Environmental Quality and Social Deprivation

R&D Technical Report E2-067/1/TR

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Statement of Use
This technical report summarises the results of research which analyses the relationship between environmental quality and social deprivation. The information contained in this document is intended to support policy development to help promote environmental equality.

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Environmental quality, social exclusion, deprivation, equality, equity, environmental justice, flooding, Integrated Pollution Control, air quality.

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EXECUTIVE SUMMARY

Aim of the Project

The aim of this project was to improve the Environment Agency's understanding of the relationship between environmental quality and social deprivation. Whilst there has been a general recognition that deprived communities are likely to experience disproportionate levels of pollution and other forms of environmental degradation, the evidence-base for policy development by the Agency and others has been lacking.

Context

Environmental protection and social justice, two of the fundamental tenets of sustainable development, are brought together by 'environmental equity' or 'environmental justice'. Environmental justice is concerned with how environmental bads (such as pollution) and goods (such as access to greenspace) are distributed across society, as well as with the equity of environmental management intervention and public involvement in decision-making. The environmental justice approach was pioneered in the USA by civil rights activists and is now receiving increased attention in Europe, in part due to the rights embodied in the 1998 Aarhus Convention.

The Existing Evidence Base

Whilst there are many dimensions to environmental equity, an important starting point is to establish the extent to which environmental quality is unevenly distributed across social groups. A wide ranging literature review, focusing on eight environmental issues, found a generally weak and limited research base in the UK. Only work on air quality and industrial emissions and wastes provided more than one or two studies. Combined with a systematic gap analysis, which identified 33 environmental variables and 12 theme areas potentially relevant to equity analysis, we therefore conclude that the gaps in the current UK evidence base are substantial.

The Equity Analyses

The prioritisation of environmental issues for analysis in this project was informed by the gap analysis and a workshop involving internal and external stakeholders. The outcome was to highlight three issues of particular relevance to the Agency: flooding, Integrated Pollution Control (IPC) sites and air quality.

For each of these issues an equity analysis was undertaken separately for England and Wales using the ward level Index of Multiple Deprivation (IMD) as social variable. The approach used for each part of the analysis was carefully developed in recognition of the many methodological complexities involved. There are inevitable limitations arising from the quality and resolution of source data sets, the spatial scale of analysis and the complexity of real-world environmental variables.

Flood Hazard and Deprivation

The indicative tidal and fluvial floodplain maps produced by the Agency were used to relate to ward deprivation data.

- For England, the tidal floodplain analysis shows a clear relationship with deprivation. Of the population living within the tidal floodplain there are eight times more people in the most deprived decile compared to the least deprived (deciles provide ten ranked groupings of wards, from the 10 % most deprived to the 10 % least deprived).

- In contrast, the fluvial floodplain is an inverse relationship with deprivation, although of lesser strength, with a higher proportion of the floodplain population in the more affluent compared to the more deprived deciles.

- For Wales, the pattern of social distribution is less distinct but shows some similarities to England. For fluvial floodplains the proportions in the least deprived and most deprived deciles are broadly comparable. For tidal floodplains the balance of disparity is again towards the poorer deciles.

This evidence of inequality provides a first view of national patterns of floodplain occupation in relation to social deprivation but has to be set against the limitations of the indicative floodplain maps. These in particular take no account of flood defences.

In making recommendations, we focus on the need to undertake further analysis when improved mapping products are available, including examination of the equity of past investment in flood protection. We also identify implications for climate change policy, given the association between tidal flood risk and deprivation, and for the targeting of flood management resources on deprived and therefore more vulnerable populations.

Integrated Pollution Control Sites and Deprivation

The IPC analysis utilised data from the Agency pollution inventory as well as the Operator Performance and Risk Appraisal (OPRA scores).

For England there is strong evidence of a socially unequal distribution of IPC sites and associated potential impacts.

- Wards in the most deprived decile provide the location for five times as many sites and authorisations and seven times as many emission sources as wards in the least deprived decile. Out of the 3.6 million estimated people living within 1km of an IPC site, there are 6 times more people from the most deprived decile compared to the least deprived.

- IPC sites are also disproportionately clustered together in deprived wards. As site and emission clusters become more concentrated, the bias towards the more deprived deciles becomes more acute.

- All of the key industrial sectors in the IPC regime show a bias towards the more deprived deciles, with the differential in the waste sector particularly extreme.

- Higher hazard authorisations (as judged by OPRA scores) are more prevalent in the more deprived deciles in absolute *and* relative terms, whilst lower hazard authorisations are more evenly distributed. There are also disproportionately more authorisations with ‘offensive characteristics’ in the more deprived deciles.

- Operator performance (as judged by OPRA scores) shows no variation with deprivation. There is also no difference in social profile between earlier and more recent authorisations under IPC - evidence which counters the possibility that developers may be targeting deprived communities, but also suggests that historic patterns are being maintained.

- Analysis of emission levels from IPC sites for particulates and carcinogenic emissions to air, show a disproportionate concentration of emissions in more deprived areas. Nitrogen dioxide emissions are less skewed.

For Wales, the analysis is less clear cut and, in contrast to England, there is some evidence of bias towards more affluent areas

- The analysis of populations within 1km shows a weak bias towards the more deprived deciles, but not the *most* deprived. There is no evidence of sites being disproportionately clustered in the more deprived deciles – indeed as the number of sites within 1km increases a small bias towards the least deprived decile emerges.

- Industrial sector data shows different patterns across the sectors. There are biases towards more deprived deciles for chemical, fuel and metal sectors, and towards less deprived for mineral, waste and other industries.

- The OPRA data for pollution hazard and operator performance shows no relationship with deprivation.

- Analysis of specific substances shows higher emission levels for nitrogen dioxide, particulates and carcinogens in the less deprived deciles

Our results show evidence of distinct inequalities particularly in England where there is a strong association with deprivation. However, the analysis is of population proximity not of specific exposures to hazard or risk, and we have only touched on issues which may help explain why these patterns of inequality exist. Relevant factors and potential responses therefore need to be debated within and beyond the Agency. Issues include implications for future siting and land use policy, compensation strategies, equity information provision and stakeholder engagement.

In making recommendations we identify a number of specific potential responses. These include the targeting of regulatory attention on IPC sites in deprived areas, giving attention to cumulative pollutant impacts associated with site clusters, working with planning authorities on potential siting implications, and developing equity appraisal techniques. We also identify a substantial profile of further research needs.

Air Quality and Deprivation

The air quality analysis addressed five pollutants: nitrogen dioxide (NO_2), fine particulates (PM_{10}), sulphur dioxide (SO_2), carbon monoxide (CO), and benzene. We also developed a simple air quality index to collectively address multiple pollutants.

- For England, overall and for all pollutants, the most deprived wards are clearly those with highest pollutant concentrations. The social distribution of NO_2 is typical, showing that people in deprived wards are exposed to concentrations higher (by 41%) than those of wards of average deprivation.

- For all pollutants (except SO_2) the *least* deprived also experience concentrations that are above those for people of average deprivation, although the elevation above the average is much less than that of the most deprived.

- The relationship between poor air quality and deprivation in England is particularly strong for peak pollutant values, including exceedences of standards. The number of people in wards above pollution thresholds increases progressively with increasing deprivation.

- For Wales, both the most and least deprived wards experience above average pollutant concentrations. However, concentrations are highest in the *least* deprived wards, although the distribution is, overall, more equitable than for England.

- The difference between the Welsh and English patterns arises because the least deprived households in Wales tend to be more urban than their English equivalents, and are mostly located in S E Wales where most of the poorest air quality occurs.

- Using the air quality index we were able to identify clusters of wards that have poor aggregate air quality and high deprivation. We identified around a dozen of these pollution-poverty 'hot-spots', with large clusters in parts of London, Manchester, Sheffield, Nottingham and Liverpool and small clusters elsewhere.

To examine future likely changes in air quality-deprivation patterns we used forecast air quality data for 2010 (NO_2 and PM_{10}).

- The 2010 data suggests that whilst the total burden of air pollution will fall, there will be little change in its social distribution. However, if we examine just those wards where air quality exceeds standards (areas which give most cause for concern) we see that the distribution becomes more equitable. The planned introduction of tighter air quality standards may lead to an increase in exceedences, and the burden of these will be borne disproportionately by the poor, although the total exposure for all will be very much less.

In interpreting and responding to this multidimensional evidence of inequality we identify several key questions around ‘polluter pays’ (do the better off also create more pollution?) and the degree of choice available in residential location.

Specific recommendations focus on the Agency working with local authorities to improve air quality within designated Air Quality Management areas and within pollution-poverty hotspots; and the need for the development of equity assessment methods for assessing the distributive effects of transport and land use policies.

Conclusions and Overall Recommendations

We have produced substantial evidence which shows, for three key areas of Agency responsibility, that a greater burden of potential environmental impact is borne by deprived populations than by the more affluent. This relationship is most acute for tidal flooding, air quality exceedences (in England) and proximity to IPC sites (in England).

We have also produced more limited evidence of inverse relationships where a greater burden is borne by the affluent, in particular for the worst air quality in Wales and for fluvial flooding in England. We have therefore been able to add to the evidence-base and provide an initial foundation for further research and policy development.

In addition to specific actions in each areas, we recommend, as a stimulus to debate in relatively uncharted policy territory, that the Agency should:

- continue to support efforts to further understand the nature and significance of the social distribution of pollution and risk;
- appoint a technical working group on environmental equity appraisal;
- work with government, local authorities, and other appropriate stakeholders to ensure that environmental equity assessment becomes more widely adopted in the environmental impact appraisal process;
- identify critical 'pollution-poverty' areas so as to identify those communities most in need of remedial action;
- develop ways of engaging and working with communities in deprived areas to ensure that their local knowledge and viewpoints are included in decision-making;
- undertake further research examining additional environmental and social variables, processes of causation and the effectiveness of potential intervention strategies.

CONTENTS

1 THE RESEARCH PROJECT

This report describes work completed under Environment Agency R&D Project E2-067/1 on Environmental Quality and Social Deprivation Data Analysis. The aim of the research was to *'improve the Environment Agency's understanding of the relationship between environmental quality and social deprivation in order to inform the Environment Agency's policy position on environmental equality'*. The objectives of the study were to:

(i) Evaluate existing data and research for the relationship between environmental quality - particularly with reference to the Agency's environmental priorities (e.g. air and water quality, flooding) and social deprivation (as measured by the index of social deprivation);

(ii) Identify gaps in the current evidence base, which restrict the development of an Agency policy on environmental equality;

(iii) Critically appraise the existing methodology used by the Environment Agency for exploring the extent to which environmental conditions vary across socially deprived wards (as identified by the index of multiple deprivation);

(iv) Identify the value of, and priorities for, more detailed quantitative analysis of environmental data sets and propose appropriate methodologies for conducting this analysis;

(v) Conduct an initial statistical analysis of data sets associated with areas for which the Environment Agency has regulatory responsibility and those relating to deprivation; and

(vi) Make appropriate recommendations for Agency policy responses and further research.

The project was structured in two main phases. Phase I covered the first four objectives and was concluded by a stakeholder workshop attended by Environment Agency staff, and representatives of government, NGO's and academics with interests and experience in environmental equity. The workshop proceedings are reported in Chalmers (2003) and summarised in the Phase I project record (Mitchell and Walker, 2003). The workshop was held to review the Phase I research findings and agree a strategy for the empirical analyses undertaken in Phase II, results of which are reported in full in Walker *et al*. 2003.

This technical report summarises the outcome of both phases of the project. The development of the environmental equity agenda is first briefly reviewed, after which each of the project objectives are addressed in turn. The empirical analysis focuses on three areas of concern to the Agency: flood hazard, industries regulated under Integrated Pollution Control (IPC), and air quality.

2 THE ENVIRONMENTAL EQUITY AGENDA

Environmental protection and social justice, two of the fundamental tenets of sustainable development, are brought together by 'environmental equity' or 'environmental justice' (EJ), concepts of growing interest to researchers and policy makers. The EJ approach was pioneered in the USA by civil rights activists concerned that landfills and polluting industries were invariably sited within predominantly black communities (Bullard, 1990). EJ is now an important part of environmental and public health policy assessment in the USA, mandated by a Presidential Executive Order (12898) requiring Federal agencies to address EJ as part of their overall mission (Wilkinson, 1998).

In neither the UK nor Europe more widely is there an EJ movement to compare with that of America. However, new European Community laws on enabling rights will ensure that environmental equity issues are taken more seriously than ever before. These laws are being driven by the 1998 Aarhus convention (UNECE 1999), a pan-European treaty that aims to give substantive rights to all EU citizens on public access to environmental information, public participation in environmental decision-making, and access to justice in environmental matters.

In the UK, the relevance of environmental equity to the sustainable development agenda through integrating environmental and social objectives has been increasingly recognised, driven in part by NGO advocacy (e.g. Friends of the Earth, Capacity Global, Green Alliance, Black Environment Network). There is growing political and governmental attention being given to environmental equity issues within, for example, the UK Sustainable Development Strategy and the Neighbourhood Renewal Strategy and in the work of the Environment Agency, Sustainable Development Commission and Social Exclusion Unit.

It is important to note that these emerging policy interests have different social and environmental foci to those of the USA, with a more encompassing framework (Stephens *et al*. 2001) and a reduced emphasis on civil rights. Emerging UK EJ activism and research is addressing access to a broad range of environmental resources, including physical needs (shelter, warmth, food, clean air and water); economic needs (transport infrastructure, access to work and services); and aesthetic, mental and spiritual needs (such as quiet and access to the countryside). The Environment Agency’s involvement in environmental equity issues therefore needs to be approached as part of a broad cross-governmental agenda of relevance to a wide range of stakeholders.

3 REVIEW OF KEY LITERATURE

The first objective of the project was to evaluate existing research on the relationship between environmental quality and social deprivation, particularly with reference to the Agency's environmental priorities.

Given the breadth of potentially relevant environmental issues, and the complexity of the issues involved in environmental equity appraisal, we concentrated on reviewing UK research. A wide ranging general literature search was conducted, followed by a more detailed review and synthesis addressing eight environmental issues for which some prior research has been conducted. These issues were: air quality, potable water quality, point source emissions and wastes, major accident hazards, contaminated land, flood hazard, surface water quality and noise.

Of the environmental themes we reviewed, only those relating to air quality and point source emissions and wastes (IPC and landfill sites) provided more than one or two UK studies. These studies represent a small and heterogeneous body of research from which it is difficult to draw any firm conclusions as to the degree of environmental inequality. In the case of air quality, which has perhaps received most attention to date (e.g. Brainard *et al*. 2002, McLeod *et al*. 2000, Mitchell and Dorling 2003), the studies address a variety of pollutants, study areas, geographical units of analysis and analytical methodologies which means that no definitive conclusion can be drawn, although the balance of the evidence suggests that deprived communities do bear an above average cost of poor air quality.

For point source emissions and wastes the findings of equity studies appear to show a fairly consistent relationship with deprivation (Friends of the Earth 2000, 2001). However the proximity-based methodologies applied to-date are simplistic and the robustness of these results has not been tested through the application of different scales and methods of analysis.

The limited coverage and depth of UK studies means that the empirical evidence for environmental inequality is rather limited. To date, there have been no attempts to firmly establish the causal mechanisms through which inequalities may have arisen, largely because emerging research is logically engaged in establishing the extent of existing environmental inequalities in the UK. We could also identify no thorough attempts to evaluate observed inequalities within a justice framework (i.e. an appraisal of whether observed inequalities are fair or acceptable) or to evaluate inequality with respect to multiple parameters (cumulative inequalities).

All of the research reviewed had followed a strongly positivist approach, although other methods of participative engagement with communities on equity issues are beginning to emerge.

4 EVIDENCE BASE 'GAP ANALYSIS'

The second objective of the project was to build on the literature review to identify gaps in the current evidence base which restrict the development of Environment Agency policy on environmental equality.

The first step in undertaking the gap analysis was to construct and refine a fully inclusive list of environmental issues potentially appropriate for equity analysis. These issues were identified from four key sources: an academic literature search; grey literature search; the Environment Agency's strategic objectives expressed by 46 targets across 8 theme areas (Environment Agency, 2003); and a range of government publications on national and local sustainability, quality of life and 'best value' indicators.

The resulting list of environmental issues derived from these sources was structured under four headings:

- Exposure to environmental impact (i.e. the distribution of environmental costs) e.g. air pollution and flood risk;
- Access to environmental resources (i.e. the distribution of environmental benefits) e.g. access to greenspace, energy, water and shelter;
- Ability to influence decisions affecting the environment e.g. community involvement in participatory processes, education and understanding of sustainable development;
- Justice *to* the environment (i.e. distribution of environmental costs and benefits between anthropogenic and ecological users) e.g. biodiversity value, SSSI status.

Having constructed a wide ranging and inclusive list of environmental issues we then began to refine the full list. An important initial filter was to ask 'is the variable a relevant equity concern within the context of this project?' This was applied because the project is focused on the relationship between environmental quality and social deprivation. It therefore has an anthropogenic focus on people and also requires that people can be meaningfully characterized in terms of spatially derived measures of social deprivation. This filter therefore excluded all of the 'justice to the environment' category and a number of other environmental issues without a sufficiently direct linkage to groups of people for whom an equity analysis could be conducted.

Having refined the initial list 33 variables addressing 12 theme areas remained. For each of these we then examined:

- whether or not the variable was a direct measures of an environmental concern or a surrogate. This revealed that in very few cases are direct measures available and that most variables are surrogates of varying quality;

- the nature of the population group with which the variable could be linked for equity analysis. This was necessary to consider as, in some cases, the population group is spatially defined and social characteristics are therefore accessible through census data or similar. In others, the population group concerned is not defined spatially but is defined by a particular pattern of use of the environment or pattern of impact;

- The extent to which the environmental issue had been addressed in UK equity research, as informed by the literature review;

- the availability of environmental data (although a thorough appraisal was not possible at this stage of the project).

