A Brief Introduction to Air Dispersion from Industry Stacks

Why tall stacks?
Frequently industrial releases are poisonous at the point of the release, so it is very important to understand how the exhaust gases are diluted and transferred before the effluents reach places at ground level where ordinary citizens are apt to breathe them. We need to know how concentrated the effluents will be over various time periods. We would like to know the highest average concentrations that will occur where people might breathe them for periods of hours, days, or a year. For some pollutants such as fine particles (PM2.5) there are health based standards set to define the difference between acceptable levels and unacceptable average concentrations.

Source differences
The concentrations that people are exposed to may come primarily from one industrial source, multiple sources, or a mix of different sources. For example, hexafluoroethane is primarily released from plants that make computer chips while fine particles can be released from chip manufacturing plants, diesel trucks, smelters, cars, and fossil-fueled power plants among others. Fine particles can also be produced in the atmosphere by the conversion of some gaseous pollutants to fine particles through atmospheric reactions.

What influences dispersion
For most pollutants, the highest concentrations in the effluent plume occur at the source, the exceptions being pollutants that are created by chemical reactions in the atmosphere. In most instances pollutants are released from stacks so that the effluent will mix with clean air and become more dilute before reaching the ground where people might breathe them. There are a number of important factors that influence the degree of dilution that can be expected in a specific instance. First many emissions are released from a stack with temperatures higher than that of the surrounding air and with a significant upward velocity. These factors cause the release to rise above the stacks so that the effect is similar to that expected for a significantly taller stack. How much taller depends upon the temperature difference and the volume flow rate (stack exit velocity) of the exhaust gases and the characteristics of the atmosphere into which the material is released. Under light-wind, mid-day, cloud-free conditions, the plumes rise higher than they do under light-wind, nighttime conditions. With high winds the plumes don't rise as high, but they are diluted by the high winds. Cold or heavy gases tend to sink toward the ground and produce higher concentrations there unless they become so dilute that their density is close to that of the surrounding atmosphere.

Role of multiple sources
Another important factor is the presence of other, nearby stacks. Two things can happen: (1) higher plume rise and (2) higher concentrations. If two stacks are very close together and both have warm or hot effluents, the gases will mix and cause the plume to rise higher in the atmosphere. The effect of the higher plume rise will be to produce more dilution before the plume mixes to ground level. However, the mixing of the plumes means that the dirty air is being mixed with more dirty air from the other stack instead of only clean air, with the result that the concentrations are higher. If the mixing between the two plumes does not occur until after the plumes have been cooled by dilution, the resulting ground-level concentrations will be about twice as high as they would have been for a single, isolated stack. Of course, if the effluents are cool and have low, stack-velocities, the effect of having two stacks will be to double the concentrations expected for a single source.

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Influence of nearby buildings

Another important factor is presence or absence of tall buildings. Buildings can produce large eddies, sometimes referred to as downdraft or downwash, so that there is enhanced mixing downwind of the building. Under these circumstances, there is a rapid dilution behind the building, but the concentrations near ground level where people can breathe them are about the same as those at the height of the stack top behind the building, frequently producing higher concentrations where people would be expected to breathe them. While the concentrations may be about the same at the ground level as they can be at the stack-top height, they are still much less than they are at the stack exit, because of the rapid dilution produced by the eddying air behind the building. In order to avoid this problem, the usual rule of thumb is that the stack height, measured from the ground, should be at least the height of nearby, upwind buildings plus one and one half times the smaller of the height or width of the buildings. This gives rise to usual two and one half building heights rule for the stack on or near a building that is as wide as it is tall. This is normally referred to as "good engineering practice." There is another view of what constitutes good engineering practice. Many engineers would say that any stack that produces enough mixing so that the resulting estimated concentrations are at or below health based ambient air quality standards (levels set by the EPA to define the borderline between polluted and unpolluted air) at ground level is good engineering practice. This thinking assumes that the standards are protective of health and the estimations are accurate or underestimate the concentrations that will be measured after there are emissions from the stack. If there is reason to believe that either of these assumptions is false, a taller stack that produces more dilution would be preferred.

Terrain influences

Terrain can also be an important factor during nighttime or early morning, low- wind conditions. If the wind is blowing toward higher terrain, the air below the plume will frequently be diverted into a different direction and the plume height above the ground will be diminished or become zero with the result that high concentrations will occur on the high terrain. If the terrain drops away in the direction of travel, cold air may flow in below the plume and reduce the concentrations. Of course, in many cases, the plume may downwash, or mix to ground before it reaches the dropping terrain and it will continue to hug the ground without enhanced dilution. The dispersion also can be influenced by the nature of the surface coverage, trees, buildings, grass or water. For example, buildings or trees cause the plume to mix to the ground faster, so that ground level concentrations approach those at plume centerline at distances that are closer than would be expected for grass or water.

How are appropriate stack heights estimated?

Appropriate stack heights are usually estimated with air dispersion models. Measurements cannot be used because the calculations are made before the time the source is operating. Furthermore, it is very difficult to measure concentrations at a sufficiently large number of points to find the highest concentrations that are of the most concern.

Dispersion models are simplified mathematical descriptions of the physical world that are based on measurements that have been made under similar situations. In some cases, the actual situation has significant complexities that are not captured by the most frequently used models. The CEWG website (http://www.intel.com/community/newmexico/cewg.htm) has illustrations and discussions of factors that influence air dispersion.

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