Importance of Safety Culture

Manny Ehrlich, *Chemical Safety Board*

In the time allotted I plan to discuss the significance and importance of A Process Safety Culture. Video clips will be used to reflect a poor safety culture and examples of strong safety culture will be discussed as well.

Connecting Ozone Exceedances in Houston TX to Variability in Industrial Emissions: Implications for federal attainment

William Vizuete, *UNC-Chapel Hill*

For regulatory purposes, it has been assumed that cities have a stable spatial and temporal distribution of emissions and the dominant factor in determining an ozone exceedance is variability in meteorological conditions. Thus, any analysis that can isolate conducive meteorological conditions should be able to accurately predict the frequency of exceedance days. This is not the case for the Houston-Galveston-Beaumont (HGB) region, where a vast majority of meteorological conducive ozone days do not produce exceedances. Conducive meteorological conditions are a necessary, but not sufficient condition for ozone exceedances in HGB. Using an expanded network of 32 monitors in HGB, my team found that the necessary conditions for high ozone were the result of the interaction of synoptic and Coriolis forces at 30 degrees N that produces a rotational wind flow and stagnant morning conditions. This interaction, and resulting daily wind, can be observed across the state including the cities of San Antonio and El Paso. The infrequency of ozone exceedance days under these meteorological conditions suggests an additional variability in emission sources. On exceedance days, the observational data suggests local sources, and the location of origin of the ozone plumes points to sources to the east of the monitor. The variability of both emissions and meteorology presents a challenge for regulatory modeling and to assumptions made in the federal ozone attainment demonstration.

IoT sensing as a tool for determining the resilience of buildings to forest fire generated PM2.5

Jovan Pantelic, *UC Berkeley*

This study describes a method and index to evaluate the resilience of the buildings to extreme pollution event like wildfire air pollution. Low-cost Internet of Things (IoT) PM2.5 sensing was used outdoors and indoors to determine the penetration of PM2.5 particles into the buildings. IoT PM2.5 sensors were placed in mechanically (MV) and naturally (NV) ventilated building. Outdoor sensing took place on the roof of each building and in 11 indoor locations in each of the buildings. We used Indoor to Outdoor ratio (I/O ratio) to calculate the penetration of PM2.5. We propose using Exceedance Index to simultaneously include the impact of the exposure period and exposure level.

Results show that I/O ratio for MV building was 0.3 and for NV building 0.5. Exceedance index for MV building was 1.2 and for NV building was 2.4.

Preliminary Results From the NuStar Refinery Explosion Monitoring in a Neighboring Community

Nicholas Spada, UC Davis Air Quality Research Center

In response to potential impacts from the NuStar Refinery storage tank explosions, speciation monitors were deployed in the nearby city of Vallejo, California. A cascading impactor collected size-segregated particulate matter in three hour time bins alongside a mobile trailer containing a complete IMPROVE sampler (Interagency Monitoring of PROtected Visual Environments). Sampling was conducted starting at 7 PM on Tuesday, October 15th (the day of the incident) and concluded on Saturday, October 26th. The retrieved samples are undergoing characterization measurements. Preliminary data will be presented.

Plenary Presentation

Managing Public Expectations in Times of Crisis, Case Study of the Torrance Refinery Explosions and AB 1646 implementation into the South Bay Region of Los Angeles County

Soraya Sutherlin, *Emergency Management Safety Partners*

On February 18th, 2015, the ExxonMobil Oil Refinery in Torrance experienced an explosion that measured 1.7 on a local Richter scale. Unified Command was established to coordinate the response, however managing the public information and expectation proved challenging in a fluid event such as a refinery explosion. In the past four years, there have been additional incidents at the refinery, prompting AB 1646 and challenging response models geared at communicating risk to the public calling into question the most reasonable way to reach and notify the public in an emergency. We will evaluate the response and provide a look into the new regional integrated emergency notification platform covering the South Bay cities.