Having undertaken the literature review and constructed the list of relevant environmental equity issues we were able to conclude that there were significant gaps in the UK evidence base. The prioritisation of further research to begin to address these gaps is discussed in section 6 below.

5 METHODOLOGICAL ISSUES

The third objective of the project was to critically appraise the existing methodology used by the Environment Agency for exploring the extent to which environmental conditions vary across socially deprived wards. In order to achieve this, we felt it appropriate to first review key methodological issues in empirical environmental equity analysis. In doing so we drew heavily on experience from the USA where there is a longer history of environmental equity appraisal.

5.1 Generic Methodological Issues

Whilst methodological questions have been aired at length in the US literature, only recently have academics started to thoroughly and critically appraise the body of empirical environmental justice research conducted over the past 20 years (Bowen 2003, Liu 2002). Overall, such appraisals have concluded that the evidence for environmental injustice in the USA is less substantive than often thought. The main problems cited are a general lack of empirical research, a focus on proximity based analysis, a poor quality of analysis and a failure to be clear about methodological limitations.

We addressed nine methodological complexities associated with equity studies:

- data quality and availability;
- impact assessment, particularly the distinction between proximity and risk;
- selection of appropriate target population groups;
- spatial analysis difficulties, including selection of appropriate spatial units;
- assessing cumulative impacts;
- statistical assessment of inequality;
- understanding causality;
- assessing injustice; and
- communicating with stakeholders.

Whilst this list of methodological complexities is substantial it is important to note that such complexity is not an uncommon feature of both environmental and social science research. The task is to find a pathway for undertaking meaningful analysis that is ‘fit for purpose’, operating within data and resource constraints, but with full recognition of the constraints integrated into the research design, and hence recognised in policy development.

5.2 Critique of the Environment Agency Equity Analysis

In September 2002, the Environment Agency carried out analysis which explored the extent to which environmental conditions vary with social deprivation for nine environmental variables. The Agency's equity analysis was published in Appendix 4 of 'Our Urban Future' and is described as an 'initial overview' of social deprivation and the environment (Environment Agency, 2002). Many of the limitations of the analysis we identified are readily acknowledged in the Agency's own discussion in Appendix 4. The primary purpose our critique, therefore, is to inform further analysis of data sets in this project.

We organised our review of the Agency analyses into in three groups: site based analyses (IPC, landfill and sewage treatment works); air quality (NO_x, ozone and PM_{10}); and river quality (aesthetic, chemical and habitat quality).

For the site based analyses, a simple analysis of proximity through measuring the density of sites within wards was provided by the Agency. We made the following methodological observations about the site analyses: it is unclear what impact is being assessed through this measure of proximity; all sites are treated equally within a category, whilst in practice they may vary in their character, physical size, level and type of emission and emission medium; the use of wards as spatial units creates several boundary problems; and that using deprivation deciles is an acceptable way of presenting results, but should preferably be based on deciles of equal population not wards.

For the air quality analyses methodological issues include: the rationale for selecting pollutants to study; the inclusion of ground level ozone as a regional scale problem; the use of annual mean standards rather than concentrations; the impact of variable ward size; and the limitations of the NETCEN grid data when used at finer spatial scales

For the river quality analyses methodological issues include the rationale for addressing river water quality within an equity frame, when, for example, it has a very indirect link with consumed water and health; the problem of assessing amenity value in terms of the characteristics of only proximate populations and when individuals assess aesthetics in different ways; the impact of large unpopulated rural areas on the analysis; and the potential distortions from relying on sampled point data sets in particular for the aesthetic and habitat quality measures.

Building on these particular critiques we identified a number of generic methodological issues for the work completed by the Agency. First, the lack of rationale for selecting the nine variables which appear to cover a mix of physiological health, psychological health and amenity impacts. Second, data quality issues and uncertainties for each of the datasets. Third, the omission of Wales from the analysis. Fourth, the lack of statistical analysis of relationships between environmental quality and deprivation and finally the need to be clearer about the ends to which an Agency equity analysis should be directed and its interface with justice theory.

6 FURTHER EQUITY ANALYSIS

The fourth objective of the research was to identify the value of, and priorities for more detailed quantitative analysis of environmental data sets and to propose appropriate methodologies for conducting this analysis. This part of the project incorporated a stakeholder workshop held in Bristol involving a range of internal and external stakeholders, the latter including representatives from government departments, environmental NGOs and academics.

6.1 The Value of Equity Analysis

We identified four key reasons why further analysis of the status of environmental equity in England and Wales is required.

First, whilst there is some evidence to support the common belief that socially excluded communities are located in areas where environmental quality is lowest, the UK evidence base for this belief is generally weak. As pressure from civil society to address perceived environmental inequalities is growing, it is important to understand the nature and extent of any such inequalities. The key value of further research is then to address primary knowledge gaps.

Second, research addressing environmental inequality provides one mechanism where sustainable development objectives may be integrated, and hence add value to each other, mutually advancing and reinforcing social and environmental agendas. There are compelling reasons for the Agency to link the analysis of environmental equity to wider policy developments focusing on inequality and social exclusion across government, for example, in the areas of health and regeneration.

Third, there are growing pressures on the Environment Agency to address equity issues. These pressures are both legislative and political. By developing further research in the environmental equity area, the Agency have a means to a wider more inclusive dialogue with stakeholders which could usefully seek to establish common ground on goals, methods, and responsibilities.

Fourth, there is a moral case for tackling environmental inequality, but there are different views as to what constitutes an acceptable degree of inequality. In other words at what point *inequality* becomes *inequitable or unfair*. The extent to which environmental inequality is considered unfair is not a technical issue. Further research on the current status of inequality in the UK is however a pre-requisite to inform this important debate.

6.2 Priorities for Further Equity Analysis

It was clear from the review and gap analysis that there is a substantive research agenda which is beyond the scope of this project to fully address. It was therefore necessary to develop priorities for data analysis based upon what was practical within the timescale and resource commitment of the project.

Identifying issues to take forward to the next phase was an iterative process. Firstly in terms of identifying issues (an iteration between the research team, the workshop stakeholders and the project board) and in terms of identifying issues for which data of adequate quality was available. Our initial prioritisation of the issues to address was based on three criteria: (a) rationale and significance of the analysis; (b) the relevance to the remit of the Environment Agency; and (c) the availability of sufficient data of adequate quality for a meaningful and scientifically robust analysis. In terms of the first of these criteria we adopted a broad ranking of issues emerging from the gap analysis which in order of priority are:

- Agency obligations re enforcement;
- Breaches of environmental standards;
- Parameters relevant to public health (but where standards may not be exceeded);
- Vulnerability to threat;
- Other variables including those addressing amenity and economic impact.

On the basis of our own appraisal we used the gap analysis discussed earlier to propose issues that were of high, medium and low priority for further environmental equity analysis (see below). These proposals were presented at the stakeholder workshop where they were discussed at length (see full workshop report in Chalmers 2003).

Issues of high priority for further equity analysis

- National Air quality standards (NAQS standards exceedences - variables selected on basis of frequency of exceedence);
- Air quality (Concentration of NAQS pollutants - to be selected);
- Potable water quality standards % compliance failure (all and/or parameter specific);
- Flood Hazard;
- Proximity to polluting sites (Including IPC sites and waste incinerators);
- Proximity to major accident hazard sites;
- Pollution incidents;
- EA permits : prosecutions, cautions and compliance;
- Facility inspection rates.

Issues of medium priority for further equity analysis

- Noise
- River water quality (aesthetic)
- Coastal water quality
- Access to green space
- Contaminated land
- Proximity to landfill
- Locally unwanted land uses not covered elsewhere (roads, sewage treatment works, pylons etc.)

Issues of low priority for further equity analysis

- Odour
- River water quality (chemical & biological)
- Contaminated land clean ups
- Local environmental quality
- Biodiversity (plants, birds)
- Planning applications approved against EA advice
- Sustainable development awareness and training programmes

- Community participation in EA participatory initiatives.

6.3 Environmental Agency Environmental Equality Workshop

The Environment Agency hosted an environmental equality workshop, attended by Agency staff, government, NGO's and academics, to consider the Phase I research (see proceedings in Chalmers 2003), and provide guidance on the scope of the second analytical phase, and on the Agency environmental equality programme more widely.

The workshop began with a series of presentations by Environment Agency staff. Peter Madden (Head of Environmental Policy) discussed drivers for addressing environmental inequality, including government policy, the rise of inequalities, and the Agency's commitment to equality, as expressed in the corporate vision. Dr John Colvin (Social Policy Manager) introduced the Agency's work on environmental equality, including the Agency's AGM on 'Achieving Environmental Equality' in September 2000, the Mapping Common Ground event in September 2001, and the initial analysis presented in 'Our Urban Future' (Environment Agency, 2002). Helen Chalmers (Social Policy Development Officer) described the proposed programme for developing the Agency's research, policy and action on environmental equality. The research team then made presentations on the evidence base for environmental inequality, and proposals for further research addressing objectives (i) to (iv) of the project (see sections 1 - 6 above).

Following the presentations, delegates met in small group and plenary sessions to discuss environmental equity research and policy needs. The sessions aimed to map the evidence base for environmental inequality in England and Wales; identify the value of and priorities for further research; and to design and agree the process for the research beyond Phase II (see Chalmers 2003). The key conclusions and recommendations of the steering were:

- More research is required to underpin policy and practice. Research should address a wider range of environmental issues (including those not the prime responsibility of the Agency), cumulative impacts, 'hot spot' areas, health outcomes, and evolution of observed inequalities. Agency policy and practice should not to be restricted by a lack of empirical evidence, but should take a precautionary approach;

- Improved tools for examining the distributional effect of policies and processes are required, as well as further debate on the nature of 'what is fair';

- Accessibility and participation of local communities is important in promoting environmental equity. Linking local experiences to national analyses, policy and process can improve understanding of inequalities, lead to better responses, and ensure that the Agency maintains the trust and confidence of excluded communities;

- The benefits to the Agency of further environmental equality research are: (a) a greater evidence base for environmental inequality; (b) identification of opportunities for mutual improvement of the environment and quality of life for excluded communities; (c) a proactive Agency response to growing legislative and political pressures to address poor environmental quality, urban renewal, poverty and inequality; (d) the Agency's ability to champion these issues and influence policy of government, the EU and other agencies and partners; and (e) an opportunity to build relationships and dialogue with new audiences, organisations and excluded communities.

- Phase II of the current project should focus on the relationship between social deprivation and issues for which the Agency has regulatory responsibility and an ability to deliver change. Three ‘benchmark’ or politically important environmental issues (identified as high priority issues under phase I were recommended for further detailed analysis: air quality, flood hazard and IPC sites.

7 INTRODUCTION TO THE EQUITY ANALYSES

7.1 Environmental Issues Addressed

The fifth objective of the project was to conduct an initial statistical analysis of data sets associated with areas for which the Environment Agency has regulatory responsibility and those relating to deprivation.

The outcome of the stakeholder workshop (Chalmers 2003) was to recommend that we focus the data analysis within the remainder of the project on just a few environmental equity issues, carrying out this analysis in some depth, rather than a more superficial analysis of a broader range of issues. Three specific issues from our high priority list were identified as particularly relevant to the remit of the Agency and most appropriate for analysis within this project:

- Flood hazard;
- Integrated Pollution Control sites; and
- Air quality.

Whilst limited to three issues, the analysis we have undertaken in fact incorporates at elements of at least seven of the nine high priority issues we identified prior to the workshop. Our air quality analysis covers both concentrations and exceedences, whilst the IPC analysis includes indicators relevant to incidents, Agency enforcement and inspection priorities. The scope of the analysis undertaken for each environmental issue is as follows:

7.1.1 Flood Hazard

Indicative floodplain maps produced by the Agency were used to relate to ward deprivation data. These maps show 1 in 100 year peak water level return periods for rivers and 1 in 200 year floods for coasts or the highest known water level. Whilst these are currently the best available national floodplain maps they have significant limitations as indicators of flood hazard or risk (see section 8.4). A sophisticated method has been used to ensure that only the population within wards that is also within the indicative flood area is counted within this analysis. Many wards will have rivers running through their area but no people actually living within the indicative flood hazard area, particularly in rural wards. Results are reported which show the percentage of population for each deprivation decile that lives within indicative flood hazard areas.

7.1.2 IPC Sites

The spatial distribution of IPC sites has been evaluated against deprivation using two different methods – ‘spatial coincidence’ which counts the number of sites with grid references falling within different wards and population proximity which uses a buffer distance around each site to characterise the location of the site. As well as counting sites we have also used data on number of authorised processes and emission sources at each site. We have also introduced differentiation into the analysis by examining patterns with deprivation within different industrial sectors, for emissions to air alone, for specific substances (NO_2, PM_{10}) and groups of substances (carcinogens) and for authorisations approved at different dates. The Agency Operator Pollution and Risk

Appraisal (OPRA) scores for authorised processes have also been used to take account of the different level of pollution hazard from each process and the performance of site operators. The IPC datasets utilised are for 2001 and required careful verification and 'cleaning' particularly in relation to producing reliable site counts.

7.1.3 Air Quality

Five variables have been analysed using 2001 annual mean data available on a 1km^2 grid: NO_2, PM_{10}, SO_2, CO and benzene. Two of these variables NO_2 and PM_{10} have also been analysed for predicted levels in 2015, in order to assess how the expected changes in concentration differentially affect more or less deprived groups. As well as analysing annual mean concentrations we have conducted separate analyses of exceedences of standards. In addition to single pollutant analyses we have attempted to identify the cumulative inequity pattern through application of an air quality index.

7.2 Social Data Sources, Analysis and Presentation

The specific techniques used to conduct the equity analyses vary for each of the three key issues addressed, and hence are described in the appropriate chapter. However, all the analyses have a number of common features, described here.

First, the spatial unit of analysis used for social data is the census ward, of which there are 8,414 wards in England and 865 in Wales. Wards are designed to contain roughly equal numbers of electors within local authority districts, thus ward size is density dependent, with small wards in urban centres and large wards in rural areas.

Second, deprivation was represented using the Index of Multiple Deprivation 2000 (IMD 2000) (DETR 2000). This has become the most widely used official data set on deprivation and was identified in the project tender document as the indicator that the Agency wished us to use. The IMD is based on six separate domains (income, employment, health deprivation and disability, education, skills and training, housing and geographical access to services), addressed by 33 separate indicators.

For each ward a score is produced for each indicator and then domain, and domain scores standardised to a uniform metric by ranking and applying an exponential transformation. Individual domain scores are then weighted and summed to create an overall score, which forms the basis for the final ranking of wards by deprivation (DETR, 2000). This procedure ensures that bias in the identification of deprivation is minimised as far as possible. Note, however, that because of the method of calculation, a ward with an IMD rank of 100 is not necessarily twice as deprived as a ward with a rank of 200. For this reason we uniformly present the deprivation data in this project in the form of deciles which maintain the ranked ordinal form of the data.

The calculation method also precludes combination of the IMD 2000 data sets for England and Wales which were derived separately. *An index value for a ward in Wales can not be taken as equivalent to the same index value for England*. For this reason we have throughout the analysis had to consider Wales separately from England.

Third, we used ward population data obtained from the Neighbourhood Statistics Branch of the Office for National Statistics. The population data are mid 1998 estimates for wards in England and Wales relating to 1998 ward boundaries and rounded to the nearest 100. The data are preferred to 1991 census data as our environmental data is much more recent, and observed data from the 2001 census were not yet available.

Fourth, we routinely present results using deprivation deciles. In order to create ward deprivation deciles, data were ranked in terms of deprivation, and the deprivation ranked wards placed into deciles of equal population. These are preferred to those of equal ward count as the analysis then gives a population based, not area based distribution of environmental quality, which is more meaningful for this purposes of this study. In all cases, decile 1 is the most deprived and decile 10 the least deprived.

Finally, we have chosen to analyse the data using simple statistical measures and indicators of inequality. There are no standard methods for analysing environmental equity issues. Of the methods most widely used to relate social and environmental data, we rejected both regression and correlation. Regression requires a well specified model supported by data on explanatory variables for the nation at ward level. This is the basis of a causality study, and is beyond the scope of this scoping project. Parametric correlation was rejected as the index of deprivation data is ranked, and ordinal data cannot be used with parametric tests. Non-parametric correlation tests could have been used but are generally weak tests and problematic for some of the data (e.g. for air quality there is a significant tied observation problem and a curvilinear relationship with deprivation not improved by data transformation). We did not conduct tests of differences between deciles (e.g. Z-tests on means) as such tests are used to make inferences about a population from a sample. We were in the unusual, but fortunate position of having access to the entire population data, hence inferential tests are not necessary. Our analysis was therefore simple, but powerful.

We have for some of our analysis calculated 'concentration index' (CI) values to provide a comparative statistical indicator of inequality. The CI is closely related to the Gini coefficient which has been widely adopted as a measure of income and health inequalities (Wagstaff *et al*. 1991) and also recently applied to environmental equity research (Lejano *et al*. 2002) The concentration index ranges in value from 1 to -1. A value of 0 indicates complete equality (so that, for example, for our application the proportion of the population within floodplain area would be identical for all deprivation deciles) whilst values of 1 and -1 indicate extreme inequality in positive or negative relationships with deprivation. The CI does not provide an indicator of the *significance* of inequality which will always be an ethical and political judgement and is best used in a comparative setting (see e.g. section 10.5 that compares air quality in 2001 to that in 2010). It is useful to note however that values for income inequality in the UK over the period from 1979 to 2001 have ranged from 0.25 to 0.35 (Shephard, 2003).

Each of the analyses we have undertaken inevitably has limitations arising from the quality and resolution of source data sets, the spatial scale at which analysis has been undertaken and the complexity of real world environmental variables which can only partially be captured. We have undertaken an environmental equity analysis which is as advanced methodologically as any existing national scale work in the UK and on a par with the better quality research undertaken in the US. However, in the discussion that follows we have sought to be fully open about the limitations of analysis and, where necessary, cautious with the conclusions that can be reasonably be made.

