9. Conclusions and Recommendations

The assessment credibly predicted ambient concentrations where there were measurements for comparison. The modeling results allow the Department to make correlations between source locations and pollution levels and observe how exposure varies with the Portland area. PATA shows the importance of diesel, motor vehicles and burning as sources of air toxics in Portland. It confirms national estimates that individuals are exposed to various air toxics above levels of concern. The assessment will guide emission reduction strategies well into the future.

The HAPEM5 exposure model, which adjusted modeled concentrations based on population activity patterns, indicates that Portland residents are actually exposed to about half of the modeled concentrations. A comparison of exposure to dispersion model concentrations shows that the ratios of the concentrations are relatively constant (from about 0.4 to about 0.7, for most of the tracts and block groups in the domain). This suggests that for future analyses, an exposure to dispersion factor could be used if time and exposure modeling or monitoring resources were constrained.

9.1 Mobile Source Pollutants

The mobile source pollutants, including acetaldehyde, formaldehyde, 1,3 butadiene, diesel PM, benzene, and arsenic show high concentrations along and adjacent to the major traffic corridors. The source pie charts show the predominance of mobile source concentrations at locations across the domain; however the urban core area has relatively greater mobile source concentrations than elsewhere.

9.1.1 Acetaldehyde

For acetaldehyde, elevated cancer risks align with major highway corridors within the Portland area, which is consistent with on-road engines. Construction equipment is also an important source of acetaldehyde.

9.1.2 Formaldehyde

According to risk values, Formaldehyde is one of the top three sources of adverse health effects and cancer risk in the Portland area. The highest cancer risk for formaldehyde aligns with major highway corridors within the Portland area, which is consistent with on-road engines as an important source of formaldehyde. The widespread nature of its other important sources, construction equipment, diesel fuel combustion, railroads, and airports, may result in a broader geographic extent of risk associated with formaldehyde. Wood burning also contributes to formaldehyde emissions.

9.1.3 1, 3 Butadiene

Geographically, the highest cancer risk aligns with Interstate 5 through SW Portland and high risks along the other major roadways, which is consistent with on-road engines as an important source of 1,3-butadiene. The widespread nature of its other important sources, lawn and garden equipment and marine recreational vehicles, may help to explain the broader geographic extent of risk associated with 1,3-butadiene.

9.1.4 Diesel PM

Diesel particulate matter is another of the top three sources of adverse health effects and cancer risk within the Portland area. On and off road diesel engines are equally important diesel sources. While risk is significant across the modeling domain, higher concentrations likely exist in the downtown area where there is a concentration of emissions from vehicles, construction, marine and rail sources.

9.1.5 Benzene

Benzene is the third of the top three sources of adverse health effects and cancer risk within the Portland area. Geographically elevated cancer risks align with major highway corridors within the Portland area, which is consistent with on-road engines as an important source of benzene. Another important source is residential wood combustion, the widespread nature of which may help to explain the broader geographic extent of risk associated with benzene.

9.1.6 Arsenic

Elevated cancer risks from arsenic align with major highway corridors within the Portland area, which is consistent with on-road engines. Oil and natural gas combustion and non-road engines are also important sources of arsenic

9.2 Area Source Pollutants

The area source pollutants nickel and chromium have high concentrations predominantly along the west bank of the Willamette River, extending northwest from the Portland urban core. Although area sources predominate, the pie charts show and important contribution from mobile sources at the downtown site. The area source pollutants acrolein and POM are higher in areas with greater population density. The results show high concentrations from the urban core east to Gresham, and from about the Tigard area northwest to Hillsboro. Modeled concentrations at the downtown site again show the influence of mobile sources.

There are two areas with somewhat elevated values in the plot of modeled perchlorethylene concentrations. Monitoring at the northwest site corresponds to modeled values and suggests that impacts within a block of dry cleaning operations may be high. The contribution from background dominates the total modeled concentrations of both perchloroethylene and chloroform however.

9.2.1 Nickel

Nickel is unlikely to pose either a non-cancer or cancer health risk in the Portland area.

9.2.2 Chromium

Chromium may pose a cancer risk at all estimated exposures in the Portland area. Geographically, elevated cancer risks may align somewhat with major highway corridors within the Portland area, which is consistent with fossil fuels as an important source of chromium. Further investigation is necessary to estimate how much of the total chromium is composed of the more toxic hexavalent chromium.

9.2.3 Acrolein

Acrolein is the main source of non-cancer adverse health effects within the Portland area. Risk from acrolein appears ubiquitously across much of the Portland area. Higher exposure and risk levels are confined to northeast and southeast and an area north of Lake Oswego, possibly along the 217 highway corridor. Wood burning, structural fires, and construction are important sources of acrolein.

9.2.4 POM

POM may pose a cancer risk at all estimated exposures in the Portland area. The highest cancer risk aligns with major highway corridors within the Portland area, which is consistent with on-road engines as an important source of POM. The widespread nature of its other important source, residential wood combustion, may help to explain the broader geographic extent of risk associated with POM. Improved emissions inventory information will help to refine POM evaluation.

