

An Investigation into Air Pollution and Health Effects for Residents and School Children within Deprived Areas in Swansea, Wales using GIS Systems

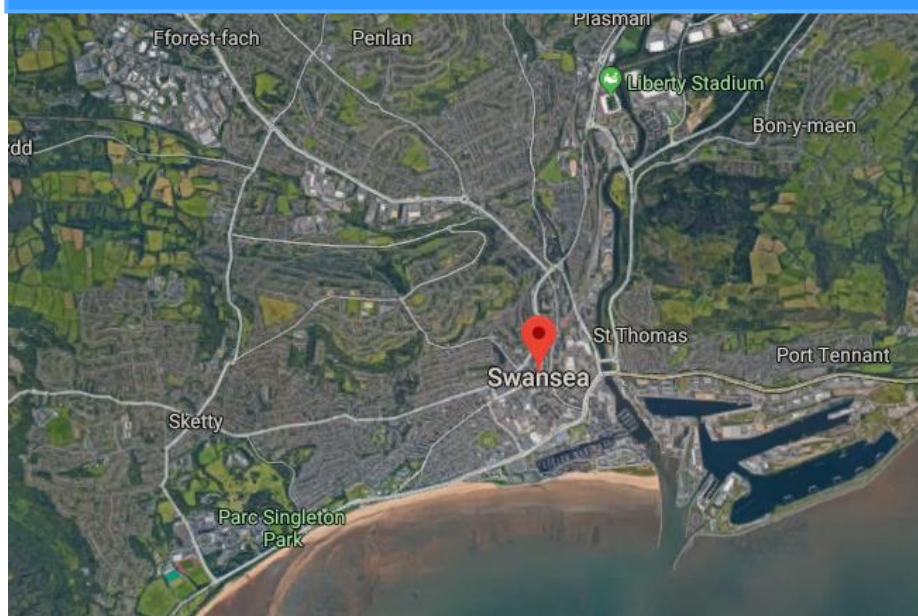


Image: Google Maps, 2019

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1. Introduction

Geographic Information Systems (GIS) /geospatial or geovisual systems provide the capability to view and understand data in a variety of ways through visual presentation (GIS Innovation Centre, 2015) that is inclusive, equitable and comprehensive to a range of audiences (Bailey & Grossardt, 2010). It offers the means to interpret graphic and alphanumeric data that can be complex and inconceivable in traditional forms, however, the data can be subject to bias from the author/interpreter of the data with regards to their objectives or nature of the project (Seguí et al., 2012), especially if data is not relevant or accurate (DeMers, 2009).

Air pollution is one issue that can be mapped using GIS systems. It is said to be the cause of major respiratory diseases, and 4.2 millions deaths globally each year (World Health Organisation, 2019), as a result of primarily particulate matter (PM10 and PM2.5) and nitrogen dioxide (NO₂), but also sulphur dioxide and ozone within ambient air (Table 1) (Department for Environment Food & Rural Affairs, 2019), due to rapid urbanisation, industrial developments and traffic emissions (Al-Zoughool, 2015).

Table 1: Air pollutants and associated health effects

Pollutant	Health Effects
PM10, PM2.5	- Aggravated asthma - Reduces child lung development - Lung cancer (World Health Organisation, 2013)
Nitrogen dioxide	- Reduced lung function - Asthma - Lung cancer - Adverse birth outcomes (Committee on the Medical Effects of Air Pollutants, 2015)
Sulphur Dioxide	- Nausea - Vomiting - Corrosive damage to airways - Skin sores, redness, blisters (Foxall, 2010)
Ozone	- Increase lung susceptibility to infection - Increase asthma attack frequency - Coughing/sore throat - Shortness of breath - Chronic obstructive pulmonary disease (United States Environmental Protection Agency, 2018)

As a collective of nations, the levels of particulate matter and nitrogen dioxide have fallen in the United Kingdom (UK) since 1992 (Figure 1 & 2).

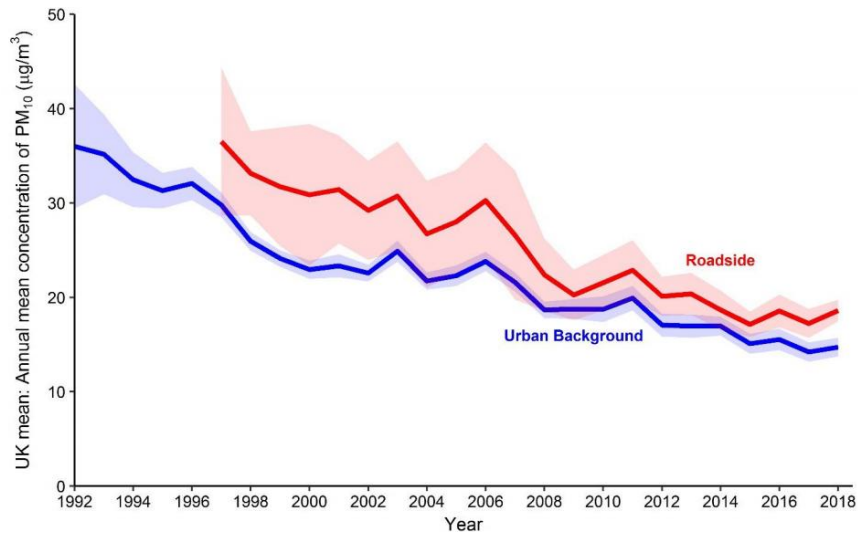


Figure 1: Annual average for PM10 within the United Kingdom (graph retrieved from Department for Environment Food & Rural Affairs, 2019)

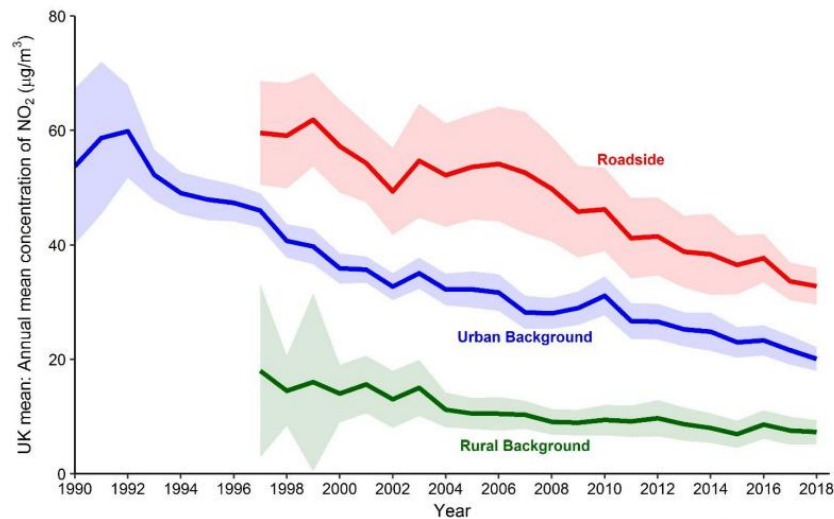


Figure 2: Annual average of nitrogen dioxide within the United Kingdom (graph retrieved from Department for Environment Food & Rural Affairs, 2019)

However, in 2018 the Welsh Government appeared in High Court after illegal levels of nitrogen dioxide were experienced in North and South Wales, and notably the Swansea Urban Area which breached the World Health Organisation recommended limit of 10 toxic particles per cubic metre of air in 2017 (Figure 3) (Hayward, 2018).



