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ASSESSING THE PERCEPTION AND REALITY OF ARGUMENTS AGAINST THERMAL WASTE TREATMENT PLANTS IN TERMS OF PROPERTY PRICES

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Abstract

The thermal processing of waste materials, although considered to be an essential part of waste management, is often sharply contested in the UK. Arguments such as health, depletion of resources, cost, noise, odours, traffic movement and house prices are often cited as reasons against the development of such facilities. This study aims to review the arguments and identify any effect on property prices due to the public perception of the plant. A selection of existing energy from waste (EfW) facilities in the UK, operational for at least 7 years, was selected and property sales data, within 5 km of the sites, was acquired and analysed in detail. The locations of the properties were calculated in relation to the plant using GIS software (ArcGIS) and the distances split into 5 zones ranging from 0-5 km from the site. The local property sale prices, normalised against the local house price index, were compared in two time periods, before and after the facility became operational, across each of the 5 zones. In all cases analysed no significant negative effect was observed on property prices at any distance within 5 km from a modern operational incinerator. This indicated that the perceived negative effect of the thermal processing of waste on local property values is negligible.

Keywords: energy from waste; thermal waste treatment; public perception; property prices

1. Introduction

Thermal waste processing with energy generation (electrical and heat) is seen as a sustainable and effective solution to both waste management and energy generation (Cheng and Hu, 2010; Institution of Mechanical Engineers, 2007; Jamasb and Nepal, 2010; Michaels, 2009; Murphy and McKeogh, 2004; Papageorgiou et al., 2009; Porteous, 2005; Porteous, 1998; Burnley et al., 2011; Haley, 1990). However, these plans are often fiercely contested by anti-incinerator groups and local residents (Jamasb and Nepal, 2010; Porteous, 1998; Achillas et al., 2011; DEFRA, 2007; Furuseth and O'Callaghan, 1991). The main protests against these facilities are related to perceived health risks, the effects on house prices and noise, smell and increased traffic (Achillas et al., 2011; Friends of the Earth, 2000; British Society for Ecological Medicine, 2008). The effect on recycling rates, depletion of resources and the effectiveness of alternative waste management solutions are also cited as reasons against such treatment options (Friends of the Earth, 2000).

Previous studies and reports largely agree that the health risks from modern thermal waste processing plants, especially increased cancer incidence related to dioxin emissions, are very small (Institution of Mechanical Engineers, 2007; Porteous, 2005; Porteous, 1998; HPA, 2009; Health Protection Scotland, 2009; DEFRA, 2004). Indeed, the reported emissions from modern facilities are significantly lower than the limits prescribed in the Waste Incineration Directive [2000/76/EC], and is considered to be “the most strictly controlled combustion process in the UK” (Porteous, 1998).

Energy from Waste (EfW), specifically Mass Burn Incineration (MBI), is widely seen as an essential part of an integrated waste management solution but the primary constraint on the widespread uptake is the negative perceptions of politicians and the public. The justification is put down to the historic memory of “dirty” incinerators of the past, but this study will demonstrate that this is no longer the case with modern incinerators "being the natural companion to practicable recycling" (Porteous, 1998).

Incinerators have a chequered history with a large negative hang over from the dirty polluting plant of the 1970s. Opposition groups range from International, such as the Global Anti Incinerator Alliance (GAIA); National, such as the United Kingdom Without Incineration Network (UKWIN) and local groups, such as the Cheshire Anti Incinerator Network (CHAIN), Guildford Anti Incinerator Network (GAIN) and Hatfield Anti Incineration (HAI). Friends of the Earth and Greenpeace are vocal opponents of incineration and actively support local groups through publications such as "How to Win: Campaign Against Incinerators" (Friends of the Earth, 2000). These groups often vary between a genuine concern for the local area and a visceral, often illogical, abhorrence of incineration on ideological grounds.

2. Arguments against incineration

There are a number of offered disadvantages of EfW facilities, which includeair pollution and health, effects on climate change and the destruction of valuable resources, toxic waste generation, noise and traffic, and poor public perception.

2.1. Air pollution and health

Health is a much cited argument against incineration. The public are very conscious of the perceived health risks, for example a study in Greece found that 43% of respondents cited health issues when asked for reasons to protest against a new incinerator (Achillas et al., 2011).

Anti-incinerator groups widely cite a report by the British Society for Ecological Medicine (2008), a charity aimed at promoting public health, as reference to the health impacts, which discusses several negative health effects of such facilities through the release of dioxins and particulates. However this report was widely rebuked by the Health Protection Agency (2005) and Enviros (2006) for using “inaccurate and outdated material” (Enviros, 2006) and confusing the issues of health impact and risk, especially with relation to alternatives to incineration.

