RE-ASSESSMENT OF THE WRPS INDUSTRIAL HYGIENE HANFORD SITE TANK VAPOR PROGRAM:

TECHNICAL BASIS AND IMPLEMENTATION

CTEH, LLC

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Executive Summary

The Hanford site, located in southeastern Washington State, was originally built by the U.S. Army Corp of Engineers as part of the Manhattan Project for the extraction of plutonium from irradiated uranium for the U.S. nuclear weapons program. Liquid chemical wastes from these and other processes were stored in underground concrete and steel tanks. The chemical wastes stored in the tanks contain various mixtures cumulatively totaling over 1,800 compounds, with over 1,200 of these compounds having been identified in the tank headspaces. In 2016, CTEH (formerly known as the Center for Toxicology and Environmental Health, LLC) conducted an independent, 3rd-party evaluation of the Technical Basis underlying the WRPS industrial hygiene (IH) vapors protection program. The present report is a follow-up assessment of progress made by WRPS in several areas of improvement that were recommended by CTEH in the 2016 report. It includes CTEH's evaluations of (1) the implementation status of recommendations made by CTEH in 2016, and (2) recommendations for ongoing efforts by WRPS to remedy tank vapor issues.

Since the release of its original assessment in 2016, CTEH worked alongside the WRPS Chemical Protection Program Office (CPPO) performing a number of tasks to evaluate changes made (or being made) to the Technical Basis itself and its implementation at the Hanford site. This included review of new and updated WRPS IH strategy and procedure documents, review of technical reports developed by the Pacific Northwest National Laboratories (PNNL) related to tank vapors exposure and toxicology, interviews with various WRPS subject matter experts (SMEs) in the IH and 222-S analytical laboratory groups, and many face-to-face meetings with groups of 1 to 150 tank farms workers. CTEH experts understand that issues of mistrust between tank farm workers, tank operations contractors, and the DOE have developed throughout the history of the site. Against that backdrop, CTEH's observations and recommendations provided in this report seek to not only improve the technical implementation of IH best practices, but also to promote the flow of sound scientific information between the stakeholders in a form useful to everyone.

CTEH's initial 2016 assessment of the Technical Basis found the report (RPP-22491), approach, and scientific underpinnings to be scientifically sound and in accordance with best practices in toxicology and industrial hygiene. CTEH still holds this position, and observes that additions of several other processes and procedures serve to strengthen the programmatic implementation and institutionalization of these best practices.

Third party (Department of Energy, NIOSH, the Tank Vapor Assessment Team, and Stoneturn Consultants) assessments of the WRPS chemical vapors program have made recommendations for new toxicological analyses and air monitoring/sampling method enhancements to address questions about potential exposures and health risks from short-lived vapor exposures. WRPS commissioned multiple studies to be conducted by PNNL. These studies represent a significant technical analysis and investment in technology and methodology that may help improve the assessment of chemical hazards and risks for potential tank farm vapor exposures. The updated evaluations of COPCs and air dispersion modeling serve to improve the level of detail and resolution regarding future tank vapor emissions. The reports for OEL development and selection provide a sound basis for utilizing OELs and derivation methods to leverage the latest toxicology data.

Historical waste disposal data and odor events suggest the existence of potential fugitive emissions sources within and outside of the tank farms where chemical waste may have historically been released to the ground. A Chemical Vapor Solutions Team (CVST)- Fugitive Emissions sub-team was chartered to help determine the location and nature of emissions sources in and around the Tank Farms. CTEH stated that a comprehensive risk assessment needed to be developed to address the potential health impact (both acute and chronic) of exposure to these vapor hazards. WRPS initiated a program to systematically quantify the risks of tank vapor exposure and health effects that is ongoing to date.

CTEH recognizes that there now exist multiple opportunities to collect and analyze air sampling and monitoring data, allowing for more robust statistical analyses of tank vapor constituent levels at various locations, times, and under various conditions. PNNL made recommendations regarding IH sampling and analysis, including recommendations for changes/additions to the information collected and reported by IHTs during the sample collection and recommendations for analytical instrumentation hardware and software upgrades that could increase confidence in chemical identification and quantification. WRPS experts in process engineering and analytical chemistry continue to apply analytical capability upgrades to instrumentation that improve confidence in identification of chemicals.

In 2016, CTEH recommended that employment as an IHT should require an intensive and on-going training, mentoring, and oversight process following hiring of personnel. Chemical Worker training has been implemented for tank farm workers, including IHTs. It is an in-depth chemical hazard training, focusing on improving the tank farm worker knowledge base underpinning several tank vapor issues. CTEH notes that IHTs now undergo specific training in risk communication and conversing during high-stress situations.

In the spring of 2018, CTEH, working with the CPPO as a WRPS subcontractor, commenced worker engagement opportunities to better understand the actual or perceived changes with regard to several of the findings from the 2016 CTEH assessment. CTEH began attending the last portion of the new Chemical Worker training courses to provide a question and answer (Q&A) session for attendees. CTEH concludes there has been significant improvement with regard to worker communication and training via the implementation of the Chemical Worker Training.

CTEH believes that the steps taken to date to improve the defense-in-depth strategy for tank farm worker health protection significantly increase confidence in the level of worker protection from adverse effects from tank farm vapors. There remains room for improvement in the way information is conveyed to and received from the workforce to ensure best science, rather than perceived or rumored suppositions, inform health risks in the minds of workers. New avenues of communication of technical information that have been employed in the last few years have shown immense promise. Making those practices a programmatic cornerstone should serve to increase trust, reduce uncertainty and misinformation, and help to reduce the potential for another return to high levels of tank vapors concerns amongst workforce members.

Recommendation: The intervals between review of new headspace and source sampling and analysis data to update the tank vapor chemical list (i.e., the inventory of all identified compounds present in the collective headspace), as described in TFC-EHSQ-S_IH-C-67 (*Maintenance of the Industrial Hygiene Chemical Vapor Technical Basis*), should be better defined, whether it is a pre-determined time period (i.e., annual, bi-annual), or an event-triggered criterion, such as retrieval/mixing of some number of tank contents. The resulting data sets would allow for better quantitative analysis of rates of actual chemistry changes over time and space, providing a solid, scientific answer to the question of how much or little the tank chemistries change over a worker's tenure at Hanford.

Recommendation: A program for effective communication of IH data analyses should parallel updates of tank vapor inventories, toxicological assessments, and COPC and COC determinations. Further, periodic summaries of IH real-time and analytical sampling data should be prepared and shared with the workforce in a format designed to (1) address questions about the extent and frequency of COPC exposures, and (2) reinforce worker knowledge of the capabilities of monitoring/sampling methods, engineered controls, and administrative controls to protect health.

Recommendation: A formal review of odor threshold data for the COPCs and non-COPC compound class representatives (e.g., short to medium chain length hydrocarbons) is needed. These analyses would help to put into perspective the potential exposures to workers that have either been measured or modeled by WRPS IH.

Recommendation: IHTs need to be able to articulate a consistent and accepted scientific response to instrument operation and exposure questions posed by field level personnel with respect to tank vapor exposures. IHTs training should include practice opportunities to explain why measurements of vapor analytes are below levels of concern.

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1.0 Introduction

The Hanford site, located in southeastern Washington State, was originally built by the U.S. Army Corp of Engineers as part of the Manhattan Project during World War II. From 1943 to 1988, plutonium for the U.S. nuclear weapons program was produced by chemical processing, purification, and separation from irradiated uranium fuel rods collected from the nuclear reactors on the site. Liquid chemical wastes from these and other processes were stored in 149 underground concrete and steel single-shelled tanks (SSTs) built beginning in 1945. In 1968, construction of 28 double-shelled tanks (DSTs) began. The purpose of these tanks was to allow for the transfer and storage of waste from the aging SSTs until final disposal of the wastes could be performed.

The chemical wastes stored in the tanks of the Hanford tank farms consist of various mixtures cumulatively totaling over 1,800 compounds (IH Tech Basis, 2006), with over 1,200 of these compounds having been identified by sampling and analysis as vapors in the tank headspaces. Analysis of prior tank waste characterization reports and review of vapor data that is continuously studied led to development of a current list of 61 Chemicals of Potential Concern (COPC). These are chemicals that have been measured in the tank headspace at concentrations of at least 10% of their respective Occupational Exposure Limit (OEL) guiding worker protection at the Hanford site, and represent compounds that, under the right conditions, could potentially exit the tanks at concentrations that are initially at or near OEL action levels prior to dilution in the tank farm air.

