**In-Depth Review**

**Point sources of air pollution**

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**Abstract**

Many people live near point sources of air pollution such as industrial sites and waste disposal operations and there are often suggestions of clusters of disease around such activities. Such alleged clusters will generate significant public concern and media interest and in many cases will warrant detailed investigation. However, the ability of current epidemiological methods to investigate such clusters is limited, particularly with regard to obtaining reliable and accurate population exposure data. In many cases, the key question is whether releases from a point source result in a significant increase in exposure or whether other sources (background exposure) give rise to the dominant exposure. This review considers some of the issues around point sources including methods of estimating exposure and briefly discusses some of the epidemiological evidence linking respiratory disease and cancer with specific industries such as coking works and incinerators.

**Key words**

Air pollution; environmental exposure; epidemiology; point sources.

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**Introduction**

There is ample evidence that air pollution can have an adverse effect on the health of susceptible people (i.e. young children, the elderly and particularly those with pre-existing respiratory disease) \(^1\). There are often suggestions of clusters of disease around point sources of pollution such as industrial sites and waste disposal operations. Such alleged clusters will generate significant public concern and media interest and in many cases will warrant detailed investigation. Many clusters occur purely by chance but, to the concerned lay people, these clusters appear remarkable confirming their suspicions of a major health risk.

**What are point sources?**

Most air pollutants arise from a wide range of sources such as industry, traffic or natural sources (e.g. sea-spray) and many are ubiquitous in the atmosphere. Air pollutants are classified into two distinct types: primary and secondary pollutants.

Primary pollutants are released directly into the atmosphere from specific sources of pollution, such as industry or motor vehicles. Once emitted into the atmosphere, some of these primary pollutants can be altered by light energy, heat or the presence of other chemicals (e.g. oxygen) to form secondary pollutants. Ozone, for example, is a secondary pollutant formed as a result of photolysis (the splitting of molecules by means of light energy) of nitrogen dioxide and subsequent reactions with volatile organic compounds (VOCs).

Many people live near point sources of air pollution, that can be defined as a stationary location or fixed facility from which pollutants are released \(^2\). Examples of point sources include power stations, steel works, foundries, incinerators, wood and pulp processors, paper mills, refineries and chemical production. Most industrial point sources release pollution into the atmosphere through chimneys at a height sufficient to provide ample dilution before the pollutants reach ground level. However, certain meteorological conditions may prevent or reduce the effectiveness of this dispersion and pollutants may become trapped near the source and descend to ground level where they may cause poor air quality. For example, in 1998 high concentrations of sulphur dioxide were recorded across much of the Midlands and South Yorkshire as a result of emissions from coal-fired power stations becoming trapped near ground level by a combination of weather conditions including a very stable atmosphere, low temperature and low winds \(^3\).

Apart from point sources, air pollution may be released from non-point sources such as mobile sources (e.g. road traffic or aircraft emissions) and area sources (e.g. emissions from many smaller stationary sources such as homes, dry cleaners, petrol stations, etc.). For many common air pollutants, motor vehicles are the largest source of emissions in the UK, e.g. traffic contributes about 49% of the total emission of oxides of nitrogen \(^4\).

It is also important to distinguish between point sources and fugitive emissions. The latter typically relate to pollutant releases from points in a process that are not associated with a defined process stream such as a stack.
Examples of fugitive releases include losses from pipe work or wind-blown dust from stockpiles. Occasionally these releases can be of significance at a local level.

Releases from point sources can include complex mixtures of substances and the pollutants released will be dependent on process input materials, type of process, etc. Examples are given in Table 1 which lists the pollutants requiring regulation under Pollution Prevention and Control [5].

A summary of the effect of exposure to these chemicals can be found elsewhere [1,6,7]. In all cases, the key question relates to the extent of exposure of the public to these chemicals. Where pollution abatement procedures are operated as prescribed, then exposure from point source emissions should be very low.

People living near point sources can be exposed through a number of pathways depending on the point source and the type of release. For most pollutants inhalation will be the main source of exposure but for some, indirect pathways such as food will assume greater importance. Pollutants may enter the food chain through deposition into soil or onto plants and subsequent uptake in crops and farm animals. Exposure via the food chain may be a potential problem if locally grown or reared produce is important to the diet of local people where groups such as local allotment owners and farmers may need particular consideration. Such processes are most important for persistent organic pollutants such as dioxins and polychlorinated biphenyls (PCBs), which because of their hydrophobicity and extreme persistence, accumulate in the lipid reservoirs of animals consuming those plants. Approximately 95% of human exposure to dioxins is estimated to occur through the diet with the consumption of fatty foods being the predominant source [8].