The main thrust of opposition is related to the emissions of dioxins, a family of cancer causing compounds. Many processes produce dioxins and it is important to put the emissions from a modern incinerator in context. Table 1 shows the comparative amounts of dioxins produced by other processes from sinter plants to domestic coal combustion. As can be seen a modern EfW plant produces around half the dioxins as a coal power plant and less than 4 times that of domestic wood combustion. .

>>>>>>Insert Table 1<<<<<<

The Institution of Mechanical Engineers describes the dioxin emissions limit for a modern EfW plant as “an equivalent concentration to one third of a sugar lump dissolved in Loch Ness” (Institution of Mechanical Engineers, 2007). Elliot et al. (2000) places the increased risk of cancer within 1 km of an EfW facility to be between 0.53 and 0.78 cases per million. Roberts and Chen (2006) state the overall risk of dying due to emissions within 5.5 km of a facility to be 2.49 x 10^{-7} or 1 in 4 million. This is compared to 10 cases of melanoma per 100,000 (from sunbathing/sunbed use) and 15,000 people a year which die from bowel cancer (which is mainly diet related) (Porteous, 1998) .

2.2. Effects on climate change and the destruction of valuable resources.

Energy from Waste proponents often report that incineration of MSW is carbon neutral (Jamasb and Nepal, 2010; Porteous, 1998). This is due to the mainly biodegradable component of the waste and the offsetting of green house gas (GHG) emissions from landfill and fossil fuel based electricity generation. For example, one tonne of waste incinerated instead of sent to landfill reduces emissions of carbon dioxide by 1.2 tonnes (Jamasb and Nepal, 2010) and electricity generated can offset 686g CO_2 kWh^{-1} for coal and 261g CO_2 kWh^{-1} for natural gas (Porteous, 1998).

Papageorgiou et al. (2009) modelled the greenhouse gas (GHG) emissions from the incineration of waste, critically including emissions from transport. The study concluded that without combined heat and power (CHP) the plant can contribute 3.93kg CO_2 per tonne of waste, although with CHP, coupled with district heating, a reduction of 148.02 kg CO_2 per tonne of waste can be obtained. Cleary (2009) reviewed a range of published studies and concluded that recycling will often be more favourable, in terms of Carbon footprint, where the processing of raw materials is avoided. As such it is important to consider the boundaries used within a lifecycle assessment.

In the case of resource depletion, this is discussed with respect to recycling and resource recovery. However the case that incineration undermines recycling rates is widely disproved in the United States and across Europe, with countries and states that accept incineration also having higher recycling rates (Michaels, 2009; Porteous, 2005; Berenyi, 2008; Kiser, 2003).

Whereas recycling saves considerable energy for aluminium, steel and glass this cannot be said of plastics, as the energy inherent in the material can be better exploited through energy recovery, especially when transport and sorting are taken into account (Lea, 1996). The case for reducing waste is accepted across the board however the economic and practical issues of such widespread change is a barrier to implementation.

Therefore it is fair to say that recycling should not be automatically chosen above incineration if the energy used and carbon emitted to recycle the waste is more than could be generated and offset by incineration (Institution of Mechanical Engineers, 2007; Porteous, 1998).One could conclude that neither recycling nor incineration represent the complete solution to sustainable waste management, and should perhaps be considered together as part of a joint solution.

The full lifecycle of materials contained within residual waste streams needs to be considered along with the Carbon costs of recovering value (recycled material or energy) before a decision can be made on the most favourable option. This needs to take into account the biogenic fraction of the residual waste along with the fossil-derived fraction, such as plastics.

2.3. Toxic waste

The use of the term "toxic waste" from incinerators is an attempt to associate the process with the negative stigma of chemical and nuclear plants. The waste products from an incinerator are in two classes, bottom ash and fly ash. Both of which require careful management to ensure minimal impacts on the environment. Bottom ash is the larger of the two waste streams with 1 tonne of MSW producing typically 0.25 tonnes of bottom ash (Porteous, 2005). This bottom ash is chemically inert and is commonly used as a road building substrate (Porteous, 1998). In the case where stable bottom ash is used as a road aggregate, the leaching properties have been reported to be environmentally acceptable for use (Toraldo *et al.* 2013). The fly ash is a small proportion, typically 40 kg per tonne of MSW, and is termed hazardous waste, due to the levels of volatile heavy metals including cadmium and mercury. The ash is currently disposed of in dedicated hazardous landfill; the fly ash is often treated through solidification/stabilisation processes prior to disposal and so leaching from the landfill into ground water is minimal (Lui *et al.* 2013).

