for these additional steps could also involve education of the dive community of OSHA requirements that pertain to both scientific and working dives within "hazardous waste sites" for the aforementioned steps (OSHA 29 CFR 1910.120).

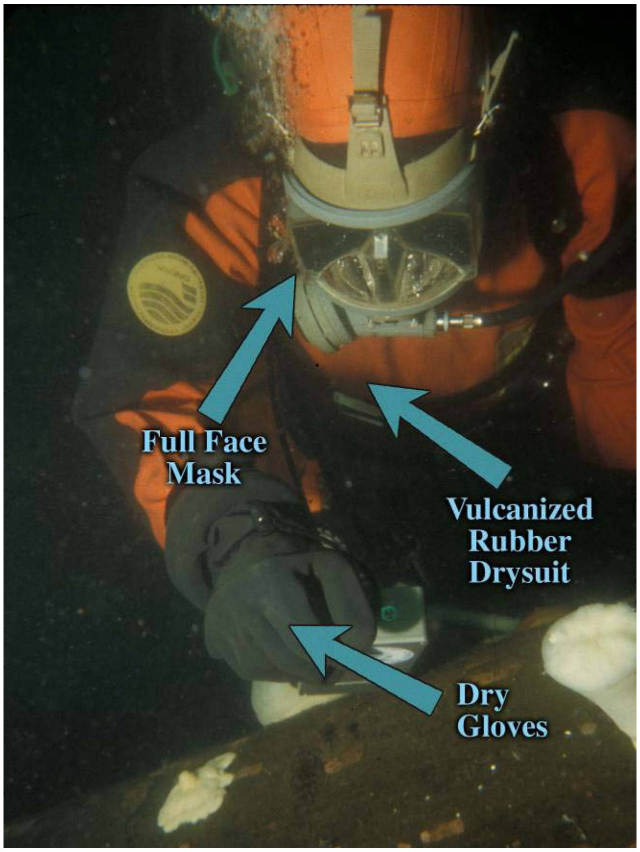

Photo 3: EPA Region 10 Diver Rob Pedersen mapping the zone of discharge along the outfall pipe at an Alaskan Seafood Processor. Photo by Sean Sheldrake, EPA Region 10 Dive Team.

Disclaimer: This paper is an illustration of steps to be taken to quantitatively evaluate and minimize exposure to the diver in hazardous environments and does not represent the official view of the USEPA or Oregon DEQ. Mention of any specific brand or model instrument or material does not constitute endorsement by the USEPA or Oregon DEQ.

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AAUS 2009 Symposium Program - Atlanta, GA

March 13th

0800 - 0810 Opening Comments

0810 - 0900 (Invited Plenary) Scientific Diving and the Law: an Evolving Relationship
Dennis Nixon
College of the Environment and Life Sciences, University of Rhode Island, Kingston, RI

0900 - 0925 Commercial Diver Exposure Scenario for the Portland Harbor Risk Assessment
Sean Sheldrake, Dana Davoli, Michael Poulsen, Robert Pedersen, Bruce Duncan
USEPA, Region 10, Environmental Cleanup Office, Seattle, WA

0925 - 0950 Submerged Cultural Resource Discoveries in Albania: Surveys of Ancient Shipwreck Sites in the Ionian Sea
Derek Smith
Hawai'i Institute of Marine Biology, 46-007 Lilipuna Rd, Kane'ohe, HI

0950 - 1015 Break

1015 - 1040 The Minerals Management Service's Seafloor Monitoring Program
David Ball
Minerals Management Service, 1201 Elmwood Park Blvd, New Orleans, LA

1040 - 1105 Underwater Acoustic Ecology
Phillip S. Lobel
Boston University, Biology Dept., 5 Cummington St, Boston, MA

1105 - 1130 Convenient Fish Acoustic Data Collection in the Digital Age
Kathryn E. Kovitvongsa, Phillip S. Lobel
Boston University, Biology Dept., Boston, MA

1130 - 1155 Use of Technical Diving to Study Deep Reef Environments in Puerto Rico
Clark Sherman, Milton Carlo, Richard Appeldoorn, Michael Nemeth, Hector Ruíz, Ivonne Bejarano
Department of Marine Sciences, University of Puerto Rico-Mayagüez, Mayagüez, PR

1155 - 1300 Lunch

1300 - 1325 NOAA's Office of National Marine Sanctuaries and the American Academy of Underwater Sciences: A Look to the Past and the Road Ahead
Mitchell Tartt, Greg McFall
Office of National Marine Sanctuaries

1325 - 1355 The 2008 Battle of the Atlantic U-Boat Survey: Archaeological Recording in the Graveyard of the Atlantic

Joseph C. Hoyt
Office of National Marine Sanctuaries

1355 - 1415 Habitat-Mediated Signal Reception by a Passive Acoustic Receiver Array as Determined by Scuba Transects: Implications for the Design of Fish Movement Studies

James Lindholm[1], Ashley Knight[1], Jeremiah Brantner[1], Les Kaufman[2], Steven Miller[3]
[1] Institute for Applied Marine Ecology, California State University Monterey Bay
[2] Boston University
[3] University of North Carolina at Wilmington

1415 - 1435 From Torrid Seas to Icebound Lakes: Shipwreck Investigations within NOAA's National Marine Sanctuaries

Tane Casserly
Office of National Marine Sanctuaries

1435 - 1505 Flower Garden Banks National Marine Sanctuary and Texas A&M University at Galveston - A Case Study: Building a Research and Learning Partnership

Kevin Buch[1], Emma Hickerson[2]
[1] Texas A&M University Galveston; [2] Office of National Marine Sanctuaries