For decades, concern has developed among members of the tank farm workforce and other stakeholders that tank vapors entering the workers' breathing zone may have caused or continue to cause adverse health effects. In 2014, the Tank Vapor Assessment Team, a group of non-WRPS occupational health, engineering, toxicology, health physics, and industrial hygiene experts, was convened to "*determine the adequacy of the established WRPS* [Washington River Protection Systems] *program and prevalent site practices to protect workers from adverse health effects of exposure to chemical vapors on the Hanford tank farms*." (SRNL, 2014). The TVAT concluded that methods used to collect 8-hour Time-Weighted Average (TWA) air concentration data were not adequate to inform potential short-term exposures required to cause short-term adverse effects (particularly upper respiratory irritation) reported by some tank farm workers. They also proposed a mechanism whereby short-lived plumes of high-concentration plumes of tank vapor chemicals would be released from tank headspaces to the worker breathing zones. A list of recommended overarching and specific changes or new implementations to the tank farm industrial hygiene (IH) program was provided for WRPS consideration.

In the Winter of 2015, WRPS and the U.S. Department of Energy's Office of River Protection (DOE ORP) formed dedicated project teams, material resources, and funding to plan and oversee remedial actions geared toward following TVAT recommendations for improvement of the WRPS IH program related to worker protection for adverse effects of tank vapor exposures. In January of 2017, DOE's Office of Enterprise Assessment (DOE EA) released a follow-up assessment of progress on TVAT-recommended actions (DOE EA, 2017). Although DOE EA reported significant progress by WRPS and ORP in achieving TVAT recommendations, some issues were identified that DOE AE felt needed further attention. These included limitations in the respiratory protection cartridge testing program, changes needed in the IH tank vapor Technical Basis, further progress in headspace sampling, changes in the process for updating the list of Chemicals of Potential Concern (COPCs) and improving technical training and qualification of IH technicians (IHTs). DOE EA also identified “cultural aspects” that it felt needed to be addressed to help remedy the tank vapors issue. These included improving worker trust by improving communication of pertinent information, increasing worker involvement in multiple areas of tank vapor protection policy and procedure development, modifying the workers’ compensation process, enhancing medical evaluation protocols for evaluating vapor-exposed workers, and focusing on tank farm worker status in performing future health studies and medical surveillance.

In the Summer of 2016, the National Institute of Occupational and Safety and Health (NIOSH) performed an assessment of the WRPS IH program as it pertained to tank farm worker protection (NIOSH, 2016). The NIOSH assessment included site visits, document and report reviews, and interviews with both management and work force stakeholders. The NIOSH team reported significant investments in technology, IHT staffing, and programs and procedures to address worker health and safety issues related to potential tank vapor exposures. They noted the historical and ongoing collection and analysis of thousands of area and personal air samples showing few, if any, exposures exceeding applicable OELs. NIOSH noted a level of distrust between many workers, union leadership, and management due to perceptions of communication transparency and skepticism over claims of worker injuries. NIOSH recommended centralization of WRPS IH procedure and policy documentation accessible by the work force, improvements in engineering and administrative exposure controls, focused efforts to engage work force representatives in the health and safety program evaluation and improvement process, and increased worker engagement in how the purpose and justification for medical surveillance measures and return-to-work decisions made following a potential exposure incident.

In the Spring of 2016, CTEH (formerly known as the Center for Toxicology and Environmental Health, LLC) was asked by WRPS to conduct an independent, 3rd-party evaluation of the Technical Basis underlying the WRPS industrial hygiene (IH) vapors protection program. This assessment (CTEH 2016) is detailed in the next section. Thereafter, CTEH was also contracted by WRPS to support the newly-established Chemical Protection Programs Office (CPPO) in the areas of toxicology and health risk communication efforts geared toward the tank farm workforce. Those activities are ongoing at the present time and are described in more detail in Section 5.0.

The present report is a follow-up assessment of progress made by WRPS in several areas of improvement that were recommended by CTEH in the 2016 report. It includes CTEH’s findings on (1) the implementation status of recommendations made in 2016, and (2) recommendations for ongoing efforts by WRPS to remedy tank vapor issues.

1.1 Brief Description of the 2016 CTEH Assessment

CTEH evaluated the Technical Basis of the WRPS IH chemical vapor program as well as its implementation (CTEH 2016). The WRPS IH chemical vapor Technical Basis derived from historical and concurrent tank waste and tank farm air monitoring, sampling, and analysis, as well as historical reports on chemical engineering, air dispersion modeling, and tank mixtures/radiolytic chemistry studies performed to date. The Technical Basis was explained in the 2006 report, *Industrial Hygiene Chemical Vapor Technical Basis* (RPP-22491, Revision 1) (IH Technical Basis, 2006). CTEH's 2016 assessment of the chemical vapor technical basis found it to be scientifically sound and to employ correct and contemporaneous toxicology and industrial hygiene concepts and methodologies. CTEH agreed with DOE EA and NIOSH that long-standing issues of mistrust served to exacerbate many vapor-related issues and delay their remedy. CTEH stated that workers' current concerns for adverse health effects from potential current tank vapor exposures pertain to acute, sometimes momentary exposures at odorous and possibly irritant levels. CTEH recommended the development of a comprehensive library of odor-generating locations outside of the tank farms related to other site remediation tasks. CTEH also recommended the derivation of a set of acute-duration OELs for short-term effects, primarily respiratory irritant and neurological effects, need to be developed and introduced into the IH program. Finally, CTEH noted that worker training in these basic concepts of human odor detection biology would help workers to better discriminate toxic versus non-toxic vapor exposures, and to better interpret results from real-time and analytical air monitoring and sampling results.

1.2 CTEH Approach to Evaluating WRPS Actions in Response to 2016 Recommendations

Since the release of its original assessment of the chemical vapor Technical Basis in 2016, CTEH has performed a number of tasks to observe and develop opinions on changes made (or being made) to the Technical Basis itself and its implementation at the Hanford site. These tasks include review of new and updated WRPS IH strategy and procedure documents, review of technical reports developed by the Pacific Northwest National Laboratories (PNNL) related to tank vapors exposure and toxicology, interviews with various WRPS subject matter experts (SMEs) in the IH and 222-S analytical laboratory groups, and many face-to-face meetings with groups of 1 to 150 tank farms workers. CTEH toxicologists and industrial hygienists, working with staff of the WRPS CPPO, observed the tracking of a variety of metrics of the implementation of the WRPS Chemical Vapors Action Plan (CVAP). The CVAP is a strategic plan developed by WRPS to address the findings and recommendations made earlier by the TVAT and other 3rd-party evaluators of the chemical vapor Technical Basis. Sections 2 through 4 of the present assessment describe CTEH's observations of progress made and recommendations for ongoing efforts to address the issues surrounding tank vapor exposures at Hanford. In working closely with tank farm workers and WRPS management as a WRPS subcontractor for over two years, CTEH experts understand that issues of mistrust between tank farm workers, tank operations contractors, and the DOE have developed throughout the history of the site. Against that backdrop, CTEH observations and recommendations provided in this report seek not just to improve the technical implementation of IH best practices, but also to promote the flow of sound scientific information between the stakeholders in a form useful to everyone. Progress in improving the practice and perception of tank farm worker safety will be made as the transparent, accurate, timely, and understandable information continues to be developed and shared, elevating the tank vapor conversation away from uncertainty and toward a basis of trust in the methods and intent of all involved.

2.0 CTEH Evaluation of the Updated Technical Basis

The WRPS IH Chemical Vapor Process Plan (TFC-PLAN-174 (Rev A-0, dated January 31, 2018) defines the Chemical Vapor Technical Basis (referred to hereafter as the Technical Basis) as the collection of documents, reports, and data informing the understanding of tank waste chemistry, chemicals in tank vapors, vapor dynamics, toxicology, occupational exposure limits (OELs) of tank vapors, and the identification of chemicals of potential concern (COPCs). A synopsis of this information is contained in the Technical Basis report (RPP-22491, Rev 1). At the time CTEH developed the current reassessment, an update to RPP-22491 has been drafted, but not finalized. Therefore, CTEH observations regarding changes to the chemical vapor Technical Basis is based primarily on review of multiple studies produced by PNNL (discussed in Section 3) and the following WRPS documents, procedures and plans:

- Industrial Hygiene Chemical Vapor Technical Basis Program Plan (TFC-PLN-174, REV A-0, dated January 31, 2018)
- Maintenance of the Industrial Hygiene Chemical Vapor Technical Basis (TFC-ESHQ-S_IH-C-67, REV A-0, dated January 31, 2018)
- Identifying Chemicals of Concern in Hanford Tank Farms (TFC-ESHQ-S_IH-C-66, REV A-0, dated January 31, 2018)
- Industrial Hygiene Exposure Assessment Strategy (TFC-PLN-34, REV F-0, dated January 31, 2018)
- WRPS IH Manual, Sections 1-4 (TOC-IH-58435, dated January 29 - April 17,2018).

