Chemical Exposure Assessment Considerations for Use in Evaluating Deepwater Horizon Response Workers and Volunteers

Oil spill response workers and volunteers may be exposed to many different chemical and environmental hazards. This document only discusses the chemical exposure portion of a comprehensive health and safety plan and is intended to provide guidance for occupational safety and health professionals involved with developing industrial hygiene sampling plans. The specific chemicals and concentrations will vary depending on the location of the oil, length of time since the oil was released into the environment, type and stage of response, materials used during spill remediation, climate conditions, use of personal protective equipment (PPE), and the workers' specific tasks. Obtaining accurate and useful worker exposure information is a crucial element in ensuring exposures are correctly characterized, risk is communicated appropriately, and sufficient information is available for making evidence-based decisions (e.g., PPE) to protect the health and safety of oil spill response workers. This document provides information and guidance for establishing successful oil spill worker exposure (industrial hygiene) assessment plans for chemical contaminants.

Exposure assessment entails the identification, characterization, estimation, and evaluation of workplace exposures and is a primary mechanism for decision-making in the prevention of occupational injury and illness. Exposure information is critical for determining if a chemical contaminant poses a risk to oil spill response workers. The success of any exposure assessment is related to its design and inherent sampling strategy. Proper advance planning minimizes sampling and measurement errors and maximizes the likelihood of obtaining useful information. This should include developing a written sampling plan with sufficient detail to describe the purpose(s), objectives, methodologies, how results will be interpreted and communicated, and how data will be managed. The following sections provide information on the elements that should be included in a plan.

The Occupational Safety and Health Administration (OSHA) has developed an oil spill initial sampling strategy with sampling and analytical recommendations, reference information regarding chemical properties, occupational exposure limits (OELs), time-integrated and direct reading monitoring results, and specific task descriptions linked to

PPE requirements (http://www.osha.gov/oilspills/oil_samplingstrategy.html). The task descriptions and associated PPE requirements provide a good mechanism for uniformly and consistently categorizing, reporting, and evaluating monitoring results and managing data. The Environmental Protection Agency (EPA) is conducting community air monitoring for contaminants associated with the oil spill; this information can be found on the EPA web site at: http://www.epa.gov/bpspill/air.html

Purpose

Exposure assessments are conducted for a variety of reasons, and the design of the strategy should be consistent with the context in which the resulting data will be used. Sampling without fully understanding the underlying need, thus how the results will be utilized and communicated, can result in obtaining information that is not useful at best, and misinterpreted, misleading, and counterproductive at worst. Thus, before collecting field samples, it is necessary to clearly articulate the purpose and objectives of sampling. Examples of reasons for collecting data include:

- Investigation (e.g., response to a complaint, reported health symptoms, or incident, determining the source of a problem, hypothesis driven assessments)
- Documentation (e.g., compliant/non compliant, comparison to a reference exposure limit, provide information to workers and other stakeholders)
- Comprehensive exposure characterization of an activity (e.g., initial task assessments, new chemical use, assessment of work practices)
- Obtaining information for worker risk/hazard communication
- Confirmatory/reassessment (e.g., control effectiveness, changing environmental condition)
- Priority setting and hazard ranking
- Hazard identification and magnitude (e.g., what contaminants are present, gain knowledge of relative concentrations)
- Determining PPE requirements or justifying the upgrade or downgrade of PPE requirements (e.g., respiratory protection and skin protection).

The purpose of the data collection, in conjunction with the availability and cost of field monitoring and laboratory analytic techniques and time sensitivity of the results, will inform the sampling strategy.

Sampling Strategy Considerations

Important parameters of the sampling strategy include the scope of the sampling (which occupations or tasks; how workers are chosen), the comprehensiveness of the sampling (screening estimates or individual level monitoring), the number, timing, and frequency of the sampling, and the methods used (air samples, dermal assessment, biomonitoring, etc.).