1505 - 1530 Break

1530 - 1555 Exceptional Areas, Significant Challenges, a Perfect Opportunity: The National Marine Sanctuary University Partnership Program

Bradley Barr, Robert Pavia
Office of National Marine Sanctuaries

1555 - 1620 The 2009 ONMS Science Needs Assessment: A To Do List for Marine Conservation

Mitchell Tartt
Office of National Marine Sanctuaries

1620 - 1645 The Etiology of Spinal Cord Decompression Sickness: A Literature Review

Dawn N. Kernagis
Center for Hyperbaric Medicine and Environmental Physiology, Duke University Medical Center, Durham, NC

1645 - 1710 The Haldane Effect

Michael A. Lang[1], Alf O. Brubakk[2]
[1] Smithsonian Institution, Office of the Under Secretary for Science, PO Box 37012 - MRC 009, Washington, DC
[2] Norwegian University of Science and Technology, Department of Circulation and Medical Imaging, 7491 Trondheim, Norway

March 14th

0800-0805 Opening Comments

0805 - 0830 Community Science for Marine Resource Management: Building a Best Practices Toolkit for Sustainable Fisheries Research

Richard B. Carey[1], Richard V. Ducey[1], Carolyn Winter[2], Miriam Kelty[1], Sally Hornor[1], Bruce Macphail[2]
[1] Magothy River Association Scientific Dive Team, Severna Park, MD
[2] World Bank, Washington, DC

0830 - 0845 Assessing Seasonal Variation in Benthic Macroinvertebrate Biodiversity with a Focus on Polychaete Biomass on Protected Oyster Reefs in the Magothy River

Elizabeth J. Ducey
Department of Biology, St. Mary's College of Maryland, St. Mary's City, MD

0845 - 0910 Exploring the 'Marine Twilight Zone' in the Gulf of Eilat, Red Sea, Israel

Oded Ben-Shaprut
Interuniversity Institute for Marine Sciences in Eilat
POB. 469 Eilat 88103 Israel

0910 - 0940 FPGA-Based Fish Detection Using Haar Classifiers

Bridget Benson, Junguk Cho, Deborah Goshorn, Ryan Kastner
Computer Science and Engineering, University of California San Diego

0940 - 1005 The Science of the National Association for Cave Diving (NACD): Water Quality, Hydrogeology, Biology, and Psychology

Donald (Skip) F. Kendrick
National Association for Cave Diving (NACD) and Department of Psychology, Middle Tennessee State University, Murfreesboro, TN

1005 - 1040 Break

1040 - 1105 Assessing the Health of Coral Reefs: Relative Dominances of Benthic Indicator Groups and Top-Down/Bottom-Up Tipping Points

Mark M. Littler, Diane S. Littler
Department of Botany, National Museum of Natural History, Smithsonian Institution, Washington, DC

1105 - 1120 Methodologies for Benthic Invertebrate and Shellfish Population Assessments in Sheffield Harbor, Norwalk, Connecticut

Ryan D. Patrylak, Robert B. Whitlatch
Department of Marine Sciences, University of Connecticut, Groton, CT

1120 - 1145 Collaborative Diving for Science: A Report on the Diving Equipment, Techniques and Collaborative Approach Used to Conduct Subtidal Shellfish Surveys in Coos Bay, Oregon

Vallorie Hodges[1], Caren E. Braby[2], Alix M. Laferriere[2]
[1] Oregon Coast Aquarium, Newport OR
[2] Shellfish and Estuarine Assessment (SEACOR), Oregon Department of Fish and Wildlife, Coos Bay, OR

1145 - 1300 Lunch

1300 - 1330 Oxygen and Hydrogen Isotopes Suggest Two Sources for Little Salt Spring
Noelle J. Van Ee, Rick Riera-Gomez
University of Miami, Miami, FL

1330 - 1400 Time Series Observations of Species Composition and Behavioral Interactions of Fish at an Ocean Observatory off the Coast of Georgia
Amy E. Paquette[1], Peter J. Auster[2], Michael D. Arendt[3]
[1] University of Connecticut, Department of Marine Sciences
[2] University of Connecticut, Department of Marine Sciences
[3] Marine Resources Research Institute South Carolina Department of Natural Resources

1400 - 1430 Tourist Charge Capacities for Recreational SCUBA Diving in Marine Protected Areas and Establishment of Interpretative Underwater Paths
Vicente Munoz-Fernandez, Alejandro Ramirez-Cordero, Eduardo Rios-Jara
Laboratorio de Ecosistemas Marinos y Acuicultura, Departamento de Ecología. Centro Universitario de Ciencias Biológico Agropecuarias (CUCBA). Universidad de Guadalajara Apartado Postal 52-114, Zapopan, Jal. 45110, México

1430 - 1500 Break

1500 - 1525 Algal Garden Cultivation and Guarding Behavior of Dusky Damselfish on Coral Rubble and Intact Reef in Dry Tortugas National Park
Valentina Di Santo, Christopher M. Pomory, Wayne A. Bennett
Department of Biology, University of West Florida, Pensacola, FL

1525 - 1550 Population Analysis of an Introduced Coral Species, *Tubastraea coccinea*, in Florida
Tonya L. Shearer
Georgia Institute of Technology, School of Biology, Atlanta, GA

1550 - 1620 Design and Evaluation of Cold Water Diving Garments Using Super-Insulating Aerogel Fabrics
M. Lew Nuckols
Mechanical Engineering and Materials Science Department, Duke University, Durham, NC

1620 - 1645 Underwater Paleontology: Recovery of a Prehistoric Whale Mandible Offshore Georgia
Scott E. Noakes, Erv G. Garrison, Greg B. McFall

1645 - 1700 AAUS Photo Collage
Derek M. Smith

1700 - 1700 Closing Comments