2.1 Overview of Changes Resulting in Improvements to the Technical Basis

CTEH notes the following changes to the WRPS process and procedures that represent improvements to the Technical Basis implementation presently and going forward. The format of the Technical Basis Program Plan (TFC-PLN-174) allows for modular refinements to key collections of information in the form of internet hyperlinked documents. This presently includes the Technical Basis reference list, Technical Basis summary, tank vapor chemical list, chemical screening concentrations, Hanford tank farm OELs, and current COPCs and their respective OELs. As data are identified and resulting downstream changes need to be made to the appropriate appendices, the modular appendix format of this information makes finding and editing this information easier and less prone to be unintentionally missed during an update cycle.

The Technical Basis process and procedure documents specify the inclusion of workforce representatives in decisions related to change in the Technical Basis. Specifically, TFC-PLN-174 calls for HAMTC safety representatives and TOC (Tank Operations Contractor) workers to be consulted to leverage their fundamental understanding of tank farm process details. This codified engagement of workforce representatives is effective to show that management can and will extend trust to workers in the maintenance of such a cornerstone compendium of IH information. Workforce inclusion in maintaining the Technical Basis is also likely to help "pass the word" through the ranks more quickly than if changes were announced after the fact. This increases transparency in the process.

Similarly, the Technical Basis maintenance procedure (TFC-ESHQ-S_IH-C-67) also specifies an assigned team approach to identifying, reviewing, and adding new information to the reference materials underpinning the Technical Basis. TOC workforce representatives team with IH professional and supporting staff, engineering staff, and external scientists to review and summarize documents that may speak to new technologies or methods being employed in tank farm work. Workforce representation in the Technical Basis maintenance will improve the workforce perception of relevance of the Technical Basis-based policies to worker safety.

In meeting with various groups of tank farm workers, CTEH experts have been repeatedly asked about the confidence in knowledge of the chemical inventory in the waste tanks. Workers also asked about the nature of chemical changes in the tanks over time due to potential cross-reactivity and radiolytic effects. Concerns were raised over how often the headspace sample data were evaluated for the presence of new compounds. At the heart of workers' concerns was the question of whether or not toxicologically significant exposures to previously unknown headspace chemicals were occurring. *Maintenance of the Industrial Hygiene Chemical Vapor Technical Basis* (TFC-ESHQ-S_IH-C-67) addresses this by establishing a detailed process (Section 4.2 of TFC-ESHQ-S_IH-C-67) for periodic review of headspace/source analytical sampling data (collected since the previous review) to determine if additional chemicals should be added to the tank vapor chemical list. Any new, confirmed compounds would then be queued for evaluation as potential COPCs. The procedure specifies participation of IH, engineering, laboratory, and workforce representatives in the data review. Steps are described for identifying potential new compounds and multiple levels of vetting of these data to confirm the presence of the compounds. The result will be a robust and current list of tank headspace chemicals posted to Attachment C of TFC-ESHQ-S_IH-C-67.

Prior to 2018, the COPC concept provided focus for air monitoring and sampling/analysis tasks to inform health-relevant potential exposures of tank farm workers. The COPC concept is useful in that it leverages a rich data set of tank headspace samples to help select chemicals to monitor and sample outside of the tanks based on the conservative criteria of being measured at 10% of a Hanford tank farm OEL. However, the presence of all COPCs in the tank headspace (and, potentially, outside of the tanks) is not ubiquitous across the tank farms. The concept of Chemicals of Concern (COC) is more informative for farm-specific protection measures. *Identifying Chemicals of Concern in Hanford Tank Farms* (TFC-ESHQ-S_IH-C-66) is the IH procedure that define the COC as "*a COPC that has been found likely to occur outside a tank farm source* [headspace, exhauster, breather filter] *at a concentration greater than or equal to 50% of its HTF* [Hanford Tank Farm] *OEL."* COCs are identified for each tank farm based on sampling data from the respective farm. COCs are statistically identified by comparing 95th percentiles of the 95% upper tolerance limits ($UTL_{95/95}$) for COPC concentrations to each COPCs Hanford OEL. If the $UTL_{95/95}$ is greater than or equal to 50% of the COPC's OEL, that COPC is added to the COC list for that particular farm. Use of the 50% of OEL criteria for COC listing is in line with standard IH practice in U.S. industry in which action levels for airborne chemicals in workers' breathing zones are set at 50% of the OEL. Use of the COC concept helps to tailor the use of sampling resources to better fit each farm. This approach also helps worker perception of protection from health risks to be better focused for the area in which they will be working.

Since the implementation of CVAP efforts, multiple studies on tank vapor dynamics, sampling and analysis, and toxicology have been commissioned, performed and reported by PNNL. The findings and/or recommendations of those studies have been subjected to various levels of evaluation by WRPS for possible implementation in part or in whole into the IH tank vapor protection program. The studies provide extensive analyses of their subject matter and serve to answer questions or fill data gaps identified previously by the TVAT, NIOSH, DOE EA, or CTEH. Summaries of the PNNL studies and commentary on their potential utility are provided below in Section 3.0.

2.2 Recommended Improvements in the Chemical Vapor Technical Basis

Upon review of new information developed by WRPS related to the Technical Basis, CTEH makes the following recommendations for further improvement.

Recommendation: The intervals between review of new headspace and source sampling and analysis data to update the tank vapor chemical list (i.e., the inventory of all identified compounds present in the collective headspace), as described in TFC-EHSQ-S_IH-C-67 (*Maintenance of the Industrial Hygiene Chemical Vapor Technical Basis*), should be better defined, whether it is a pre-determined time period (i.e., annual, bi-annual), or an event-triggered criterion, such as retrieval/mixing of some number of tank contents. The resulting data sets would allow for better quantitative analysis of rates of actual chemistry changes over time and space, providing a solid, scientific answer to the question of how much or little the tank chemistries change over a worker's tenure at Hanford.

Recommendation: A program for effective communication of IH data analyses should parallel updates of tank vapor inventories, toxicological assessments, and COPC and COC determinations. Further, periodic summaries of IH real-time and analytical sampling data should be prepared and shared with the workforce in a format designed to (1) address questions about the extent and frequency of COPC exposures, and (2) reinforce worker knowledge of the capabilities of monitoring/sampling methods, engineered controls, and administrative controls to protect health.

In time, these changes would help to move the conversations about worker protection away from the PPE-centric tenor that currently dominates the tank farms work site. CTEH believes that narratives of such summaries should be consistently delivered to workers face-to-face by IH professionals and technicians. This would encourage data-driven dialogue between these groups and begin to change the perception of many workers regarding the engagement level and risk communication competence of in-field IH staff. Concurrent electronic communications (such as those being developed by CPPO) and Q&A opportunities with IH, laboratory, and occupational health SMEs can reinforce the message being delivered by the in-field IH staff.

2.3 Summary of CTEH Evaluation of the Chemical Vapor Technical Basis Documentation

CTEH's initial 2016 assessment of the Technical Basis found the report (RPP-22491), approach, and scientific underpinnings to be scientifically sound and in accordance with best practices in toxicology and industrial hygiene. CTEH still holds this position, and also finds that additions of several other processes and procedures serve to strengthen the programmatic implementation and institutionalization of these best practices. Specifically, the inclusion of periodic reviews of the Technical Basis RPP-22491 document, updating of the IH Manual, and development of the IH procedures TFC-PLN-34, TFC-PLN-174, TFC-ESHQ-S_ IH-C-66, and TFC-ESHQ-S_IH-C-67 will serve to increase confidence that the basis on which vapor data is collected and utilized is both technologically current, transparent, and scientifically grounded. Further development of a schedule for periodic review of the tank vapor chemical list will help to minimize uncertainty voiced by the workforce in the TOC's knowledge of "what is actually in the headspaces." Finally, programmatic communication of new and periodic analyses by IH filed staff to the workforce will help to increase worker awareness of the multiple layers of information that make up the defense-in-depth safety concept and increase their confidence in IH field competence to address vapors-related questions, concerns, and incidents.

3.0 Commissioned Studies to Support WRPS IH Decision Making

Third party assessments of the WRPS chemical vapors program (TVAT, NIOSH, DOE EA, and CTEH) collectively made recommendations for new toxicological analyses and air monitoring/sampling method enhancements to address questions about potential exposures and health risks from momentary, short-lived vapor exposures. As a result, WRPS commissioned multiple studies to be conducted by PNNL. Those studies are discussed here briefly. As a group, the studies represent significant new data and tools for use in better understanding potential health impacts and managing exposure to tank vapor chemicals.