However, many of the pollutants arise from a wide range of sources and are hence ubiquitous in the environment [9]. So, releases from a point source may result in only a negligible increase in exposure.

Table 1. Indicative list of pollutants (to air) requiring regulation under Pollution Prevention and Control [5]

- Sulphur dioxide and other sulphur compounds
- Oxides of nitrogen and other nitrogen compounds
- Carbon monoxide
- Volatile organic compounds (including benzene, 1,3-butadiene)
- Metals and their compounds (e.g. lead, arsenic, cadmium, nickel)
- Dust (e.g. particulate matter)
- Asbestos (suspended particulates, fibres)
- Chlorine and its compounds
- Fluorine and its compounds
- Cyanides
- Substances and preparations that have been proved to possess carcinogenic or mutagenic properties or properties that may affect reproduction via the air
- Polychlorinated dibenzoepoxides and polychlorinated dibenzofurans

When investigating possible effects of pollutants emitted by a point source, it is highly desirable to have some direct measurement of exposure. Personal or biological monitoring may be helpful in establishing current levels of exposure or estimating dose levels. Personal air monitors that can be worn during normal day-to-day activities are almost never used to measure environmental exposure despite the fact that they can provide actual data on individual exposure. Biomarkers can help demonstrate that exposure has occurred and can be used to help identify exposed populations for investigation, e.g. urinary thioether assays can be used as biomarkers for electrophilic chemicals such as polycyclic aromatic hydrocarbons (PAHs) [10]. Biomarkers can also provide an estimate of past exposure provided the pollutant under investigation has a long half life in the body and is relatively easily detected (e.g. dioxins).

In the absence of biological measurements or personal monitoring, exposure has to be estimated through some other method. Typically these are:

- use of residence or proximity as an indicator of exposure;
- environmental measurements, e.g. air monitoring;
- dispersion modelling.

Direct measurements of exposure from industry are seldom made and often the distance from the source is used as a proxy for exposure. This approach assumes that exposure decreases with increasing distance from the source. Typically a series of concentric rings are drawn around the source to help identify potentially exposed populations (Figure 1). Depending on the source, the type of exposure and the population under investigation, these rings can have varying radii but typically start in the region of 0.5–1 km and may increase to 5–10 km. Within each concentric circle, every individual is considered to have the same degree of exposure.

This is a simple, easy to use and cost-effective technique. However, the sole use of proximity as an indicator of exposure leads to much misclassification. It is an approach that takes no account of the influence of meteorological conditions or process characteristics such as stack height, efflux velocity, plume temperature, etc. Furthermore, since the zones of influence can often be very large there is the strong possibility that the exposed community may be exposed to pollution from other industries or sources or may not be exposed at all. The inclusion of people who may not be exposed may dilute any effect that may be estimated and might result in a true greater effect downwind of the point source being missed. Individuals will also move within and outside of these zones (to work, school, etc) and many people will not reside within the zone for most of the day.

It is inevitable that there will be a large degree of variability in terms of exposure within each of these
concentric circles and this approach may be able to do no more than distinguish between possibly exposed and unexposed populations. Even then, such broad classifications may not be valid. Despite its flaws, it is a commonly used technique. In a review of 45 epidemiological studies of air pollution around point and non-point sources, 29% determined exposure solely on proximity measures and most used a combination of proximity and environmental measurements [11].

It is preferable to have some direct measurement of exposure, ideally data on pollutant concentrations at ground level. Emission data alone can be extremely useful in identifying the pollutants concerned, but are not a useful surrogate for environmental measurements especially when considering personal exposures.

In the UK, ground level pollutant monitoring takes place at many sites that can be classified according to their location, e.g. city centre, urban background, industrial and rural. There are three basic ways of monitoring pollution at ground level: automatic point monitors that provide real time measurements, semi-automatic (or active) samplers that involve the collection of pollutant samples by physical or chemical means for subsequent analyses and passive samplers such as diffusion tubes.

The UK has two automated monitoring networks. The Automatic Urban and Rural Air Quality Monitoring Network (AURN) can provide considerable data on background levels of air pollution and ‘hotspot’ monitoring at urban roadsides and, occasionally, around point sources [9]. In addition, the Ambient Hydrocarbon Air Quality Network monitors approximately 25 VOC species at various urban and rural locations [9].

Where such automated monitoring sites are located near point sources, they can provide valuable data on likely levels of exposure, but in many cases monitoring sites may not be advantageously located or are unable to measure specific pollutants of concern. In such cases, semi-automatic or passive samplers can be located around or downwind of point sources. Such instruments can be useful in highlighting ‘hotspots’ of pollution, but since they take less frequent measurements, detailed monitoring may be required to better quantify local concentrations.