2.4. Noise, traffic and visual impact

The noise, traffic and visual impact are usually citied with respect to some health concerns, i.e. particulates from lorry traffic, but also with the effects on local house prices. The most widely cited studies of the economic impacts on house prices are by Kiel and McClain (1995a; 1995b). They have published two studies on the effect of an EfW plant, built in 1985 in North Andover, Massachusetts, USA, on local house prices.

Keil and McClain (1995a) attempted to model the impact of the EfW plant using the hedonic pricing method. The study was concerned primarily with assigning a cost associated with distance to the incinerator over 5 time periods from 1974 to 1992.

They found that each time period had a different impact on the local house prices, with the construction phase amounting to a cost of $2283 within the first mile (distance from the incinerator), the on-going operation at $6607, rising to a peak of $8100 during the online, early operation, stage.

Kiel and McClain (1995a) found that the negative effect of the incinerator was only found within three-quarters of a mile (1.2 km) from the incinerator. However properties further from the incinerator benefited from an increase in the house prices up to a maximum distance of approximately 3.5 miles (5.6 km). This premium was found to persist at least 7 years after the facility started operating (Kiel and McClain, 1995a) .

Kiel and McClain followed up the study with another on appreciation rates (Kiel and McClain, 1995b). In this study they used the same area of North Andover, Massachusetts, USA and applied two different approaches, an income capitalisation model and repeat-sales technique. In this study they found similar results to the previous work with reducing distance to the incinerator leading to a decrease in house value.

The Centre for Economics and Business Research (CEBR) (2003), produced a report into the economic impact of an EfW in Newhaven, UK. Along with using the Kiel and McClain (1995a) model and a DEFRA landfill study, a separate analysis was carried out on 10 incinerators in England and Wales. The results showed that house prices were around 18% lower closer to the incinerators and increased with distance. These studies demonstrate properties close to an Energy from Waste plant are subjected to a negative cost due to a local disamenity,

2.5. Public perception

The review of anti-incineration groups and the arguments used would suggest that the public is widely against the use of incineration as part of a waste management strategy. However, surveys indicate that only 13.3% of US residents (Furuseth and O'Callaghan, 1991) and 6% of UK residents (Bredee and Georgeson, 2011) are generally opposed to the use of waste incineration. “The public is not as opposed to incineration as people might think” (Achillas et al., 2011).

Although this is not the whole story, as when respondents were asked about siting an incinerator in their local area the survey results highlighted a different effect, with 68.9% (US) (Furuseth and O'Callaghan, 1991) and 23% (UK) (Bredee and Georgeson, 2011) opposing such schemes. These results demonstrate that the public's perception of the technology is independent of the location of such facilities. This is commonly described as the NIMBY (Not In My Back Yard) effect and is generally cited with reference to any large industrial construction in local areas.

Public engagement is of paramount importance when encountering opposition to planning. Bull et al. (2010) produced a case study of two incinerators built by the same company in different areas and with different council cultures with respect to the engagement process. Their results clearly demonstrate that fairness, compatibility, awareness and impact on the decision process produced a more positive outcome.

Compensation schemes are used by waste companies to help with public engagement. A recent survey into the attitudes to community buy-in by SITA UK demonstrated that 71% of people surveyed would be happy to accept a new facility if there was a compensation scheme, which is higher than the 58% that would support a waste treatment facility in their local area without compensation (Bredee and Georgeson, 2011). Although without a universal measure into the disamenity the level compensation would be subjective and is often seen as a bargaining tool by local residents (Snell, 2012).

It can be summarised that there is a widespread campaign against incineration based on health, economic and ideological grounds that can be seen to influence the public perception of such facilities.

This study aims at building on the existing knowledge by assessing the effect of the public perception of thermal waste treatment plants on local neighbourhoods in terms of property prices.

3. Method

A list of all operational EfW plants in the UK was compiled and parameters such as location, size, local area type, operation date, planning date and distance to the closest dwelling were collated. Data was to be sourced for at least 7 years after the plant became operational, as Kiel and McClain (1995a) suggested that an impact was seen at least to this time frame, and for a couple of years before planning was announced as a baseline for comparison.

The data was sourced from the Land Registry price paid dataset as their data was considered to be the most comprehensive, reliable and commercially available in the UK. A constraint of using this data were the options available to obtain data by a geographical area and the absence of detailed property information, for example size and number of bedrooms. It was not possible to directly obtain sales records within a set distance of the location of an incinerator, as data could only be searched based on Local Authority, District, Postcode District or Region. Therefore, using GIS software (ArcGIS), the postcode districts surrounding the short listed plants were identified.

The postal districts were analysed by the proximity to the plant, surrounding geographical features and number of postcodes within the districts in a 5 km radius of the plant. For example SO40 was chosen as the only relevant postal district in the area around Marchwood EfW as it was the only district to have properties within 1km of the plant. The postal districts on the opposite shore of Southampton Water were discarded as the sea was considered a buffer to the effects of the incinerator. A preliminary search was then carried out to find the total number of property sales records in the selected postal districts between 1st January 1998 and 30th June 2012

(Table 2).