Hanford Tank Vapors FY 2017 Chemicals of Potential Concern Update (PNNL-26820): This report documents the tank headspace sampling analyses and recommendations on tank vapor COPCs performed in 2017. An updated set of tank vapor data and revised $_{HTF}$OELs for some of the chemicals (identified in FY 2016) were used to evaluate the COPC list. The study authors made two COPC-related recommendations, identifying a new nitrosamine as a candidate COPC, and retaining two furan-class compounds that had been previously considered as misidentified analytes. The report also included recommendations for reducing potential data ambiguities introduced by the recording of serial sorbent tube sampling trains.

Recommendations for Sampling and Analysis of Hanford Waste Tank Vapors Leading Indicators (PNNL-26828): Study authors evaluated the technical and procedural challenges to sampling, analyzing, identifying, and quantifying the headspace compounds in the waste tanks. They proposed that IH provide more information on the conditions of sampling, which would help the laboratory analysts in determining the best instrument settings to use to get maximum information from each sample. PNNL authors also reviewed a number of state-of-the-art analytical chemistry technologies that could or should be added to the WRPS laboratory instrumental suite to increase confidence in the headspace compound identification and quantification. PNNL also explored the concept of increasing the level of personal breathing zone sampling using passive analytical or real-time monitoring technologies to develop a "tank farm vapor dose reporting program, similar to the existing radiological program…"

Proposed Acute Exposure Concentration Limits for COPCs with Regulatory Guidelines (PNNL-26850): In an effort to identify OELs for exposure durations less that hours to full work shifts (i.e. closer in duration to momentary exposures reported by tank farm workers), PNNL consulted OEL databases from authoritative government agencies and scientific bodies. Established acute OEL sources included the American Conference of Governmental Industrial Hygienists (ACGIH), United States Environmental Protection Agency (USEPA), the American Industrial Hygiene Association (AIHA), DOE, the Occupational Safety and Health Administration (OSHA), NIOSH, National Research Council, and the German Research Foundation. Acute exposure concentration limits were identified and recommended for 12 COPCs. Recommendations for deriving additional COPC acute $_{HTF}$OELs from existing toxicological data were presented for consideration of future use.

Proposed $_{HTF}$OELs for Chronic Exposures – COPCs with Regulatory Guidelines (PNNL-26777): In this report, PNNL identified time-weighted average OELs for 34 of the 61 current COPCs that were previously-established by authoritative government agencies and scientific bodies. Established OEL sources included ACGIH, DoE, NIOSH, and OSHA. Recommendations for development of time-weighted average OELs for the other 27 COPCs (4 nitrosamines, 14 furans, 8 nitriles, and 2,4-dimethylpyridine) were reported in the three PNNL reports summarized next.

Proposed $_{HTF}$OELs for Chronic Exposures – Nitrile-Class COPCs and 2,4-Dimethylpyridine (PNNL-26819): PNNL considered data underpinning previously-established chronic OELs for acetonitrile, propanenitrile, and butanenitrile. Data from these compounds' OELs were used as surrogates for the 5-, 6-, and 7-carbon alkylnitriles. The OEL established by NIOSH for methacrylonitrile was selected as a surrogate $_{HTF}$OEL for 2-methylene butanenitrile and 2,4-Pentadienenitrile based on structural chemistry similarities. The previously-established DoE OEL for 2,4-dimethylpyridine was selected as the $_{HTF}$OEL for this compound.

Proposed Risk-Based Approach for Nitrosamine Chemical of Potential Concern (PNNL-26787 Rev A): This report proposed a different approach to deriving $_{HTF}$OELs for five N-nitrosamine compounds already listed as COPCs and two others being considered for inclusion on the COPC list. Historically, the five nitrosamine COPC $_{HTF}$OELs were based on German Maximum Arbeitsplatz Konzentration (MAK) values. However, recent NIOSH policy (NIOSH, 2017) calls for applying risk-based approaches to OEL development for genotoxic occupational carcinogens. PNNL proposed a risk-based approach to calculate risk-specific exposure levels for occupational exposures to N-nitrosamine COPCs. The report contains a range of derived nitrosamine inhalation exposure levels, experienced over a working lifetime of 45 years, that are associated with various risk levels for use in protecting tank farm workers.

Proposed Occupational Exposure Limits for Furans (PNNL-26775 Rev A): This report provides an evaluation of the $_{HTF}$OELs for furan and 13 chemically-related furan-class COPCs that did not have OELs previously established by regulatory or scientific bodies. Toxicological research has shown that furan causes liver toxicity and cancer in laboratory animals. More recent data from animal studies indicate that furan exerts its carcinogenic effect via a non-genotoxic mechanism of action. Using this information and other new toxicological data, the study authors recommended changing the furan $_{HTF}$OEL for furan from 1 ppb to 1.9 ppb. Data for the other 13 furan-class COPCs are still limited. However, their mechanism of toxic action is hypothesized to be similar to that of furan. Thus, PNNL recommends the continued use the furan $_{HTF}$OEL as a surrogate for the other 13 substituted furans until adequate data for those compounds are generated and available for further evaluation.

The APGEMS-TF Atmospheric Dispersion Model for Tank Farms Applications (PNNL-27530): This report describes the development and testing of the Air Pollutant Graphical Environmental Modeling System – Tank Farms (APGEMS - TF) software. The original APGEMS software was designed to predict radiological particle dispersion at the Hanford Site. This software was modified to be specifically applicable to tank farms (APGEMS-TF), particularly with the ability to simulate multiple simultaneous vapor emission points. Locations for potential 200 East Area A Corridor tank vapor emission sources and estimates of COPC emission rates were built into the software. Single and multiple emission point test cases were used to evaluate the capabilities and limitations of the APGEMS-TF version 1.0 model. Following release of the report, version 1.0 of the software was further developed to version 1.1, which demonstrated simulated COPC plume profiles that better reproduced data from the tests cases.

Leading Indicator Process Development Report (PNNL-25533) and *FY18 Leading Indicator Phase 2 Report* (PNNL-27449): These studies together describe a process for identifying Leading Indicator (LI) compounds in the tank headspace that may be used to predict or place bounds on the concentrations of other of other COPCs which cannot be readily measured in real-time for use across the tank farms. The 2016 Phase 1 report relied on pairs of analytical sampling data from the Tank Waste Information Network System (TWINS) and Site Wide Industrial Hygiene Database (SWIHD), while the Phase 2 report took advantage of additional data that was not previously available, including data from the respirator cartridge filter testing program, and the mobile laboratory collected during both static and tank disturbing work activities. The Phase 2 report used a different statistical approach than used in the Phase 1 report. The study authors reported that the trio of ammonia, nitrous oxide, and mercury may together serve as LIs for up to 45 of the 61 total COPCs and 21 of 24 COPCs found on Tank Vapor Information Sheets (TVIS) for individual tank farms. All three of these candidate LI compounds are routinely monitored by WRPS IH using real-time direct reading instruments.

The studies that have been conducted by PNNL on behalf of WRPS IH in the past two years represent a significant technical analysis and investment in technology and methodology that may help improve the assessment of chemical hazards and risks for potential tank farm vapor exposures. The updated evaluations of COPCs and the introduction of the APGEMS-TF Fire Data Simulation (used in quantitative exposure risk assessments) air dispersion modeling software (in concert with other modeling packages used by WRPS) may serve to better predict the potential areas of impact from tank vapor emissions. This will aid in improving the ability to effectively react to potential vapor release event, as well as explore future strategies for designing air monitoring and sampling regimens to better characterize situation-specific exposure scenarios. The reports dealing with OEL development and/or selection provide a sound basis for utilizing scientifically-robust OELs and derivation methods to leverage the latest toxicology data. While an effort has been made to establish acute OELs based on available ceiling and short-term exposure limits,

Recommendation: A formal review of odor threshold data for the COPCs and non-COPC compound class representatives (e.g., short to medium chain length hydrocarbons) is needed. These analyses would help to put into perspective the potential exposures to workers that have either been measured or modeled by WRPS IH.

4.0 WRPS Implementation of CTEH 2016 Recommendations

Based on areas of improvement identified in the 2016 CTEH assessment of the Technical Basis, CTEH offers the following observations on implementation actions performed by WRPS related to those areas. These include understanding, responding to, and communication of technical information germane to odor incidents; air monitoring and sampling related to short-term exposure incidents; promoting risk-based decision making; and preparing IHT staff to be sources of exposure information to a level that elevates their professional confidence and the workforce perceptions of their technical competencies.

4.1 AOP-015 Process Improvements

CTEH recommended that the Abnormal Operating Procedure for *Response to Reported Odors or Unexpected Changes to Vapor Conditions* (TF-AOP-015) be revised so as to remove implications that any odor encountered at Hanford is abnormal as well as change subsequent actions that need to be taken when odors are encountered. At the time of CTEH's 2016 assessment, the TF-AOP-015 document qualified odors of concern as "stronger than normal," which was deemed by CTEH to be too subjective and potentially confusing to the workforce. Further, CTEH stated that AOP-015 investigation and reporting, which can take as long as 30 days, needed to be expedited considerably, with workers receiving information related to their health in a timely fashion.