Figure 3: British cities that exceeded the World Health Organisation limit of toxic particles per cubic metre of air in 2017 (visual retrieved from Hayward, 2018)

It is estimated that approximately 2,000 deaths occur each year in Wales due to health effects caused by air pollution such as asthma and lung cancer, from which children and residents within “deprived areas” are most at risk (Abernethy, 2018).

Residents within deprived areas are deemed to be at more risk of contracting diseases and experience negative health effects from air pollution, due to increased exposure to pollution through work or proximity of housing, and increased sensitivity to pollution as a result of poorer health due to lesser socioeconomic status (Science for Environment Policy, 2016).

Additionally, four million cases of diagnosed childhood asthma in the UK are a result of traffic pollution and NO₂ (BBC News, 2019). The ongoing development of children’s lungs, as well as developing immune systems and other organs cause them to be more vulnerable to air pollution than adults, as well as other diseases such as bronchitis, reduced lung function, and bacterial pneumonia (Global Action Plan, 2019).

Based on this information, this report will use geographic information systems to investigate the feasibility that residents of deprived areas are more likely to suffer from air pollution, more specifically nitrogen dioxide within the Swansea area. It will also explore the likelihood of childhood respiratory diseases based on the air pollution levels in relation to school location, and its links with deprived areas.

2. Methodology

The investigation was carried out using MapInfo v.16.0, a desktop GIS software, in order to map the air pollution, areas of deprivation and the schools within the Swansea Urban Area.

Data was gathered from the UK Data Service website in order to construct a Townsend Index that could be mapped onto Swansea using “output areas”, also retrieved from the site (Figure 4). The Townsend Index was constructed using Microsoft Excel package that included the following factors that determine deprivation based on lifestyle as opposed to other forms of measuring deprivation such as income (Mack, 2016): economic activity,

vehicle ownership, tenure, and number of beds within in a property. The areas shaded in red present more deprived areas that scored lower based on these criteria, whereas in contrast, areas shaded in green reveal more affluent areas, or those who score higher on the index.

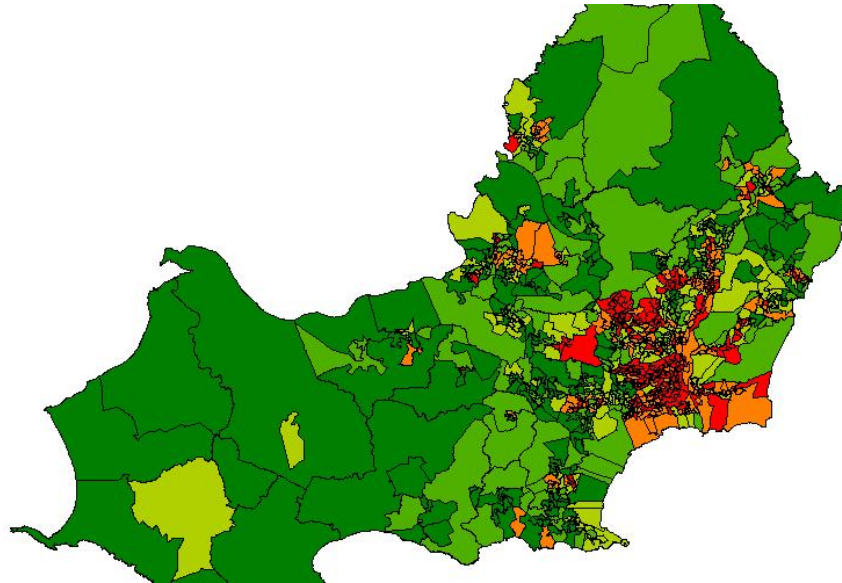


Figure 4: Townsend Index mapped on to Swansea city revealing deprivation levels

Data was also acquired from the Welsh Government website regarding the pollutants and five air quality monitoring stations in Swansea. These stations are presented below in Figure 5 and were used to create “points” on MapInfo, from which would be used to create buffer zones to reveal the levels of pollution around Swansea within deprived areas and the proximity of primary schools.

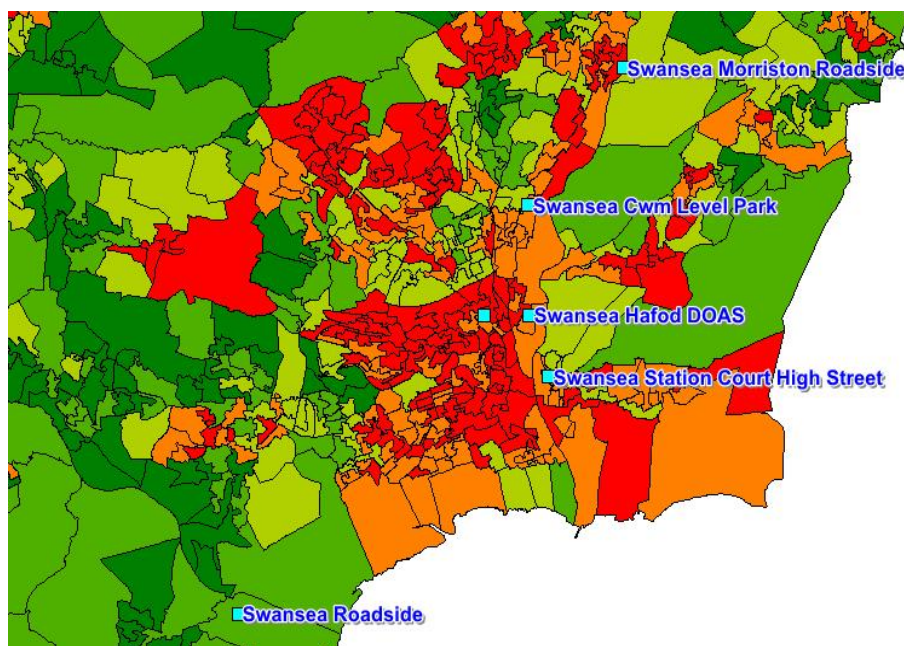


Figure 5: Air quality monitoring stations (expressed by aqua squares and corresponding labels) mapped on to Swansea city

Daily nitrogen dioxide averages were chosen due to consistency within the dataset for Swansea city, as well as contributing to the most harmful pollutants within the UK (Department for Environment Food & Rural Affairs, 2019), especially causing child asthma (BBC News, 2019).