With respect to practicality of the data sets, three incinerators, Marchwood, Chineham and Kirklees, where chosen out of the short list of six (Table 2) which resulted in 49,299 records. The Newlincs facility was discounted due to the relatively large distance from the nearest dwelling. Marchwood and Chineham were chosen over the Sheffield and Portsmouth facilities as these allowed an insight into two significantly different locations (coastal industry and rural respectively), Additionally Marchwood is closer to the nearest houses development than the Portsmouth EfW (also coastal industry) and so was regarded as more appropriate for this study. The Kirklees facility, along with the Sheffield EfW is based in a city, however Kirklees is significantly closer to the nearest domestic dwelling over a wider area, and has been in operation for longer.

Once the property sales data had been obtained it was necessary to find the distance from each property to the incinerator. This was done using GIS software (ArcGIS) and the Code-Point® Open postcode data. The distance from each postcode to the incinerator was then converted into 1 km zones, for example properties within 1 km of the incinerator were assigned to zone 1, between 1-2 km to zone 2 etc.

>>>>>Insert Table 2<<<<<<

To compensate for the fluctuations of property prices and inflation over the period, each sale price was divided by the local house price index, also obtained from the Land Registry, for the month the sale took place.

As detailed information on the property sales, such as number of bedrooms, house and garden size etc. was not available with the Land Registry dataset, it was not feasible to construct a model using the hedonic pricing method as with the previous Kiel and McClain (1995a; 1995b) studies. Therefore a statistical analysis of the effects of distance, sale price and operation of the incinerator was designed.

To provide a robust comparison it was necessary to determine properties that had been sold prior to the operation of the facility and also after the plant became operational to ensure that the analysis was based on a like-for-like approach. The postcode and property name/number were used to produce a unique property identifier. This identifier was then used to match sales for each property before and after the operation of the incinerator in each location. Where a property had sold more than once during a single period the earliest sale was used.

Properties that were sold as leasehold were excluded from the analysis as the effect of lease duration was not possible to be identified. Due to the large dataset and complex matching, the data was manipulated using database software (MySQL).

A total of 3,458 matching pairs, indicating the same property sold before and after the incinerator was operational, were found across the three locations (Table 3). To reduce the residuals the natural log of the prices sold in each pair, before and after, divided by the index, was calculated. A repeated measures factorial ANOVA statistical analysis was carried out on the data, with zone as an independent variable, using statistics software (Statistica 11).

>>>>>Insert Table 3<<<<<<

4. Results & Discussion

The results of the statistical analysis are shown in Figures 1-3. To provide an equal comparison, only results up to 5 km are shown as this was the maximum distance of properties found in the Kirklees analysis. The primary hypothesis, as detailed previously, suggested the operation of the plant will reduce the sale prices in the local area closest to the facility. However none of the incinerator locations demonstrated a statistically significant ($p < 0.05$) decrease in property prices after operation of the plant with regard to distance up to 5 km.

>>>>**Insert Fig 1.**<<<<<<

>>>>**Insert Fig 2.**<<<<<<

>>>>**Insert Fig 3.**<<<<<<

Under close inspection, the results of Marchwood (Fig. 1) revealed a small increase in sale prices between zone 2 and zone 1 before operation of the plant, which was reversed after the plant became operational. This effect was in line with the primary hypothesis but was not statistically significant ($p < 0.05$). The sales prices in zone 3 were much higher than in all other zones, both before and after the plant was operational. Although the error bars were also very large and the results for this zone are therefore not considered to be reliable. zones 4 and 5 indicate an overall lower property value compared to zone 1 and 2 over both time periods. The results in zone 4 and 5 show that the property values after the facility become operation are significantly higher than before, with the smallest error bars for the result set demonstrated in zone 5. The price rises across the zones, excluding zone 3, in the period after operation are not statistically significant. Although there is a significant indication, before operation, of lower prices between zones 1 and 4.

Chineham (Fig. 2) demonstrated a statistically significant effect with distance, although this was contrary to the hypothesis and other studies, as closer to the incinerator resulted in higher prices. Kirklees (Fig. 3) illustrated a statistically significant effect with distance that was in agreement with the hypothesis, however no effect due to the operation of the incinerator could be found. The results of Chineham (Fig. 2) and Kirkleess (Fig. 3) indicated property prices were higher in the period after the plant started operation; however this was not statistically significant.

In this study there were some limitations with the data. Firstly the postcode data used to find the distance from the incinerators was the most up to date in October 2012. The postcodes and boundaries are subject to change and therefore some of the older sales no longer had valid postcodes and were therefore discarded. It could be possible to obtain historic postcodes however this was not possible due to the constraints of this project.