Objectives:

1. Mass Notification (Culture of Change)- How we have evolved as a culture
2. The paradigm that challenged the way by which we interface with the community Social Media vs Conventional Media

3. How the media created fear, uncertainty, doubt, and outage without accurate information Emergency Management
4. Lessons Learned- The good, the bad, and the ugly truth behind emergency response Crisis Communications
5. Public expectation vs. actual risk (weighing the outcomes in notification)
6. AB1646- How the law changes the playing field

Critical Takeaways:

1. Critical Lessons Learned in Managing Public Expectations vs Information Management
2. Tiered EOC Activation tied to notification processes Social Media vs. Conventional Media
3. How to use the best to your ability Template Management for messaging the public Unified Command and Public Information Management

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Episodic Measurements

Managing and Reducing Uncertainties in ORS Based Flux Measurements

Marianne Ericsson, *Fluxsense Inc.*

The uncertainty of Optical Remote Sensing based emission measurements are typically estimated to ~ 30% for total site emissions. The largest source of error in ORS measurements of emission fluxes is the wind measurements. The flux is directly proportional to the wind speed (at average plume height) and to the cosine of the wind direction relative to the driving direction. The wind error is a combination of errors in the wind measurements themselves and errors due to the assumption that the measured wind or wind profile is representative of the average plume velocity.

Wind profile data, as supplied by a LIDAR, has the major advantage of allowing an average wind for an arbitrary height interval to be calculated, and the LIDAR data can also be used to estimate the sensitivity of the wind error to the error in the mixing height.

The 30% statistical uncertainty is frequently used as a key reason for why ORS based measurements are not reliable. However, the uncertainty of characterizing the emissions of a specific facility can be significantly reduced through strict adherence to measurement protocols and by repeated measurements at different times of year, operating conditions and wind directions.

This presentation will discuss how to reduce the uncertainty of ORS measurements for a specific facility and also present results from more than10 quarterly measurements in the SCAB.

Development of an unmanned aerial vehicle (UAV) for episodic air pollutant measurements

Zhaodan Kong, *University of California Davis*

Spatially-resolved ambient measurements provide a method to monitor air pollutants that are released accidentally. It also helps in identifying the source of pollutants, which in many cases is unknown. In this talk, we will present our recent research effort on i) leveraging unmanned aerial vehicles (UAVs) to collect three dimensional, time series data of pollutants, such as CO_2 and NO_2, in a plume and ii) developing data-driven methodologies to train plume models. Specifically, the testing is conducted in the vicinity of a stack of a biomass plant that releases smoke into the air; concentration data is collected by installing NDIR gas sensors in a multi-rotor UAV and moving it perpendicular to the airflow direction at various distances from the source of emission; the collected data is used to train two types of models, one based on non-linear regression and the other on Gaussian process; finally, the two data-driven models are compared with state of the art plume models. The project is conducted by Aravind Sreejith and Dr. Zhaodan Kong from the Department of Mechanical and Aerospace Engineering at UC Davis, together with Dr. Ajith P Kaduwela from the UC Davis Air Quality Research Center.

Inverse Modeling of Episodic Measurements for Conventional and Real Time Applications

Jay Olaguer, *Michigan Department of Environment*

Ambient air measurements based on optical, chemical ionization, or other contemporary monitoring techniques can now be interpreted either off-line or in real time using inverse methods for source attribution and emissions quantification based on Gaussian dispersion or 3D microscale chemical transport models. Examples of inverse modeling applications drawn from the chemical industry will be provided, including the following: 1) estimation of ethylene oxide emissions from an industrial facility based on conventional Summa canister samples and a simple, steady-state Gaussian plume model; 2) inverse modeling of refinery emissions of chemically reactive formaldehyde based on mobile Quantum Cascade Laser measurements and the adjoint method for 4D variational data assimilation; and 3) rapid detection and quantification of underground pipeline leaks of benzene based on mobile Proton Transfer Reaction—Mass Spectrometry and a 3D Eulerian transport model.

Jack Rabbit II Source Description for Atmospheric Dispersion Modeling

Tom Spicer, *University of Arkansas*

Sponsored by the Chemical Security Analysis Center (CSAC) of the U.S. Department of Homeland Security, the Defense Threat Reduction Agency (DTRA) of the U.S. Department of Defense, and Transport Canada, the Jack Rabbit II tests were designed to release liquid chlorine at ambient temperature in quantities of 5 to 20 T for the purpose of quantifying the behavior and hazards of catastrophic chlorine releases at scales represented by rail and truck transport vessels. In 2015, five successful field trials were conducted in which chlorine was released in quantities of 5 to 10 tons through a 6-inch circular breach in the tank and directed vertically downward at 1 m elevation over a concrete pad. In 2016, three additional trials were conducted with releases of 10 tons also through 6-inch circular breaches at different release orientations. A final 20 ton test was conducted in 2016. This paper summarizes an analysis of the available data that quantifies the source characteristics for input to atmospheric dispersion models including estimates of the chlorine rainout based on temperature measurements and available video data analysis.