8 FLOOD HAZARD AND DEPRIVATION

8.1 Introduction

Flooding is a key area of responsibility for the Agency, which has a statutory responsibility under the 1991 Water Resources Act to identify areas that are at risk from flooding. The need to incorporate social vulnerability into the flood hazard appraisal process has been increasingly recognised and a number of steps have been taken to develop social vulnerability maps incorporating a range of demographic and social variables. However, to our knowledge, no research has been conducted that specifically assesses the demographic characteristics of populations within UK flood hazard areas from an equity perspective.

8.2 Flood Hazard and Deprivation in England

At first sight there appears to be a general relationship between deprivation and the proportion of the population in wards in each decile living within a floodplain in England (Figure 8.1). Of the population living in a floodplain 13.5% are in the most deprived decile, compared to 6.1% in the least deprived decile, and the concentration index value of 0.14 indicates a weak bias towards the deprived deciles.

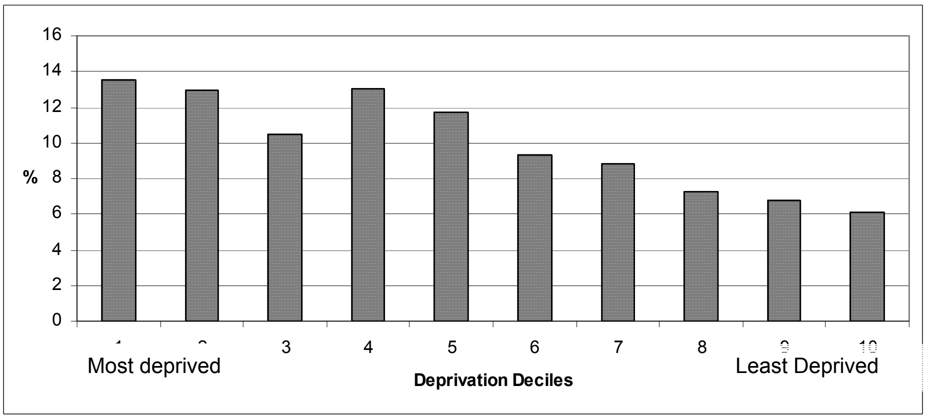


Figure 8.1: Percentage of population living in a floodplain by population weighted ward deprivation decile for England (Concentration Index = 0.14)

However, when the data is disaggregated into fluvial and tidal floodplain populations (Figures 8.2 and 8.3) it becomes clear that the overall relationship with deprivation observed in the aggregated data is attributable entirely to the tidal floodplain element. For the tidal floodplain there is a clear relationship with deprivation with a more marked tailing off in the least deprived deciles. Of the population living within the tidal floodplain 18.4% are in the most deprived decile compared to only 2.2% in the least deprived. The proportion of the population in the floodplain in the most deprived decile is eight times that of the least deprived decile, and the CI value of 0.33 indicates a substantial inequality. In contrast, for the fluvial floodplain there is an inverse relationship with deprivation, although of lesser strength (CI value of -0.11), with a higher proportion of the population within the floodplain in the less deprived compared to the more deprived deciles. Only 13% of the population within a fluvial floodplain comes from the 20% most deprived wards compared to 22% from the 20% least deprived.

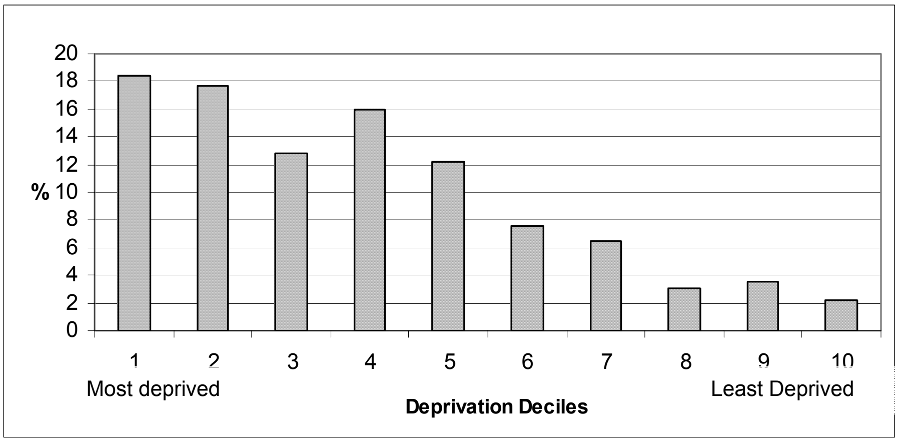


Figure 8.2: Percentage of population living in a tidal floodplain by population weighted ward deprivation decile for England. (Concentration Index = 0.33)

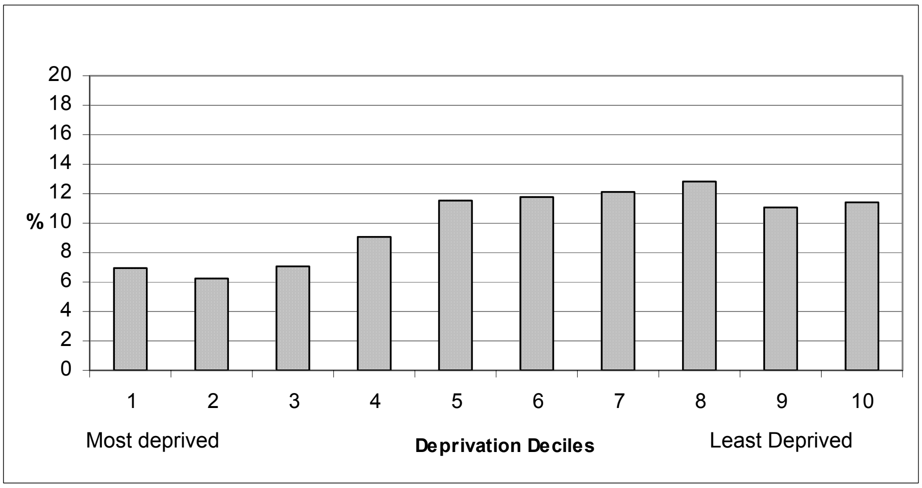


Figure 8.3: Percentage of population living in a fluvial floodplain by population weighted ward deprivation decile for England. (Concentration Index = -0.11)

8.3 Flood Hazard and Deprivation in Wales

The pattern of social distribution of floodplain populations in Wales is less distinct but shows some similarities to England (Figure 8.4). The overall floodplain population is most concentrated into deciles 3 and 5. Comparing quintiles the most deprived 20% has 17.9% of population within the overall floodplain compared to 7.9% in the least deprived decile, indicating a bias towards deprived wards. The CI value of 0.15 is similar to that for England but the focus of the disparity is less orientated towards the most deprived deciles.

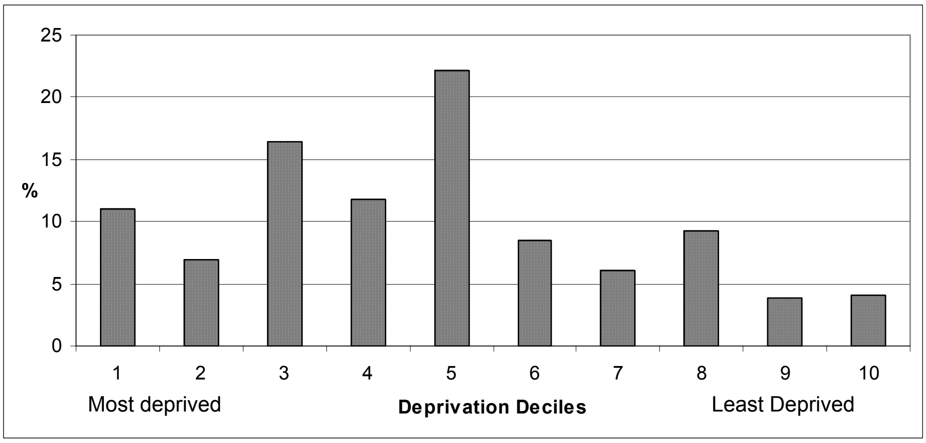


Figure 8.4: Percentage of population living in a floodplain by population weighted ward deprivation decile for Wales (Concentration Index = 0.15)

After disaggregation into fluvial and tidal areas the patterns against deprivation (Figures 8.5 and 8.6) become complex. For fluvial floodplains there are peaks in deciles 3 and 5 whilst the proportions in the least deprived and most deprived deciles are very similar. The CI value of 0.09 indicates a low comparative level of inequality, but no overall bias towards the *less* deprived deciles as in England. For tidal floodplains there is a peak in decile 5, but the proportion in the most deprived decile (14.9%) is much higher than in the least deprived (1.6%). The balance of disparity is towards the more deprived deciles (1-5) although the CI value of 0.21 is not as strong as for England.

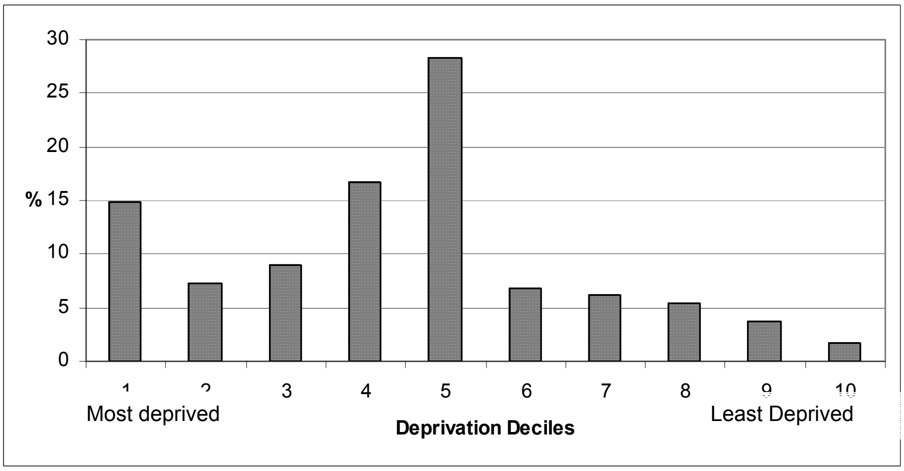


Figure 8.5: Percentage of population living in a tidal floodplain by population weighted ward deprivation decile for Wales. (Concentration Index = 0.21)

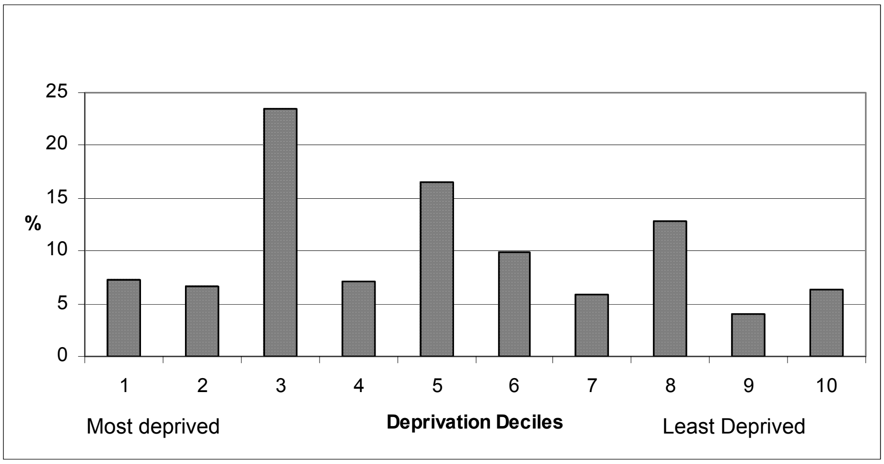


Figure 8.6: Percentage of population living in a fluvial floodplain by population weighted ward deprivation decile for Wales. (Concentration index = 0.09)

8.4 Discussion of Flood Hazard Equity Analysis

The analysis we have undertaken provides a first broad view of national patterns of floodplain outlines against social deprivation. It has made use of the Indicative Floodplain Map (IFM) produced by the Agency and publicly available over the Internet. Whilst the best available floodplain map for England and Wales, it has a number of key limitations. Most crucially it takes no account of flood defences and therefore presents a precautionary view of the area potentially at risk from flooding. The floodplain outlines indicate where flooding from rivers, streams, watercourses or the sea is possible but do not provide an indication of the level of risk (which will be higher in undefended low-lying areas near rivers or the sea and lower in areas where flood defences offer some protection) or the hazard which is dependent on factors such as velocity and depth of flow.

The social equity patterns revealed in the data for England and Wales are in part predictable and in part more surprising. That fluvial floodplain populations show some weak bias in England towards the more affluent deciles is to be expected given that much of the floodplain area is rural rather than urban in character and rural wards are generally more affluent than urban wards. Riverside locations generally also have a premium value in terms of property prices - although this very local social patterning is unlikely to be picked up in ward level data, and may serve on the ground to further accentuate the proportion of the better-off population living within fluvial floodplains.

The strong relationship between deprivation and location in tidal floodplains for England (and weaker for Wales) is perhaps less expected. Examining the pattern of distribution of the most deprived quintile (deciles 1 and 2) for England reveals the populated poor areas potentially at risk are focused on London and the Thames Estuary, Hull and the Humberhead levels, the Lincolnshire coast and Teesside; with further pockets in South Kent, various locations along the North West coastline and Tyneside. A regional breakdown of the population within this quintile particularly highlights the size of the population at risk in London and the Thames Estuary. Of the 747,000 estimated people living within the tidal floodplain in the most deprived 20% of wards, 438,000 (59%) are in the Thames region of the Agency. For Wales, the most significant populations within deciles 1 and 2 are located in Cardiff extending northwards, near to Llanelli, various locations along the North Wales coastline and north of Deeside, Barmouth and Pwllheli.

These varying patterns of association between delineated floodplains and deprivation raise a number of questions for policy response. First, judgements need to be made as to the adequacy of the evidence of inequity we have presented, given that it is reliant on the IFM. As indicated in recommendations below, there are a number of ways in which further analysis could enhance the quality of the evidence base for Agency action and immediate policy responses may therefore be considered inappropriate. The case of tidal flooding along the Thames clearly illustrates the issues involved. A substantial proportion of the most deprived potentially flooded population is in this area, but the IMF fails to take account of the major flood protection measures already in place to protect London and upstream communities from tidal flooding.

Second, the identification of a pattern of bias in England towards *less* deprived populations living in fluvial floodplains, raises the question of the need for policy responses where environmental impacts are focused more on the prosperous than the deprived. Whilst it could be argued that an even-handed approach should involve responses to *any* evidence of inequality, a counter argument would be that those who are more prosperous are typically able to exercise greater choice as to where they live than the poor. As long as that choice is informed about flood hazard (which cannot necessarily be presumed) then the case for policy intervention may be weakened. For flooding those people with greater access to financial resources may also be more likely to have good quality insurance cover and be more resilient to flood impacts.

Third, and closely related to the last point, is the extent to which deprivation can reasonably be associated with greater vulnerability. Social vulnerability has been shown to be a multifaceted phenomenon related to factors such as community networks and social capital, as well as age and family composition (Tapsell *et al*, 2002). The part played by deprivation may be both directly contributory, as well as being associated with other factors such as long term ill health, and thus provide a reasonable indicator of social vulnerability to flood hazard. The inequity of greater numbers of deprived people being exposed to tidal flooding potential, may therefore be seen as being compounded by the greater vulnerability they also face.

8.5 Recommendations

At the current time there are significant changes taking place in the Agency's approach to both flood mapping and flood management, many of which are recognising the social vulnerability dimensions of flood hazard. In this evolving context we can point to four recommendations for Agency action. The first three of these are largely focused on the need for further research and data analysis, the last towards broader policy priorities:

1. Over the next few years significantly more precise and complex flood mapping products are to be released by the Agency, differentiating flood potential, from flood hazard and risk within a GIS environment that includes relatively detailed postcode based information. We recommend that the Agency undertake further equity

analysis using these new flood maps in order to compare the results obtained to those we have produced in this project;

2. Decisions on past flood protection investments have traditionally been driven by economic considerations which balance the cost of the investment with the estimated economic loss from flood events. This has been criticised as inequitable leading to a marginalisation of areas for flood protection which contain poor communities and only low value economic activity. We recommend that new flood maps are used to investigate whether or not populations that have been protected by flood defence investments are indeed the 'better off'. Such analysis could be undertaken at both national and regional levels;

3. The evidence that tidal flooding potential is biased towards areas of deprived population suggests that the potential impacts of increased coastal flood risk due to climate change will be felt more acutely by the poor in England and to a lesser extent in Wales. There may therefore be a case on social justice grounds for particular attention to be given to the management of future tidal flood risk in deprived areas, and more generally, an additional argument for the reduction of greenhouse gas emissions as a precautionary measure. However, given the limitations of the IFM and of the scale of analysis we have undertaken, we recommend that the Agency undertake further analysis of the social distribution of tidal flood risk in order to inform the development of climate change related policy measures. This analysis could use more sophisticated flood maps which take account of coastal flood defences (as discussed above); involve analysis of both current and future flood hazard under climate change scenarios to see how future patterns in the social distribution of hazard are likely to evolve; and incorporate a range of social variables relevant to flood vulnerability.

4. As discussed above, where there are associations between flood hazard and deprivation it can reasonably be argued that particular population vulnerabilities may exist. We therefore recommend that the Agency considers the case for targeting flood management measures towards those deprived communities that are at risk from flooding.