The TF-AOP-015 document has been revised five times since the drafting of CTEH's 2016 assessment. The document revisions are briefly discussed here. Revision G-2 (January 2017) added distinct requirements for responding to odors detected inside vs. outside tank farm boundaries, including instruction to identify respiratory protection appropriate for the location at which the odor was detected.

Revision G-3 of TF-AOP-015 (March 2017) added a Communication Template and Follow-Up Event Summary as attachments to the document. The Communication Template (Attachment 2 of TF-AOP-015) asks for the number of workers who reported odors and were taken to the health clinic or declined medical evaluation. It also requests a description of the work being performed at the time of reported odors and whether the workers were in an area that requires use of supplied air respiratory protection. The Template includes a conformation that workers were instructed to leave the area and that access to the area was restricted. The user of the Communication Template is instructed to complete it “as soon as enough information is available”.

The Follow-Up Event Summary (Attachment 3 of TF-AOP-015) requests information on the date and time of the odor event, the number of workers involved, the number of sampling results collected, and a narrative summarizing the event. Similar to the Communication Template, the Follow-Up Event Summary describes the event, the number of workers who were taken to HPMC or declined medical evaluation, and notes whether workers were in an area that requires use of supplied air respiratory protection. It also includes a statement confirming that workers were instructed to leave the area and that access to the area was restricted. The Follow-Up Event Summary also discusses air monitoring activities performed by IHTs in response to the event. Direct-reading instrument (DRI) data are provided and analytical sampling data are provided if the results are available. Lastly, the Follow-Up Event Summary notes the return to work status of workers involved in the event. The attachment indicates that the Follow-Up Event Summary is to be completed “once event is stabilized and all details are known”.

Revision G-4 of TF-AOP-015 (March 2018) updated authentication requirements for IH data sheets. The current version of TF-AOP-015, revision G-5 (June 2018) indicates minor text formatting changes: emphasis on the words IF and CALL in the statement “IF emergency assistance is required, CALL Hanford Fire Department.”

The CTEH 2016 assessment recommended that WRPS consider creating a short event report that is quickly published following an AOP-015 event, which could increase trust among the workforce by providing results in a timely fashion. The inclusion of the Communication Template and Follow-Up Event Summary attachments in recent revisions of the TF-AOP-015 document is a noticeable improvement towards addressing worker concerns following these events. The communication and event summary templates can facilitate timely communication of these events to the workforce. However, there is no delivery timeframe requirement included in the TF-AOP-015 document, and delayed communication and summary releases may concern workers.

In addition to TF-AOP-015, WRPS has also released an additional odor-response protocol: *Response to Readily Apparent or General-Purpose Facility Odors* (TFC-OPS-OPER-C-67). Entry into the AOP-015 or C-67 odor response protocol depends on the reported odor characteristics and the location where WRPS personnel and subcontractors are performing work:

1) TF-AOP-015 applies to workers in 200 East Area, 200 West Area, and the WRPS-controlled work at 600 Area. It also applies to odors detected by or resulting in symptoms to multiple personnel, or to stronger-than-normal odors detected by multiple personnel outside of areas where potential tank vapor exposures are expected.
2) TFC-OPS-OPER-C-67 also applies to workers in 200 East Area, 200 West Area, and WRPS-controlled work at 600 Areas. However, it applies to odors at a general-purpose facility or odor sources that are readily apparent, such as vehicle exhaust, septic systems, herbicides, pesticides, and animal odors.

The TFC-OPS-OPER-C-67 procedure can allow the IH program to distinguish certain odor events and associated exposure data from events triggered by tank vapor odors. However, the language in the TF-AOP-015 and TFC-OPS-OPER-C-67 documents may cause confusion in initiating the appropriate response. It is not clear from language in these protocols how a worker will distinguish “stronger than normal odors detected by multiple personnel outside of areas where potential or actual vapor concerns are expected” from “odor sources that are readily apparent, such as vehicle exhaust, septic systems, herbicides, pesticides, and animal odors”, as there is the potential that tank farm odors could be similar to these other odors. CTEH’s above recommendation to generate a list of COPCS and their odor characteristics for each tank farm could address this potential issue.

WRPS indicates they are taking steps to further develop an improved, integrated odor response process with clear roles, responsibilities, authorities, and accountabilities. On March 12 - 15, 2018, WRPS hosted an Environmental Safety, Health, and Quality (ESH&Q) Lean Management Value Stream Analysis event with the objective to improve the flow of documentation and feedback in the odor response process. The team identified the following action items during this event: 1) develop a plan defining roles, responsibilities, authorities, and accountabilities (R2A2) following an odor event; 2) align odor response procedures; 3) streamline the event summary report format and replace redundant reports; 4) provide one-on-one communication with affected workers; 5) track and trend HAPSITE data; and 6) improve the interface between WRPS and HPMC. The ESH&Q Lean event noted that the recommended adjustments to the odor response investigation process would reduce IH response information flow time (325 hours fewer and 5 fewer people in process) and eliminate operations investigation touch time (currently 48 hours) and flow time (currently 1144 hours, 72 people in process). If implemented, these changes would effectively address CTEH’s recommendation that the time period of AOP-015 investigations and the delivery of results be considerably shortened.

4.2 Cataloging Odor-Generating Locations/Fugitive Emission Sources

CTEH noted previously that potential exposure points within the tank farms have been examined by WRPS, previous Hanford contractors, and third parties. The WRPS IHT-Vapors group was formed in response to the TVAT (2014) report recommendations to better characterize potential odor sources inside and outside of the tank farms and perform routine monitoring of identified emission points. It has since been retired. This group was involved with testing and implementing new monitoring technologies implemented during a pilot-stage of deployment, which continues today.

Historical IH and waste disposal records suggest potential fugitive emissions sources may exist within and outside of the tank farms where chemical waste may have historically been released to the ground. These sources may result in re-entrainment of chemicals and their associated odors from soil into the air during remediation work being conducted independent of tank farm operations. Since the drafting of the 2016 CTEH assessment, a Chemical Vapor Solutions Team (CVST) – Fugitive Emissions (FE) sub-team was chartered to help determine the location and nature of emissions sources in and around the Tank Farms, prioritize the order of investigation of the sources, evaluate and characterize the sources, and develop a library of the chemical makeup of emissions sources around the tank farms. The CVST-FE will direct source location and fingerprinting investigations of suspected fugitive emissions sources on the Hanford site. The Investigation Plan for the Fugitive Emissions Identification and Characterization Demonstration Project (RPP-PLAN-60656, Rev. 0) plan presents the purpose, scope, and organizational structure of the fugitive emissions initiative. It provides the following strategy for executing the fugitive emission investigation:

1) Determine areas of interest where odors are an issue and prioritize the order of investigations.

2) Develop an investigation plan using all available information available for the area of interest.

3) Identify (pinpoint) the source(s) within the area of interest using a limited number of instruments.

4) Develop a sampling and analysis plan to determine the types of laboratory sampling that will be required and determine if any special methods will be required for the analysis.

5) Execute sample collection and analysis – including on-site analysis where applicable.

6) Report data and add to a source database for all identified sources.

7) Use modeling to predict source dispersion relative to hygiene and odor thresholds.

8) Provide process methods and procedures for future investigations.

9) Document and communicate investigation findings to the CVST/workforce.

The CVST-FE team identified the area near Buffalo Street from 4th Street to the C-Tank Farm as the area of interest for the initial fugitive emission investigation. Over the past four years, multiple AOP-015 events were reported in the general vicinity of this area. Due to the large number of potential emission sources in this area, and the large number of chemicals identified as having been used in the area, the team plans to conduct an initial fugitive emissions investigation in the area in and around the 244AR building, a known location in the Buffalo Street and 4th area where multiple odor events have occurred. Based on an evaluation of potential emissions sources in this area, the team identified a list of potential chemicals and narrowed it down based on a comparison of these chemicals' odor profiles to the odors reported in various AOP-015 events near the 244AR building. The team compiled data collected during AOP-015 events, locations of currently operating systems (sanitary sewers, portable toilets, and diesel generators), the locations of Waste Information Data System (WIDS) sites, results from soil sampling performed in the general area, available meteorological data, and historical reports detailing past operations and spill locations. The team then used this information to select analytical methods to locate and characterize fugitive emission sources in the area.