BTEX Observations by UV Absorption Spectroscopy: From Research to Monitoring

Jochen Stutz, *University of California Los Angeles*

Episodic releases and fugitive emissions of aromatic hydrocarbons, such as benzene, toluene, ethyl-benzene and xylenes (often summarized as BTEX), from industrial facilities have received considerable attention in recent years, due to the well-known detrimental impact of BTEX on human health. As a consequence, fenceline monitoring of BTEX is being implemented at many petrochemical facilities in the United States, in most cases using long-path Differential Optical Absorption Spectroscopy (DOAS) in the ultraviolet wavelength range. Path-integrated DOAS measurements offers a number of advantages, such as high specificity, near real-time observations, and long-term stability. However, several challenges and limitations to this method must be considered for successful BTEX measurements.

Here I will review the BTEX DOAS measurement approach from a theoretical and practical point of view. Research grade instruments and data analysis software will be presented and used to illustrate the capabilities of modern DOAS instruments. Special attention will be given to precision and accuracy of atmospheric DOAS measurements and challenges in the use of DOAS for operational fence-line BTEX monitoring. State-of-the-art two-dimensional DOAS BTEX monitoring on the neighborhood scale and inside refineries will also be discussed.

Developing a community air monitoring network to assess the impact of refinery emissions

Olga Pikelnaya, *South Coast Air Quality Management District*

Industrial facilities such as refineries and oil processing plants can be sources of smog-causing chemicals and substances adversely affecting human health, such as benzene, toluene and xylenes (BTEX), formaldehyde, and others. Field measurement campaigns conducted in recent years resulted in compelling evidence that emission inventories for many pollutants, particularly VOCs, are largely underestimated, and that actual air toxic emissions from petroleum refineries are often greater than reported. As a result, there is an increased concern in communities adjacent to such facilities about air pollution exposure.

In December 2017 the South Coast Air Quality Management District (SCAQMD) adopted Rule 1180 (Refinery and Community Air Monitoring) that requires to collect real-time data on air quality at the fencelines of major petroleum refineries in the region and in the near-by communities. To achieve this objective, SCAQMD is establishing a network of refinery-related air monitoring stations designed to collect time-resolved data on comprehensive list of air toxics, and deliver this data to the public via dedicated web-site. In this presentation, we will discuss instrument selection, citing, and other considerations of developing such a network. We will also present concepts for public data display and community education planned for this unique refinery-related air monitoring network.

Use of Open Path UV-DOAS as an Alternative Method to Meet Fence-line Monitoring Provisions for Federal Benzene Monitoring Rule - A Case Study

Mark Wicking-Baird, *Argos Scientific Africa Inc.*

On December 1, 2015, the EPA finalized the Risk and Technology Review for petroleum refineries. Among other things, the finalized rule requires petroleum refineries to conduct fence-line monitoring on a continuous basis. Benzene was defined as the target compound, and an annual average, action level of 9 Âµg/m3 was established, triggering a refinery lead root cause analysis and corrective action. The fence-line monitoring provisions found in 40 CFR 63.658 describe the use of a network of passive diffusive tube samplers placed along the refinery's boundary as the primary method for detecting fugitive emissions of benzene.

The fence-line monitoring provisions allow a refinery owner or operator to submit a request for an alternative test method, such as the use of open-path instrumentation. The use of this type of technology presents the opportunity to meet the requirements of the rule in a more simplified and cost-effective way, while offering advantages in terms of time resolution and potentially identifying and eliminating data points that correspond to non-facility emission sources. A field validation study has been conducted using latest generation, open-path UV-DOAS technology to detect benzene at a refinery fence line on a continuous basis. This study includes the development of a quality assurance program that is compliant with the ISO-17025 standard for the operation of a gas analyzers as a field analytic laboratory. The analysis includes a case study on the lessons learned in developing this program, and presents a path forward in utilizing the open-path fence-line monitoring systems installed at refineries in California to meet the federal fence-line rule for benzene monitoring.

Lessons Learned During BAAQMD Required Refinery Fence Line Monitoring Program Development – Available Technology & Data Quality System Update

Jerry Bovee, *BAAQMD*

The Bay Area Air Quality Management District (BAAQMD) recognized that data suggested emissions inventories from petroleum refineries likely underestimated fugitive emissions. As a result, BAAQMD took first-in-the-nation action to address fugitive emissions likely to have the most impacts on nearby populations by requiring fence line monitoring at refining facilities and took the further step of committing to install additional monitoring stations in refinery communities. These actions were taken to better understand localized impacts of these major emission sources.