9 INTEGRATED POLLUTION CONTROL SITES AND DEPRIVATION

9.1 Introduction

The regulation of Integrated Pollution Control (IPC)[1] sites is a key responsibility of the Agency. Included within the remit of the IPC regime are the most substantial sources of pollution from industrial and related sources in England and Wales. Each IPC site can have multiple authorised processes operating and each process may have multiple authorised emissions. In the UK there have been three published equity studies examining IPC site locations in relation to deprivation, which have each shown a strong bias towards more deprived areas (Environment Agency 2002, Friends of the Earth 2000, 2001). The IPC analysis we have undertaken in this project has sought to significantly extend the analysis in these studies. Specific objectives include to:

- use two alternative methods for assessing spatial relationships with deprivation (‘site in ward’ counting and ‘population proximity’ analysis);
- differentiate between industrial sectors;
- undertake an analysis just for sites producing emissions to air and for levels of emission of key air pollutants;
- analyse Operator and Pollution Risk Appraisal (OPRA) scores to examine patterns of operator performance and the distribution of pollution hazard.

The key data sets used in the analysis are the Agency Pollution Inventory records and OPRA authorisation database for 2001.

9.2 IPC Sites and Deprivation in England

For sites, authorisations and emissions Figure 9.1 shows a strong relationship with deprivation, with wards in the most deprived decile providing the location for five times as many sites and authorisations and seven times as many emission sources as wards in the least deprived decile.

[1] We have used the term IPC in this report although a transition is taking place towards regulation under the new Integrated Pollution Prevention and Control (IPPC) system. For 2001 95% of sites were still regulated under IPC.

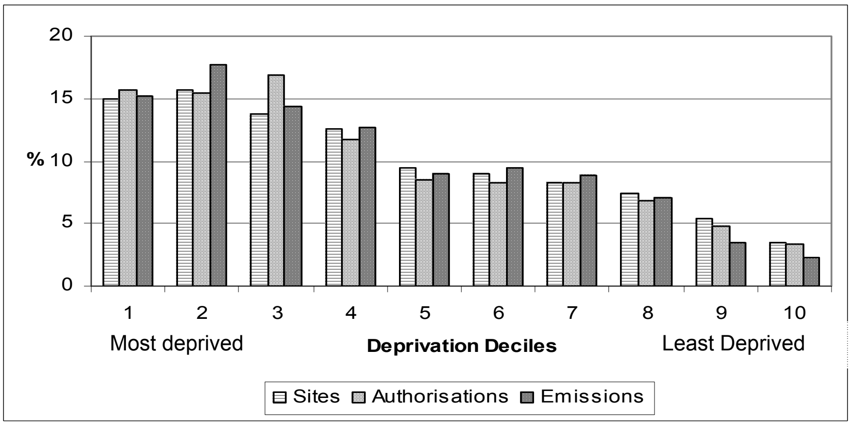


Figure 9.1: Percentage of Sites, Authorisations and Emissions by population weighted deprivation decile for England (using 'site in ward' counting method).CI values = 0.22 (sites) 0.25 (authorisations) and 0.26 (emissions)

There are only 92 sites and 656 emission sources in the 20% least deprived wards (deciles 9 and 10), compared to 316 sites and 3782 emission sources in the 20% most deprived wards (deciles 1 and 2). As indicated by the CI values, counting sites provides the marginally weaker relationship with deprivation, whilst counting emission sources provides the strongest, indicating that the sites in the more deprived wards have a greater number of emissions per site (on average) than sites in the less deprived wards.

Undertaking a similar analysis using the 'population proximity within a buffer' method - which provides a more consistent method for characterising the deprivation characteristics of people living near to IPC sites - produces a similar but more accentuated relationship with deprivation. Fig 9.2 show populations within each deprivation decile living within two different distances from IPC sites – 500m and 1km (analysis was also undertaken for 2km and 4km buffers).

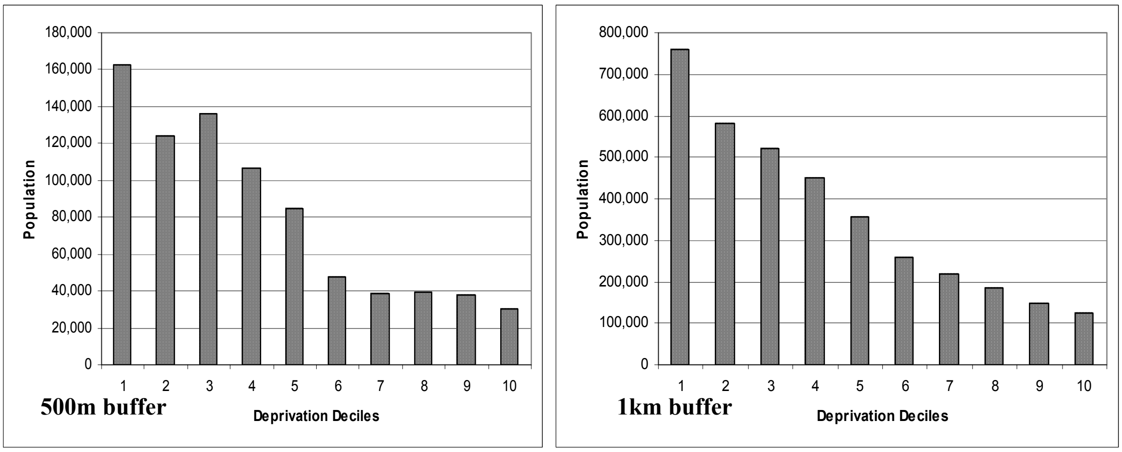
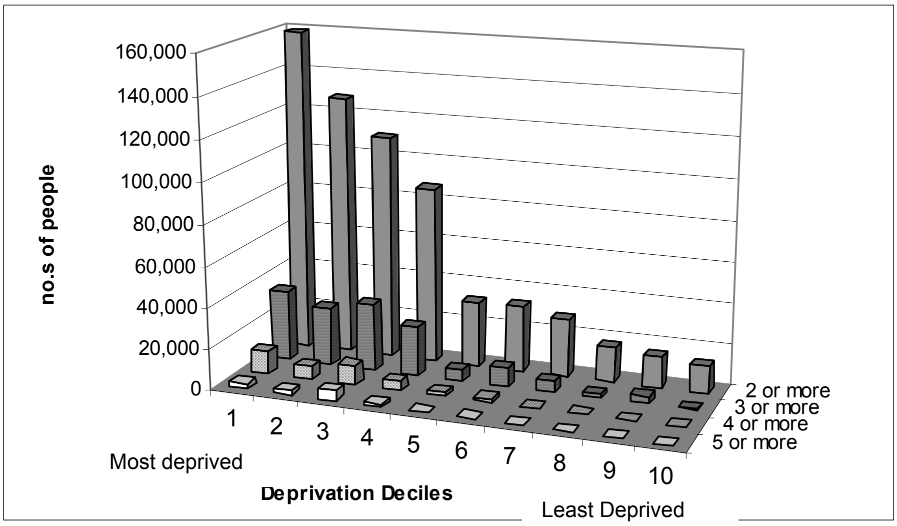


Figure 9.2: Total estimated populations living within 500m and 1km of an IPC site by population weighted ward deciles for England (CI = 0.31 for 500m and 1km)

This population proximity data produces a stronger and more consistent relationship between deprivation and site location than using 'site in ward' counts. An identical CI value of 0.31 for 500m and 1km buffers indicates greater inequality than the CI value of

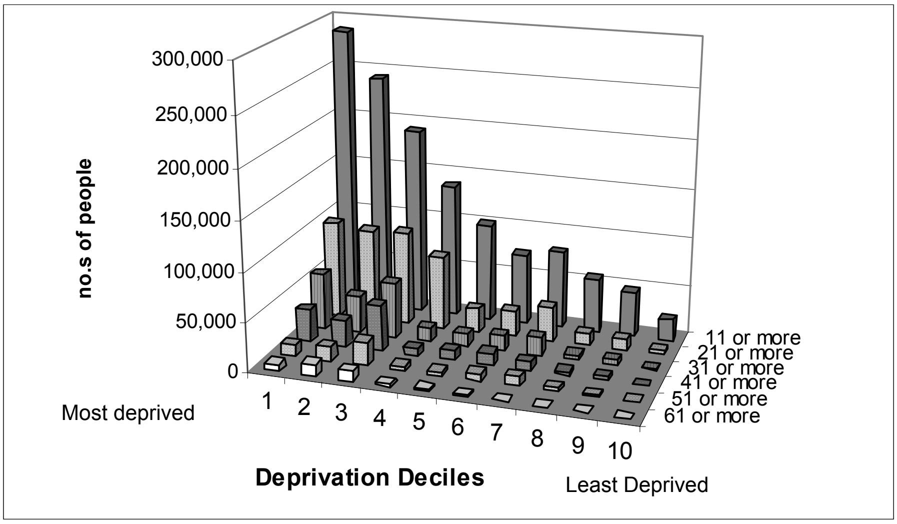
0.22 for the site in ward count method. Out of the 3.6 million estimated people living within 1km of an IPC site, there are 6 times more people from decile 1, the most deprived, as from decile 10.

A further more involved analysis was also carried out to examine the deprivation characteristics of people living within 1km of more than one site (i.e. where buffers overlap). Contrasting the most and least deprived deciles in Figure 9.3 there are 159,031 people in the most deprived decile living near to 2 or more sites, and only 13,301 in the least deprived. There are *no* people living near to 4 or more sites in the least deprived decile, compared to 11,523 in the most deprived. As the number of sites within 1km rises the bias towards the more deprived deciles becomes more acute – as shown by the graduation of CI values in Figure 9.3 rising from 0.31 to 0.59. The analysis for proximity to multiple emission sources shown, in Figure 9.4, displays a similar relationship with deprivation, with the CI values again increasing as the number of multiple emission sources rises.



Concentration Index Values				
≥5	≥4	≥3	≥2	≥1
0.59	0.59	0.48	0.44	0.31

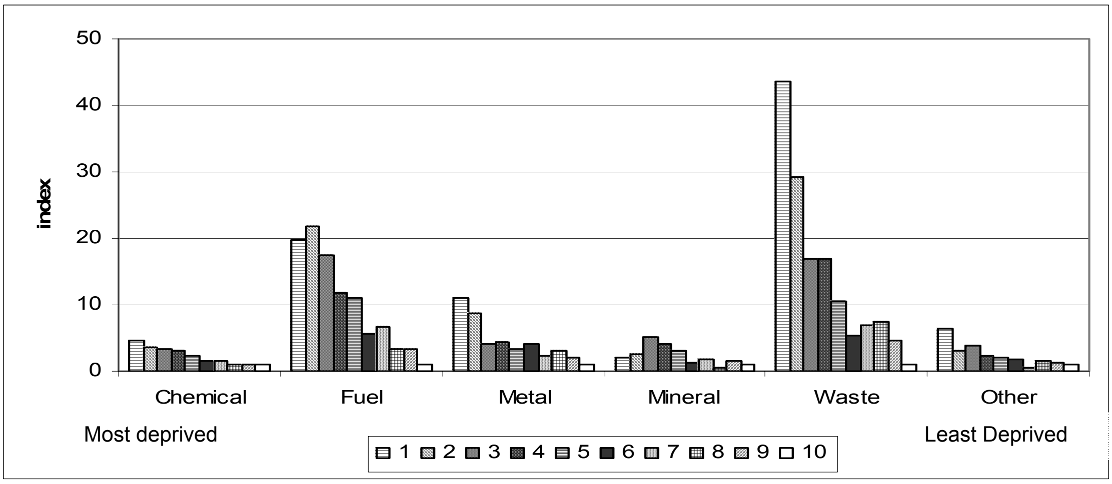
Figure 9.3: Numbers of people living within 1km of multiple (x or more) IPC sites by population weighted deprivation deciles for England



Concentration Index Values						
≥61	≥51	≥41	≥31	≥21	≥11	≥1
0.50	0.36	0.44	0.43	0.41	0.36	0.31

Figure 9.4: Numbers of people living within 1km of multiple (x or more) IPC emission sources by population weighted ward deprivation deciles for England

Within the IPC regime and the pollution inventory database, sites are categorised into one of six industry sectors – chemical, fuel and power, metal, mineral, waste and other. Analysis of site in ward counts for each of the sectors shows that apart from minerals there is a broad gradient indicating a higher number of sites in the more deprived ward deciles. The mineral sector shows a weak inverse pattern so that more of the sites are in the less deprived deciles 6, 7, and 8.



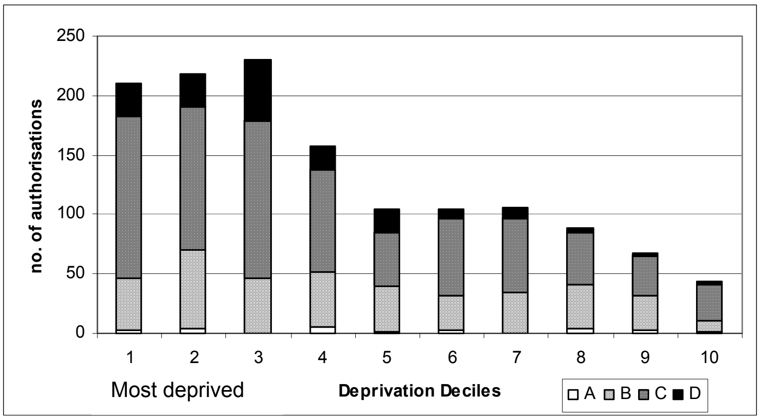
Concentration Index Values						
All sites	Chemical	Fuel	Metal	Mineral	Waste	Other
0.31	0.29	0.38	0.34	0.21	0.45	0.34

Figure 9.5: Index of ratio between least deprived and other ward deciles for proportion of population within 1km of IPC sites in different industry sectors (index = 1 for decile 10, apart from minerals where 1 = decile 9)

For the 1km buffer population proximity analysis Figure 9.5 charts an index ratio based upon the lowest decile in each sector (which is given a value of 1). All of the sectors, including minerals, show an inequality bias towards the more deprived deciles with the differential in the waste sector standing out as particularly extreme (CI value of 0.45). The proportion of the population in the most deprived decile living within 1km of an IPC waste site is 43 times higher (113,768 people) than in the least deprived decile (2,619 people).

In order to differentiate IPC sites in terms of the level of pollution hazard, the Pollution Hazard Appraisal (PHA) scores assigned to each authorisation by Agency inspectors were utilised. These scores provide a multidimensional indicator of the level of pollution hazard from each authorised process taking account of the nature and amount of substances released and the pollution control technology in place. Band A indicates that the authorisation has a low pollution hazard, band E a high pollution hazard. The majority of authorisations fall into PHA band C with very few in the lowest hazard band A, and none at all in the highest band E.

Higher hazard band C and D authorisations are more prevalent in the more deprived deciles in absolute *and* relative terms (Figure 6.6), whilst band A and B authorisations are more evenly distributed. There are 55 sites with the highest pollution hazard rating in the most deprived 20% of wards, compared to only 4 in the 20% least deprived. The graduation in CI values - from 0.07 for Band A to 0.4 for Band D - also demonstrates the more equal distribution of low hazard sites and the bias towards more deprived deciles for high hazard sites. There are therefore more IPC sites and more high hazard IPC sites in deprived compared to more affluent wards.



Concentration Index Values				
A	B	C	D	All authorisations
0.07	0.17	0.28	0.4	0.26

Figure 9.6: Pollution Hazard Appraisal (PHA) scores of authorisations located in population weighted deprivation deciles (A = low pollution hazard, D = high)

One element of the PHA rating which is particularly relevant to the day to day experience of living near to an IPC site is the score given to 'offensive characteristics' that are likely to give 'local annoyance'. In absolute terms there is again a far higher number of authorisations with offensive characteristics in the high deprivation bands than in the lower ones. For the two worst scores on the offensiveness rating (4 and 5) there are 52 authorisations in wards in the most deprived decile, compared to only 9 in the least deprived decile. In relative terms there is also a bias towards the more deprived deciles – the CI value for authorisations with a score of 5 is 0.34 indicating a stronger inequality than the value of 0.26 for all authorisations.

An indicator of operator performance, or how well a site is being run, is provided by the Operator Performance Appraisal (OPA) score within the OPRA framework. Examining the spatial pattern of operator performance provides an indicator of whether or not the quality of operator performances is potentially related to the social characteristics of the nearby population – one hypothesis might be that sites in 'better off' areas are subject to more articulate and politically powerful lobbying than in more deprived areas and that they may consequently make a greater effort to keep up pollution control standards and avoid pollution incidents. Looking at the best run sites falling into band A, there is a higher than average proportion of well run sites in the most deprived decile but *also* in the *least* deprived decile. For the worst run sites in Bands D and E there is little proportional variation between the deciles.

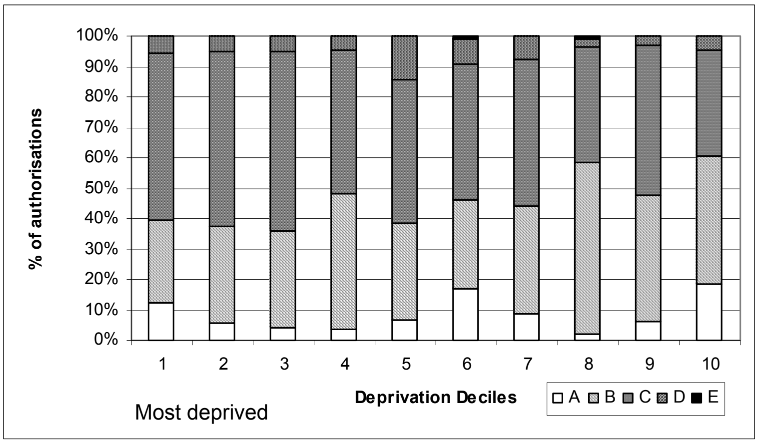


Figure 9.7: Percentage Operator Performance Appraisal (OPA) Bandings for IPC Authorisations within population weighted ward deprivation deciles (A = good performance, E = poor)

One way to begin to explain the cause of unequal social distributions of IPC sites is to examine any differences in the dates at which authorisations are granted. Dividing the authorisations into two time periods found few differences between authorisations approved during 1991-1996 and 1997-2001. The first period has by far the greater number of authorisations as it encompasses the years during which the IPC regulations were first introduced.