The unique property identifier used for matching property sales before and after the plant became operational was based on the postcode and property name/number, as previously described. Due to the changing postcode boundaries, some properties may have had different postcodes in each time period and therefore would have been ignored during the matching process. A unique property identifier based on the address or geographic location may lead to more matching pairs.

The results displayed wide error bars across certain zones. These discrepancies can be explained by the number of data points for each location, especially in zone 3 at Marchwood and in zone 5 at Kirklees (Table 4). These zones have a very low concentration of properties at both sites as they are primarily agricultural with very few properties. This may explain the large sale price increase in zone 3 of Marchwood (Fig. 1) which only consisted of 17 data points, primarily higher value detached properties. Whilst the house price data was normalised against the local house price index, these larger rural properties are likely to be more desirable, resulting in higher prices, and may not follow the same trend as an average property in the area. The relatively few data points is a likely source of error within the presented data, as demonstrated by the large error bars in the results for this zone (Fig. 1). Kirklees (Fig. 3) demonstrated a similar increase in zone 5 with only a single data point recorded.

>>>>>Insert Table 4<<<<<<<

The analysis of Chineham (Fig. 2) indicated a significant increase in sale prices close to the site of the incinerator. This was contrary to the expected results. This could be explained by the location of these properties and the site of the incinerator itself. The Chineham incinerator is in a rural location, surrounded by agricultural land with the closest properties 600 m from the plant. These properties are on an estate which is separated from the site by a main road (A33), open countryside and is shielded by mature trees. It is believed that the amenity of this open countryside to the properties could be masking any small effect that the incinerator may have. This may be demonstrated as greater distances from the incinerator mirror greater distances from the surrounding countryside. The results exhibited an inversely proportional relationship of sale price to distance of both factors.

At Marchwood (Fig. 1) a similar effect may be at play before the incinerator became operational. The incinerator at Marchwood is in the middle of a large industrial estate, but the closest properties are surrounded by open greenfield space on the opposite sides, with one estate also bordering on Southampton Water. The proximity to the sea was considered to be the primary benefit to the area, as is demonstrated in zone 1 before operation of the incinerator (Fig. 1). However once the incinerator began operation a reversal in property prices was observed. This effect was in agreement with Kiel and McClain's (1995b) results that indicate house prices are lower within three-quarters of a mile (1.2 km) of an operating facility than before it was operational.

The Marchwood incinerator is the largest of those analysed and has a very distinctive design. It can be seen from a number of locations in the local area and would be immediately recognisable to local residents. This visual impact could be a cause of the decrease in sales prices in this area. However, it must be noted that the reduction in sales price was not found to be statistically significant in the analysis.

Kirklees is an inner city incinerator and is located in a heavy industrial zone adjacent to a railway line. Properties in Kirklees have the lowest average value of the areas studied. These effects in themselves may explain the reduced sale prices closer to the plant that are demonstrated in the results (Fig. 3). This general disamenity can be identified as prices were also lower before the operation of the incinerator, therefore the effect of the operation of the incinerator cannot solely explain the reductions.

All the locations analysed were on the sites of previous incinerators. However, each had been non-operational before the planning and construction of the new plant. This may have had a lingering effect on the surrounding properties, which may have already been discounted, and could explain why no significant effect was discovered between the periods before and after operation of the new facilities.

Many studies have been carried out into the economic impacts of hazardous waste sites and nuclear power plants (Farber, 1998). These studies agree that house values are reduced close to the site and increase with distance. However these studies are not considered to be comparable to EfW facilities due to the large differences in perceived risk factors.

The results obtained from this study are not in agreement with the previous studies by Kiel and McClain (1995a; 1995b) or the CEBR (2003). The negative costs associated with distance calculated by Kiel and McClain (Kiel and McClain, 1995a) are not compared to other costs or benefits that may be contributing to the final house price and therefore the final proportion of the effect of the incinerator cannot be quantified. Although it is considered that the Kiel and McClain studies were carried out at a time when incinerators had a worse perception than today. It is posited that the negative perception of incineration is less pronounced now than in the 1980s and 1990s, due to the increased emission controls of the Waste Incineration Directive in 2000 and increased public engagement by waste companies. It was acknowledged that a weakness in the CEBR work was that no assertion of causality could be proved. This was due to using a single point in time, Q4 2002; this criticism was not valid for the North Andover studies (Kiel and McClain 1995a; 1995b) which used a continuous time series.

The effect found in the CEBR study could be attributed to the general industrial nature of the locations in which many of the incinerators studied were sited and that other factors in these zones, such as industrial noise, pollution or increased heavy goods traffic, could be compounding the results. The general disamenity of industrial estates is demonstrated by the results found at Kirklees in this study.