9.2.5 Perchloroethylene

PATA suggests that perchloroethylene poses a cancer risk in the Portland area only when exposures are significantly elevated. At median exposures, mean cancer risk is within acceptable levels. Modeling results show that geographically any elevated cancer risks posed by perchloroethylene appear at two specific locations within the Portland area where major dry cleaning operations exist. This is consistent with dry cleaners as an important source of perchloroethylene

9.2.6 Chloroform

Like perchloroethylene, chloroform poses a cancer health risk in the Portland area only where levels are significantly elevated. Geographically, elevated cancer risks align with the pulp and paper operation at Camas, Washington (a source which has been eliminated since data for this assessment were first collected). Although wastewater treatment facilities can be important sources of chloroform, there is no indication from the mapping that this is the case within the Portland area.

9.3 Exposure to Multiple Air Toxics

Even without considering diesel particulate matter, simultaneous exposure to multiple air toxics, even at median exposure levels, creates the potential for adverse health outcomes, including cancer. Diesel particulate matter alone contributes to 90-99 percent of the cumulative non-cancer and cancer risk in the Portland area. When it is excluded, the principle contributor to cumulative non-cancer risk is acrolein, while principle contributors to cumulative cancer risk are benzene and formaldehyde.

9.4 Confidence in the results

The PATA to NATA comparison shows general agreement. However, the more detailed inventory of toxic pollutants in the PATA study, including the modeling of dry cleaners in the point source inventory, the mobile source analysis by METRO, and the local meteorology and topography, adds detail and specificity to modeled results that are not reflected in the NATA results. The modeled output at census tract and block group centroids gives greater spatial resolution to the modeled concentrations. The comparison does show the usefulness of NATA in identifying general areas of concern for which additional modeling, at a finer scale with a more refined inventory such as PATA, could be carried out. The use of local data and information adds a level of credibility to the PATA results that is missing from the more generic NATA.

9.5 Confidence in the risk estimates

There are many factors that affect the confidence in risk estimates. PATA estimated concentrations for 12 air toxics that appeared to be important in the Portland area based on NATA. However, limiting the number of air toxics considered in the assessment could result in an underestimation of risk, particularly cumulative risk. Using the HAPEM5 exposure model generally increases confidence in the study results. It uses more realistic representations of people's behaviors and activities. As a result, risk exposure estimates are neither grossly over nor under-estimated.

The use of a median (50^{th} percentile) and 90^{th} percentile for the exposure point air concentrations was designed to reflect a central tendency and reasonable maximum estimate of the true exposure. Thus, while the median concentration is unlikely to overestimate actual exposures, the 90^{th} percentile may in fact be an overestimate.

A standard component of an exposure assessment is analysis that determines all of the routes of exposure associated with a pollutant. This risk assessment evaluated the inhalation exposure route only. The true health impacts may be underestimated by an unknown amount as a result of ignoring other pathways like soil or water deposition, and dermal or ingestion pathways. A more thorough multi-pathway risk assessment based on additional monitoring and/or modeling data could reduce this uncertainty.

A key uncertainty in the use of toxicity values is the adequacy of the database available to assess the dose-response relationship, as this is essential for deriving a representative toxicity value. Uncertainty is also introduced when the effects on especially sensitive populations are not considered in the dose-response relationship. The addition of safety factors can result in "conservative" toxicity values that may lead to overestimates of risk.

For nickel and chromium assumptions that humans are exposed to the air toxic entirely in its most toxic form likely result in overestimates of the potential health impacts.

Adding risk from multiple air toxics within the study area ignores the potential for synergisms or antagonisms among air toxics, effectively assuming that all of the air toxics have a similar mechanism of action and metabolism in the human body. This assumption would tend to overestimate risk if antagonistic effects occurred, and would underestimate risk if synergistic effects were to occur.

9.6 Value of PATA

PATA has given the Department a better understanding of air toxics in the Portland area by producing more accurate estimates of the most significant air toxics and characterizing their risks. While NATA estimates pollutants at the county level, PATA produces more detail with estimates for census tracts and census blocks, which can be grouped according to neighborhoods. PATA also shows how pollutants are distributed spatially, with distinct gradients related to highways and other areas of emission density. This will help DEQ understand exposure patterns and the locations of areas with elevated risk from air toxics. PATA can be used for making better land use decisions and possibly remedying past practices. Because PATA attributes air toxics to specific categories of sources, it gives the Department a credible foundation for developing risk reduction strategies on a sector basis. PATA will also serve as a baseline for tracking trends and progress in reducing air toxics as reduction strategies are implemented in the future. The model can be revisited for specific information about sources and help to define geographic areas of most concern in the Metro area.

Local scale modeling, along with additional monitoring and a continuously improving emission inventory will serve as the foundation for future emission reduction planning. This process will involve local stakeholders and community members. PATA enables the Department to communicate about air toxics and promote voluntary reductions in Portland in advance of a more prescribed planning process. Local, specific inputs lend credibility to the results and encourage the community buy-in necessary to address the various issues highlighted by the study.

10. References

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Chemical Industry Institute of Toxicology, 1999. Formaldehyde: Hazard characterization and dose-response assessment for carcinogenicity by the route of inhalation. Revised edition. Research Triangle Park, North Carolina

Data spreadsheets of model or exposure concentrations are available in EXCEL format. Please contact Phil Allen at 503-229-6904 or email allen.phil@deq.state.or.us.