Regulation 12, Rule 15, in addition to collecting specific processing data, required refineries to submit fence line air monitoring plans to BAAQMD for approval, which were based on BAAQMD air monitoring guidance. The guidance addressed minimum monitoring program requirements and included the establishment of a quality system to transparently prescribe procedures and processes to help ensure the collection of quality data to better inform the public and refineries regarding fugitive emissions. Air monitoring plans have been submitted and conditionally approved by BAAQMD and refineries are working on Quality Assurance Project Plans (QAPPs) outlining proper fence line performance parameters and metrics to ensure ongoing collection and reporting of qualified data. In addition, BAAQMD is conducting siting analysis to identify appropriate locations for additional air monitoring stations in refinery communities that incorporates citizen and stakeholder input.

This presentation will provide a summary of the lessons learned during refinery monitoring plan development, necessary program design elements, specific technologies and quality control/quality assurance metrics that have been identified for inclusion in the refinery QAPPs and quality programs based on those technologies.

Emissions Estimation

Estimating air pollutant emissions from co-processing raw bio-oil in petroleum refineries

Arpit Bhatt, *National Renewable Energy Laboratory*

Organic liquid fraction (referred to as raw bio-oil or biocrude) produced from lignocellulosic feedstocks via thermochemical conversion processes is a promising intermediate to produce renewable hydrocarbon fuels. Co-processing this raw bio-oil with petroleum intermediates such as vacuum gas oil (VGO) in a petroleum refinery has gained considerable attention due to its potential for producing partially renewable hydrocarbon fuels compatible with existing infrastructure and reducing greenhouse gas emissions with minimal capital requirements.

Prior to implementing raw bio-oil co-processing with petroleum intermediates, a petroleum refinery would need to consider several unit and process modifications, which can lead to varying levels of increase in air pollutant emissions from the refinery depending on bio-oil co-processing ratio, co-processing capacity in the existing units, and size of the refinery. In this analysis, we consider co-processing raw bio-oil at 5% (by weight) with 95% (by weight) VGO in the petroleum refineries in the U.S., which are equipped with fluid catalytic cracking (FCC) unit(s). We group refineries into three FCC size categories to estimate the potential increase in emissions of the pollutants, which are regulated under the New Source Review program, due to co-processing bio-oil. Depending on the equipment or operations, from which air pollutants are emitted, we estimate the increase in emissions using different approaches, including material balance, emission factors from EPA's emission factor (AP-42) database, and source-specific models such as TANKS4.09D.

Insights from our analysis can help inform refinery owners of the resulting changes in air emissions from the required modifications to the process and unit operations for co-processing raw bio-oil in their existing facilities to produce partially renewable hydrocarbon fuels. Our analysis also provides regulatory agencies with much needed information and data when reviewing and approving permit applications for bio-oil co-processing.

Establishing Refinery Emission Inventories - ORS Measurements or Permit Based Calculations

Marianne Ericsson, *Fluxsense Inc*

1965 the US Public Health Service issued its first comprehensive list of emission factors. The EPA has since adopted and expanded these factors which have become widely used in emission inventories. EPA early on recognized that there were significant uncertainties associated in the factors and has continued to update them; however large uncertainties still remains. For example in 2015 EPA declined to adjust the Tanks Model as it would not be feasible to reflect the actual spread of tank emissions in a model.

ORS measurements of facility emissions have been available since the late 1980's, first introduced by Shell/BP/NPL in the UK (DIAL) and then by FluxSense in Sweden in early 2000 (SOF). ORS is becoming a standard in Europe.

US industry has been reluctant to adopt ORS based facility emissions for emissions inventory reporting. Current inventories reflect permit based calculations based on size and processes, not current conditions. ORS measurements usually show a discrepancy of 3 to 10 times of measured vs. reported emissions.

A common concern of ORS based measurements is the statistical uncertainty and that measurements only provide a "snapshot" of the facility emissions. This presentation will discuss how these concerns can be mitigated and how using ORS based data in emissions inventories improves the reliability of air quality modeling and mitigation efforts.

