IMAAC Technical Operations Hub

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TITLE: Potential Off-site Hazard from Hydrogen Fluoride Releases from PES Facility, 21 Jun 2019		
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EVENT SUMMARY

AT 4:00 AM local on 21 Jun 2019, the Philadelphia Energy Solutions (PES) refinery in Philadelphia, PA suffered a leak of a gas which contained hydrogen fluoride (HF) in addition to various hydrocarbons (mainly propane). At approximately 4:02 the cloud exploded. A subsequent fire with additional explosions burned for the next 21 min and 30 sec.

REQUEST DETAILS

EPA Region 3 and the City of Philadelphia asked IMAAC, using information from PES, to model potential HF hazards outside the refinery perimeter caused by both the gas cloud and the subsequent fires.

BOTTOM LINE UP FRONT

Information provided by PES was used to construct atmospheric transport models of 1) dense gas propagation (first two minutes), and 2) subsequent fire scenarios.

- For both cases, modeled HF concentrations outside the facility perimeter were low, on the order of a few parts per billion (ppb) or below (depending on assumptions – see below).
- These levels are considerably below generally accepted health hazards for HF.

TECHNICAL RESPONSE

PES provided substantial data from the event, which were used to model the two release scenarios discussed individually below. The threshold for HF to cause human effects are concentrations on the order of 1 parts per million (ppm) – sensors near the initial gas release detected concentrations in excess of 10 ppm, hence the concern about possible offsite effects to the surrounding population.

1) First Two Minutes: This scenario involved the release of a dense cloud of hydrocarbon components along with HF. The primary hydrocarbon present was propane, with a small fraction of HF. This cloud was visible and captured on multiple videos. At 2 minutes, this cloud exploded, at which time the HF hazard was simulated via a separate model (see Subsequent Fire below). IMAAC modeled the propagation of this dense propane cloud and derived HF concentrations based on the fraction of the cloud that was HF.

Results were compared to videos of the cloud and sensor information from the facility. Models were run with multiple weather conditions, and in one case using high-resolution terrain and building data. All model results were broadly consistent – a cloud with concentrations of 10 ppm or higher of HF propagated approximately 200 meters from the leak location. Outside a distance of about 200 meters from the leak, concentrations were below 10 ppm.

The conclusion from this model was that significant HF was unlikely to have crossed the facility perimeter. This is due to the fact that the wind speeds were relatively light and the terrain is not particularly steep, so the gas simply can't move far enough in 2 minutes to get off the property. Given the significant number of sensors, the video of the incident, and the physical constraints that limit how far the gas can travel, confidence is relatively high for this conclusion.

2) Subsequent Fire: The fire (or at least the portion involving HF releases) began approximately two minutes after the hydrocarbon leak, initiated by a large explosion of the hydrocarbon gas cloud. Over the next 21 min and 30 sec, a series of fires and leaks occurred in various parts of the system. Using PES estimates of the hydrocarbon composition and the HF content, IMAAC constructed a model of the fire and its buoyant rise, which drives the transport and dispersion behavior of the entrained HF.

There are two major caveats about this modeling. First, any estimate of combustion in a real scenario will have significant uncertainty. This is especially true given factors like fuel heterogeneity, quality of the burn, time-varying burn rates, etc. Second, although HF concentrations at ground level are estimated, these concentrations are very sensitive to the atmospheric stability and the gas buoyancy. Small differences in these parameters can significantly affect the plume behavior.

IMAAC performed modeling with two weather conditions:

1) The PES-provided nearby surface observation
2) 3-dimensional numerical forecast weather model (12 km North American Model)

The weather model can be useful because it provides an explicit vertical profile of the atmosphere, which is critical to capturing accurate behavior of the buoyant rise and subsequent fall of the hot gas and HF, rather than an implicit profile from the observation.

The IMAAC modeling looked at the HF concentrations near ground level outside the facility. In the case of the observation weather, HF concentrations near ground level did not exceed approximately 3 ppb outside the facility (greater than two orders of magnitude below the typical level of concern). In the case of numerical weather model, levels were below 1 ppb outside the facility. In both cases, high (greater than 10 ppm) concentrations of HF were present close (within tens of meters) to the fire location, but this is obviously well inside the facility perimeter.

The conclusion from the fire models was that significant HF was unlikely to have crossed the facility perimeter. This is due to a combination of the relatively low HF release rates, the buoyancy of the fire lifting HF off the ground and the HF undergoing substantial dilution before settling back to the ground. Unfortunately, there is not as much corroborating data for this scenario compared to the initial dense gas cloud, although two mobile handheld sensors deployed by PES along the facility perimeter did not detect any HF. Given the reduced data availability and given the number of estimates required for this modeling endeavor, confidence on the modeling for this phase of the incident is lower than for the initial two minutes.

Modeling Caveat: *All modeling carries uncertainty. Additionally, observed data from historical field tests have shown the presence of localized hot spots of higher concentration than the mean model estimates. Therefore it is impossible to say with absolute certainty that the concentrations off-site did not reach 1 ppm levels, merely that the evidence suggests that it was unlikely.*