Environmental Protection

Health Effects of Inhalable Particles: Implications for British Columbia - Overview and Conclusions

Prepared for the Air Resources Branch, British Columbia
Ministry of Environment, Lands and Parks
June, 1995

The following sections were abstracted from the report Health Effects of Inhalable Particles: Implications for British Columbia (June, 1995) prepared by Dr. Sverre Vedal, Department of Medicine, University of British Columbia, Vancouver Hospital and Health Sciences Centre for BC Environment.

Table of Contents

Overview

I. Introduction

Air pollution can cause harmful effects in people that range from annoying symptoms to death. This has been shown most dramatically by air pollution disasters that occurred earlier in this century. However, there is now also a large amount of scientific evidence that has shown that even the lower concentrations of air pollution that we are exposed to now in our cities

and towns can cause the same effects on health, only less dramatically than in the earlier disasters. Particles in the air make up one component of the many impurities present in air pollution. These particles may be responsible for more serious health consequences than other components of air pollution. The purpose of this document is to review the health effects of particles in the air, and to then estimate the impact of the particles we have in the air in British Columbia on the health of British Columbians. It is hoped that this work will have direct implications for air pollution policy in the Province.

II. Inhalable particles and health

A. Background

Particles in the air come from industrial sources, such as oil refineries and pulp mills, from residential burning, such as home wood burning, from motor vehicles and from natural sources such as dust blown by wind. The concentrations of particles in the air can be measured either as an average over a defined time period, usually one day, or continuously using some of the newer types of particle monitors. Concentration is expressed in micrograms of particles per cubic meter of air sampled (µg/m3). Particles get into the body through our lungs. Only particles that are smaller than 10 micrometers in diameter (10 µm) can be breathed into our lungs to any extent and are known as *inhalable* particles (abbreviated PM10); larger particles settle in our mouth and nose. Inhalable particles settle in different parts of the lungs; where they settle depends primarily on the particle size. The smaller the particle, as a rule, the deeper it can be breathed into the lungs. Particles smaller than 2.5 µm (abbreviated PM2.5) are known as *fine* particles. While the PM10 measurements can include substantial amounts of particles of natural origin (windblown dust), PM2.5 measurements are not significantly influenced by these particles. It is not well understood how particles actually damage the lungs, although recent scientific experiments have provided some insight into the mechanisms that are involved.

B. Review of health studies

The most troubling finding from many recent scientific health studies is that increases in particle concentrations in air are associated with increases in the risk of dying (or mortality), and that this association is seen for concentrations of particles in air that are similar to those present in the cities and towns throughout British Columbia. Most of the evidence shows increasing mortality due to particles starting above a PM10 concentration of 20 µg/m3, although one cannot be sure yet that effects on mortality do not occur even at PM10 concentrations lower than 20 µg/m3. An estimate based on the health studies as a whole is that daily mortality increases by 1% for each 10 µg/m3 increase in PM10. As one would expect, the increase in mortality associated with increases in particles includes death from

lung disease (respiratory mortality); however, death from heart disease (cardiac mortality) is also linked to increases in particles. Daily respiratory mortality is estimated to increase by 3.4% for each 10 µg/m3 PM10 increase, while cardiac mortality increases 1.4%. There is recent evidence that exposure to higher PM10 concentration is also associated with an increased risk of dying from lung cancer, although this evidence is much weaker than the evidence for overall mortality.

For the association between increased PM10 concentrations and mortality to be plausible, it would be expected that increases in PM10 would also be associated with less severe effects on health than death. There is now good evidence that increases in PM10 concentrations cause a wide variety of effects on health. These include increases in hospitalization for lung and heart problems, increases in hospital emergency room visits for lung problems, increases in days of restricted activity in adults and school absenteeism in children, increased reporting of symptoms that indicate mild respiratory illnesses, and small reductions in measured levels of lung function. For each 10 µg/m3 increase in PM10, the estimated impacts are: a 0.8% increase in hospitalizations and a 1.0% increase in emergency room visits for respiratory illnesses, a 9.5% increase in days of restricted activity due to respiratory symptoms, a 4.1% increase in school absenteeism and a 1.2% increase in reporting of cough. For hospitalizations, emergency room visits and respiratory symptoms there is evidence that the increase in risk can also be detected at a PM10 concentration above 20 µg/m3. Persons who are most sensitive to these impacts of PM10 include the elderly, those with pre-existing lung and heart disease, and probably children.