Artificial Intelligence Models for the Predictive Analysis of Flaring Performance

Helen Lou, *Lamar University*

Petroleum Refinery Sector rule (RSR) aimed to control and monitor toxic pollutions from process industries. As regulated by RSR, the refineries should ensure high flare combustion efficiency and smokeless flaring under any circumstance, including start up, shut down and maintenance. Since many factors can influence flare performance, a quantitative model that can guide operators to optimize the flaring process and to enable flare control is very instrumental. In this work, artificial intelligence algorithms were deployed to predict flare performance based on various operation and design variables. This will give engineers and operators valuable guidance on operation. The efficacy of these models were validated by various testing data.

Routine Modeling

Regional Shelter Analysis: Assessing the Protection US Buildings Provide Against Outdoor Particulate Hazards

Michael Dillon, Lawrence Livermore National Laboratory

During normal (i.e., passive) operations, buildings can protect their occupants from outdoor hazards, including airborne pollutants. We have utilized a recently developed, regional-scale methodology - called Regional Shelter Analysis (RSA) - to account for both building protection and the distribution of people within and among buildings. The RSA approach allows us to examine the protection against the inhalation of airborne particles for each US Census tract with the aim of providing representative values for the US building stock. In this talk, we will briefly summarize the published literature relevant to indoor particle losses that underlies this approach, including (a) deposition to indoor surfaces, (b) losses that occur when particles penetrate through the building envelope, and (c) HVAC system filtration efficiencies as well as general building operating conditions.

Our analysis suggests that the building protection against inhaling particulate hazards varies strongly, by orders of magnitude, with building use (occupancy) and particle size. Single family homes, manufactured homes, and multi-unit apartment buildings have similar (within a factor of 2) protection values. The protection for people within US Census tracts is broadly similar during the night and the workday. On average, there is slightly better protection during the night when people are at home. The protection within a given US Census tract often spans one or more orders of magnitude. (Prepared by LLNL under Contract DE-AC52-07NA27344)

Using Dispersion Modeling and Monitoring as a Basis of Estimating Emissions from Refineries

Shari Libicki, *Ramboll*

Regulatory Gaussian dispersion models are often used to estimate emissions from refineries for permitting and risk assessment purposes. This work explores the use of dispersion modeling for predicting emissions from the refinery using a large data set, including monitoring data. The City of Richmond, California, in cooperation with the Bay Area Air Quality Management Agency (BAAQMD), has established a three-year community air monitoring program (http://www.fenceline.org/richmond/) intended to monitor emissions from the Chevron Richmond Refinery. The inputs and approaches to using dispersion modeling, monitoring data, other data and data analytics techniques to determine whether we can see a signal corresponding to a level of emissions from the refinery are described. This signal may be seen once the impact of meteorological and other parameters are taken into account through dispersion modeling and direct input of wind speed, wind direction, distance to the sources, and numerous other parameters. This paper describes the work to date, the analysis of the monitoring data, and the approach we are taking to incorporate modeling into the analysis system.

Forecasting Wildfire Smoke PM2.5 using the AIRPACT5 Air-Quality Forecasting System: recent experience, emerging approaches and a near-term application

Joseph Vaughan, *Laboratory for Atmospheric Research, Washington State University*

AIRPACT5 is an automated air-quality modeling system providing PM2.5 and O3 forecasts for a Pacific Northwest region that covers the states of Washington, Oregon and Idaho with a 4-km scale grid. AIRPACT5 uses WRF forecasts, from the University of Washington Department of Atmospheric Sciences, to drive the MCIP/SMOKE/CMAQ modeling suite to forecast hourly air chemistry. Chemical and particulate boundary conditions are obtained from the global WACCM model operated by NCAR. Wildfires have proved an increasingly important, and difficult, part of the forecasting challenge over the last decade. AIRPACT5 uses satellite fire detects to locate fires, assumes that wildfires persist for the day after detection, and injects smoke aloft by treating fires as point emissions. Plume rise is calculated using an approach by Idaho DEQ that utilizes heat flux and stipulates both smoldering and flaming contributions of smoke. Beyond the deterministic AIRPACT5 forecast, machine learning elements are being developed and implemented, in part with a view to supporting health risk advisories.

VOC Source Signatures and Source Apportionment Studies from Automated Gas Chromatography Data in Houston, TX

Bradley Flowers, *AECOM*

In urban areas with petroleum refineries, understanding air quality impacts of petroleum refining involves separation of refining from other urban volatile organic carbon (VOCs) in ambient data. Analysis of this type can be challenging because of the similarity between VOCs emitted from refinery and urban sources.