Furthermore, “points” were also created for the fifteen most populated primary schools within the Swansea area (Figure 6), as stated by most recent official Swansea Council List of Primary Schools (2006/2007) (Swansea Council, 2006), whilst considerations were made for closed and merged schools during the time period between 2006 and 2019. These “points” allow for the analysis of air pollution with regards to the school year and deprived areas: proximity (through location), term-time and holidays (averages of pollution were calculated for these time periods). Road maps were also downloaded from Digimap website in order to demonstrate areas of high road concentration, and areas of development/construction which would increase pollution.

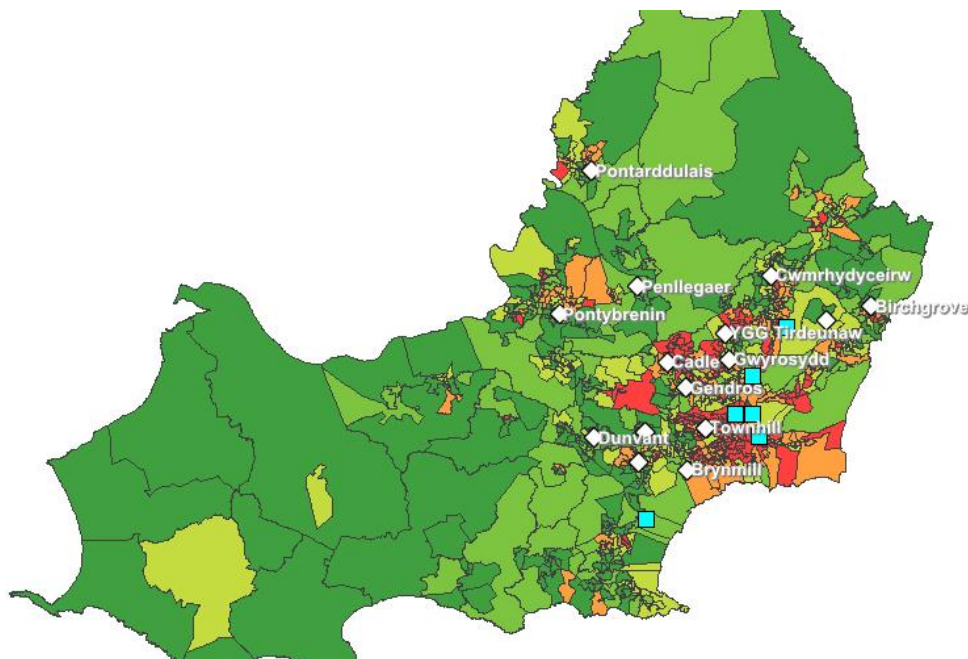


Figure 6: The fifteen most populated schools (expressed by white diamonds and corresponding labels) mapped on to the Swansea area

The air pollution data is restricted to one point due to monitoring stations being situated in one location with one reading per day. From this data, averages were calculated for time periods (school terms, summer, winter etc.), and a radius of 3.5km was set around each monitoring stations, as dispersal rates were not able to be determined. As a result of this, concrete calculations could not be made for the distance of dispersal of pollution for these time periods, and would be affected by factors such as weather, including wind speed, precipitation, and atmospheric pressure (Finnish Meteorological Institute, 2019).

3. Results & Discussion

The previously explained methodology will provide the basis for an analysis of the pollution levels in Swansea and how this affects local residents, namely inhabitants within deprived

areas and school children.

3.1. Areas of Deprivation and Pollution

Air pollution is said to be higher in areas where there is higher activity, for example city centres that consist of more roads, housing and industry (Care4Air, 2019). In the majority of cities, this is where the highest levels of deprivation exist, especially within Wales (Abernathy, 2018), and this is also the case within Swansea (Figure 7).

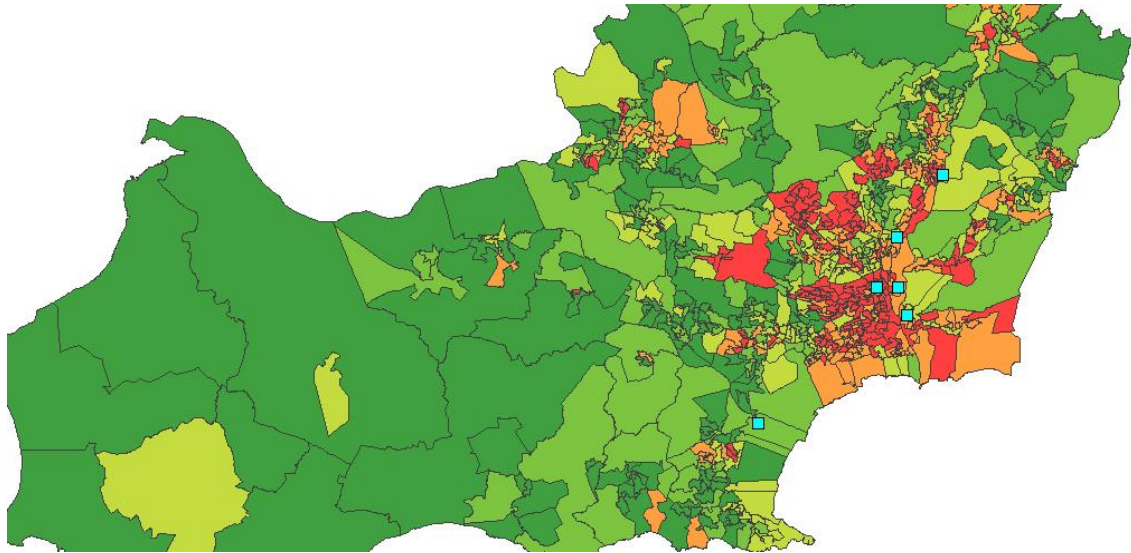


Figure 7: The levels of deprivation concentrated within the city centre of Swansea, where the majority of air quality monitors are also located

The positioning of the monitors (expressed by aqua squares) indicates that these areas are those where monitoring is necessary (most polluted), which also corresponds with the areas of deprivation (highlighted in red according to the Townsend Index), suggesting that deprived areas experience higher levels of pollution.