Analyses that will contribute to determining these parameters include:

- Determining the number of workers potentially exposed
- The type of job activities or tasks to be assessed, materials present
- The physical states of the substances to be sampled
- Identifying and evaluating existing engineering and management (administrative) controls
- Potential hazards involved in collecting and shipping the samples
- Understanding the job requirements and tasks to identify activities of highest potential exposure
- Identifying appropriate Reference Values/Occupational Exposure Limits for evaluating results, including Short-Term Exposure Limits (STEL), Ceiling Limits, and Time-Weighted-Averages (TWA)
- Considering additive/synergistic effects from simultaneous exposure to mixtures of substances with similar toxicological endpoints
- Ensuring appropriate adjustments for non-traditional work shifts (e.g., 10 or 12 hour shifts)
- Ensuring representative samples are obtained using appropriate sample strategy approaches (randomized or worst case sampling strategies, depending upon sampling objectives)
- Recognizing and addressing reported health problems and concerns of workers
- Identifying PPE requirements, standard operating procedures, and worker training
- Recognizing other stressors (heat, fatigue, noise) that may be present
- Assessing all routes of exposure (dermal, ingestion, inhalation).

It is important to note that one sampling strategy will not likely satisfy every scenario and multiple strategies are often necessary. For example, strategies for workers involved with in-situ burning will be very different than those for workers involved in beach cleanup. There are contexts in which the goal is to provide data for developing a "worst-case" or "highest potential exposure" scenario. For instance, limited data may be sufficient to inform judgments about particular exposure situations, help with prioritization for more in-depth evaluations, or identify appropriate PPE. When a more limited sampling approach is used to evaluate a worst case scenario, one must be explicit about the assumptions inherent in the choices about where and when to sample so that decision makers are aware of the uncertainty associated with conclusions they might draw from the analysis. In some cases, the results of more limited monitoring may not alleviate concern or questions, thus, the next step may be to obtain data that allows more precise and representative estimates.

Before implementing a monitoring and sampling program, a sampling strategy should be developed to maximize information gained and identify an appropriate number of samples collected to monitor exposures, job tasks, or activities. Several pieces of information must be known in advance to plan a strategy, including the workforce size, accuracy of sampling and measurement method employed, and the confidence level one wishes to have in estimating the exposure of the workforce. Different strategies lead to different levels of our ability to interpret the results and estimate exposure.

One approach is to identify Similar Exposure Groups (SEGs)[1] . SEG's are usually defined observationally and assume similar exposure profiles for the contaminants because of the similarity and frequency of worker tasks and performance methods, materials, and processes. An exposure profile (or exposure distribution) is an estimate of the exposure intensity and how it varies over time (days) for an SEG, usually expressed quantitatively as a mean (arithmetic and/or geometric mean; AM and GM) and geometric standard deviation (GSD). Information used for defining the exposure profile may include qualitative or quantitative data, or both. Data about jobs, processes, tasks, control equipment, and materials used are considered when dividing workers into SEGs. As discussed above, OSHA has developed an oil spill initial sampling strategy that uses task descriptions with associated PPE requirements for categorizing workers into task-based SEG's.

For many study purposes, determination of time-averaged air concentrations is an appropriate monitoring goal and there are many chemical agents and study approaches for which quantitative integrated personal samples are more desirable than instantaneous measurements or area sampling. It is critical to understand the advantages, disadvantages, and limitations of the sampling methodology used. For example, although passive monitors are less burdensome in field conditions, they are not recommended for ceiling or short-term exposure sampling or for collecting unknown organic vapors. For the purpose of determining short-term peak exposures or for rapid determination of approximate air concentrations, direct reading instrumentation is very useful. Many direct reading methods cross-respond to multiple chemical agents or other airborne material (e.g., water vapor) and are not agent specific or quantitative. Direct reading instrumentation is often used to conduct semi-quantitative area monitoring, or to assess unknown atmospheres for a wide variety of potential contaminants. Information from direct reading instruments can identify contaminants requiring a more in-depth characterization, target specific job tasks or activities for assessment, and provide trend information regarding contaminant concentrations. Depending upon the purpose of the investigation, it may be necessary to conduct more in-depth sampling and analysis to identify potential chemical interferences that can affect the performance of direct reading instrumentation. It is important to understand and consider the limitations of these approaches when interpreting results. For example, unless used in a continuous monitoring mode, this type of monitoring only provides a "snapshot" of conditions. Additionally, depending on the direct reading instrument (e.g., non specific photo-ionization detector), data interpretation such as specific chemical identity, or interpreting the health consequences of exposure can be difficult or not possible (e.g., mixtures).