Sulfur-containing organics are believed to be the primary source of odors detected during previous AOP-015 events. The CVST-FE team notes that odor thresholds for many sulfur-containing compounds are in the parts per billion (ppb) to parts per trillion (ppt) concentration range and recognizes that additional mobile equipment with lower detection limits than those currently being tested at the tank farms will need to be acquired and demonstrated to effectively evaluate fugitive emissions of these compounds. However, the CVST-FE plans to perform its initial investigation using instrumentation currently available through the IH organization and Vapor Monitoring and Detection System (VMDS) equipment developed by the VMS&R project at Hanford. The CVST-FE team's initiative has been funded to perform testing in FY19, and the team intends to rollout instrumentation to the initial area of interest during the first quarter of FY19.

Direct-reading instrumentation to be deployed for the initial phase of the CVST-FE investigation, such as TVA1000 portable photo ionization detectors (PIDs) and MultiRAE/AreaRAE PIDs and electrochemical sensors, will generally be capable of detecting many odorous chemicals at concentrations below those that are hazardous to human health. However, these direct-reading instruments are not capable of detecting compounds in the low ppb through ppt range. For example, methyl mercaptan, believed to be associated with dirty sock odors, has an odor threshold of 2 ppb whereas MultiRAE/AreaRAE PIDs will not detect this compound until it has reached an airborne concentration of 65 ppb. Therefore, it is possible that a dirty sock odor may be experienced by a worker/CVST-FE investigator while direct-reading instruments are showing non-detect and are unable to pinpoint the emission source.

Open Path-Fourier Transform Infrared Spectrometers (OP-FTIR) and Gastronix Fixed Instrument Skids (FIS) will also be deployed at locations in the initial investigation area to perform continuous air monitoring. These instruments will be able to detect a large number of compounds, including many of the sulfur containing compounds expected from the odors detected, and the detection limit of these instruments is much lower than the direct-reading devices mentioned above (detection limits can be as low as 10s of ppb). However, even these instruments may not have sufficient sensitivity to detect compounds with low odor thresholds.

The CVST-FE team indicates additional instruments will be deployed later in the investigation, including TVA2020 FID/PID handheld devices, HAPSITE GC/MS instruments, and the mobile laboratory (PTRMS and GC/MS); however, the project plan does not indicate whether or not these devices have sufficient sensitivity to detect compounds at low odor thresholds. CTEH recommends that the CVST-FE team provide an evaluation of instrument sensitivity compared to odor threshold data for suspected compounds emitted in the area of interest to demonstrate that the instrumentation selected is appropriate for the investigation.

In addition to the CVST-FE investigation, WRPS has discussed the possibility of enlisting a 3rd party odor investigation group to confirm the specific compounds associated with odors near the tank farms (i.e., dirty sock, onion, cat urine, etc.). Such an effort would benefit the CVST-FE investigations as analytical methodology and instrument sensitivities can then be better focused to measure these compounds.

4.3 Development and Implementation of a Comprehensive Risk Assessment Process

In its 2016 assessment, CTEH stated that a comprehensive risk assessment needed to be developed that lists all known tank vapor hazards to the workforce, the potential health impact (both acute and chronic) of exposure to these hazards, the frequency or potential frequency of exposure, number of workers potentially impacted and engineering controls in place with an estimation of effectiveness. As part of this recommendation, CTEH also stated that the workforce needs to be educated as to the health risks from exposure to tank vapor odors, and that workers should not expect an odor-free environment, as this is not the case or expectation in other industries associated with the manufacture, handling, or use of chemicals.

WRPS initiated a program to systematically quantify the risks of tank vapor exposure and health effects that is ongoing to date. The program entails identifying the chemical hazards in tank headspaces, describing potential exposure points, estimating potential exposures under various meteorological and working conditions, and determining the health risks associated with such exposures.

Tank vapor hazard identification is captured in the IH Tank Vapors Information Sheets (TVIS). The TVIS are information sheets developed for each farm that list COPCs identified in the tank headspaces by previous sampling and analysis. Section 4.2 of TFC-ESHQ-S_IH-C-67 now calls for periodic review of headspace/source analytical sampling data and should help to keep current the TVIS inventory data.

The process of assessing potential tank vapor exposures is now described in Section 4.3.1 and 4.3.2 of the updated IH manual, as well as in the *Exposure Assessment Strategy* (TFC-PLN-34), TFC-ESHQ-IH-C-69, and the quantitative exposure risk assessments, which leverage air dispersion with computational fluid dynamics methods. This process includes evaluation of TVIS information and work tasks to classify work in specified risk classifications. Exposure points are evaluated (active exhausts and passive breather filters), including procedures for identifying fugitive vapors sources within the farms at locations such as cabinets and valve pits in addition to the designed ventilation points.

Computational air dispersion modeling has been used in the past for tank farm worker safety decision making but is now being employed on a more regular basis in the WRPS vapor risk assessment process. For each of the tank farms, computational fluid dynamics modeling is being used to simulate potential movement of COPCs from tank sources to downwind receptors. Various tank conditions (e.g., quiescent vs waste-disturbing activities) and meteorological conditions were modeled to calculate the probability of exposure of workers to tank farm vapors. Quantitative exposure risk assessments are being authored for each farm. A second air dispersion model, APGEMS-TF (described above in Section 3.0) is also being used to simulate potential exposures or respond to vapor release events and aid in decisions to minimize worker exposures. Results from air monitoring and sampling, as well as air dispersion modeling, are being used in concert to estimate health risks to workers and, subsequently, apply appropriate methods to reduce exposure and minimize adverse health risks.

4.4 Industrial Hygiene Program Improvements

In 2018, WRPS implemented a revised Industrial Hygiene Manual to provide a process for updating existing exposure assessment activities, TVIS, Similar Exposure Groups, and associated sampling plans. The term Similar Exposure Groups (SEGs) was replaced by the term Risk Classification (RC) to describe the types of work associated with the specific sampling plan activities for each tank farm. Risk Classifications remain in 4 separate tiers with recommendations for the type of personal protective equipment (PPE) required in addition to the IH sampling plan requirements.

CTEH recognizes this update as an improvement to the overall IH program as some of the TVIS had not been updated in several years. The document update process provided in the IH manual update is key to keeping IH documentation current.

4.5 Air Sampling and Monitoring Practices

CTEH noted in 2016 that all real-time and analytical air sampling methods should follow conventional sampling practices and that any variations must be verified for adequate sampling and analytical performance before being implemented. CTEH recognizes that there now exist multiple opportunities to collect and analyze air sampling and monitoring data, allowing for more robust statistical analyses of tank vapor constituent levels at various locations, times, and under various conditions. Data from the filter cartridge testing, the mobile lab, and exhaust stack monitors allow for these robust analyses.

PNNL made recommendations regarding IH sampling and analysis of samples in their report (PNNL-26828) released in 2018. This report includes recommendations for changes/additions to the information provided by IHTs during the collection of samples to allow for better-defined analysis of data trends. There were also recommendations made regarding analytical instrumentation hardware and software that could be implemented to provide better resolution of constituent levels on headspace source samples. CTEH held discussions with WRPS experts in process engineering and analytical chemistry and learned of upcoming analytical capability upgrades to instrumentation that improve confidence in identification of chemicals. These improvements align with many of the recommendations made in the PNNL report.

4.6 IHT Training

CTEH’s 2016 assessment of the WRPS IH program noted that the IHTs represented the least trained group for the type of work they are asked to perform. At the time of the 2016 assessment, the education requirement was viewed as low and had provisions for being waived (TFC-BSM-TQ-STD-01 and TFC-BSM-TQ-MGT-C-01). CTEH recommended that employment as an IHT should require an intensive and on-going training, mentoring, and oversight process following hiring, including education requirements being maintained to prevent excessive retraining of personnel. The expectation was not that the IHTs have the same level of educational background as an IH Professional, but rather a consistent and thorough minimum level of technical ability.

WRPS has improved both the IHT hiring criteria and the training/qualification process. The initiation of the Crucial Conversations training for IHTs is a positive step. This training aids workers in preparing for and responding appropriately in real-time to high-stake conversations that may be highly charged. However, CTEH experts have observed a mixed bag of vapors-related communications to the workforce, ranging from highly effective explanations of odors and instrument readings to minimal descriptions of monitoring activities and their justifications.

Chemical Worker Training has been implemented for tank farm workers (including IHTs) at Hanford. It is an in-depth chemical hazard training, focusing on improving the tank farm worker knowledge base underpinning several tank vapor issues. This training has received positive reviews by less tenured or new

IHTs while more experienced IHTs tend to view it as boring and repetitive. Overall CTEH views the updated Chemical Worker training to be a move in the right direction.

Recommendation: IHTs need to be able to articulate a consistent and accepted scientific response to instrument operation and exposure questions posed by field level personnel with respect to tank vapor exposures. IHTs training should include practice opportunities to explain why measurements of vapor analytes are below levels of concern.