However, it could be argued that the results would not present an accurate representation of pollution levels, as the monitors are not evenly distributed throughout the city, leaving both deprived and more affluent areas in northern and western parts of the city excluded from data due to the lack of monitors.

That aside, the time year, can reveal that the deprived sections of the city centre experience higher levels of pollution than more affluent areas located further away from the centre in both winter and summer in Figures 8 and 9.

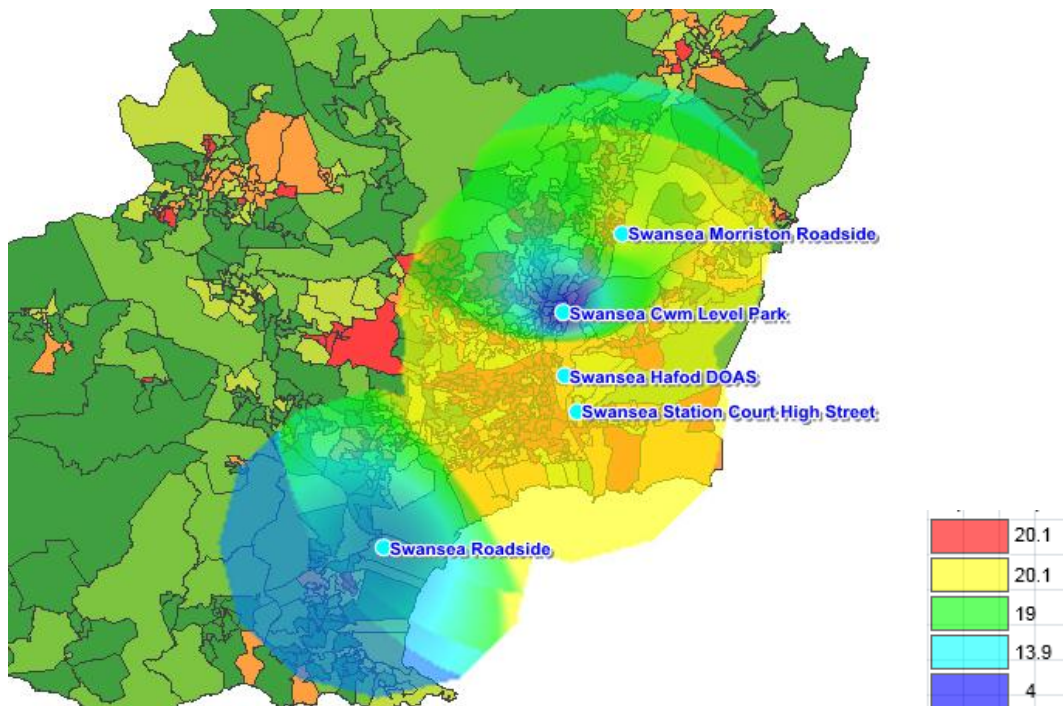


Figure 8: Nitrogen dioxide levels across the city centre on 1st January 2018 (winter)

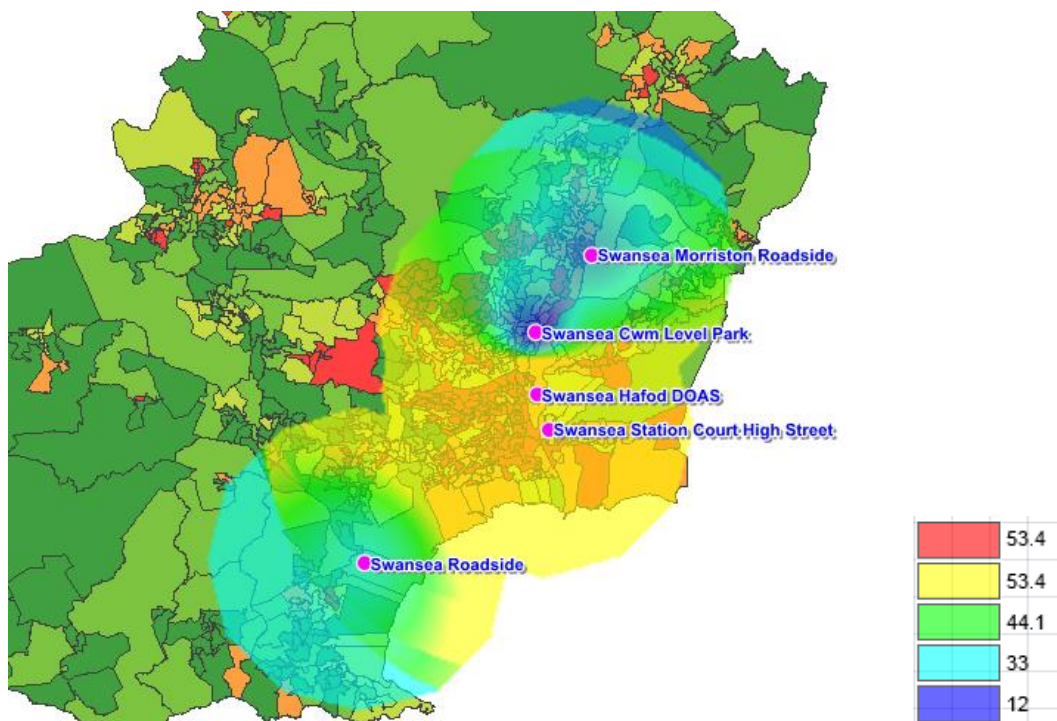


Figure 9: Nitrogen dioxide levels across the city centre on 1st June 2018 (summer)

Additionally, Figures 8 and 9, the pollution levels within the middle of summer extended into the western areas of the city (represented by the change from blue into green and yellow nearest the Swansea Roadside monitoring station), notably the Mumbles area. Given the time of year, this could be due to increased traffic to tourist destinations such as west Swansea, and the dramatic increase and prolonged high temperatures of summer 2018

within the UK, as it was described as “warmest summer since 2006, the driest since 2003 and the sunniest since 1995” (Kalnay, 2018), highlighting that the lack of wind and precipitation, as well as high pressure prevented the dispersal of pollution (Finnish Meteorological Institute, 2019). Furthermore, tourism brings additional people into the city, as Swansea is the last major city before reaching West Wales, the Gower and the Pembrokeshire coastline, which could also account for the increase in pollution levels within deprived areas acting as a thoroughfare.