The final part of the analysis was to differentiate the emissions into different media, and to examine patterns for specific substances (nitrogen dioxide, particulate matter and carcinogens). By examining patterns of emission to air, which present a more direct health impact than emissions to water or to solid waste streams, we were able to conclude that the relationship with deprivation is broadly the same for all IPC sites and for those making emissions to air across all of the variables examined. A selection of CI values is shown in Table 9.1 to demonstrate this general parity.

Table 9.1: Comparison of Concentration Index Values for All Sites and Sites with at least One Emission to Air

	Sites	Authorisations	Emissions	1km buffer	≥2 sites within 1km	PHA Band D
All Sites	0.22	0.25	0.26	0.31	0.44	0.4
Sites with emissions to air	0.23	0.26	0.25	0.32	0.41	0.4

Two significant air pollutants that feature within the National Air Quality Strategy and a group of substances with potential carcinogenic impacts on humans were investigated both in terms of the locations of emission sources and the total amounts released to air. Results are presented here as quintiles rather than deciles to smooth the data and better represent relationships. Emissions of nitrogen dioxide (Figure 9.8) show a peak in the third quintile due to the influence of a few very large emission sources (this quintile has

18% of emission sources by number but 45% of total emissions by weight) and this balances with the substantial emissions in the lowest quintile to produce a low CI score.

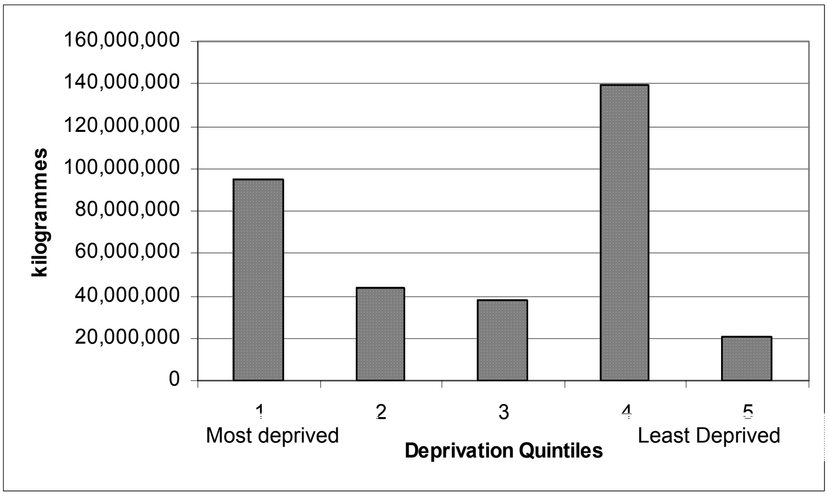


Figure 9.8: Total Emissions of NO_2 from IPC sites in England by population weighted ward deprivation quintile (CI = 0.07).

Emissions of particulates (PM_{10}) show a strong relationship with deprivation (Figure 9.9). The highest absolute and percentage emissions are in lowest quintile. The most deprived 20% of wards are the location for 42% of all PM_{10} emissions from IPC sites in England, whilst the least deprived 20% of wards are the location for less than 0.5%. That there are substantial emissions in the more deprived wards is relevant to the air quality 'pollution-poverty' hot spot analysis discussed in section 10.6.

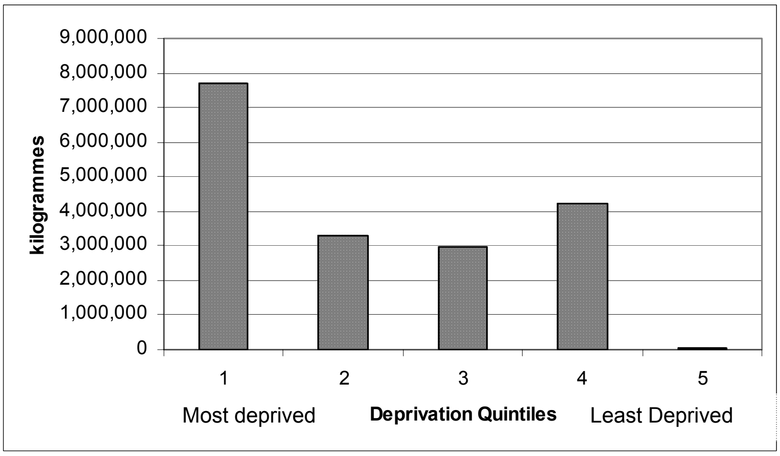


Figure 9.9: Total Emissions of PM_{10} from IPC sites in England by population weighted ward deprivation quintile (CI = 0.28).

Carcinogenic emissions cover 35 substances released to air from at least one site in 2001. We utilised a definition of carcinogenic (and mutagenic) substances provided to the Agency by the Department of Health and analysed both the distribution of site locations and the total quantities released[2]. This analysis reveals a strong relationship with deprivation (Figure 9.10). The most deprived 20% of wards is the location for 55% of total aggregated emissions, compared to 9% in the least deprived. These results are not as acute as those produced by Friends of the Earth (2001) which found 66% of emissions in the most deprived 10% of wards. The difference in results may be due to a number of factors – a different definition of carcinogenic substances, different year of data and our use of population weighted ward deciles.

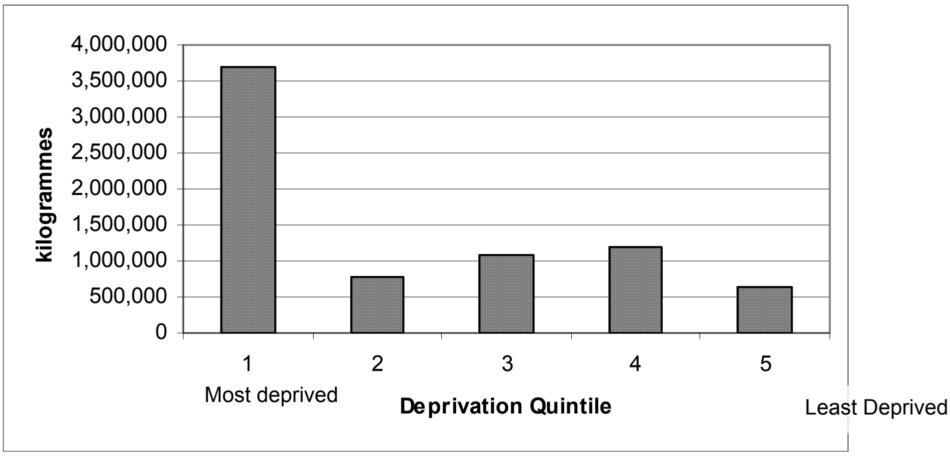


Figure 9.10: Total Emissions of Carcinogenic Substances to air from IPC sites in England by population weighted deprivation quintile (CI = 0.28).

9.3 IPC Sites and Deprivation in Wales

In Wales there are approximately a tenth of the number of IPC sites in England. The 'site in ward' counts for sites, authorisations and emissions show no clear relationship with deprivation with the highest numbers in the 4th and 7th deciles and the lowest numbers in the most deprived decile (Figure 9.11). The CI values indicate a very marginal bias towards the *less* deprived deciles which is slightly stronger for emissions.

[2] Aggregating the quantities released provides only a crude indicator as different substances will have different carcinogenic properties.

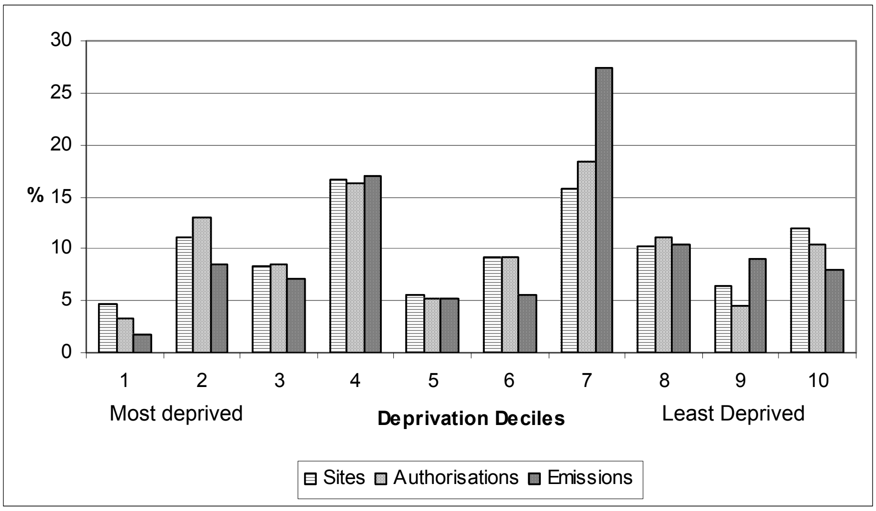


Figure 9.11: Percentage of Sites, Authorisations and Emissions by population weighted ward deprivation decile for Wales (using 'site in ward' counting method) CI values = -0.04 (sites) -0.03 (authorisations) -0.11 (emissions).

Using the population proximity method a different pattern emerges with contrasting evidence of a disparity towards the *more* deprived deciles. The profiles shown in Figure 9.12 and the CI values of 0.26 and 0.18 indicate an overall bias towards the lower deciles - but to a lesser degree than for England which had equivalent CI values of 0.31. The inequality is also less skewed in Wales towards the most deprived decile 1. This disparity between the methods suggest that the population proximity data is picking out populations near to IPC sites, but not located within the same wards as the sites.

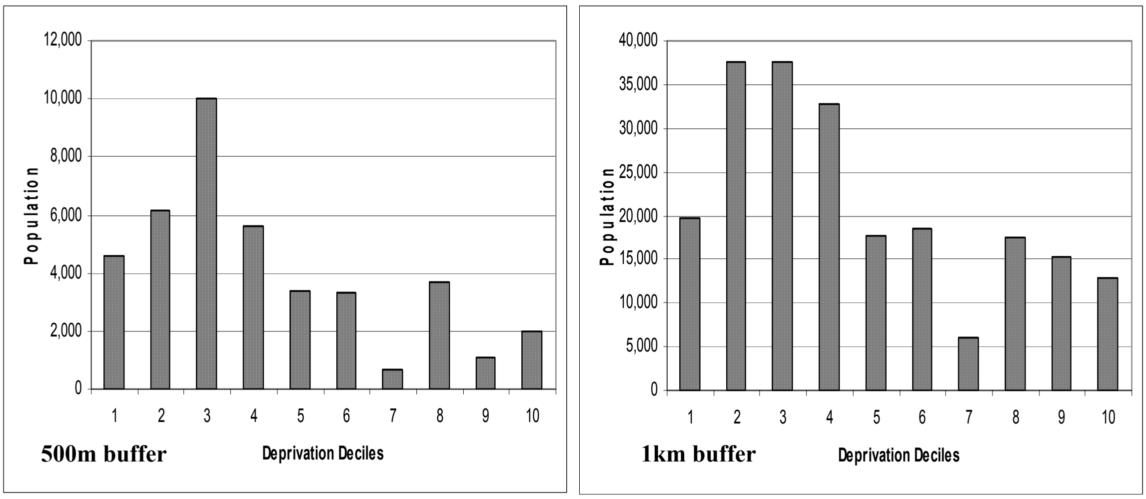
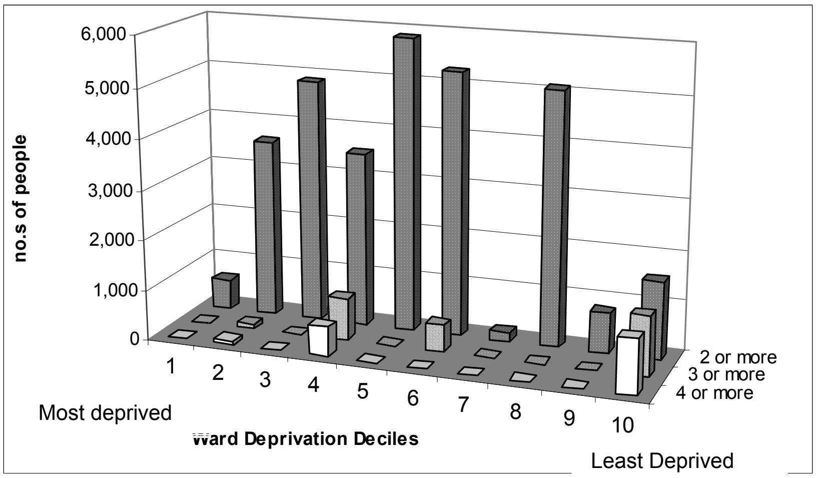


Figure 9.12: Total populations living within 500m and 1km of an IPC site by population weighted ward deprivation deciles for Wales. CI values = 0.26 and 0.18.

The numbers of people living in proximity to multiple sites and the concentration of multiple sites in Wales is much lower than in England (Figure 9.13). There is also little evidence of multiple sites being disproportionately located in the more deprived deciles

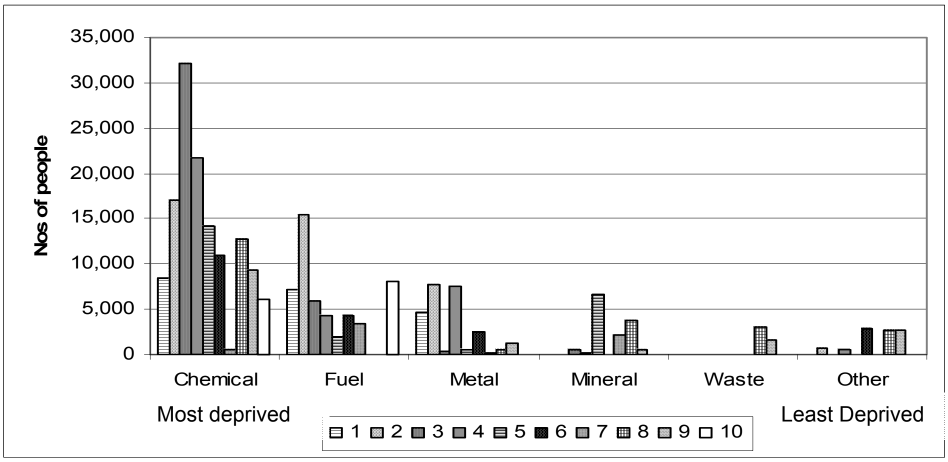
- indeed the CI values show a bias towards the *less* deprived deciles as proximity to multiple sites increases.



Concentration Index Values			
≥4	≥3	≥2	≥1
-0.43	-0.30	0.07	0.18

Figure 9.13: Numbers of people living within 1km of multiple (x or more) IPC sites by population weighted deprivation deciles for Wales

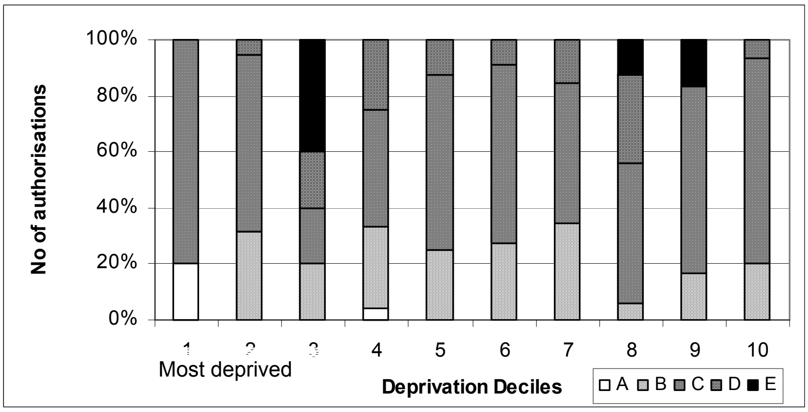
The analysis of data by industry sector for Wales is hampered by the low total number of sites in some sectors. For the waste sector there are only two sites, minerals eight and metals 13. For the two sectors where there are a greater number of sites (chemicals and fuel) there is no evident relationship with deprivation through counting site locations in wards. However, the 1km buffer population proximity analysis again reveals more distinct patterns (Figure 9.14). There are biases towards deprived deciles for chemical, fuel and metal sectors, and towards less deprived for mineral, waste and other industries. For the two waste sites the entire population within 1 km is to be found in the more affluent deciles 8 and 9.



Concentration Index Values						
All sites	Chemical	Fuel	Metal	Mineral	Waste	Other
0.18	0.18	0.25	0.43	-0.14	-0.57	-0.31

Figure 9.14: Numbers of people living within 1km of IPC sites by industrial sector for Wales

Using the PHA scores to differentiate IPC sites in terms of the level of pollution hazard they present, produces no evident pattern with deprivation (Figure 9.15). The highest hazard sites in band E occur in deciles 4, 8 and 9 and the CI values are all close to zero.



Concentration Index Values				
B	C	D	E	All authorisations
0.02	-0.06	-0.05	0.04	- 0.03

Figure 9.15: Pollution Hazard Appraisal (PHA) scores of authorisations in Wales by deprivation deciles (A = low pollution hazard, E = high)

The score given to 'offensive characteristics' also showed an indistinct pattern but focusing on authorisations with the highest score of 5 there are marginally greater proportions of these towards the *less* deprived deciles, but the trend is not strong.

Using the Operator Performance scores it is again hard to pick out any pattern (Figure 9.16). All of the best run sites in category A are in decile 4. The worst run sites in band D (there are none in band E in Wales) are distributed across the mid range of deciles rather than at either extreme. This data therefore provides no evidence of a clear relationship between operator performance and deprivation. Examining patterns by date of authorisation shows that there has certainly been no particular bias towards the lower deprivation deciles with the highest % of new authorisations in deciles 4 and 7 and no new authorisations at all in decile 1.