Skin contact can be a significant route of exposure that should not be overlooked; many of the contaminants that oil spill response workers will come in contact with have high molecular weights that exhibit low volatility, and may not be present in significant airborne concentrations. Depending upon the purpose of the investigation, air sampling may not provide a sufficiently comprehensive characterization of exposure. Skin contact can occur directly or through secondary contact with contaminated tools, work surfaces, or PPE. Methods for evaluating potential dermal exposure include qualitative approaches such as observation of work tasks/activities, an assessment of concentrations on PPE used, housekeeping, and decontamination protocols, in conjunction with knowledge of the chemical and physical properties and dermal absorption characteristics of the compounds encountered. Biological monitoring (e.g., analysis of blood or urine samples or exhaled breadth) is available for some compounds for which dermal contact is the major route of exposure. Biological monitoring provides information on the total dose, including inhalation, dermal, and ingestion. Unfortunately, validated biological monitoring methods and applicable biological exposure limits are only available for relatively few agents. Those specific to oil spill contaminants include polynuclear aromatic hydrocarbons (PAH's), benzene, ethyl benzene, toluene, and 2-butoxy ethanol (possible dispersant component). Skin exposure assessments through monitoring to assess the amount of contaminant deposited on the skin can be useful for evaluating potential exposure, the efficacy of PPE, and the need for additional controls or changes in work practices. A number of techniques are available for evaluating skin exposure via dermal sampling. These include wipe sampling, absorbent pad and clothing sampling, and glove/hand wash sampling. Additional information on dermal exposure effects and assessment, including references for additional information, can be found at: http://www.cdc.gov/niosh/topics/skin/. Interpretation of dermal exposure assessments and biological monitoring can be difficult, and it is critical to have a well developed plan with standardized assessment approaches. Selection of the method of assessment should be consistent with the purpose of the investigation. Screening level investigations may rely on less intensive approaches than individual-level assessments for damage compensation.

Sampling and Analytical Considerations

The sampling and analysis method is selected after determining the survey design and sampling strategy (e.g., initial exposure characterization' in-depth characterization of exposures by SEG, job, or task, etc.). A qualified industrial hygienist experienced with conducting exposure assessments in a response environment should conduct, or provide close oversight to those who conduct, the sampling surveys. A laboratory accredited by the American Industrial Hygiene Association, which has experience and expertise in analyzing industrial hygiene samples, should be used. The following web links provide a list of these laboratories, and for which test methods they are accredited:

http://www.aihaaccreditedlabs.org/Pages/default.aspx

List of AIHA accredited labs:

http://apps.aiha.org/qms_aiha/public/pages/reports/publicscopeview.aspx?ProgramCode=40

It is imperative to establish good communication and collaboration between planners, field sampling personnel, and the laboratory to ensure samples are collected, handled, and shipped and received properly (e.g., there may be a need for sample refrigeration or other special requirements), and the appropriate analytical methodology is used. The sampling and analytical considerations that must be addressed in any sampling plan include:

- Identification of all contaminants to be sampled and expected concentrations.
- Selection of Sampling Type (e.g., Area vs Personal, Time- Integrated vs Short-Term, Active vs Passive, Qualitative vs Quantitative).
- Selection of supporting samples (Wipe, Bulk, Area, Direct Reading, bio-assay and bio-medical monitoring).
- Frequency and number of samples to be collected
- Selection of proper sampling methodology and use of validated methods (e.g., NIOSH Manual of Analytical Methods: http://www.cdc.gov/niosh/docs/2003-154/, OSHA Sampling and Analytical Methods: http://www.osha.gov/dts/sltc/methods/index.html).
- Specificity and sensitivity (Limit of Detection/Limit of Quantification) requirements.
- Selection of sampling media and need for analysis of multiple components.
- Climatic and environmental conditions that can influence the sampling (e.g., humidity, temperature, wind, sea spray).
- Collection of sufficient field and media blanks (10% field blanks is a rule of thumb, the laboratory will assist in identifying the appropriate number of media blanks, lot blanks, and back ground samples).
- Potential interferences and limit of detection problems that could influence sample results or alter strategy.
- Sampling equipment calibration.
- Sample flow rate and volume necessary for the limit of quantitation required.

- Need for equipment that meets intrinsic safety requirements for potentially hazardous atmospheres
- Proficiency of staff on sample collection and operation of direct reading instruments.
- Sample Management and Integrity: collection, storage, shipping, chain-of-custody requirements with proper recordkeeping.

Important information to document in a systematic fashion during the sample collection phase includes:

- Date, time, location (GPS coordinates, offshore, nearshore, onshore, etc.), photos (if feasible), name and contact information of individual collecting the sample
- Background readings, locations, and number of samples taken
- The activity/task being evaluated (e.g., designated category, consistency with a "normal" work day), number of workers exposed, job description of worker being monitored, length of task, length of shift
- If direct reading or area samples, location of sample
- Chemicals monitored, volumes/concentrations in use, other hazards present
- Controls in place: engineering, administrative and/or PPE used
- Frequency and duration of activity
- Environmental conditions (wind, temperature, humidity)
- Sampling details (calibration, flow rate, sample duration, media, lot number, sample type [area, personal], sample and lab numbers, blanks submitted, qualitative, quantitative, direct reading, etc.)
- Quality Assurance/Quality Control
- Record of all personnel sampling devices and readings
- All data must be converted to the same units of measurement
- Analytical method reference number
- Reference OEL (TWA, STEL, or Ceiling)

Compounds of Interest for Sampling and Available Reference Methods

It is important to conduct a complete inventory of all potential compounds that could be present to ensure the sampling effort is comprehensive and that appropriate techniques are utilized. Oil spill response workers can be exposed to materials associated with the oil spill directly or indirectly from materials used or encountered during the response. Below is a list of potential contaminants that could be encountered and each is accompanied by a link to reference sampling method that have been validated by

NIOSH and EPA for specific purposes. Certified industrial hygienists or other qualified experts should determine the appropriateness of these methods for the intended purpose (as discussed above), consistent with the strengths and limitations noted in the documentation.

Oil spill related compounds and reference sampling method(s)

Chemical compound	Sampling method
Benzene, Toluene, Ethyl Benzene, Xylenes (BTEX)	NMAM Method 1501 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/1501.pdf); NMAM Method 2549 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/2549.pdf)
Volatile Organic Compounds, including those from cleaning material and marine fuel	Hydrocarbons – NMAM Method 1500 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/1500.pdf); Aromatic hydrocarbons – NMAM Method 1501 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/1501.pdf); Naphthas – NMAM Method 1550 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/1550.pdf); Thermal Desorption Tubes - NMAM Method 2549 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/2549.pdf)
Hydrogen Sulfide	NMAM Method 6013 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/6013.pdf)
Sulfur Dioxide	NMAM Method 6004 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/6004.pdf) NMAM Method 3800 – (Organic and Inorganic Gases by 3800, Extractive FTIR Spectrometry) (http://www.cdc.gov/niosh/docs/2003-154/pdfs/3800.pdf)