These high levels in the centre and the increase within the summer is confirmed by looking at the difference of pollution between winter (1st January) presented in aqua, and summer (1st of June) presented in fuschia, specific to each monitoring station (Figure 10). The stations located in areas that are represented as having the highest levels of deprivation by the Townsend Index (shaded in red): Swansea Hafod DOAS, Swansea Station Court High Street, experience a more dramatic increase in pollution levels in the summer, and a higher level of pollution in total all year round, in comparison to other stations such as Swansea Roadside which is located in a less deprived area.

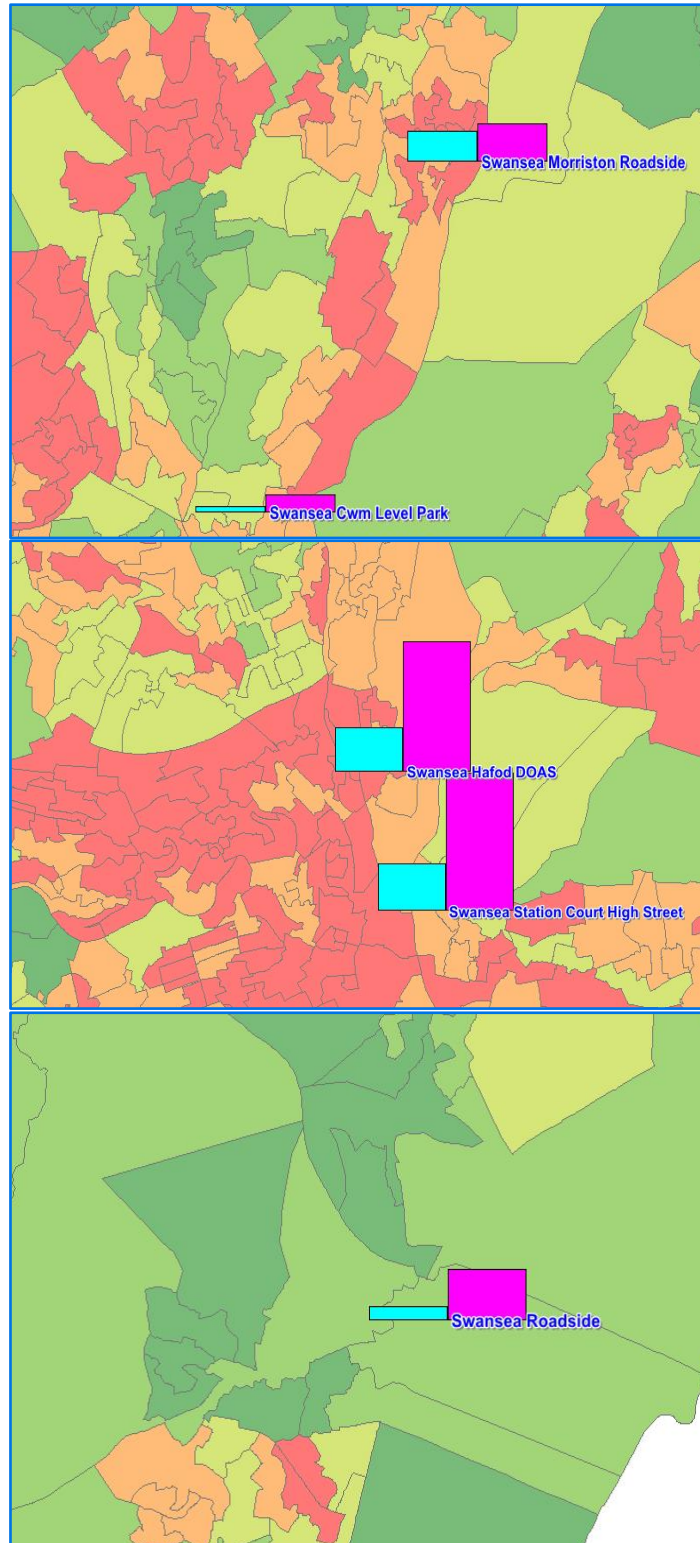


Figure 10: The difference in nitrogen dioxide levels at each monitoring station in Swansea for 1st January (aqua) and 1st of June (fuschia)

Other disparities among polluters and recipients can be demonstrated through the analysis of lifestyles. For example, the quantity of people/households that possess vehicle/s are more likely to be those living in more affluent areas, leaving those in more deprived areas without

vehicles subject to pollution caused by traffic, that is not a direct result of behaviours by the inhabitants of these areas (Figure 11).

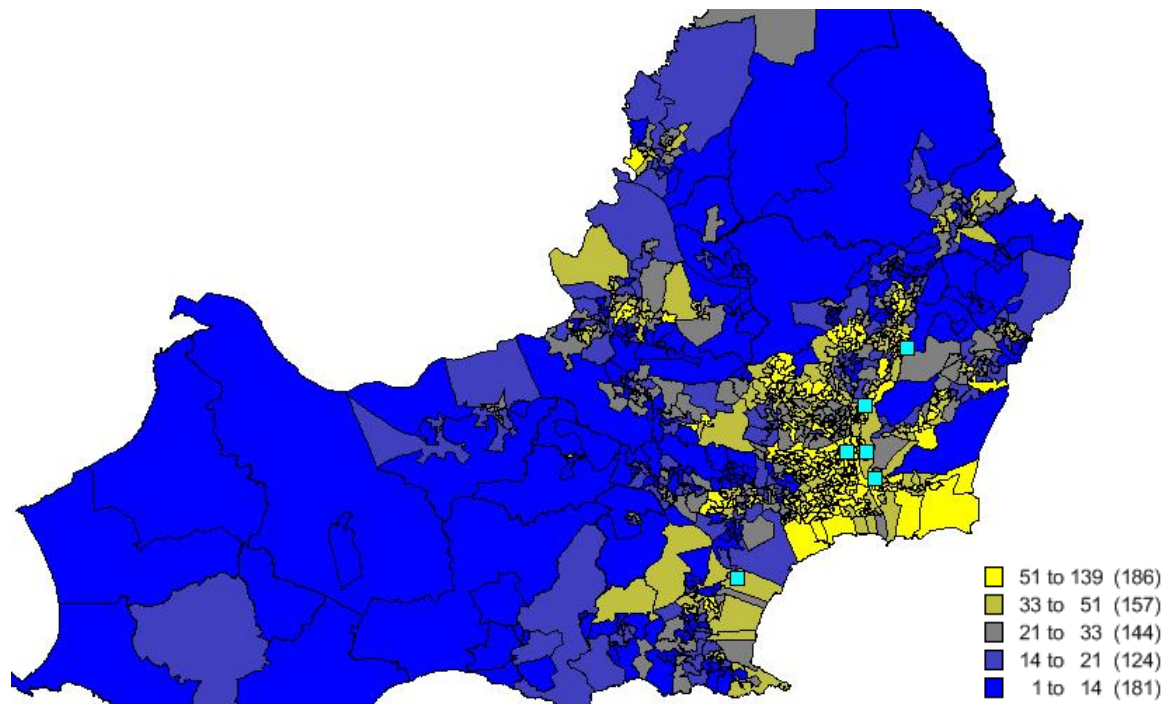


Figure 11: Areas corresponding to the number of households that do not own a vehicle

The deprived areas as shown in Figure 4, correspond with the areas that consist of the highest quantity of households that do not own a car in Figure 11 (shaded in yellow), yet as previously demonstrated, these are those that suffer the highest levels of air pollution throughout the year. This indicates that car owners are contributing to pollution in other areas due to, assumingly, work and facilities found in city centres (shopping, leisure centres, eateries etc.) where inhabitants of more deprived areas are located.