Useful data on background exposures can also be obtained from maps showing levels of air pollution on a variety of geographical scales, e.g. NO₂ is typically mapped on a 1 x 1 km spatial scale [12].

Apart from atmospheric data, environmental monitoring of soil, vegetation and water can also help identify exposed communities. Analysis of soil and vegetation downwind of a point source can often prove to be a good indication of exposure. Following the release of a large quantity of dioxin from an accident at a pesticide plant in Seveso, Italy, the extent and level of dioxin contamination in soil in the prevailing wind direction was used to identify the most exposed areas [13]. Subsequent analysis of dioxin levels in the plasma of people from these affected areas showed that body burden was closely correlated with levels of environmental contamination.

Figure 1. Use of concentric circles to identify potential exposure populations, in this case people living near a foundry. Acknowledgement: Crown Copyright Ordnance Survey: An Edina Digimap/JISC supplied service.
Another approach is to use computer models to predict exposure. The use of air dispersion models is a long established and well-accepted methodology for regulating emissions to atmosphere from major industries. Such models require information on the release rates of pollutants, together with data on the height of release and meteorological data such as temperature, wind direction and wind speed to predict ground level concentrations. Most models typically predict the maximum ground level concentration over the short- and long-term around point sources including concentrations within the nearest area of housing (Figure 2). As a result, the exposed population can be more accurately defined than through the use of proximity as a surrogate.

The accuracy of dispersion models is heavily dependent on the quality of the input data. However, it is generally considered that atmospheric dispersion models can often provide a good approximation to ground level concentrations, particularly over the long term. The best dispersion models have been extensively validated by comparing their predictions against concentrations measured downwind of pollution sources. In an ideal situation where the release rate is well known and the local topography uniform and fairly flat, dispersion models will typically give predictions within a factor of two of true concentrations [14].

It is important to obtain as much accurate information on potential exposures as possible, as poor quality monitoring and modelling can be very misleading [15]. Detailed exposure assessment should not be undertaken unless the health concerns are properly defined and there is some element of biological plausibility (i.e. that emissions from the point source could cause that specific condition). Measurements should be concentrated in those areas where ill-health is alleged, focus on pollutants emitted by the source under investigation and comply with recognized standards [15]. Poor quality data can weaken any study, may raise expectations in the local community and may incur unnecessary costs.

**Health studies**

There is considerable epidemiological evidence to demonstrate that, at the population level, increases in the levels of air pollution are related to increases in hospital admissions and mortality [1]. However, the ability of current epidemiological methods to fully investigate point sources is more limited. Many of the studies examining possible health effects are retrospective (i.e. they were triggered by complaints of apparent ‘clusters’ of ill-health in areas around point sources) and employ routinely collected data such as cancer registrations, birth and death records. Such observational studies can provide evidence of association between a health outcome and an environmental pollutant; however, they are not able to demonstrate a cause and effect relationship. The interpretation of these findings is also crucially dependent on well-known limitations, including possible sources of bias and confounding, together with the ever-present difficulty in obtaining reliable and accurate population exposure data.

A common problem relates to the small number of cases that may be under investigation. Most studies around point sources examine ‘small-areas’ where the numbers (exposed or actual cases) involved are small,

![Figure 2](image.png)  
**Figure 2.** Dispersion modelling of sulphur dioxide concentrations around a hypothetical municipal solid waste incinerator.
thus reducing the statistical power of the study to distinguish between chance occurrences. Very often, even in well-designed studies, there will be a high probability that any reported effect might be due to chance alone. It is generally accepted that single site studies of effects of air pollutants on health are unlikely to have sufficient statistical power to confirm or refute assertions of effects and there is a significant risk that the results of such investigations will be impossible to interpret [15].

A problem is that many studies examine industries that operated some time in the past, particularly where the effect under consideration is cancer, which can have a noticeable lag period between exposure and the onset of disease (typically many years). As a result, it may be very difficult to obtain accurate information on past exposure and any data that is collected may not be relevant to more modern facilities that will have a significantly different exposure profile. For example, until the mid-1990s, incinerators in the UK were fitted with rather rudimentary emission controls and, therefore, emitted quite significant amounts of air pollutants. Newly constructed incinerator plants have to meet much stricter controls on emissions and are significantly cleaner [16]. Therefore, when reviewing studies of point sources it is important to know the details of the period of operation.