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Oil spill related compounds and reference sampling method(s) (Continued)

Chemical compounds	Sampling methods
Poly Nuclear Aromatic Hydrocarbons	NMAM Method 5506 – HPLC-FL (http://www.cdc.gov/niosh/docs/2003-154/pdfs/5506.pdf) NMAM Method 5515 – GC-FID (http://www.cdc.gov/niosh/docs/2003-154/pdfs/5515.pdf) NMAM Method 5800 — Flow injection - FL (http://www.cdc.gov/niosh/docs/2003-154/pdfs/5800.pdf) Benzene Soluble Fraction and Total Particulate NMAM Method 5042 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/5042.pdf)
Oil Mist	NMAM Method 5042 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/5042.pdf)
Dispersant Components: Propylene Glycol, Petroleum distillates, 2-ButoxyEthanol	2-Butoxyethanol – NMAM Method 1403 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/1403.pdf); Propylene glycol – NMAM Method 5523 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/5523.pdf); Petroleum distillates – NMAM Method 1550 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/1550.pdf); NMAM Method 2549 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/2549.pdf)

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Oil spill related compounds and reference sampling method(s) (Continued)

Chemical compounds	Sampling methods
In-Situ Burn Components: aerosols (smoke/combustion products), Nitrogen Dioxide, Carbon Monoxide, Sulfur Dioxide, VOC's, Aldehydes	NMAM Method 2549 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/2549.pdf) Nitrogen Dioxide — NMAM Method 6700 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/6700.pdf) Nitrogen Dioxide — NMAM Method 6014 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/6014-1.pdf) Formaldehyde — NMAM Method 2916 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/2016.pdf) Aldehydes- High Performance Liquid Chromatography— EPA TO-11A (http://www.epa.gov/ttnamti1/files/ambient/airtox/tocomp99.pdf) Aliphatic Aldehydes — NMAM Method 2018 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/2018.pdf)
Broad Spectrum Qualitative Scan	Summa Canisters, TO-15 Thermal Desorption Tubes — NMAM Method 2549 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/2549.pdf)
Diesel Exhaust (elemental Carbon)	NMAM Method 5040 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/5040.pdf)
Carbon Monoxide	NMAM Method 6604 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/6604.pdf)
Organic sulfur compounds	Mercaptans, Methyl, Ethyl and Butyl — NMAM 2542 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/2542.pdf) Benzothiozole and Other Sulfur Compounds — NMAM 2550 (http://www.cdc.gov/niosh/docs/2003-154/pdfs/2550.pdf)

Responding to Short-term Health Symptoms and Odors

A significant oil spill and resulting clean-up efforts can result in situations where response workers notice unusual odors or experience health problems/concerns that may be associated with oil spill response activities. Often, these are short-lived events which may have resolved before an investigation can be organized or environmental sampling conducted. Thus information regarding whether unknown exposures are responsible for any health symptoms or odors experienced, potential contaminants and concentrations that may have been present, and why the event occurred can be difficult to ascertain. Odor thresholds for chemicals associated with oil spills can be found at the OSHA website: http://www.osha.gov/oilspills/oil_samplingstrategy.html. Those responsible for the safety and health of oil spill response workers should establish a mechanism to systematically collect data regarding events such as these to assist in evaluating, assessing, and determining what occurred. This information is helpful for communicating with workers and other stakeholders, and identifying actions that need to be taken to prevent future incidents. This could entail developing a reporting form for personnel supervising the various oil-spill response activities to utilize if an odor or suspected chemical exposure event were to occur. Information that may provide useful and pertinent for communication includes:

- Date, time, duration, and location (GPS coordinates or offshore, near shore, beach) and duration of the event
- Details of activities being conducted when the event occurred
- Number of workers present/vessels involved, number of workers affected
- Location of workers during event (e.g. inside/outside)
- Description of event (odor description, health symptoms experienced)
- Suspected source(s), unusual circumstances encountered
- Climatic conditions, portable weather stations (wind, temperature, humidity, etc.,)
- PPE (if any) worn by workers during event
- Actions taken to investigate, address concerns, identify the source
- Recommended follow-up actions
- Contact information for investigator follow-up and dissemination of information

In some cases (e.g., recurring situations with no readily available explanation) it may be appropriate to identify personnel and provide training and materials so real-time samples (e.g., summa canister or other vacuum sampling technique) could be collected during a future event. All collected information should be provided to those responsible for the health and safety of oil spill response workers for determination of necessary follow-up actions, including the treatment of those affected and appropriate modifications to PPE requirements.

Data Interpretation, Reporting and Management

A uniform and consistent mechanism to collect, interpret, communicate, and manage data is necessary so worker exposure risk can be systematically and comprehensively evaluated (e.g., assessment of trends) and documented. This is critical to ensure that interpretable and actionable data are collected and reported, and conclusions, recommendations, limitations and uncertainties are clearly communicated. Questionable monitoring results (e.g., insufficient supporting information, methodological errors, invalid or incorrect analytical techniques, incorrect measurement units, lack of clear purpose, etc.,) can lead to under- or over-estimations of risk, contribute to worker mistrust and anxiety, inappropriate decisions, loss of confidence in those charged with protecting workers, and impact future communication and cooperation with workers.

Note that it is necessary to consider other routes of exposure (dermal, ingestion) when evaluating exposure. Direct comparison to OELs will likely underestimate exposure if dermal exposure is occurring. As previously noted, many chemicals, including those associated with oil, have low vapor pressures and may present more of a dermal than inhalation hazard. Assessing all routes is an important component of any comprehensive exposure assessment

Information collected (described above) and evidence supporting any conclusions or recommendations should be included in the investigation report.

Communication of Results

All reporting must be done clearly and accurately so that readers from differing backgrounds (such as workers, managers, physicians, etc.,) can understand and take necessary actions based on the information provided in the report. Interpretation of monitoring results for substances that have no recognized or applicable exposure criteria can be difficult. It is important that limitations associated with this data, and the conclusions that can be drawn, are clearly communicated. Consultation with occupational toxicology and other health professionals may be necessary to better define the extent of any hazard associated with exposure to substances that do not have applicable exposure criteria.

It is important to provide all clinically relevant sampling results to exposed workers, other health professionals, management, Federal, State, and Local agencies, and other stakeholders in a timely, transparent, and effective manner. Data that are not clinically meaningful at this time may prove very useful and could support resolution of future questions regarding past exposures. Thus preservation and maintenance of collected data in an occupational exposure database is important. Consistent recording of data, tasks, activities, and other information can expedite the use of data to answer questions.

Management and Oversight

There are numerous administrative and logistical considerations and details that must be addressed in pre-planning to help ensure the success of an exposure assessment sampling plan. These include identifying appropriate contacts (employee/employer representatives) at the worksite to obtain background information regarding activities, concerns, schedules, and to coordinate all aspects of the sampling survey. Sampling personnel must be familiar with the management structure, process, special conditions, PPE requirements, etc., prior to arrival at the worksite.

All stages of the exposure assessment process (hazard identification, defining the purpose of the survey, selection of analytical methodologies, developing the strategy, interpreting and communicating the results, and managing the data) should be continuously reassessed and modified/revised as necessary.

For More Information

For more NIOSH information and recommendations for Deepwater Horizon response workers, see http://www.cdc.gov/niosh/topics/oilspillresponse/

To receive NIOSH documents or more information about occupational safety and health topics, contact NIOSH at

1–800–CDC–INFO (1–800–232–4636)
TTY: 1–888–232–6348
E-mail: cdcinfo@cdc.gov

or visit the NIOSH Web site at www.cdc.gov/niosh.