This representation could highlight to local authorities potential emissions reducing strategies in deprived areas such as vehicle restrictions, or present the necessity of improved public transport in order to reduce the number of personal vehicles within the city, especially with regards to extending routes out to suburbs, which would improve relieve the pollution and improve the air quality for those who live in the city centre.

Additionally, these demonstrations also indicate that this would affect school children within more deprived areas where the higher levels of pollution exist within Swansea city.

3.2. Primary Schools and Pollution

In the UK, school (primary) admissions are dependant upon catchment area in the majority of cases. However, exceptions include religion, special needs support, sibling attendance, entrance exams or feeder schools (Swansea Council, 2019), which can determine school commutes, and attendance at school in a different area to home. School consumes around 25% (six hours) of a child's day (not including commute), which suggests that the risk of

being exposed to pollution could increase for a significant part of a child's everyday life, if the school is not located in an area of "low" pollution.

As mentioned, the dispersal of pollution in Swansea is undetermined in this study, and as the monitoring stations are located mainly within the city centre, this does not give an accurate representation of pollution around schools outside of the centre, similarly to the deprived areas that are located outside of the centre.

The likelihood of child exposure to air pollution could come from both the location of the school in relation to highly polluted areas (as previously demonstrated more prominently, deprived areas), as well as the location of schools in proximity to major developments causing pollution events, which increases the risk of respiratory diseases such as asthma.

A comparison between the school holidays and school term can demonstrate the differences in pollution, and the difference between areas of deprivation and more affluent areas. For example, during the first half of the winter term (1st of January to 8th of February) pollution levels, as expected, are higher in the city centre (deprived areas), where six primary schools are located (expressed by white diamonds in Figure 12). Whereas less pollution is experienced in schools located within suburban areas, such as Cwmrhydyceirw.

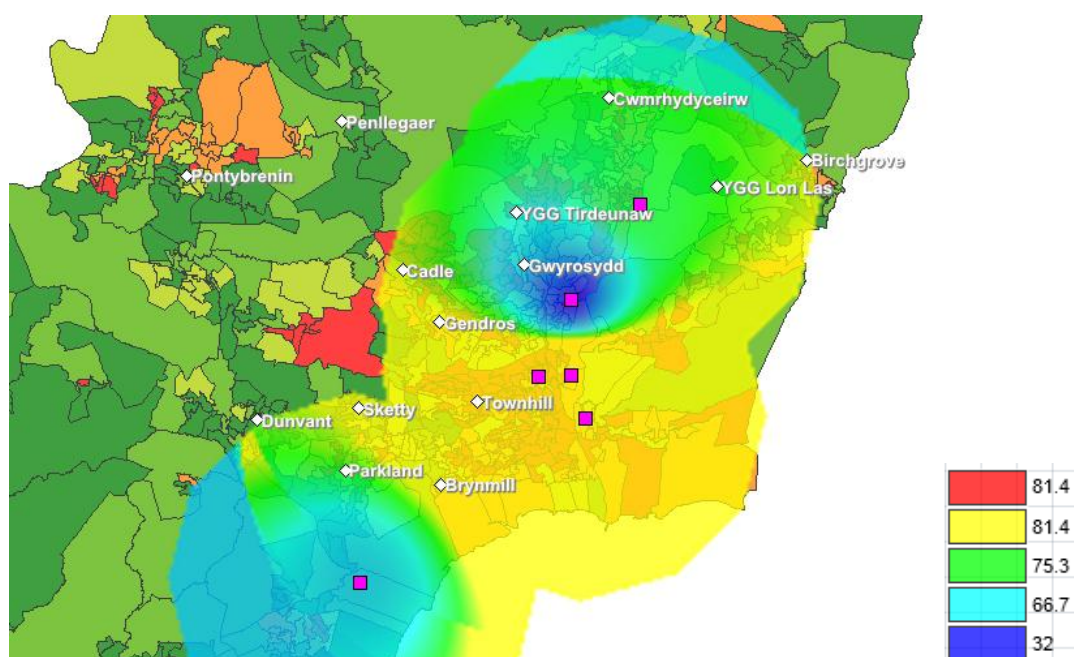


Figure 12: Average pollution levels within the proximity of primary schools within Swansea city for winter term between 1st January and 8th February 2018.

This is also the case during winter half term (9th February to 16th February 2018), however the pollution levels are much higher (Figure 13, reference key). It may be expected that pollution levels are higher during working weeks and school weeks due to commuting traffic and continually high activity, but it could also be argued that during holiday time the number of people taking time off work for childcare increases, consequently increasing pollution levels in areas where there are facilities such as the city centre, as well as public celebration days such as valentines day, or even sporting events such as the Six Nations rugby tournament which was held between 3rd February and 17th March 2018 – explaining the

higher levels of pollution during half term, based on the averages for this period.

