ASSESSMENT OF TEMPORAL DATA FOR HOSPITAL ADMISSIONS FOR ASTHMA PATIENTS IN COMPARISON WITH AMBIENT NITROGEN DIOXIDE LEVELS IN GUERNSEY, CHANNEL ISLANDS

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Abstract

There are some significant parallels between the environment in the island of Guernsey and that of coastal and island environments in Scotland. Although Guernsey enjoys milder temperatures in the summer months, the winter season experiences stormy weather fronts from the Atlantic and heavy rainfall.

This research examines the temporal variation in nitrogen dioxide (NO2) levels in Guernsey and the hospital admissions of pre-existing asthmatics. Whilst air quality in Guernsey is generally good, the levels of NO2 exceed Scottish standards in several locations. The evidence indicates that people suffering from asthma have exacerbation of their symptoms if exposed to elevated levels of NO2, although this research has never been carried out in Guernsey before.

For the first time in Guernsey, this research has examined NO2 levels in correlation with asthma patient admissions to hospital. The data showed a temporal correlation between NO2 levels and the number of hospital admissions. Statistical analysis of the data shows a direct correlation for both these variables.

The relationships established should aid our understanding and serve as a base for directing future studies in this research area of improving health outcomes for asthmatics, and the respiratory health of the wider population.

Introduction and background

Asthma is a debilitating ill-health condition caused by the inhalation of an allergen which causes an allergic reaction. The symptoms that follow include sneezing, coughing, wheezing and shortness of breath, which can be mild or more severe and can occasionally lead to death. There are three variations in symptoms: these are airway obstruction, inflammation and airway irritability (Cameron and Oduyemi, 2009; WebMD, 2017).

A huge amount of research has been undertaken into the impacts on respiratory health from ambient (outdoor) air pollution such as particulates and gases from road traffic emissions and industry (Beverland et al, 2007; Prescott et al, 2000). The evidence indicates a direct inverse correlation with the spatial and temporal levels of pollutants and the respiratory health of the local population. As the level of air pollutants increase, the respiratory health of the population decreases (Di Giampaolo et al, 2011).

It therefore follows that interventions in the environment to improve air quality will bring about a direct improvement in the health and wellbeing of asthmatics, and the respiratory health of the wider population.

Whilst one would expect a direct correlation with hospital admissions for respiratory disorders with increases in ambient air pollution, this may well be contributed to by other exposures indoors. The research will examine the correlation between hospital admissions for asthma and air quality measurements recorded in Guernsey from 2010-2015 to establish and validate the nature of any temporal correlation. This work will add to our understanding, prediction, and management of the health of pre-existing asthmatics.

There is a large body of evidence about many of the air pollutants that impact on asthmatics, especially particulate matter (Beverland et al, 2007; Asthma UK, 2017; HSE, 2008; Prescott et al, 2000), although exposure of asthmatics to NO2 is less well researched. NO2 is therefore the air pollution indicator used in this present study.

In addition, it should be noted that the study of NO2 dispersal, distribution and impact is related directly to the current research into the impacts on the respiratory system from ultra-fine particles (i.e. less than PM1) as it is assumed the ultra-fine particles are likely to disperse in gaseous fashion.

In Guernsey, although the UK NAQS does not apply directly, the standards are used as a benchmark until local legislation is passed to implement local air quality controls. NO2 is the only environmental pollutant in Guernsey that is likely to exceed NAQS ambient air quality standards (States of Guernsey, 2010) and there are three locations currently where this is happening due to traffic congestion namely; Fountain Street, Bulwer Avenue and the Bridge (see Figure 2). These areas are the most highly populated on the island and therefore, exceedances in air quality objectives and standards, have the greatest impact on population health. Fountain Street, Bulwer Avenue and the Bridge experience high traffic flows during peak times, usually between 8-9am and 4-6pm, and the resulting higher concentrations of NO2.

NO2 is a gas that causes irritation of the airways often leading to mucous production. In some studies, mucous production leading to infection of the respiratory tract has demonstrated an increased likelihood of asthma attack in children. (Linaker et al, 2000).

NO2 can also cause irritation to the eyes and nose. High dose exposure can result in pulmonary oedema and diffuse lung damage (US EPA, 2017).

Studies have shown that healthy adults have little or no respiratory response to the low levels of NO2 typically found indoors. However, asthmatics will have an increased response to allergens if exposed to NO2 before or at the same time and children exposed to levels of NO2 are 20% more likely to develop mucous and respiratory infections causing wheezing (Tunnicliffe et al, 1994; Chauhan et al, 2003; COMEAP, 2004).

In 1992, Hasselblad et al reported that long-term chronic exposure to levels of NO2 in the home as low as 15ppb caused a 20% increase in the risk of respiratory disorders in infants compared with a similar less exposed cohort, although this was refuted by Samet and Basu (1999) who claimed that there was no correlation of such exposures and impacts on infants. Further studies by Samet and Bell (2004) have recognised a correlation with elevated concentrations of NO2 and exacerbation of asthmatic symptoms.