5.0 CTEH On-site Activities in FY2017-18

5.1 Worker Engagement

In the spring of 2018, CTEH, teaming with the CPPO as a WRPS subcontractor, commenced worker engagement opportunities to better understand the actual or perceived changes with regard to several of the findings from the 2016 CTEH assessment. These meetings included participation in Plan-of-the-day (POD), pre-job, safety tailgate, and small worker group meetings. CTEH experts also visited the tank farms outside of the fenced areas during project work to observe and learn about various projects types within the farms, as well as be available to answer health-related questions of the workforce present at that time.

CTEH experts, participating in CPPO worker focus groups, facilitated single worker interviews to learn more about workforce perception of WRPS' handling of the tank vapors issue. These interviews entailed private one-on-one discussions between a CTEH industrial hygienist and individual workers. A cross section of Hanford technical staff was interviewed from the industrial hygiene, health physics, and HAMTC safety representatives. The objective was to determine which changes had occurred or were perceived to have occurred in the preceding eighteen months with respect to topics such as: IH Technician Training, Chemical Worker Training, the Tank Vapors program, availability of resources to perform work, etc. The results of the answers to these questions were assessed for common themes and general perspectives as opposed to using a ranking scale.

Common themes were identified with both negative and positive connotations. In response to the question regarding "having enough resources to do my job", both HPT and IHT technicians resoundingly said "yes" and "absolutely"; however, many technicians identified a logistical challenge of having available vehicles to get from one place onsite to another in a timely fashion.

Other themes that emerged include positive responses to being asked about frontline manager support and generally having enough or correct equipment to perform work. When asked "how prepared do you feel you are for your role?", the clear majority indicated they felt very well prepared for their work. When asked to describe "Support from management", the responses were positive for direct supervision. Responses indicated room for improvement with regard to support from middle and upper leadership.

For the question "what is your greatest challenge?", the requirement of mandatory SCBA usage was repeatedly given in response. Communication was also the most common answer to the question "what needs most improvement?”. When pressed for details this seemed to be referencing top down communication reaching the field personnel. This appears to be a challenge to digital communication filtering down to the field level workers effectively.

The technical section of the interviews focused on AOP-015 and tank vapor program understanding. The majority of all groups had excellent recollection of the AOP-015 process and understood the purpose of Tank Vapor program activities as well as their respective roles in each topic.

The topics of transparency and trust were brought up during multiple interactions between CTEH® and workers. During these interactions, workers related an impression that the medical outcomes of AOP-015 events were under communicated. CTEH® recognizes the Health Insurance Portability and Accountability Act (HIPPA) prevents the release of certain health information for the privacy and security of patients and may limit or impair reporting detailed information regarding the medical outcomes of AOP-015 events.

In the summer of 2018, CTEH began attending the last portion of the Chemical Worker training course to provide a question and answer (Q&A) session for attendees. The Chemical Worker training class is required for ACEable workers. The purpose of the Q&A sessions was to engage workers in a face-to-face setting and create an open dialog regarding chemical vapor concerns.

During the Q&A sessions, CTEH toxicologists introduced the reassessment, risk communication, and engagement activities conducted by CTEH before opening the forum to questions. As time has passed, CTEH experts note that questions have generally shifted from concern over specific chemicals or health effects to justification for strategic worker protection practices and processes. The most frequent questions included:

1) What consideration had been given to the unknown chemicals in the tank vapors that are either unidentifiable or not associated with human health concerns at this time?
2) As a toxicologist, would you feel safe working in the tank farms? What is CTEH’s evaluation of the IH program in comparison to IH programs in other industries?
3) What are the health effects of exposure to the COPCs, and has there been data to demonstrate associations of increased health risk among Hanford tank farm workers?
4) What is the basis of the occupational exposure limits for COPCs which have limited data available?
5) What is the risk for dermal exposures to tank waste chemicals, including vapor and condensate?
6) If the numbers indicate the air is safe, why are workers still on supplied air respiratory protection? If engineering controls take precedence over PPE, why are supplied air respirators used?

CTEH addressed toxicology-related questions and deferred engineering and IH questions to WRPS subject matter experts. The Chemical Worker training engagement provided insight and an open dialog to discuss worker concerns. The perceived worker concerns were consistent with those addressed during one-on-one interviews, and feedback indicated perceived value in toxicology training material provided during the class.

Based on the various worker engagement activities mentioned above, CTEH concludes there has been significant improvement with regard to worker communication and training via the implementation of the Chemical Worker Training. CTEH recommends continuing in-person communications as opposed to digital training media, especially to address concerns regarding SCBA usage among other topics. In addition, worker feedback indicated a desire for increased visibility and accessibility of middle and upper management on-site.

5.2 Development and Delivery of Toxicology and Industrial-Hygiene Based Informational Presentations

CTEH's 2016 assessment recommended training workers on the basic concepts of human odor perception in order to help workers discriminate toxic versus non-toxic vapor exposures as well as understand the important differences between health hazards and risks. To this end, WRPS and CTEH experts produced a five-part educational presentation reviewing olfactory anatomy, odorant properties, physiological effects of odors, and the warning properties of odors. These presentations were distributed to the workforce via Safety Starts in June 2017 and incorporated into the Chemical Worker training class. Section 5.1 of this reassessment discussed the most frequent questions received during the Chemical Worker training CTEH Q&A sessions. Although not definitive, the notable absence of odor-related questions is observed as progress towards eliminating worker misconceptions surrounding odor and toxic vapor exposures.

CPPO and CTEH experts developed additional educational presentations were prepared for toxicology subjects such as nitrosamines, furans, dimethylmercury, ammonia, and nitrous oxide. Presentations on IH subjects were also prepared, including exposure assessment, air-purifying filter testing and functional basis, and analytical chemical analysis principles. These educational pieces were meant to provide a comprehensible introduction to concepts and technical issues related to the Hanford site. In conjunction with in-person conversations and formal presentations at worker meetings (e.g., CVST Meetings), the presentations aid in the overall communication to, and training of, the workforce.

CPPO and CTEH engineers, industrial hygienists, and toxicologists engaged in several in-depth exchanges with subject matter experts from the 222-S laboratory, industrial hygiene, operations, engineering, and HAMTC safety leads. Each exchange allowed for a two-way exchange of technical, historical, and operational information that aided in CPPO/CTEH development of workforce communication pieces and well informing WRPS of worker concerns and suggestions for vapor hazards and their prospective remedies.

6.0 Conclusions

CTEH conducted a reassessment of the WRPS IH chemical vapor Technical Basis and its implementation at the Hanford site. Overall, the Technical Basis remains sound from both a toxicological and industrial hygiene standpoint; changes made to WRPS process and procedures literature further improve implementation of the Technical Basis. Following the 2016 CTEH assessment of the Technical Basis, WRPS has implemented improvements to the response and reporting of odor incidents, air monitoring and sampling related to short-term exposure incidents, and the training programs for IHT staff who are often relied upon as the initial onsite source of exposure information to the workforce. Specific observations from the CTEH reassessment are summarized in the following sections. The CTEH recommendations are repeated here as well.

6.1 Updated Technical Basis Document

Several changes were made to WRPS process and procedures documents that improve the Technical Basis' implementation. The new Technical Basis Program Plan (TFC-PLN174) has a modular format that will facilitate future refinements to the Technical Basis program and procedure documents by allowing information to be found and edited more efficiently during an update cycle. For decisions related to changing the Technical Basis or supplementing its reference materials, the Technical Basis process and procedure documents specify the inclusion of workforce representatives (i.e., HAMTC safety representatives and TOC workers). This codified engagement of workforce representatives demonstrates that management can and will extend trust to workers in the maintenance of such a cornerstone compendium of IH information. Workforce inclusion in maintaining the Technical Basis is also likely to help "pass the word" through the ranks more quickly than if changes were announced after the fact. This increases transparency in the process.

Maintenance of the Industrial Hygiene Chemical Vapor Technical Basis (TFC-ESHQ-S_IH-C-67) establishes a detailed process for periodic review of headspace/source analytical sampling data to determine if additional chemicals should be added to the tank vapor chemical list and evaluated as potential COPCs. This procedure document should improve worker confidence in the knowledge of the chemical inventory in waste tanks and effectively address worker concerns regarding how often the tank headspace sample data are being evaluated for the presence of new compounds.

Recommendation: The intervals between review of new headspace and source sampling and analysis data to update the tank vapor chemical list (i.e., the inventory of all identified compounds present in the collective headspace), as described in TFC-EHSQ-S_IH-C-67 (*Maintenance of the Industrial Hygiene Chemical Vapor Technical Basis*), should be better defined, whether it is a pre-determined time period (i.e., annual, bi-annual), or an event-triggered criterion, such as retrieval/mixing of some number of tank contents. The resulting data sets would allow for better quantitative analysis of rates of actual chemistry changes over time and space, providing a solid, scientific answer to the question of how much or little the tank chemistries change over a worker's tenure at Hanford.