We report on the use of observed ambient concentration ratios for alkanes as a tool for identifying refining and petrochemical events at automated gas chromatography (Auto-GC) monitoring locations. In the Houston area there are

10 Auto-GC monitoring sites located around the Houston Ship Channel area. We will discuss the use of iso-pentane/n-pentane and other VOC isomer ratios as a marker for refinery and urban emissions and will place these results in context with source apportionment and air-mass back trajectory analysis.

Episodic Modeling

Jack Rabbit II Inter-model Comparison Exercise

Joe Chang, *RAND Corporation*

The Jack Rabbit II field experiments were conducted in 2015 and 2016 at Dugway Proving Ground, Utah, and involved nine releases of pressurized liquefied chlorine. Trials 1 through 5 in 2015 involved 4.5 to 8.3 tons of chlorine and a staggered CONEX container array to mimic an urban environment. All trials were vertically downward. Trials 6 through 9 in 2016 involved 8.4 to 18 tons of chlorine with the container array removed. Two trials were vertically downward, one trial was vertically upward, and one trial was 45 deg downward and in the downwind direction. Chlorine concentrations were mainly measured from 0.2 to 11 km downwind by four types of sensors with different dynamic ranges and 1- to 3-s resolutions. A collaborative inter-model comparison was undertaken to improve modeling capabilities for releases of toxic chemicals using the Jack Rabbit II data. The exercise involved 17 models run by researchers from seven countries and the European Commission. The initial phase of the exercise focused on Trials 1, 6, and 7, where observed arc-maximum concentrations at 0.2, 0.5, 1, 2, 5, and 11 km were compared with model predictions. Both observed and predicted arc-maximum concentrations closely followed the x-5/3 power low, where x is the downwind distance. Model predictions at a downwind distance generally spanned one to one and a half orders of magnitude, and observations were always inside the range of model predictions. About two thirds of the models had predictions within a factor of 2 of observations about half of the time. Three top-performing models had predictions within a factor of 2 of observations about 75% of the time. The exercise is to be expanded to consider more trials and comparisons of cloud widths and heights.

Employing Machine Learning Techniques to Determine Emission Sources at Industrial Facilities Use of Open Path Air Monitoring Systems

Don Gamilles, *Argos Scientific, Inc.*

The next step to using the data from fence-line air monitoring programs is using the information generated by the systems to identify emission sources and predict downwind community exposure. This can be achieved by using the data sets from open-path systems and data sets generated from point monitors in the same area. This data can be used to assess the overall health impact on those communities. A novel approach is to analyze the information from multiple data sets using machine learning systems to evaluate relationships between long-path and point monitoring systems. This artificial intelligence accession utilizes statistical and data processing algorithms to identify emission sources in near real-time. Data generated by the program can then be used to determine downwind health impacts associated with the release of fugitive emissions.

Data will be presented showing how open-path UV air monitoring data that is generated by a long-path, fence-line air monitoring system is currently being used, along with point sampling data collected by an automated field gas chromatography point analyzer to identify fugitive emission sources. Data from both systems are combined in a manner to estimate the plume diameter of fugitive emissions crossing the fence line boundary. This information is then combined with meteoritical data to determine fugitive emission sources. Once identified, activities can occur to mitigate those sources. In addition, modelling is then employed to determine the overall health impact to the downwind community.

Overview of HSE's approach to dispersion modelling of major accident hazards in Great Britain

Simon Gant, *Health and Safety Executive*

The UK Health and Safety Executive (HSE) is responsible for a number of regulatory functions in Great Britain that relate to major hazard sites (such as refineries and chemical plants) and major accident hazard pipelines. HSE sets a land-use planning consultation distance around these major hazard installations, within which the planning authority must consult HSE over the public safety risks relevant to proposed new developments that may increase the population around these sites. HSE is also one of the agencies responsible for enforcing the Control of Major Accident Hazard (COMAH) Regulations 2015, and it investigates serious incidents and prosecutes operators of sites who have breached provisions under the Health and Safety at Work Act 1974, which aims to protect workers and those at risk from activities at major hazards sites.