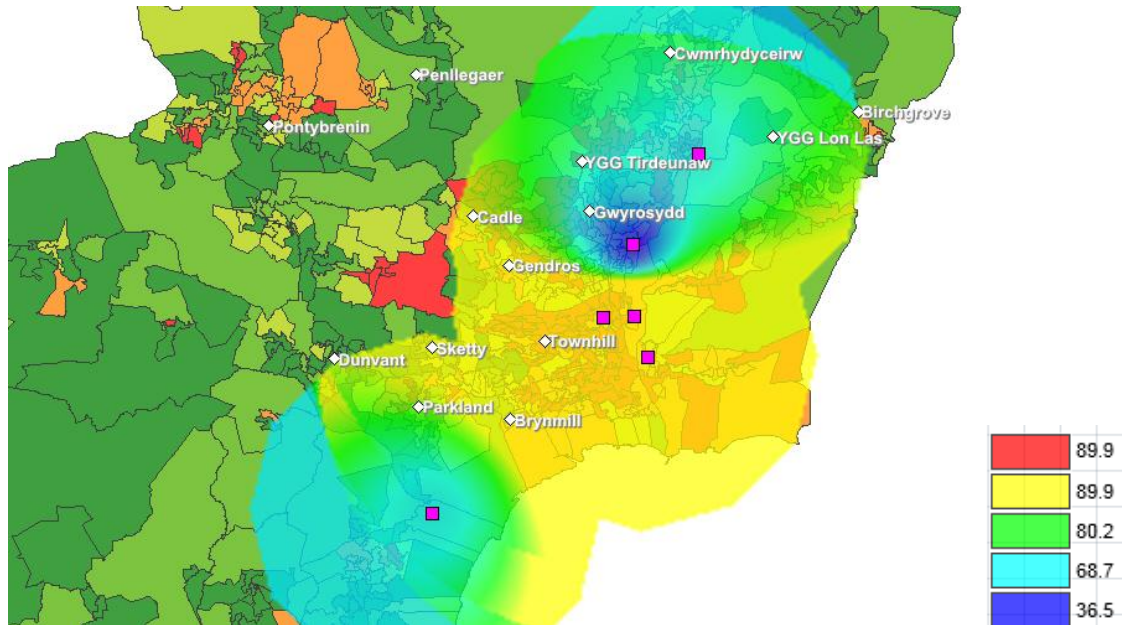


Figure 13: Average pollution levels within the proximity of primary schools within Swansea City for winter half term 9th February to 16th February 2018.

Based on these results, it appears that even during what could be expected periods of lower levels of pollution, deprived areas within the city centre (from which it can be assumed that children within the catchment areas of the primary schools suffering high pollution reside close by) experience consistently higher levels of pollution than suburban areas of the city throughout the year.

Additionally, the concentration of roads within deprived areas, and the city centre is much higher than other areas located away from the centre (Figure 14). Due to an increase in accessibility for cars, this implies that more cars will utilise the area and therefore increase pollution levels, again causing residents and schools children to suffer higher levels of pollution than other areas in the city.

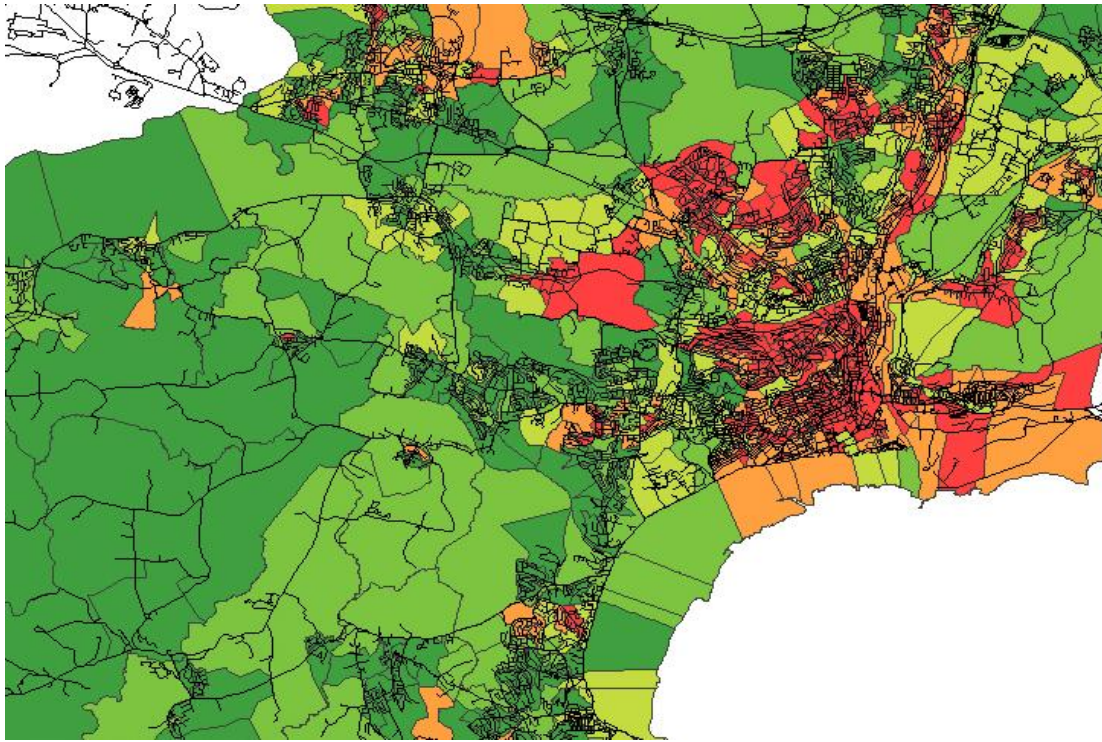


Figure 14: Concentration of roads around Swansea: the city centre having the highest concentration.

Furthermore, effects of pollution events or developments such as road developments, for example, the Kingsway road between May 2018 and autumn 2019 (Swansea Council, 2018) can influence pollution levels around primary school as well as in deprived areas. Highlighted in purple in Figure 15, the Kingsway is located in a deprived area, as well as in close proximity to two primary schools: Townhill and Brynmill, indicating that construction works in this area will increase pollution levels within the immediate area having an affect on primary school children and increasing the risk of developing respiratory diseases such as asthma.