Kiel and McClain (1995a; 1995b) briefly discuss compensation programs for the local residents and conclude that current schemes are inadequate as they do not take into account the changing costs over time as discovered in their study. However the results of this study call into question the validity of compensation schemes that are intended to reimburse the perceived cost of the facility to the local residents. If no negative effect on property prices can be quantified due to the operation of a new facility, it would render the argument for compensation moot. Although it is more likely that such schemes are offered to facilitate the planning process.

This study is a starting point for more research into the public perception of modern incinerators and their effect on local economic variables. Recommendations for further research are detailed below.

As in the Kiel and McClain (1995b) study more phases of the development and operation of the incinerator could be considered. a long period after the operation that could be broken down into further phases to identify any effects of long term operation. The period before operation could be split into a baseline, before any planning notifications, a planning and a construction phase. This could be used to identify any effects from the construction that may have been included as the baseline used in this study.

The number of matched price pairs for Kirklees was smaller than both other facilities (Table 3), mainly due to the short time period between the operation of the plant (2000) and the start date of the Land Registry price dataset (1998). To provide a clearer baseline an equal time period before operation of each facility could be acquired, however the analysis in this study is considered to be robust.

The zones chosen in this study were in 1 km increments. Smaller increments could be analysed to identify if at very close range there is a statistically significant effect of the operation of the incinerator. However it should be noted that the records of matched pairs would be significantly fewer and could affect the robustness of the study.

The data used in this study was obtained from the Land Registry and did not include any details apart from the type and tenure of the property. Further data could be obtained to provide a more thorough analysis of the other local effects contributing to the sale price. A full hedonic pricing model would enable a cost to be attributed to the incinerator and comparative local benefits.

The distances calculated in this study were from the postcode for each property. A postcode may have multiple properties associated with it and therefore the distances for each property were approximate. Individual positions for each property may help to eliminate this issue and provide more accurate distance calculations.

The action of supply and demand is generally agreed to be the primary effect on the setting of market prices. The analysis of the sales frequency at the sites in this study could provide more insight into the perception of the facilities and possibly identify any change in demand across the time periods.

Large opposition groups can sway the perception of the public and a qualification of the strength of opposition to the incinerator should be carried out and quantified to identify any effect. This could include a review of local and national newspaper articles about the planned incinerator to deduce the sentiment, identify the number of official oppositions to the planning applications and the arguments provided, conduct interviews with company representatives to gauge the level of opposition they experienced and interview local people to identify their perception of the plant before and after operation.

Compensation schemes could have been used to improve the perception of the incinerator and operating companies detailed in this study. Identification of the use of these schemes, if any, and the quantification of any effect that this may have had on the perceived disamenity could be carried out.

The Marchwood incinerator is a large dome-shaped facility that is visually distinctive from the standard "grey box" of traditional incinerators. Additional research into the effect of the design of the plant on local residents and whether the design was chosen to help with public engagement could be undertaken.

5. Conclusion

The results indicate that if there is a perceived cost of living close to an operational incinerator, then this value would be greatly outweighed by local benefits such as proximity to open countryside, access to the sea, transport links and possibly catchment areas for local schools.

In conclusion this study did not find any significant negative effect on property prices at any distance within 5 km from a modern operational incinerator. However, more research is suggested which could include:

- Additional time periods, such as the different phases of development and operation.
- Longer time periods before facility operation;
- Additional zones, allowing for smaller increments between zones (i.e. zones smaller than 1 km);
- Acquisition of additional housing data, such as the type of house and the number of residents;
- Identify the effects of facility design including whether the design was chosen to help with public engagement.