What allows a particle to cause lung damage is not well understood. It appears, however, that particles formed from the burning of fuels, such as oil or wood, are more harmful than particles from natural sources, such as particles from windblown dust. The harmful effect does not require that the particles be acidic or that other types of air pollutants also be present, since the health effects of particles are seen in the absence of acid particles or other air pollutants. Also, while it might seem reasonable to expect that fine particles that can be breathed very deeply into the lung would cause more damage than other inhalable particles, the evidence for this is not strong.

The findings of the scientific health studies on particles have not been accepted without criticism. The following criticisms are the most significant: 1) most people who are considered to be at risk of dying from particle exposure are ill and are therefore indoors where particle concentrations are different from those outdoors, 2) it is not known how breathing these "everyday" concentrations of particles can cause death, and 3) the analysis of the studies has not adequately accounted for other factors, such as other pollutants or changes in weather, that could possibly explain the findings thought to be due to particles. Very fine particles are present indoors in similar concentrations as outdoors and, if these very small particles are responsible for deaths due to particles, could explain why people are dying indoors. While it is true that the mechanism by which exposure to modest concentrations of particles could cause death is not known, it is not unusual for findings of good scientific studies to provide strong

support for a cause-effect relationship, even in the absence of a known mechanism of action. Finally, since the relevant health studies have been done in a variety of settings with different air pollutants and under many climatic conditions, it seems unlikely that these factors could account for the apparent relationship between particles and effects on health. Therefore, unless new solid evidence becomes available to call the relationship into question, it seems reasonable to conclude that exposure to particles in air can cause many ill effects on health.

III. Inhalable particle health burden in BC

A. Impact of inhaled particles

In order to estimate the impact of particle exposure on health in British Columbia it is first necessary to estimate the population exposure to particles. Estimating exposure from particle monitor measurements is difficult. While some regions in BC have a very extensive air monitoring network, such as the GVRD, other regions have little monitoring. Also, sometimes the locations of the monitors are selected to monitor an area suspected of having high air pollution concentrations because of its close proximity to a source of high pollution emissions. These monitoring sites may not reflect the particle concentrations for the rest of the regions in which they are located. Only rough estimation of particle exposure of the population in BC is therefore possible.

BC Environment operates 75 particle monitors throughout BC that measure PM10 as an average over a 24 hour period. Eleven additional monitors measure PM10 continuously throughout the day. The Greater Vancouver Regional District (GVRD) has 9 monitors that also measure PM10 continuously. Based on recent measurements of PM10 from these monitors, it is clear that, in general, sites outside the GVRD, Capital Regional District (CRD), and the Nanaimo Regional District (NRD) tend to measure significantly higher PM10 concentrations than monitors within these regions. Increases in health effects can be detected for every 10 µg/m3 increase in PM10 above a concentration of 20 µg/m3. An "increment" of PM10 for health purposes can then be defined daily for each 10 µg/m3 increase above a concentration of 20 µg/m3. For example, a daily PM10 concentration from 30 µg/m3 to 40 µg/m3 constitutes one PM10 increment, from 40 to 50 µg/m3 two PM10 increments, from 50 to 60 µg/m3 three PM10 increments, and so on. Since there is little confidence that an increase in health effects occurs until at least a 10 µg/m3 increase above 20 µg/m3 is experienced, a daily PM10 concentration less than 30 µg/m3 counts as no increment for that day. Monitoring sites within the GVRD monitoring network average 32 such PM10 increments per year. Monitoring sites within the CRD and NRD average 43 PM10 increments per year. The site average for the rest of BC is 232 PM10 increments per year.

By making use of BC data on rates of mortality, hospitalization and respiratory symptoms, and

estimated BC rates of emergency room visits, activity restriction and absenteeism, combined with the health study estimates of health impacts for 10 µg/m3 increases in PM10 concentration, and the average number of PM10 increments that the population experiences, it is possible to estimate the health impacts due to PM10 pollution in British Columbia. It is estimated that increases in PM10 pollution cause 82 extra deaths in BC every year, of which 24 are due to lung disease and 27 due to heart disease. It is also estimated that 69 extra hospitalizations for lung disorders, 60 for heart disorders and 17 for asthma are caused by PM10 pollution increases every year. For emergency room visits, it is estimated that 283 extra visits for asthma and 71 extra visits for chronic bronchitis or emphysema each year are due to increases in PM10. Much larger impacts are estimated for activity restriction, school absenteeism and respiratory symptoms. It is estimated that 3% of all days in which usual activity is restricted because of respiratory symptoms and 1.5% of all school absences due to illnesses are due to increases in PM10 pollution.