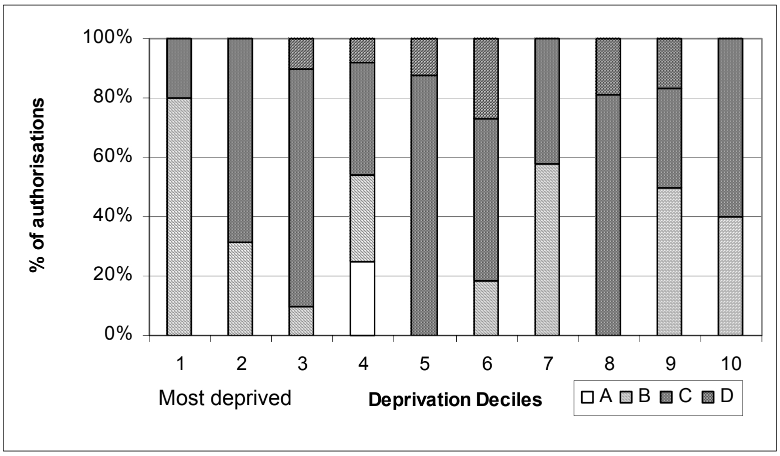


Figure 9.16: Percentage Operator Performance Appraisal (OPA) Bandings for IPC Authorisations within deprivation deciles (A = good performance, E = poor)

The analysis of emissions of specific substances shows in each case an inverse relationship with deprivation (Figures 9.17–9.19). For NO_2, PM_{10} and carcinogens the CI values are all negative, with the strongest relationship for NO_2. These patterns contrast with England in showing higher emission levels in less rather than more deprived areas.

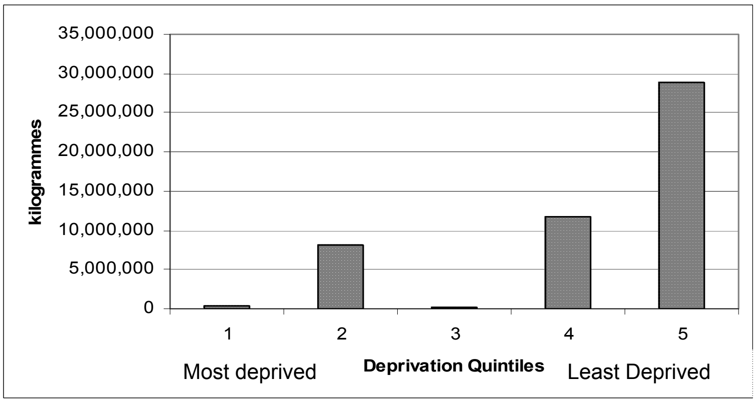


Figure 9.17: Total Emissions of NO_2 from IPC sites in Wales by population weighted ward deprivation quintile (CI = -0.43).

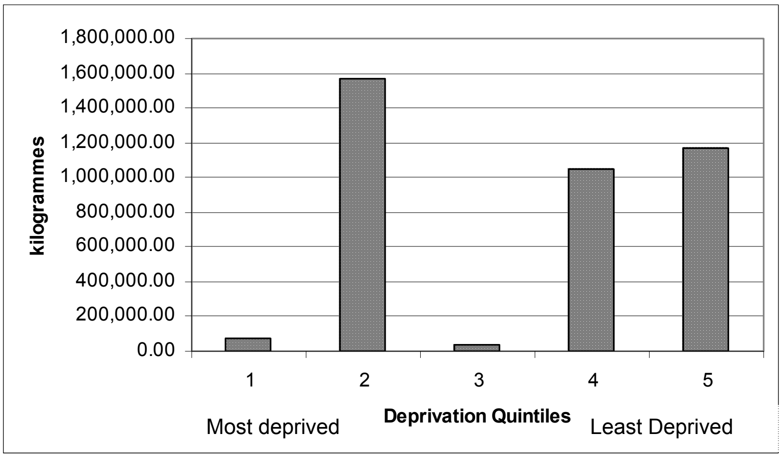


Figure 9.18: Total Emissions of PM_{10} from IPC sites in Wales by population weighted ward deprivation quintile (CI = -0.16).

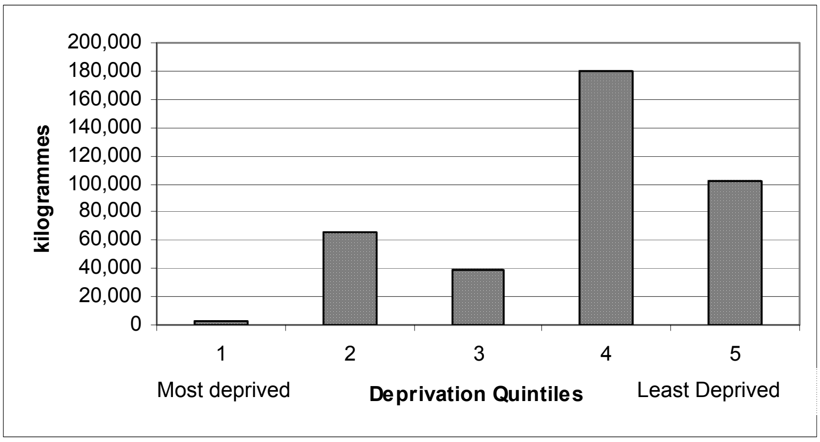


Figure 9.19: Total Emissions of Carcinogenic Substances to air from IPC sites in Wales by population weighted deprivation quintile (CI = -0.27).

9.4 Discussion

There is compelling evidence of a socially unequal distribution of IPC sites in England. These significant sources of pollution are disproportionately located in more deprived areas. IPC sites are also more clustered together in deprived areas, on average produce greater numbers of emissions and present a greater potential pollution hazard in deprived areas. They also produce more 'offensive' pollutants which are likely to have an impact on the day-to-day quality of life. Through simple mapping though many tight clusters of sites in deprived industrial-urban areas can be identified – including the North West in the area running from Liverpool through to Manchester, Leeds and Bradford, Sheffield, Birmingham, Teesside, Tyneside and in London running out along the Thames estuary. The fact that waste sites in particular stand out as being disproportionately located in more deprived areas raises particular issues for waste policy regarding the social distribution of local impacts from incinerators at a time when a substantial programme of new construction is planned.

In contrast to England the patterns of distribution of IPC sites in Wales shows a less distinct relationship to deprivation. The locations of sites in wards analysis shows no association with deprivation, although the population within 1km of an IPC site does exhibit some bias towards more deprived deciles (but not the *most* deprived) – suggesting that the distribution of sites and populations in Wales is particularly sensitive to the method of spatial analysis utilised. There is no evidence of a greater concentration of emission sources or of processes producing a greater pollution hazard in more deprived areas. Indeed the data for proximity to multiple sites and for levels of emissions of specific substances show a bias towards the less deprived, more affluent deciles. An explanation for the social pattern of site locations in Wales and the differences between England and Wales appears to rest in part with the geography of deprivation in Wales. The most deprived wards particularly in the South Wales valleys have few IPC sites – due to the particular industrial history of these areas.

9.5 Inequality, Inequity and Causality

Whilst there is strong evidence that in England there is a distributional inequality in the location of IPC sites, the extent to which this is seen as inequitable and unfair and in need of redress is a question of judgement. There are a number of dimensions to this judgement, that will be evaluated in different ways by different stakeholders. These dimensions include:

- the extent to which population proximity to sites and emission sources can be reasonably assumed to produce undesirable impacts of various forms. Proximity can only be a surrogate for exposure to hazard, risk or disamenity, which is an important limitation of site based equity analyses;

- the extent to which the spatial and social distribution of the benefits gained from IPC sites, such as employment, can be seen to balance with or compensate for the negative dimensions of proximity (although a pattern of significant employment in the immediate community around an industrial site cannot nowadays be presumed);

- the extent to which 'informed choice' is considered to have been exercised by people living in areas near to IPC sites (remembering that the degree of choice in residential location is not equal across social groups);

- whether there are particular decision-making processes operated by public or private bodies that make sites in deprived areas more potentially or actually hazardous (such as greater management or regulatory attention being given to sites in more wealthy and politically articulate communities);

- whether there are particular discriminatory decision-making processes operated by public or private bodies which have created or are reinforcing the unequal distribution of IPC sites.

In our analysis we have only been able to begin to touch on some of these questions through the examination of national data sets. In particular, issues of causality - why the association between deprivation and site location exists - are very difficult to address through a national level statistical analysis and may need to be explored through alternative and more locally focused research methods. However, we have been able to establish that:

- for emissions to air, which are more directly linked to health impacts, the social distribution of site locations is largely the same as for all IPC sites.

- there no evidence from the scores given by the Agency for operator performance that sites are being worse run in deprived areas and therefore are potentially presenting a greater hazard due to poor site management.

- there is no evidence from our analysis that the Agency's site inspection priorities discriminate against deprived areas. As inspection priorities are guided by OPRA scores the higher pollution hazard ratings in deprived areas should rather focus attention on sites in more deprived areas. This is, however, only a limited indicator of inspection practices on the ground.

- there is no evidence that authorisations applied for and granted more recently are disproportionately biased towards more deprived areas. Whilst this provides some rebuttal of the hypothesis that companies have become more sensitive to NIMBY reactions and could therefore be deliberately targeting less organised and mobilised communities in new site investments, it also shows that patterns of new authorisations are not becoming more equitable than they have been in the past. In other words past patterns are being maintained.

One line of argument emerging from the considerations outlined above could be that whilst there is an inequality in location and population proximity, there is either too little known about the resulting impacts, in particular on health, or the causes of this inequality, to warrant policy action. If, however, we accept that the many dimensions of the unequal distribution of IPC sites we have found (in England at least) *can* reasonably lead us to a conclusion that this situation is unfair and needs to be addressed in some way, what potential responses exist? The range of possibilities to be considered are numerous, but include:

- *directing new IPC sites away from deprived areas.* Whilst not addressing the situation that currently exists, such a policy would ensure that the inequality of distribution did not worsen further. Such a response could in theory be achieved through land use planning policy but would go against typical current planning presumptions that polluting industry (or other undesirable activities) should be clustered together in areas of poor environmental quality rather than 'spread around'. Many further questions are raised by this form of response. By what criteria could such a policy be applied; is greater distributional equity being sought at a national, regional or local scale; what if deprived communities want to attract new industry to create jobs; is it politically realistic to direct say new incinerators into leafy suburbs?

- *applying higher standards in deprived areas in particular with multiple sites/emissions* The only way of addressing the current unequal situation (unless wholesale site relocation is to be advocated) is to take measures that disproportionately seek to reduce the impacts from IPC sites in deprived areas. A targeted approach could for example particularly focus on areas where there are multiple sites and multiple hazardous/offensive emissions and deprived populations.

However, a number of difficult questions also need to addressed here. How much of a concentration of sites or emissions or perhaps 'degree of cumulative risk' warrants a particular claim of injustice? How should be impacts of 'applying higher standards' be measured - through reductions in numbers of emissions, levels of emissions, improvement in environmental management standards?

- *providing information on deprivation within decision-making processes.* Rather than laying down a general siting policy as under the first option, an alternative is to seek decision-making that is informed about deprivation implications. Information on deprivation (and other social characteristics of affected populations) is not routinely produced within, for example, project or strategic Environmental Assessments but could be seen as a relevant addition to sit alongside other information produced for planning and policy decisions. Sharing such information with the local community could be seen as a particularly important dimension of local engagement.

- *developing compensatory benefits for deprived communities.* The concept of compensation derives from an economic view of the need to balance the unequal distribution of cost and benefit and has been proposed particularly as a solution to problematic siting processes for 'locally unwanted land uses'. If particular communities are taking the burden of costs for the wider societal good, then they maybe should receive compensatory benefits which in some form match the costs borne. Arguments for compensation may be particularly strong where deprived communities are taking the burden of costs, whilst benefits are gained more by the wealthy. Compensation can take a range of monetary or non-monetary forms, including, for example, greater investment in public services such as health and education and improvements in general environmental quality.

- *strengthening general emission and operator performance standards.* If IPC sites are disproportionately located in deprived areas it can be argued that across the board action to reduce emissions and improve operator performance will therefore help the poor more than others. An additional social justice argument is thus added to the case for investment of resources into environmental regulation and management more generally.

9.6 Recommendations

1. The Agency should consider whether or not a targeting of regulatory attention on IPC sites in more deprived areas is warranted by the overall pattern of association between deprivation and site location in England. This could be implemented in a number of ways such as an adjustment to OPRA scores, which are used to prioritise a number of Agency actions, to reflect deprivation data.

2. Whilst the Agency does not have decision-making powers over land use planning decisions it should consider entering into dialogue with the ODPM and local planning authorites over possible planning and siting responses to the inequity of IPC site location (as discussed above).

3. The fact that IPC sites are agglomerating particularly in deprived areas raises the question of whether sufficient significance is being given to the accumulation and

concentration of multiple emissions in such areas. We therefore recommend that the Agency considers whether the evidence of social inequality in site distribution should stimulate further attention to be given to assessing the risks of cumulative and synergistic exposure to emissions from IPC sites.

4. Our analysis of air quality data has identified particular ‘poverty-pollution’ hot spots. One of the contributory sources to pollution in these areas could be emissions from IPC sites, providing a direct way in which the Agency can work with local authorities and others to address local air quality problems. We therefore recommend that the Agency undertakes further work to examine the relationship between poor air quality and IPC emissions in these ‘hot spot’ areas.

5. The generation of information on the social characteristics of communities living near to polluting sites has been one of the key responses made by the EPA in the US to the commitment to build environmental justice concerns into its policy and operating practices. That information is then used in a number of ways to inform decision making and work with local communities. We recommend that the Agency considers similar action by developing techniques for social equity appraisal for IPC sites that can be used within the Agency and by other key partners such as local planning authorities.

6. Whilst our research has provided a more detailed and wide ranging analysis of the social equity dimensions of IPC site locations, emissions, hazards and operator performance than previously available, there are still inevitably unanswered questions and ways in which the analysis could be extended. Areas for further specific IPC related research include:

   - undertaking analysis in relation to other social variables (such as age, ethnicity, health);
   - more intensive regional or local analysis (perhaps focused on agglomerations of polluting sites);
   - analysis of processes of causation through more detailed longitudinal case studies of the sequencing of locational decisions (between sites and nearby development) and changes in the social make-up of local communities;
   - analysis of the distribution of a wider range of emitted substances and groups of substances; detailed investigation of patterns of site inspection and other aspects of Agency intervention;
   - use of improved spatial information such as site boundaries within analysis and the finer grained social information available from the 2001 census;
   - analysis of pollution incident data including the pattern of incidents at IPC sites.

10 AIR QUALITY AND DEPRIVATION

10.1 Introduction

Air quality has been subject to more UK equity research than any other environmental issue to date. However, the studies are very diverse in nature, addressing different pollutants, spatial scales, spatial units, social characteristics and analytical methods. This diversity, in what is collectively a small body of research, has prevented broad conclusions on the relationship between air quality and deprivation from being drawn.

We report here on further research on the relationship between air quality and deprivation. In addressing all of England and Wales at ward level, our intention was to overcome problems associated with earlier studies that addressed individual cities, or which operated at the local authority district scale, and which consequently drew very conflicting conclusions. We build upon the only previous ward scale national analyses (Environment Agency 2002, Mitchell and Dorling 2003) by addressing the following objectives, agreed at the April workshop:

- Address poverty using the Index of Multiple Deprivation (IMD 2000) (DETR 2000a);
- Extend the analysis to cover Wales, as well as England;
- Increase the range of atmospheric pollutants previously studied;
- Attempt equity analysis that addresses multiple pollutants collectively; and
- Investigate how environmental equity patterns vary over time.

10.2 Data and Methods

The study addressed five National Air Quality Strategy (NAQS) (DETR, 2000b) pollutants for which small area national concentration data were available: nitrogen dioxide (NO_2), fine particulates (PM_{10}), sulphur dioxide (SO_2), carbon monoxide (CO), and benzene. The data are annual mean concentrations for each 1 km^2 grid cell centroid in the UK, for 2001 and 2010 (NO_2 and PM_{10}). Concentrations are forecast at the National Environmental Technology Centre, using inputs from the national emission inventory, box-modelling, and calibration against a network of air quality monitoring stations (Stedman *et al*. 2001a, 2001b) The data are widely used in local authority NAQS air quality management strategies.

Using a GIS, for each pollutant we calculated ward mean concentrations, values that formed the basis of our analysis. In principal, codepoint data can be used, in a similar manner to that of the IPC analyses, to provide a more refined analysis that does not rely on ward mean concentration values. However, a national analysis of air quality using codepoint data is computationally highly intensive, hence given the resource limitations of this scoping study, we chose to analyse the social distribution of ward mean concentrations.

We also developed a simple air quality index so as to collectively address multiple pollutants. The index related modelled concentrations to NAQS standards, in an additive, non-weighted manner, which we felt best reflected current knowledge on the combined health effects of multiple pollutants (DoH, 1998). The index has the form:

$$AQI_j = \sum_i^4 (C_{ij} / S_{ij})$$

Where: AQI_j is the air quality index for ward j
C_{ij} is the concentration of pollutant i in ward j
S_{ij} is the standard or guideline value for pollutant i

Annual mean NAQS standards exist for PM_{10}, NO_2 and benzene but not for SO_2 or CO. We therefore used the WHO guideline value for annual mean SO_2, which is 50 ug/m^3 (WHO, 2000). All CO standards are based on short averaging times, hence CO was not included. The index is most sensitive to NO_2 and PM_{10}, which generally have higher concentrations that are closer to permitted standards than is the case for benzene or SO_2. The index is unitless, with values ranging from, in theory, zero to infinity, but in practice values are unlikely to exceed 4, the equivalent of a site where concentrations of all four pollutants are at their respective standards.

For individual pollutants, and the air quality index, we examined the social distribution (pollutant distribution by deprivation) of: (a) ward annual mean air quality; (b) ward mean exceedences of NAQS standards; and (c) the distribution of wards with the poorest air quality, irrespective of standards.