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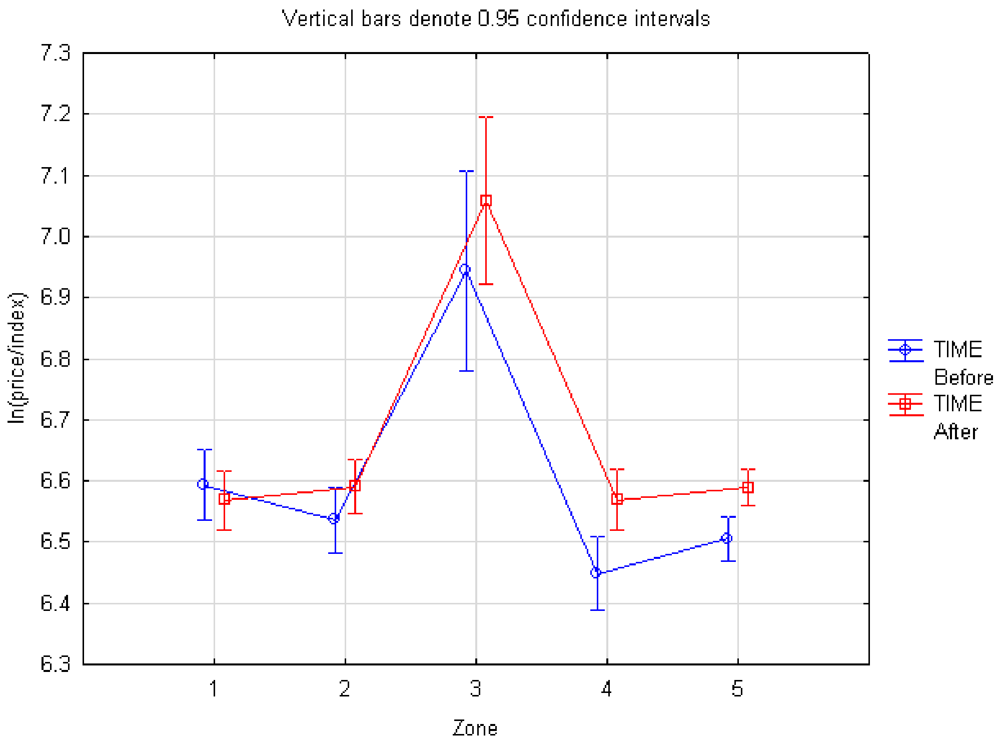

Figure 1. Value of properties sold, ln(price/index), in zones 1-5 before (1998-2004) and after (2005-2012) operation of Marchwood EfW. Error bars denote 0.95 confidence intervals

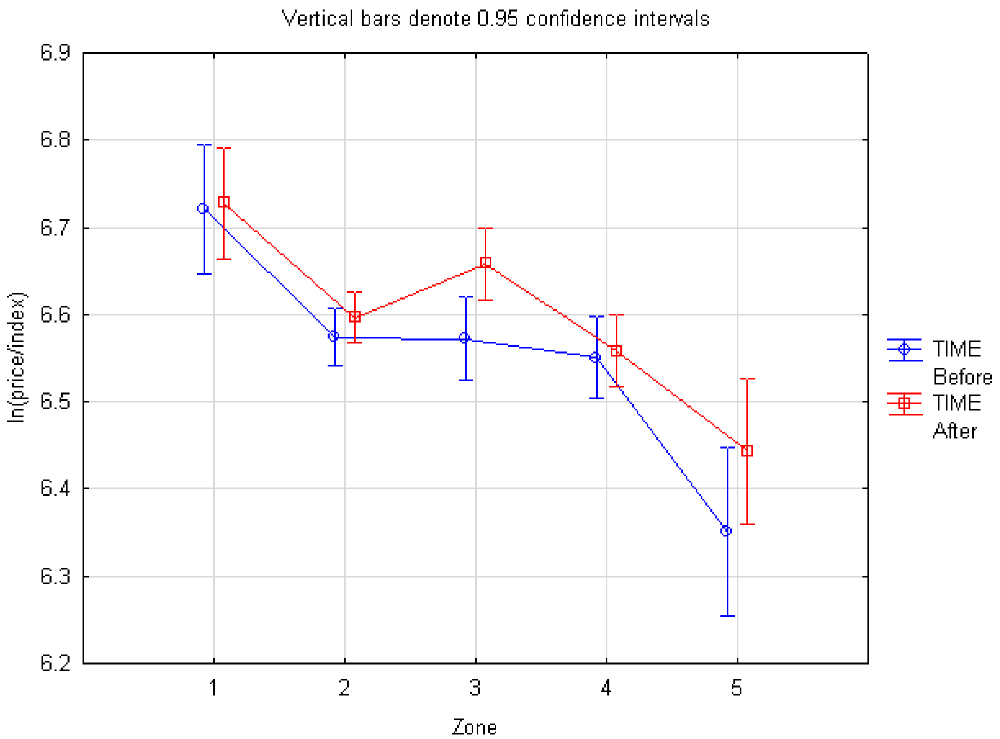

Figure 2. Value of properties sold, ln(price/index), in zones 1-5 before (1998-2002) and after (2003-2012) operation of Chineham ERF. Error bars denote 0.95 confidence intervals.