Rusznak et al (1996) concluded that asthmatics exposed to elevated levels of NO2 before or during exposure to allergens enhanced and exacerbated the airway response to the inhaled allergen. NO2 exposure to levels of 400ppb for one hour caused exacerbation of symptoms which were prolonged for up to 48 hours after exposure. In other studies, exposure to NO2 concentrations of 500ppb for half an hour showed a significant reaction which was measured by analysis of increased release of histamines in patients. (Bylin et al, 1988; Samet and Bell, 2004).

Chauhan et al (2003) examined personal exposure to NO2 and the severity of asthmatic symptoms following viral infection. 114 children were monitored over a 13 month period and it was recorded that there were significant increases in lower respiratory tract infection and asthma exacerbation with continuous exposure of NO2 during the study period at levels from 5-20 µg/m3 (2.6 – 10.5ppb).

In some asthmatics moderate bronchial obstruction appeared to be followed by significant increases in bronchial sensitivity and when exposed to allergens and low concentrations of NO2 (Orehek et al, 1976).

By contrast other studies have shown there to be little exacerbation of asthma symptoms during exercise or at rest if the levels of NO2 exposure is 250ppb measured over one hour (Jorres et al, 1998). Other studies showed concentrations of up to 600ppb had shown little airway challenge to asthmatics over short periods. (Goodman et al, 2009).

These studies need to be considered in context, many being very short term studies i.e. half an hour or an hour of exposure to NO2 and an allergen, whereas 8 hour exposure needs to be considered in the workplace and total exposure assessment needs to underpin any risk assessment carried out for pre-existing asthmatics if symptoms are to be managed effectively and holistically. Peaks in NO2 levels have shown correlation to exacerbation of asthmatic symptoms.

Sunyer et al (2002) reported that asthmatics had a higher risk of dying from asthmatic episodes when levels of ambient NO2 were higher, regardless of season and that higher levels of Ozone in warmer weather had a similar effect. NO2 is a pre-curser to atmospheric Ozone and was considered during this study. The relationship between NO2 and Ozone is an important factor in the increasing numbers of patients with asthma and allergic disease. Shea et al (2008) reported that climate change, increasing levels of ground level Ozone and other air pollutants such as NO2, were contributing to, and were predicted to escalate, the rising number of asthma sufferers by the end of the twenty first century.

Sunyer et al (2002) also reported that the asthma symptoms experienced during this study were not confounded by the presence of increased allergen triggers like pollen and spores and that hourly average concentrations of NO2 from 9 -177 ppb (42ppb 75% of the time) were recorded during the 5 year study period.

Studies undertaken by Gauderman et al (2005) across 10 communities in California, USA, indicated that the respiratory health of asthmatic children was negatively affected by ambient exposures to NO2 associated with freeways and major roads near their places of residence. The study highlighted the importance of regulation of pollutants, including NO2 at local level.

At the European Respiratory Society conference in Barcelona in September 2013, roadside pollution was cited as a major impact on respiratory health. Lead author of the report presented at the conference, Pieter Goeminne, stated that the study findings should encourage policy makers to make air quality a key focus of any transport policy which must consider the proximity of roads to residential areas in an attempt to reduce the impact of NO2 and other traffic related pollutants on people living nearby.

The aim of this research is to examine whether ambient air quality is a good proxy for impacts on the health of asthmatics by examination of temporal variations in hospital admissions in Guernsey, for patients with asthma during 2010-2015 in comparison with ambient air quality data for NO2.

Data collection and methodology

This section describes the data collection and methodological approach taken for this research.

The study location

The island of Guernsey (see Figure 1) is located about 70 miles south of the south coast of England and 30 miles from the coast of France. It is bordered by the English Channel and the Atlantic Ocean and covers about 24 square miles. It is occupied by around 63,000 people. The island is divided into ten parishes and is mostly rural with the main urban centre of St Peter Port. There are two main harbours, which contribute to air pollution in St Peter Port (the town) and St Sampson (the Bridge).

Figure 1: Location Map.

Most of the commercial development focuses on St Peter Port, St Sampson and the Vale parishes. The road network connects all parishes (see Figure 2) with the town and consequently traffic flows in and out of the town are congested at peak times resulting in elevated vehicle emissions during those times. It is estimated that vehicles contribute about 29% of the total of emissions to atmosphere on the island (States of Guernsey, 2013).

Figure 2: Map of Guernsey.

The island has one diesel power station, one hospital incineration plant and a number of commercial boilers on vinery sites. The rest of the island's air pollution is contributed by domestic heating systems.