Despite such limitations there have been some studies around point sources with many investigating cancer and respiratory disease. In the UK, coking works have been implicated as causes of respiratory disease in local communities [17–20]. Aylin et al. [17] reported that there was a significantly higher risk of hospital admissions for respiratory disease and asthma among children living near a coke works at Teesside. However, when hospital admissions from all of their six study areas were combined, no association between living near coke works and respiratory illnesses could be made. Furthermore, since Teesside contains a large number of industries it was not possible to directly link respiratory ill-health with any particular type of industry.

An excess of respiratory problems has also been reported in the community living around the Monkton coking works in South Tyneside, UK [18]. However, the study used GP data to quantify local health problems, which is open to interpretation bias and differences in GP diagnostic practices, which could have influenced the results of this study [21]. The study also attempted to link exposure to sulphur dioxide with GP attendance on the same day, which is not plausible as the time it takes for an exacerbation to occur following exposure and for the individual to be able to get an appointment at their general practitioner surgery is very unlikely to be encompassed within the space of a few hours.

A small excess in mortality from cardiovascular and respiratory causes among residents near coke works has also been reported but any effect would probably be outweighed by the effects of socio-economic factors (i.e. deprivation) or bias resulting from inexact population or exposure estimates [19,20].

Communities living around steel industries have also been investigated. Findings from the US state of Utah, where hospital admissions, symptoms and primary care attendances fell when a local steel mill was closed only to rise again on re-opening, suggest that local point sources can plausibly cause health effects [22–24]. This study used time series methodology that is powerful in detecting effects because a large population is followed over time. Similarly in Holland, a panel study of adults with respiratory conditions living near a steel mill showed that both particulate matter (as PM$_{10}$) and iron content of the air were related to changes in lung function, symptoms and treatment use on a day-to-day basis [25]. Both studies appear to provide good evidence of point source pollution causing health effects in both children and adults.

The health of the population of the coastal Australian town of Lake Munmorah, that is located near two power stations, has also been extensively investigated [26–28]. Two studies consistently reported evidence of an increase in respiratory illness, including asthma, in children in Lake Munmorah when compared with a control population [27–28]. However, it is not possible to determine whether this increase was the result of differences in air quality and/or genetic factors between the two communities. Confounding factors such as exposure to other pollutants, socio-economic factors, genetics and atopy might explain all or some of these findings.

Several studies have examined possible adverse effects on respiratory health among people living near incinerators. The most credible studies are those that examined the respiratory health of six communities in North Carolina, USA, three of which were exposed to emissions from biomedical, municipal or hazardous waste incinerators [29–32]. Despite detailed investigations, there were no significant differences in the concentration of particulate pollution (PM$_{10}$) or in the overall respiratory health in those communities near the incinerators relative to comparison communities.

It has been hypothesized that exposure to dioxins and furans (either directly via inhalation or indirectly via the food chain) are responsible for some cancers in communities around incinerators. Despite a number of studies, there is not, to date, any consistent or convincing evidence of a link with incineration [33–41]. In the UK, the large epidemiological studies by Elliott et al. [33–35] examined an aggregate population of 14 million people living within 7.5 km of 72 municipal solid waste incinerators. Despite the inclusion of incinerators with
emissions of potential carcinogens orders of magnitude higher than would occur from today’s modern incinerators, no excess of cancers could be found once socio-economic confounding was taken into account. Given that the emissions of dioxins and furans from modern incinerators are orders of magnitude lower than from older incinerators, it can be said with some confidence that impacts on cancer rates in local people will not be significant.

Despite the results from many of these studies being tentative and open to question, there is clear evidence of point sources causing ill-health. Good examples of this are the outbreaks of asthma attacks seen in populations living near castor bean processing factories [42–43] and the epidemics seen in Barcelona on days of soya bean unloading at the docks [44]. All these studies confirm that local point source emissions can have an impact on public health if the conditions for high exposure are right and the individual is susceptible to the effects of the exposure. It is worth noting that the affected individuals in these outbreaks had all been recurrently exposed over a long period thus becoming sensitized to the allergens in bean dust and then, on a particular day, the high exposure triggered a severe attack.

Conclusion

While it is well documented that raised ambient concentrations of air pollution can have an effect on susceptible people, it is very difficult to predict the likely size of such effects from a single point source. The reality is that current epidemiological methods cannot conclusively relate effects with specific emissions and many studies suffer from poor estimates of exposure or small numbers. Any effect at a local level is likely to be very small.

References

2. European Environment Agency. EEA multilingual environmental glossary. Available at http://glossary.eea.eu.int/EEAGlossary


42. Ordman D. An outbreak of bronchial asthma in South Africa, affecting more than 200 persons, caused by castor bean dust from an oil-processing factory. *Int Arch Allergy* 1955;7:10–24.