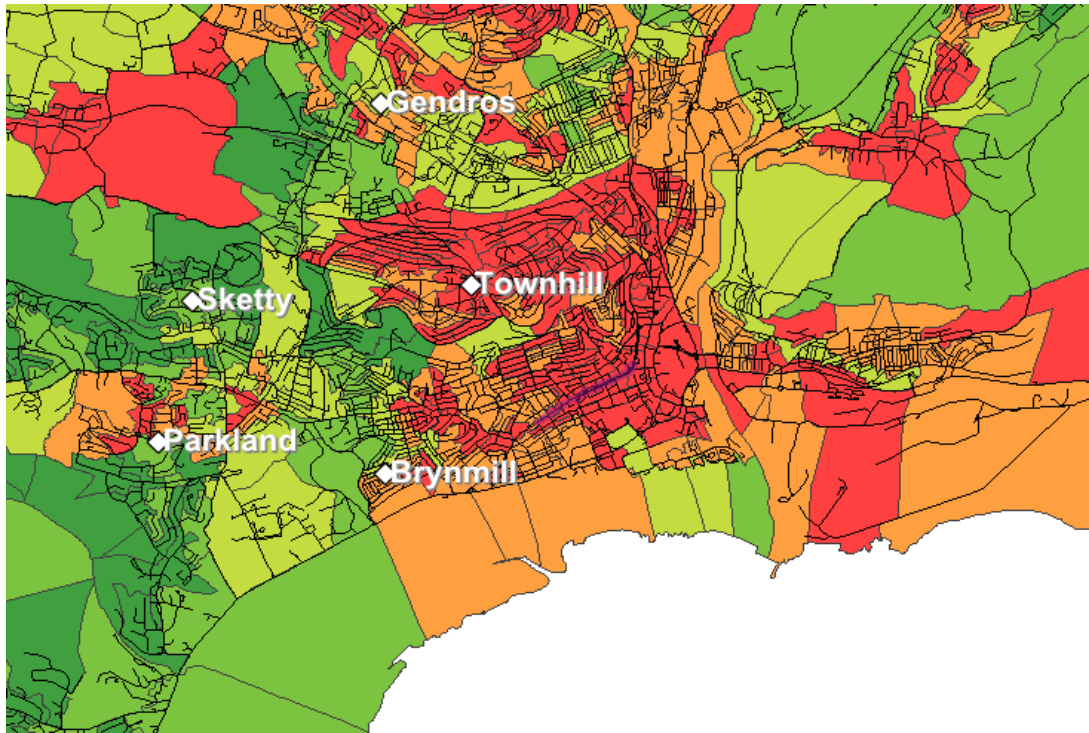


Figure 15: The Kingsway road (highlighted in purple) located in a deprived area as scored by the Townsend Index, within the proximity of two primary schools

Figure 16 presents two primary schools experiencing considerably higher levels of pollution based on the nearest monitoring stations, the second Monday of April and May were used in order to represent a similar time-period and day within the month, as well as include a “working” day when construction is likely to be carried out.

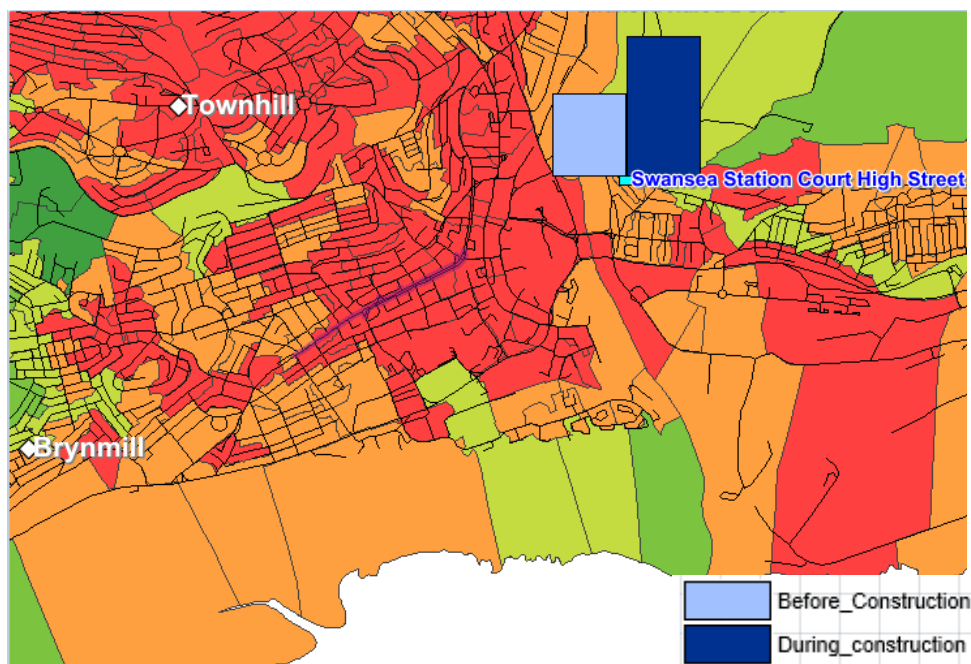


Figure 16: Pollution level increase at monitoring station closest to Kingsway (purple) during construction of new road development

After a number of construction projects had been completed (14th May 2018), including pavement installation, road and junction changes (Swansea Council, 2018), the pollution levels being recorded at Swansea Station Court High Street monitoring station (nearest the primary schools and the development), were significantly higher in comparison with pollution levels before the Kingsway construction works, (Monday 16th of April). This highlights that developments increase pollution within immediate areas, in this case in the deprived areas, affecting children during school time and at home, based on the assumption of catchment areas, as well as residents.

The previous findings suggest that there is a strong correlation between the levels of pollution suffered in deprived areas and primary school children, as it can be assumed that catchment areas would include the immediate surrounding localities. The findings also suggest that due to the location of monitoring stations, the deprived areas are found where the activity is the highest and therefore suffer the highest pollution levels, which can in turn affect the health of residents and primary school children, consequently causing respiratory diseases. This also confirms that having high levels of air pollution contributes to poorer health as a result of lesser socioeconomic status.

This representation could aid decisions of school selection based on the increased risk of suffering negative health effects due to pollution levels. It also confirms that inhabitants within deprived areas are at more risk of contracting diseases due to increased exposure especially for those who are most vulnerable (children) (Science for Environment Policy, 2016), as catchment areas would suggest young residents are experiencing pollution both at school and at home.

4. Conclusion

Geographic Information Systems can aid the representation of data in a way that is comprehensible to a range of audiences, including for globally debated topics such as air pollution.

In this case study, levels of deprivation have been presented using buffer zones to demonstrate the disparity among society with regards to suffering air pollution as a result of location. Deprived areas within the Swansea area suffer higher levels of pollution which could in turn contribute to poorer health as a result of lesser socioeconomic status. Additionally, it appears that whilst traffic is one of the main factors to increasing pollution within an area, those in deprived areas are less likely to own/have regular access to a vehicle, highlighting that the source of pollution comes from those outside of deprived areas.

Furthermore, buffer zones have been used to demonstrate the levels of pollution in the proximity of primary schools in order to highlight the potential effects that could be caused due to high numbers of young pupils accessing such areas for prolonged periods of time. It is also evident that primary schools in the city centre/deprived areas within Swansea are subject to higher levels of pollution than primary schools in the suburbs, or those located further away from the city centre. This indicates that the location of these schools (being within the catchment area for those in deprived areas) contribute to the higher levels of pollution being inhaled by primary school children (as well as older residents), and

consequently increase the risk of children contracting respiratory diseases.

These systems can be used as a way to analyse the current situation with regards to air pollution within cities and act as an effective tool for authorities to implement strategies to protect human health. For example, building schools outside of renowned areas of high pollution, initiating vehicle-use restrictions in deprived areas and in areas of high activity, as well as improve public transport to reduce the number of vehicles in the city.

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