B. Policy and regulatory implications

It is recommended that strong consideration be given to abandoning the past practice of setting air quality objectives around an absolute particle (or PM10) concentration in favor of basing objectives on the frequency of PM10 "increments". PM10 "increments" can be used to directly estimate the health impacts of PM10 pollution increases and thereby allow consideration of PM10 increases that might be deemed acceptable from the perspective of policy making. At this time there seems little justification for attempting to define objectives based on an annual average, since it is not clear that long term effects of particles on health are not solely due to short term increases in concentrations that would be addressed by objectives for daily PM10 concentrations. Finally, because PM10 measurements can be highly influenced by particles from windblown dust, and because these dust particles may have less significant health impacts, it is reasonable to consider basing particle air quality objectives on measurements of fine particles (PM2.5).

C. Research needs

The most urgent research needs for British Columbia in the area of particle air pollution are to: 1) better characterize particle exposures of all segments of the population, 2) determine whether effects of short-term, high peak concentrations of PM10 have more deleterious health effects than similar daily concentrations without such peaks and 3) generate conclusive health data on whether particles from natural sources are less damaging than those generated by fuel burning. It is also important to know what the sources of particle pollution are in different parts of BC, and what climatic conditions influence the relative contributions of these sources. Finally, although it seems reasonable to accept for now that particles in air can cause significant health effects, insight into the mechanisms by which these effects occur would strengthen the case for causation.

Conclusions

1. There is now good epidemiologic evidence that short-term increases in ambient inhalable particles (PM10) concentrations are associated with:

i. increases in total mortality, as well as in mortality from respiratory or cardiac disease,
ii. increases in respiratory, and probably cardiac, hospitalizations,
iii. increases in emergency room visits for asthma and other respiratory conditions,
iv. increases in functional limitation as reflected by restricted activity days and, in children, by school absenteeism,
v. increases in the daily prevalence of respiratory symptoms and
vi. small decreases in the level of pulmonary function in children and in adults with obstructive airways disease.

2. While these observations are consistent across many studies and provide a cohesive picture in that, as one would expect, there are effects on many different respiratory health outcomes, there remain legitimate questions as to the causal nature of the associations. These questions center on issues of plausibility, exposure misclassification and inadequate statistical analytical methods.

3. Population subgroups that are particularly sensitive to PM10 effects, in the sense that they experience more severe adverse health effects for a given particle exposure, include the elderly and subjects with pre-existing lung or heart disease. Younger children may also be more sensitive.

4. There is evidence that PM10 pollution produced from crustal (natural) sources is significantly less harmful than PM10 generated from combustion processes.

5. The health effects of PM10 appear to be independent of the presence of other ambient pollutants. There are no good data that effects of PM10 are potentiated by other pollutants.

6. There is no good evidence, based on epidemiologic data, that there are firm threshold concentrations for PM10 below which no population impacts are detectable.

7. There are no data available to support the notion that, for equal daily concentrations, high particle concentrations for brief periods are more harmful than relatively constant concentrations. Therefore more research is needed before air quality objectives based on shorter than 24-hour averages are proposed.

8. Population exposures to PM10 in British Columbia are likely poorly estimated. However, persons in many smaller communities outside the GVRD and the Victoria area (CRD) are likely exposed to higher concentrations of PM10 than persons within the GVRD or CRD.

9. Based on relatively naive estimates of population particle exposures, and making several explicit assumptions, it is possible to roughly estimate health impacts of increased PM10 concentrations in British Columbia. There are estimated impacts on mortality, hospitalization and emergency room visits, but these are relatively small. Estimates of impacts on restriction of activity, absenteeism and incidence of respiratory illness are great by comparison.

10. Strong consideration should be given to basing air quality objectives on increases in PM10 concentrations rather than on absolute PM10 concentrations. Focussing on the frequency of daily 10 µg/m3 PM10 increments above an absolute concentration of 20 µg/m3 is a starting point given the weight of current scientific evidence. Determinants of the number of PM10 increments that are acceptable can be based on acceptability of the health impacts predicted for selected numbers of PM10 increments.

11. There is little convincing evidence that particles of some size ranges within the PM10 fraction are more deleterious to health than others. Nevertheless, there are compelling reasons for basing ambient particle regulations on fine particles rather than the larger inhalable particles, although this will clearly have major implications for the monitoring networks already in place.

12. There is yet no convincing evidence that chronic health problems are produced from long-term exposure to PM10 pollution, independent of the effects due to repeated short-term exposures. Air quality objectives based on an annual average should not be proposed at this time.

13. Areas in which further research is most urgently needed are:

i. population particle exposure estimation in BC,
ii. effects of brief peaks of particle exposure,
iii. dose-response relationship of local (BC) particles, including comparison of effects due to combustion particles and crustal particles.
iv. source apportionment for inhalable and fine particles in BC and
v. experimental work on the mechanisms of particle health effects.

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