In addition to these regulatory roles, HSE's Science and Research Centre undertakes a wide range of scientific research projects on a collaborative and commercial basis with UK and international partners. For example, HSE was commissioned by the Fire Protection Research Foundation (FPRF) and the US Pipelines and Hazardous Materials Safety Administration (PHMSA) to develop and maintain the LNG Model Evaluation Protocol, which PHMSA uses to assess and approve dispersion models for use in siting studies for LNG terminals.

One of the key tools used by HSE to quantify the potential hazards relating to atmospheric releases of toxic or flammable substances at major hazard sites in the UK is the dispersion model, DRIFT. HSE has conducted a number of validation exercises aimed at assessing the capabilities and limitations of this model, and has also funded the development and validation of source models that provide inputs to DRIFT for simulating jet releases, catastrophic vessel failures, evaporating pools and other phenomena. For some incident investigations, such as the Buncefield fuel storage depot explosion, HSE has used Computational Fluid Dynamics (CFD) to model vapour dispersion.

The aim of this presentation will be to provide an overview of HSE's approach to dispersion modelling of major accident hazards, with some examples of recent incident investigations and a summary of current challenges and knowledge gaps in the field of dispersion modelling.

Recent Improvements to Industrial Chemical Safety, Preparedness, and Response Modeling

Michael Dillon, *Lawrence Livermore National Laboratory*

This presentation will discuss recent advancements in chemical preparedness by Lawrence Livermore National Laboratory and collaborators. We will provide an overview of select (a) modeling development and validation efforts as well as (b) related efforts to review and improve whole community response capabilities and capacities. Brief synopses are provided here.

Much of the preparedness and response modeling focuses on identifying "at risk" areas and populations, i.e., people and places that could be adversely affected. This approach is useful to rapidly identify general regions and populations that are likely to not require intensive support. However, "at risk" approaches can overestimate the areas and populations that are significantly impacted. To improve the targeting of limited preparedness and response resources, we have focused on enhancing modeling approaches to more realistically reflect likely impact areas and populations. We will discuss recent advances in this area intended to support enhanced response strategies including (a) the protection buildings naturally provide their occupants, (b) improved estimates of required medical countermeasures, and (c) extensions to the Emergency Response Guide (aka Orange Book) methodologies.

Data from the Goldfish field experiment, which studied the near-full scale releases of Hydrogen Fluoride (HF), have been widely used for research and regulatory purposes. The Goldfish dataset has been particularly helpful in evaluating and guiding improvements to dispersion models and investigations into HF-water thermochemical-dynamics, including water spray mitigation. After the field experiment, four conference papers containing preliminary results were published, but a full technical report and dataset were never released. Due to the continuing concern about potential impacts of large HF releases; we have gathered project records and developed a more complete description of the experiment as well as a single repository of the available data.

The Response Risk Assessment (RRA) process was developed under the sponsorship of the DHS Office of Health Affairs (now Countering Weapons of Mass Destruction Office). The RRA process evaluates the community's capacity and capability to respond to a chemical spill or release. The RRA evaluation occurs through a multi-stage process that starts with gathering critical response information using research, direct interaction, and facilitated focus group discussions with partners and stakeholders. The gathered information is used to model the response and identify limitations by assessing the degree to which the current capabilities can respond to hypothetical, yet realistic scenario(s). In partnership with the greater Galveston, TX community, the University of Texas Medical Branch, Texas A&M Engineering Extension Service - Emergency Services Training Institute, and the Federal Emergency Management Agency; we have examined Galveston County chemical preparedness. We will discuss an overview of the RRA process and place in it the context of the Galveston community's efforts to improve whole community preparedness.

Prepared by LLNL under Contract DE-AC52-07NA27344. LLNL-ABS-779853

Experimental Program to Model Chlorine Reactivity with Environmental Materials in Atmospheric Dispersion Models

Tom Spicer, *University of Arkansas*

The amount of chlorine that reacts with environmental materials is an important factor in determining the impact of a potential atmospheric release. In previous experimental work by others, laboratory experiments were conducted to measure the rate of chlorine removal by reaction with selected environmental materials, and these experiments showed that there was a maximum amount of chlorine that could react with the material. Atmospheric dispersion models represent the reaction process (surface deposition) as a series of resistances including the effect of atmospheric turbulence and surface reaction, but models typically do not account for the maximum amount of chlorine that can be removed. This paper discusses approaches to modeling these effects in current atmospheric dispersion models. The findings of an experimental program that quantified how environmental materials react to high chlorine concentrations (initially 1000 ppm) in flows with turbulence levels that are comparable to that of the atmosphere.