10.3 Air Quality and Deprivation in England

For all pollutants studied, we find considerable variability of pollutant concentration within each deprivation decile, but overall, the most deprived wards are clearly also those with highest pollutant concentrations. The social distribution of nitrogen dioxide (Figure 10.1) is typical, showing that people in deprived wards are exposed to NO_2 concentrations higher (by 41%) than those of wards of average deprivation. This finding is consistent across all pollutants studied, with 2001 ward mean concentrations in the most deprived decile that, depending on pollutant, are 11-76 % greater than those of the mid deciles (Table 10.1).

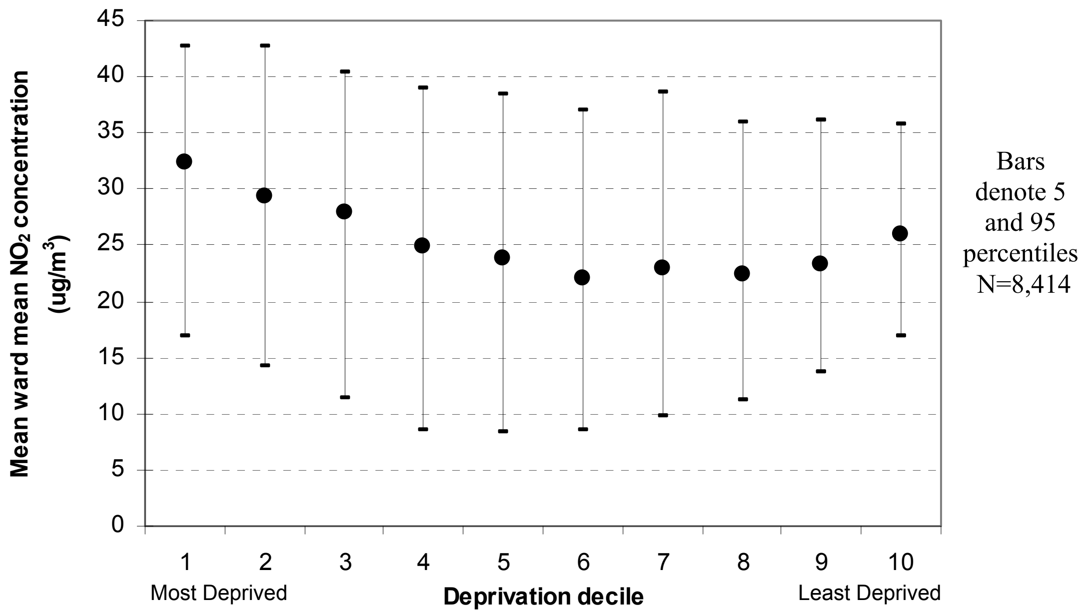


Figure 10.1: Social distribution of nitrogen dioxide (NO_2) in England, 2001

Note, however, that no simple linear relationship between ward mean concentration and deprivation exists. For all pollutants (except SO_2), the least deprived also experience concentrations that are above those for people of average deprivation, although the elevation above the average is much less than that of the most deprived, no more than 13 % (Table 10.1). The consistency of this curvilinear pollution-deprivation relationship is illustrated by Figure 10.2, that shows the social distribution of the air quality index.

Table 10.1: Social distribution of air quality, standardised to mean deprivation

Air quality parameter	**Year**	**Air quality standardised against mean deprivation**		
		Most deprived (decile 1)	**Mean deprivation (deciles 5 & 6)**	**Least deprived (decile 10)**
Nitrogen dioxide	2001	141*	100	113
	2010	146	100	112
Particulates PM_{10}	2001	111	100	104
	2010	110	100	103
Sulphur dioxide	2001	127	100	97
Carbon monoxide	2001	138	100	108
Benzene	2001	176	100	109
Air Quality Index	2001	130	100	109

* i.e. concentration is 41 % above that experienced by mean deprivation wards

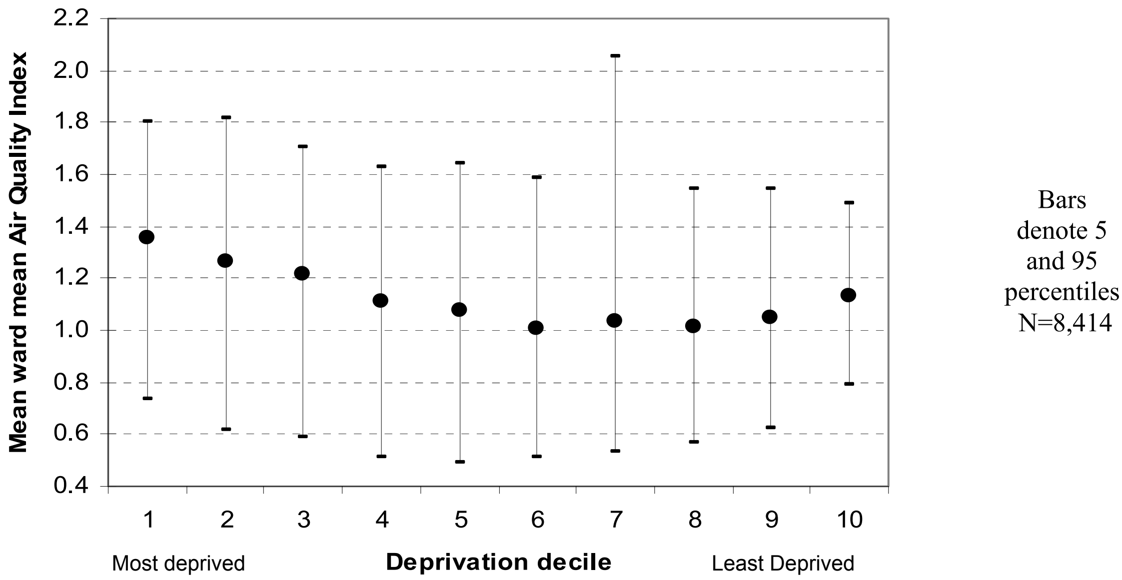


Figure 10.2: Social distribution of the Air Quality Index in England, 2001

Examining those wards with the highest pollutant concentrations, we find that the distribution is no longer curvilinear, but that the number of people resident in wards above high pollution thresholds increases progressively with increasing deprivation. For example, of the 2.5 million people in England resident in wards with a mean NO_2 concentration above the NAQS standard (40 ug/m^3 as an annual mean), we find that over half are in the most deprived quintile, and just 1 % in the least deprived decile.

If we examine the deprivation characteristics of populations exposed to the highest ward concentrations (most are within NAQS standards) we find this pattern occurs for all pollutants. For example, of the 10 % of the population resident in wards with poorest air quality, we typically find that half reside in wards that are amongst the 20 % most deprived in the country (Table 10.2, Figure 10.3). In contrast, typically only 5 % of this 'most exposed' group are in the least deprived 20 % of the population. Thus whilst the poorest air quality is found in the most and least deprived communities, the poor bear the greatest burden (by an order of magnitude more than the least deprived).

Table 10.2: Social distribution of greatest (worst 10%) air quality concentrations

Air quality parameter	Year	% population in deprivation quintile resident in wards with highest pollutant concentration				
		Q1 (Most deprived quintile)	Q2	Q3	Q4	Q5 (Least deprived quintile)
Nitrogen dioxide	2001	47 *	22	16	10	5
	2010	47	24	14	9	5
Particulates (PM_{10})	2001	50	26	10	9	5
	2010	54	24	10	7	4
Sulphur dioxide	2001	33	26	20	12	9
Carbon monoxide	2001	47	26	14	9	5
Benzene	2001	45	27	13	9	6
Air Quality Index	2001	48	23	15	9	4

* i.e. of the 10 % of the national population resident in wards with the poorest air quality, 47 % also live in the most deprived 20 % of wards.

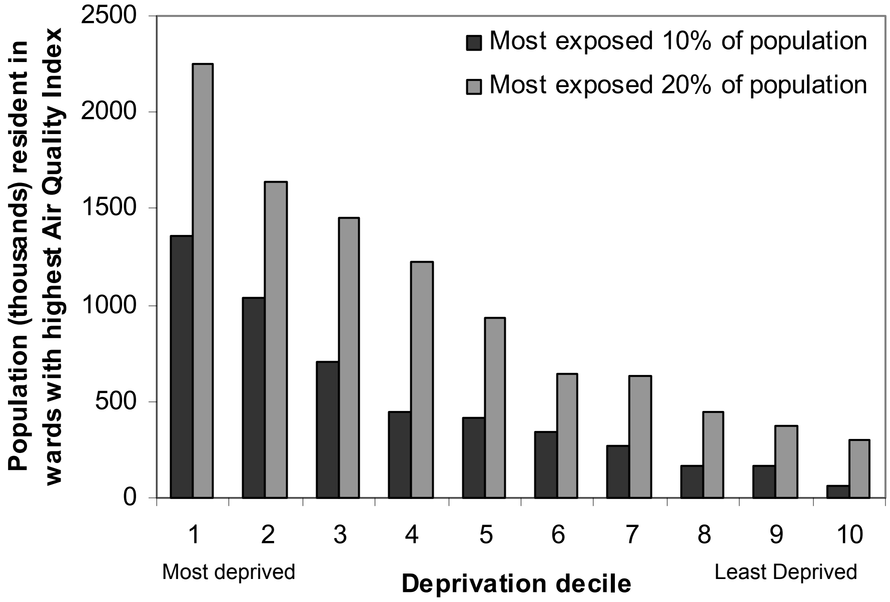


Figure 10.3: Distribution of highest ward mean Air Quality Index (2001)

10.4 Air Quality and Deprivation in Wales

At first sight, the results for Wales suggest the same relationship between air quality and deprivation as seen for England. Figure 10.4 shows the social distribution of ward mean NO_2, a pattern characteristic of all the pollutants studied. Again, there is a curvilinear relationship, with both the most and least deprived wards experiencing concentrations above those of wards of average deprivation. However, in contrast to England, pollutant concentrations in Wales are highest in the least deprived wards, although the distribution is, overall, more equitable than that observed for England (Table 10.3).

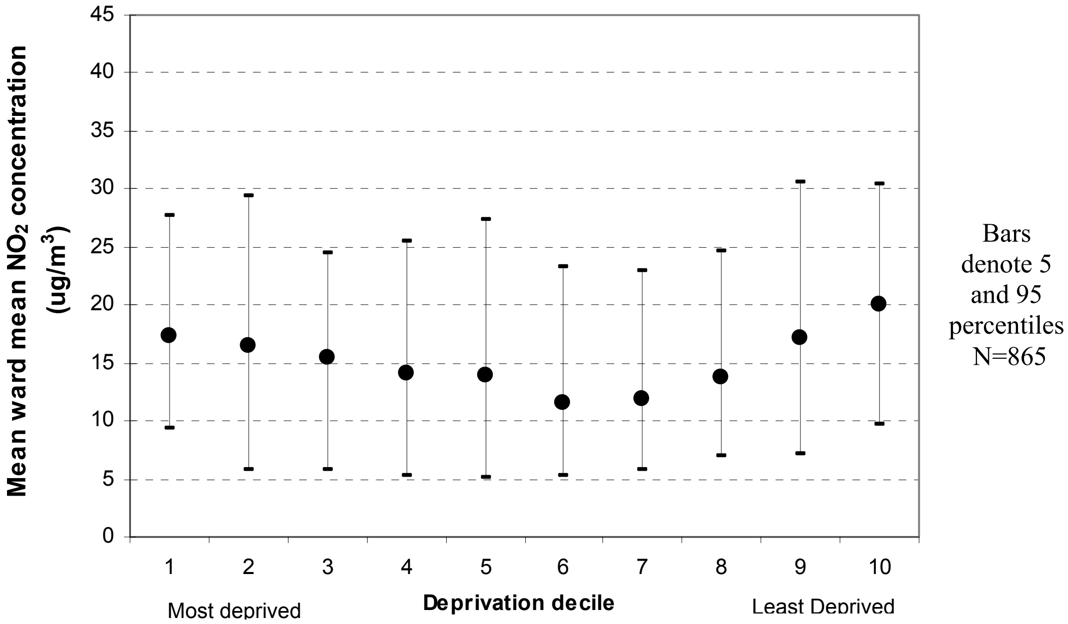


Figure 10.4: Social distribution of nitrogen dioxide in Wales, 2001

Table 10.3: Social distribution of air quality, standardised to average deprivation

Air quality parameter	Year	Air quality standardised against mean deprivation		
		Most deprived (Decile 1)	**Mean deprivation (Deciles 5 & 6)**	**Least deprived (Decile 10)**
Nitrogen dioxide	2001	138 *	100	158
	2010	139	100	162
Particulates PM_{10}	2001	110	100	112
	2010	109	100	111
Sulphur dioxide	2001	128	100	123
Carbon monoxide	2001	119	100	130
Benzene	2001	155	100	159
Air Quality Index	2001	125	100	135

* i.e. concentration is 38 % above that experienced by mean deprivation wards

The social distribution of poor air quality in Wales displays greater variability than that of England, in part due to a smaller population. However, the poorest air quality is disproportionately found in the least deprived wards (Figure 10.5). For example, of the

10 % of the Welsh population with the greatest exposure to CO and NO_2, over 40 % are resident in the least deprived 20 % of wards. This is twice that which would occur if this pollution was equally distributed by deprivation. Typically there are three to four times as many 'affluent' people resident in wards with the worst air quality, as there are poor (Table 10.4).

The difference between the Welsh and English patterns arises because the least deprived households in Wales tend to be more urban than their English equivalents, and are mostly located in S E Wales where most of the poorest air quality occurs. It is likely that these affluent households are more urban than might be expected, as they are geographically constrained to Cardiff by the sea to the south, and by the deprived valleys to the north. Note also that air quality in Wales is generally better than England, and hence poor air quality (and correlates such as noise and congestion) is a weaker deterrent to locating in the city. Cardiff may not be unique in the UK (indeed we see above average pollution in affluent English wards), but it dominates the Welsh situation, and exerts a major influence on the national pattern.

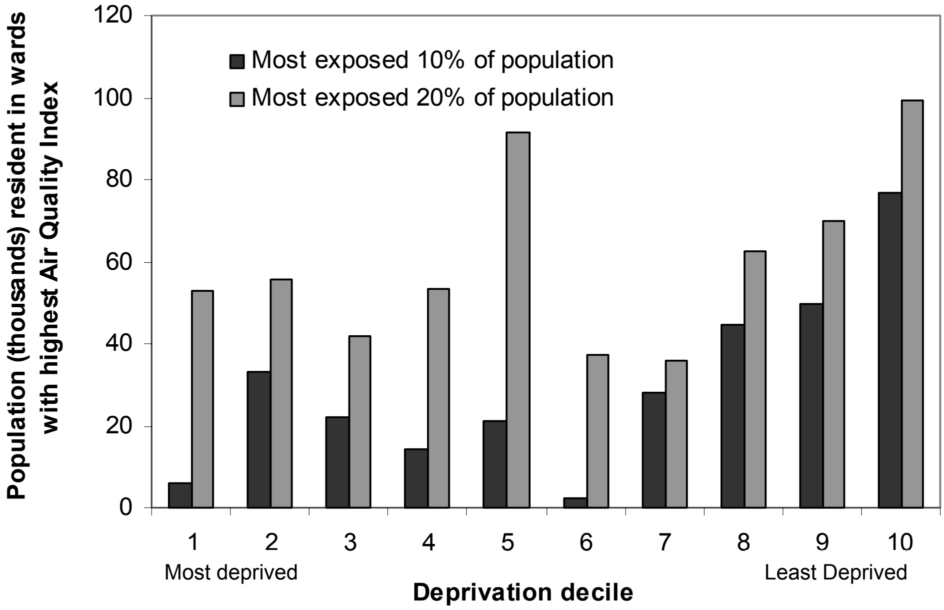


Figure 10.5: Distribution of highest ward mean Air Quality Index in Wales

Table 10.4: Social distribution of greatest (worst 10%) air quality concentrations

Air quality parameter	Year	% population in deprivation quintile resident in wards with highest pollutant concentration				
		Q1 (Most deprived quintile)	Q2	Q3	Q4	Q5 (Least deprived quintile)
Nitrogen dioxide	2001	11*	13	11	24	41
	2010	16	11	14	23	36
Particulates (PM_{10})	2001	17	11	19	19	34
	2010	18	11	20	21	29
Sulphur dioxide	2001	21	16	25	18	19
Carbon monoxide	2001	11	15	7	23	43
Benzene	2001	13	12	8	24	42
Air Quality Index	2001	14	13	13	24	35

- i.e. of the 10% of the population resident in wards with the poorest air quality, 11 % also live in the most deprived 20 % of wards.

10.5 Longitudinal (temporal) Analysis

Our analysis of changing air quality-deprivation patterns (from 2001 to 2010), is to some extent constrained by the availability of good data for 2010, particularly with respect to the representation of spatially dependent emission processes. Nevertheless, our analysis is sufficient to suggest that whilst the total burden of air pollution will continue to fall, there will be relatively little change in the social distribution of that pollution, although the distribution of the poorest air quality should become more equitable.