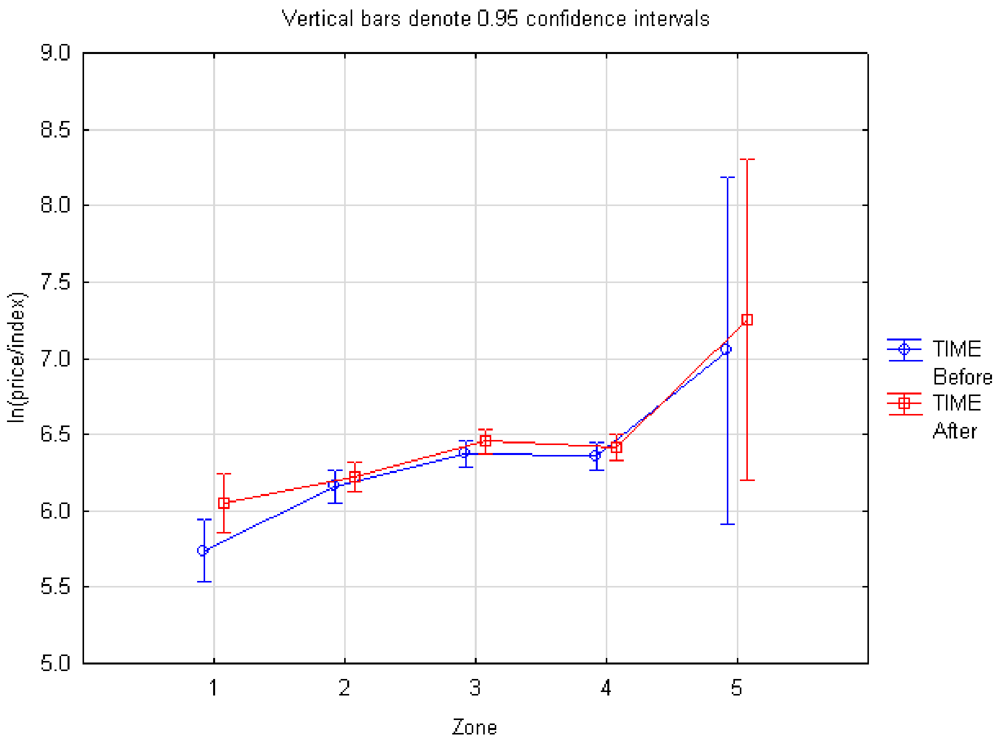

Figure 3. Value of properties sold, ln(price/index), in zones 1-5 before (1998-1999) and after (2000-2012) operation of Kirklees EfW. Error bars denote 0.95 confidence intervals.

Table 1. Comparison of dioxin levels from different processes 2011

Process	**Amount of dioxins produced (grams International Toxic Equivalent)**
Power Stations – MSW	0.66g
Power Stations – Coal	1.26g
Road transport – cars (petrol)	1.27g
Sinter plants – iron production	20.73g
Electric arc furnaces – steel production	10.94g
Domestic combustion - wood	3.07g
Domestic combustion - coal	1.45g
Landfill – escaping methane	0.63g
Crematoria	10.23g

Source: adapted from National Atmospheric Emissions Inventory (2013).

Table 2. Incinerator short list

Incinerator	Operating company	Plant Capacity (ktpa)	Plant Location	Distance to closest dwelling (m)	Planning year	Operational from	House price data points
Marchwood	Veolia	210	Industrial	300	2001	01/12/04	SO40 12,877
Chineham ERF	Veolia	102	Rural (w/water treatment)	600	2000	01/01/03	RG24 11,107 RG27 6,158
Kirklees	SITA	150	Industrial	150	1999	2000	HD1 4,829 HD2 6,840 HD5 7,488
Sheffield	Veolia	225	Industrial	450	2002	2006	S4 43,216 S2 31,889
Portsmouth	Veolia	210	Industrial	450	2001	2005	PO2 47,991 PO3 17,932
Newlincs	Cyclerval UK & TIRU Group / Newlincs Development Ltd	56	Industrial	2,700	2001	2004	DN41 1,845 DN40 2,789 DN31 3,496 DN37 5,429

Table 3. Number of data points for each incinerator

		Before operation		After operation		
Incinerator	**Operational year**	**Number of sales**	**Properties sold**	**Number of sales**	**Properties sold**	**Matched pairs**
Chineham	2003	3,773	3,067	5,499	4,465	1,547
Marchwood	2005	6,745	5,095	4,617	3,948	1,426
Kirklees	2000	1,057	1,028	7,614	5,635	485
	Totals	11,575	9,190	17,730	14,048	3,458

Table 4. Property type breakdown per zone for each incinerator

	Chineham				Marchwood				Kirklees			
Zone	**Detached**	**Semi**	**Terrace**	**Flat**	**Detached**	**Semi**	**Terrace**	**Flat**	**Detached**	**Semi**	**Terrace**	**Flat**
1	57	26	36	1	29	23	83	3	3	0	6	21
2	195	92	292	1	49	47	68	0	23	1	35	59
3	100	61	131	1	13	3	1	0	64	1	46	66
4	94	29	166	0	21	46	59	0	53	1	42	63
5	10	9	52	0	111	145	102	0	0	0	1	0