WRPS also implemented a procedure for identifying COCs (*Identifying Chemicals of Concern in Hanford Tank Farms,* TFC-ESHQ-S_IH-C-66) for each tank farm, which will help to tailor the use of sampling resources to better fit each farm. It also supports a worker perception that health-protective programs are focused for the area in which they will be working.

Recommendation: A program for effective communication of IH data analyses should parallel updates of tank vapor inventories, toxicological assessments, and COPC and COC determinations. Further, periodic summaries of IH real-time and analytical sampling data should be prepared and shared with the workforce in a format designed to (1) address questions about the extent and frequency of COPC exposures, and (2) reinforce worker knowledge of the capabilities of monitoring/sampling methods, engineered controls, and administrative controls to protect health.

Recommendation: A formal review of odor threshold data for the COPCs and non-COPC compound class representatives (e.g., short to medium chain length hydrocarbons) is needed. These analyses would help to put into perspective the potential exposures to workers that have either been measured or modeled by WRPS IH.

The narratives of these summaries should be consistently delivered to workers face-to-face by IH professionals and technicians to encourage data-driven dialogue between these groups.

6.2 Implementation of CTEH 2016 Recommendations

CTEH's 2016 assessment of the Technical Basis found the report, approach, and scientific underpinnings to be scientifically sound and in accordance with best practices in toxicology and industrial hygiene. Areas of improvement identified in the 2016 assessment included understanding, responding to, and communicating technical information for odor incidents, air monitoring and sampling related to short-term exposure incidents, promoting risk-based decision making, and preparing IHT staff to be sources of exposure information to a level that elevates their professional confidence and the workforce perceptions of their technical competencies.

The TF-AOP-015 procedure continues to qualify odors of concern as "stronger than normal". As discussed in CTEH's 2016 assessment, this statement is too subjective and implies that detecting an odor is abnormal. Tank vapors should be understood to be a normal character of Hanford. Each tank farm should have a specific list of COPCs, odor characteristics, and concentrations that are expected to be normal on that particular farm. Only odors that do not appear on the characteristics list should be considered abnormal. WRPS released the *Response to Readily Apparent or General Purpose Facility Odors* (TFC-OPS-OPER-C-67) procedure, which in theory will allow the IH program to distinguish certain odor events and associated exposure data from events triggered by tank vapor odors. However, the language in the TF-AOP-015 and TFC-OPS-OPER-C-67 documents may cause confusion in initiating the appropriate response. It is not clear from language in these protocols how a worker will distinguish "stronger than normal odors detected by multiple personnel outside of areas where potential or actual vapor concerns are expected" from "odor sources that are readily apparent, such as vehicle exhaust, septic systems, herbicides, pesticides, and animal odors", as there is the potential that tank farm odors could be similar to these other odors.

WRPS has implemented additional programs that promote risk-based decision making at Hanford. WRPS initiated a program to systematically quantify the risks of tank vapor exposure and health effects, which involves describing potential exposure points to chemical hazards in tank headspaces, estimating potential exposures under various meteorological and working conditions, and determining the health risks associated with such exposures. This process is described in the updated IH manual as well as in the *Exposure Assessment Strategy* (TFC-PLN-34). Computational air dispersion modeling is also being used in risk assessment analysis to simulate potential movement of COPCs from tank sources to downward receptors. Qualitative exposure risk assessments are being authored for each farm, which include the results from air monitoring and sampling as well as air dispersion modeling to evaluate potential health risks to workers and suggest appropriate controls.

CTEH's 2016 assessment noted that the IHTs represented the least trained group for the type of work they are asked to perform. WRPS has since introduced a revamped training program for IHTs and other workers at Hanford in the form of Chemical Worker Training, an in-depth chemical hazard training, focusing on improving workforce knowledge base for atmospheric and physiological behaviors of tank vapors. Overall, CTEH views the training to be a move in the right direction towards improving workforce education. CTEH continues to recommend that on-going training, mentoring, and oversight processes be implemented to maintain a consistent and thorough level of technical and communication ability in the IHT workforce.

6.3 A Path Forward

The effective communication of health risk information to the tank farm workforce is key to making considerable progress in resolving tank vapor concerns. In the past, numerous technical analyses of tank wastes in general and tank vapors in particular have been performed by multiple tank farm contractors as well as experts from PNNL. In more recent years since release of the TVAT assessment, significant hardware and process additions have been made to the suite of WRPS engineered controls for limiting tank vapor exposures. CTEH has observed instances in which findings from older studies and newer data collection and analysis efforts, if integrated cohesively with information for newly operational processes and hardware, could help the workforce understand more fully the significance of the novel approaches in providing defense-in-depth for worker health protection. The strategy for dissemination of this integrated health risk reduction message should include face-to-face time for workers to hear from and question experts in addition to roll-out through supervisors.

CTEH understands that the problem of tank vapor health concerns has been cyclic; involving an increase in actual or perceived injuries, upgrading of worker PPE requirements, initiation of advanced scientific data collection and analysis activities, and downgrading of PPE at some point until the next crisis of health concern again increased. CTEH has not seen, prior to 2014, programmatic communication to workers of how changes in IH practices impact worker health or how periodic scientific analysis of the issues inform issues of health risks. Tank farm workers have shared common accounts of various changes in processes and engineered exposure reduction that they have recalled over the years but have not shared recall of efforts to communicate to the workforce at every step the impact on health protection of process and engineered changes to the tank farm work.

The level of IH technology and effort that has been brought to bear, and continues to be rolled out by WRPS, for understanding and preventing impacts to worker health is, in CTEH's experience, unparalleled at any other site in the U.S. Tools ranging from predictive computer modeling, permanent exhaust infrastructure, personal and real-time monitoring, and hazard characterization together comprise an impressive array of defense-in-depth protections. However, there should be a programmatic means of employing great technical advances and improvements while at the same time explaining the basis and magnitude of these efforts to workers and offering the opportunity for feedback. CTEH has observed that workers more fully appreciate and acknowledge the benefits of new technologies when they are presented in a way that allows workers to quickly learn the basic principles underlying the technology, ask questions to reinforce that learning, and arrive at their own conclusion about the effectiveness of the new measure. Rollout of advanced new technology without a lay-level explanation of how the technology will reduce exposure risk may represent a missed opportunity to improve workforce trust in the commitment of WRPS to vapor-related worker health protection.

For the past two years, the CPPO, working with SMEs from WRPS IH and engineering and CTEH, has prepared and presented “bite-sized” communication pieces designed to explain various aspects of the tank vapors resolution process in the context of new technologies and scientific studies, previously-developed studies, and basic principles of engineering, IH, and toxicology. Whereas these products were made available to WRPS workers online and were rolled out to workgroup supervisors, the advantage of SMEs discussing these products face-to-face with workers has been significant. During the dozens of question-and-answer sessions that have taken place between SMEs and workers, the ability to effectively simplify and communicate technical nuances brought up in conversation has resulted in many “ah ha” moments, with workers leaving with a better grasp of the issues and remedies than if the face-to-face interaction had not happened. The systematic inclusion of ongoing face-to-face meetings of SMEs with groups of workers as new technology and data are developed and implemented will be helpful gaining worker trust in the health protection process.

The levels of investment in hardware, software, and technical IH acumen in the past few years is testament to the commitment of WRPS to understand and address hazards as they may impact worker health risks at the sight. However, the need for IH personnel to communicate the “story” of how chemical exposures may arise and what will be done to mitigate them needs to be elevated . CTEH has observed many pre-job evolution meetings in which RadCon representatives presented a cohesive story of how certain phases of a project may incur different risks for radiation exposure and what would be done to mitigate that event, should it occur. At the same meetings, IH representatives typically presented a list of analytes being measured and their respective action levels. Presenting a more informative narrative of why certain analytes are being measured, when potential exposures may be highest, what odors may be result, and the planned course of action should improve the perception of professional competency of the IH division in the eyes of the workforce.

Recommendation: IHTs need to be able to articulate a consistent and accepted scientific response to instrument operation and exposure questions posed by field level personnel with respect to tank vapor exposures. IHTs training should include practice opportunities to explain why measurements of vapor analytes are below levels of concern.

CTEH believes that the steps taken to date to improve the defense-in-depth strategy for protection of tank farm worker health has been effective. However, there remains room for improvement of the way information is conveyed to and received from the workforce to make sure that a solid understanding exists of the actual, rather than perceived or rumored, health risks from tank vapor exposure. New avenues of communication of technical information that have been employed in the last few years have shown immense promise and have been endorsed by both workers and members of management. Making those practices a programmatic cornerstone should serve to increase workforce/management trust, reduce uncertainty and propagation of misinformation, and help to reduce the potential for another cyclic return to high levels of tank vapors concerns amongst workforce members.

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