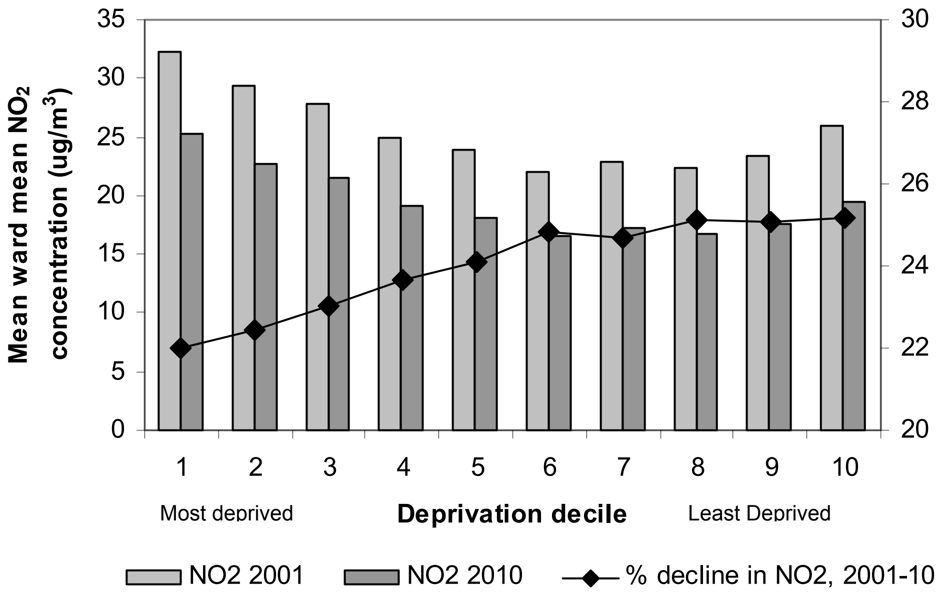


Figure 10.6: Change in social distribution of ward mean NO_2, 2001-2010 (England)

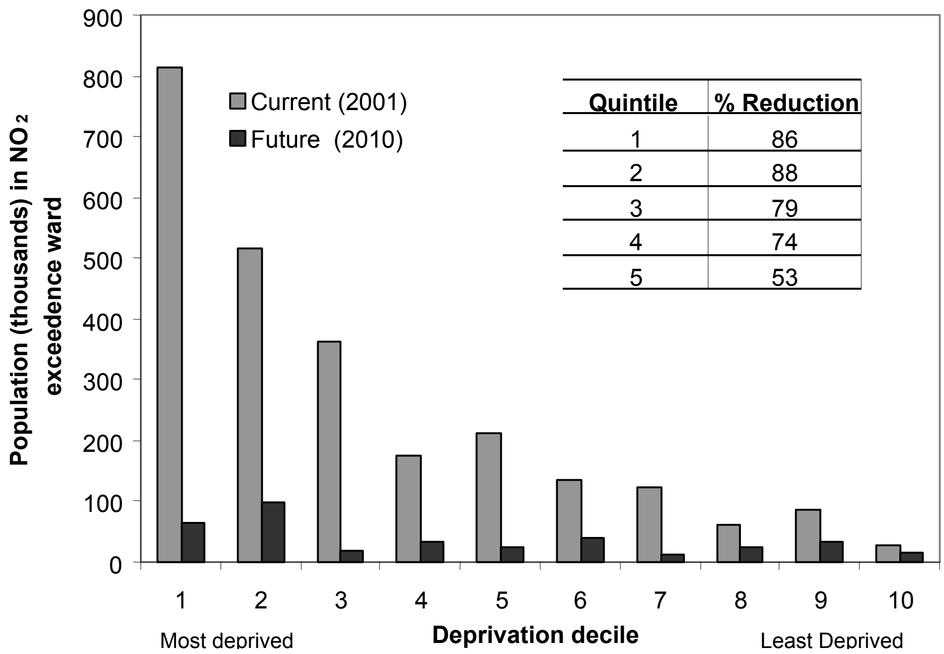


Figure 10.7: Population in an NO_2 exceedence ward, 2001-2010 (England)

In absolute terms the poor will enjoy the greatest benefits of air quality improvement. Figure 10.6, for example, shows that the most deprived decile experiences a reduction in ward mean annual NO_2 of 7.1 ug/m^3 from 2001-10, compared to 5.5 ug/m^3 for people of average deprivation and 6.5 ug/m^3 for the least deprived decile. In relative (% change) terms however, the poor do not enjoy the same improvement in NO_2 as others, although the differences are small (Figure 10.6).

If we examine the social distribution of the poorest air quality, we see that the poor enjoy greater benefits than others. Figure 10.7 shows that, of the two million people 'removed' from an NO_2 exceedence ward by air quality improvement, most will be poor. Note however, that the poorest quintile continues to bear over half the NO_2 exceedences that remain in 2010. Plotting the data from Figure 10.7 using Lorenz curves (cumulative distributions), we see that the social inequality in distribution of NO_2 exceedence (wards where annual ward mean NO_2 > 40 ug/m^3) declines. Thus air quality improvement leads to a more equitable distribution in peak concentrations.

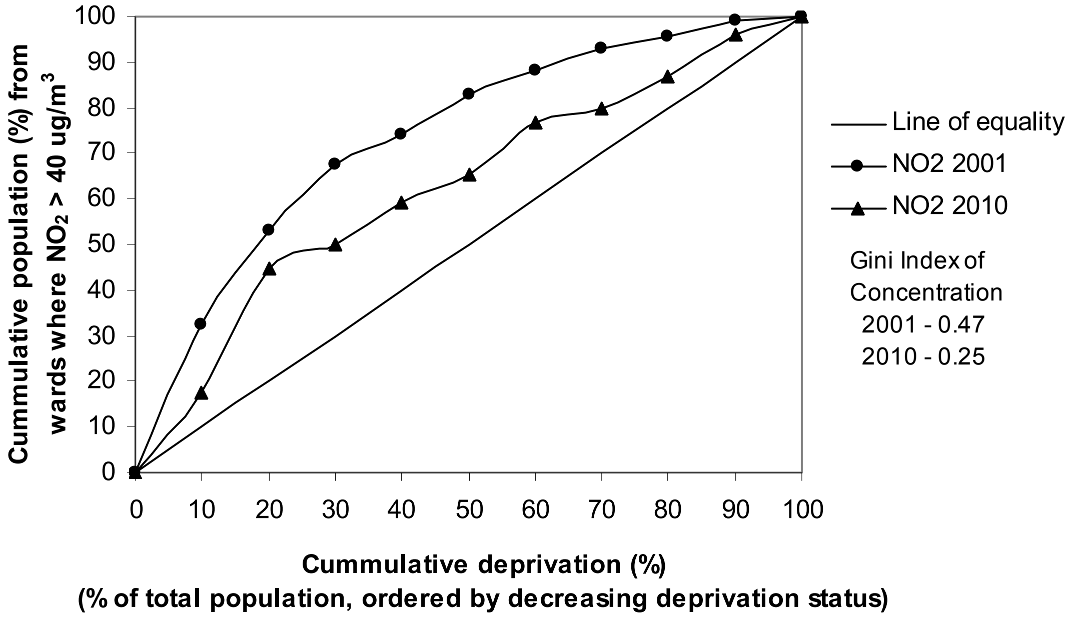


Figure 10.8 : Social distribution of high annual ward mean NO_2 (England)

The introduction of tighter air quality standards may lead to an increase in exceedences, and the burden of these new exceedences is likely to be borne disproportionately by the poor (note that changing the standard does not affect actual exposure). This is the case with the 20 ug/m^3 PM_{10} standard to be introduced in 2010 (DEFRA 2003). Figure 10.8 illustrates Lorenz curves for 2001 and 2010, addressing people in wards where annual mean PM_{10} is forecast to exceed 20 ug/m^3. Note that, unlike NO_2, the distribution of peak values becomes more inequitable. This pattern arises as by 2010, all people resident in wards where PM_{10} > 20 ug/m^3 are in the poorest three deciles, with none in any other decile. Note however, that overall the total number of people in a PM_{10} 'exceedence' ward falls from 650,000 in 2001 to just 25,000 in 2010.

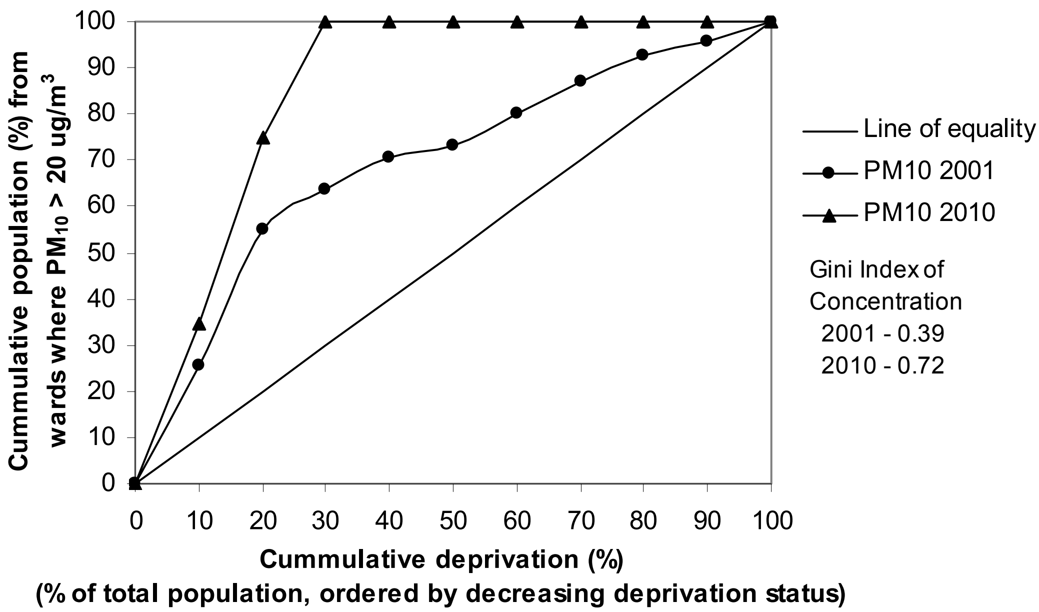


Figure 10.9: Social distribution of high annual ward mean PM_{10} (England)

The temporal analyses illustrates that equity analyses are sensitive to characteristics of the data (e.g. whether thresholds are applied to environmental data) and that results should be interpreted carefully. On balance, our temporal analysis shows that the social distribution of pollution is likely to change little when considering all wards, but that when examining only those wards where air quality is poorest, we find that the social distribution of pollution becomes more equitable. As air quality continues to improve, its social distribution could appear increasingly inequitable. This is because the poorest air quality is largely confined to urban areas which tend to be more deprived. However, these areas will enjoy very much better air quality than at present.

We note that the impact of air quality management area (AQMA) actions is not represented in the NETCEN air quality data. AQMA's are intended to eliminate standard exceedences, and because they are largely in urban areas, should act to make a more equitable distribution. There remains, however, a danger that AQMA's could cause pollution to be redistributed, possibly to more deprived areas.

10.6 Pollution-Poverty 'Hot Spots'

We used the Air Quality Index to identify clusters of wards that have poor air quality (AQI>1.5), and high deprivation (decile 1). We identified around a dozen of these pollution-poverty 'hot-spots', with large clusters in parts of London, Manchester, Sheffield, Nottingham and Liverpool, and small clusters (< 5 wards) in Bristol, Derby, Essex, Leicester, Luton, Tyneside, W. Midlands and W. Yorkshire. This technique is a useful way of identifying areas for further more detailed analysis and possible remedial intervention. However, the selection of appropriate air quality and deprivation thresholds is a subjective process that merits more widespread discussion and agreement.

10.7 Air Quality and Social Justice

Our analysis has established that there is an unequal social distribution of air quality in both England and Wales, with the most deprived bearing a greater air quality burden than people of average means. However, in both countries the least deprived also bear an above average air pollution burden. This brings into focus the issue of equality and justice. That is, are the observed social distributions unfair? In part, this is a subjective and political decision, which we have discussed at length (e.g. with reference to welfare theory) in the Phase I Project Record (Mitchell and Walker, 2003). However, the air quality analysis highlights several other practical issues which are also pertinent to the wider debate on environmental equality.

First, we note that we do not have agreed means of identifying a social distribution of pollution that most would consider unfair. There is a lack of agreement on appropriate metrics describing target groups, adverse effects (e.g. exceedences or concentrations?), and acceptable inequalities in distribution of adverse effects.

Second, it may be appropriate to consider the issue of polluter pays. Claims that 'traffic pollution is mainly caused by the better off, but the poor feel its effects', have been made but are not empirically supported. Mitchell and Dorling (2003) demonstrated there is no ward level relationship between deprivation and emission, and that the poor contribute just as much NO_X emission as the affluent (they have fewer but older more polluting cars). Inequalities can be identified (e.g. when considering emission, concentration and deprivation collectively), but a more careful interpretation is required.

Finally, we note that freedom of choice is a significant issue in interpreting inequality. The deprived that drive older more polluting cars, for example, may have little choice to do otherwise, due to a lack of access to public transport, and the higher cost of cleaner vehicles. Conversely, those that suffer higher air pollution in urban areas may choose to do so given the greater access to jobs and services, whilst others may be economically constrained to a particular more polluted location, without equivalent compensatory access. Thus in interpreting distributions of air quality (or other environmental 'bads') there is a need to consider the wider distribution of costs and benefits.

10.8 Recommendations

1. Our analysis indicates that there is a strong relationship between poor air quality, and social deprivation. The relationship is particularly strong when considering peak pollutant values, including exceedences of air quality standards, and the upper (population weighted) decile of pollutant concentration. Improving air quality where it is worst, should act to reduce this inequality. We therefore recommend that the Agency extend any necessary support to local authorities seeking to meet NAQS objectives through the designation of air quality management areas (AQMA's).

2. There are numerous mitigation measures that can be adopted in AQMA's to reach NAQS objectives. These may include measures that redistribute emissions (e.g. traffic management). We also note that local transport plans (LTP's) include measures which will impact upon air quality. The distributional impacts of these

measures are not widely understood, and there is a need to ensure that they do not produce an undesirable redistribution of pollution to the deprived. We therefore recommend that the Agency, in partnership with local authorities and transport planners, seek to understand the equity implications of AQMA's and LTP's.

3. AQMA's are designated on the basis of exceedence of NAQS air quality standards. However, compliance with a standard does not imply freedom from a health impact. Health impacts can occur at all concentrations (and may have different impacts on different groups), and standards do not adequately address chronic effects. As there is an inequitable burden of air pollution that complies with current standards, there is thus a need to agree on appropriate adverse effect thresholds for use in equity assessment. More generically, there is a need to agree methods for air quality equity appraisal, addressing the issues identified in our report. We therefore recommend that the Agency develop technical guidance on air quality equity appraisal.

4. The Agency should identify critical 'poverty-pollution' areas, and support efforts to improve air quality in these areas. There are various means of identifying these areas (e.g. using different variables and thresholds) hence there is a need here for technical guidance on evaluating inequality in air quality (see 3 above). It is probable that critical areas identified using deprivation plus exceedence data will be addressed by AQMA's. However, this should be verified.

5. In the future, the greatest influence on the changing spatial pattern of air quality, and hence its changing social distribution, is likely to be development, not specific air quality management measures. Therefore, the Agency should promote the inclusion of equity assessment in the appraisal of developments which are likely to impact on air quality. Key partners in this process would include the Highways Agency and planning authorities.

11 OVERALL RECOMMENDATIONS

11.1 Recommendations for Policy and Practice

1. There is an unequal social distribution of pollution and risk, but a very limited knowledge base upon which to develop appropriate responses. As a matter of general policy, the Agency should therefore continue to support efforts to further understand the nature and significance of such distributions, and aim to identify appropriate measures to reduce inequalities which are unacceptable. Reducing inequalities through an overall reduction in environmental burden, not through the redistribution of existing burdens, is a more sustainable approach.

2. There are currently no standard methods for assessing environmental equality. The lack of agreed methods hampers the identification of inequality, and therefore the development of sound environmental equity policy and practice. The Agency should therefore appoint a technical working group on environmental equity appraisal. The purpose of the group would be to develop, in consultation with appropriate stakeholders, strategic guidelines on the appraisal of environmental equity in England and Wales. The guidelines would be used to: (a) support the appraisal of policy and practice within the Agency; and (b) provide a basis from which the Agency can comment on the equity implications of the policies and plans of external bodies.

3. There is a need for more widespread use of environmental equality assessment. Therefore, the Agency should work with government, local authorities, and other appropriate stakeholders to ensure that environmental equity assessment becomes more widely adopted in the environmental impact appraisal process. Wider recognition of equity issues in environmental appraisal may range from developing environmental equity indicators in government sustainability indicators sets, to specific treatment of equity issues in development appraisal (e.g. in Environmental Impact Statements).

4. Environmental inequality can be tackled by specifically addressing those target communities which bear the greatest proportion of environmental burden, and develop appropriate remediation strategies for those areas. Such strategies may tackle existing inequality (e.g. traffic management to improve air quality), or may minimise the imposition of further environmental burdens (e.g. tighter discharge consents; presumption against planning permission for further hazardous facilities etc.). Through the research summarised here, we have made a preliminary identification of 'pollution-poverty hotspots' with respect to air quality and IPC sites. However, our analyses are based on our own subjective assessment of appropriate thresholds. We therefore recommend that the Agency identify critical 'pollution-poverty' areas, based on criteria agreeable to the Agency and its stakeholders (see 2 above), so as to identify those communities most in need of remedial action. Critical areas can be identified with respect to individual and/or multiple risks, and at the national and/or regional level. Possible remediation strategies are best developed following a more detailed investigation of these critical areas.

5. Questions of environmental equity and deprivation are clearly of particular relevance to communities that experience a high burden of environmental 'bads' of various forms. The Agency therefore needs to develop ways of engaging and working with communities in deprived areas to ensure that their local knowledge and viewpoints are included in policy decisions and management measures. This raises questions of procedural equity which sit alongside and interrelate with those of distributional equity on which we have focused in this project.

11.2 Recommendations for Additional Research

We have made specific recommendations for further research for each of the three environmental issues covered in this project. In addition there are a number of more generic research needs:

1. further equity analysis for other environmental variables identified as relevant and important by the stakeholder workshop (see Chalmers 2003);

2. further equity analysis examining variables other than deprivation, making use of small scale output area data of the 2001 census. As the census output areas are now postcode based this would also enable the linking of other datasets such as lifestyle data and house price data;

3. case study equity analyses that focus on particular local communities, examining the net distribution of environmental goods (costs and benefits) experienced in that area. Such studies would seek to identify appropriate remediation responses, and to understand the causes of observed environmental distributions, so as to increase the effectiveness of remediation strategies.

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