Ambient air quality monitoring is undertaken by the Office of Environmental Health and Pollution Regulation (OEHPR). There has been an air quality monitoring programme on the island for around 20 years which involves the monitoring of particulate matter 10 microns and below (PM10), oxides of nitrogen (NOx including NO, and NO2) , sulphur dioxide (SO2), ozone (O3) and carbon monoxide (CO). There are 3 stations where various parameters are continuously monitored and currently nine locations where monthly NO2 diffusion tubes are located. Over the years NO2 has been measured at over 30 locations but now the programme has been prioritised to the areas of greatest exposure (States of Guernsey, 2010). During 2013, BTX (benzene, toluene and xylene) diffusion tubes were also deployed on the island around the power station and the airport to assess hydrocarbon emissions. In 2015, the OEHPR undertook an air quality screening and assessment exercise which considered all of the objectives of the UK NAQS in the Guernsey context. The assessment revealed that the levels of the majority of parameters measured were well within the objectives for the standards set in the UK except for NO2, where there are three locations that periodically exceed the standard, Fountain Street in St Peter Port, Bulwer Avenue and the Bridge. This research, therefore, focuses on NO2 emissions as there has been no research into the extent of exceedances that may have an impact on population respiratory health and consequently asthmatics in Guernsey.

It should be noted that the monitoring equipment deployed provides data measured over various exposure periods in ppb. The NAQS provides standards

in various units, some in parts per billion (ppb) and some in micro-grams per cubic metre (µg/m3).

This study analyses data that has been measured in ppb, but where required this has been converted to µg/m3 to allow comparison with UK standards. The conversion factor for NO2 is 1pbb=1.9125 µg/m3 (UK Defra, 2017).

Ambient air quality monitoring and equipment

Bulwer Avenue is a location between St Peter Port and the Bridge where there are heavy traffic flows and likely impacts from the Guernsey Electricity power station, where another real-time analyser monitoring station is located. This station is sited adjacent to the States' Environment department building. At this location the equipment includes an ET 200E NOX analyser, and ET 200E SO2 analyser and a Rupprecht and Patashnik Co. 1400a TEOM particulate analyser (Tapered Element Oscillating Microbalance utilising mass sensors). The NO2 data measured at this station have been used as the ambient air pollution indicator in this study, because of the evidence in the literature that the worsening of the health of asthmatics to episodes of high levels of air pollution.

Figure 3: Aerial view of the Bulwer Avenue site.

Figure 4: External photo.

This research study employed real-time measurements of NO2 and a study of temporal NO2 concentrations in Guernsey in comparison with hospital admissions data for asthmatic episodes, between 2010-2015 (Rosas et al, 1998; Price, 2007).

Throughout the research, the NO2 monitoring studies were undertaken concurrently whenever possible to avoid adjusting the results due to climatic condition variation.

The data for November to March were also analysed separately, based on the evidence that asthmatic episodes are exacerbated during the winter months and that higher indoor concentrations tend to be found in the winter months due to lower temperatures, damper weather conditions, etc. (Price, 2007; Wark et al, 2006).

Collection of patient statistical data

The collection of patient statistical data in the Princess Elizabeth Hospital (PEH) was via an electronic patient health information system which logged all information for patients from the admission stage, through treatment or care pathways, through to discharge from the service. All data was coded using the International Statistical Classification of Diseases and Related Health Problems (ICD) for causes of morbidity and mortality.

The WHO publishes and distributes the ICD classification system, which is now in its tenth edition so is named ICD-10.

Asthma admissions were classified as J46 and J47 within the ICD-10 classification system, so it was these categories that were of interest to this study. When a patient was admitted to hospital the medical or clinical practitioners would keep detailed records about the patient's condition, experiences and treatment pathway. From the patient record information, clinical coders were able to add an alphanumeric code to that patient's electronic record for easy sorting, grouping and data evaluation and assessment. The clinical coders at the PEH used UK guidance on ICD-10 which details how to undertake their coding activities and input the data onto the hospital EHSCR information system. This consistent approach allowed the data to be compared with UK data if required.

For many patients, there were a number of diagnoses made by the various clinicians involved with the case and therefore a number of alphanumeric codes were applied to the electronic record. The clinical coders in the PEH provided assistance for the data to be extracted which included the data for admissions in categories J46 and J47, which related specifically to asthma, during the period of research study.

The data were anonymised for this research to protect the identities of the patients, but the data were grouped

to provide date of birth, gender, parish of residence, and date of admission for all patient admissions.

Data were extracted using bespoke health information software – EHSCR – and exported into Microsoft Excel spreadsheets to allow data manipulation and comparison.

This study was concerned with hospital admissions for asthma exacerbations that included acute or sub-acute episodes of progressively worsening shortness of breath, coughing, wheezing, and chest tightness or any combination of those symptoms. (Camargo et al, 2009).

Results and discussion

This study aimed to assess and evaluate data to identify whether there was a correlation between hospital admissions for patients suffering exacerbated asthmatic symptoms and ambient NO2 levels. NO2 was specifically selected for this study because it was the only air pollutant in Guernsey that exceeded NAQS standards (States of Guernsey, 2010). All other pollutants within the NAQS were well below the standards and it was assumed that these would not have a significant impact on respiratory health in Guernsey. In addition, the literature indicated that there was an exacerbation of symptoms when asthmatics were exposed to NO2.

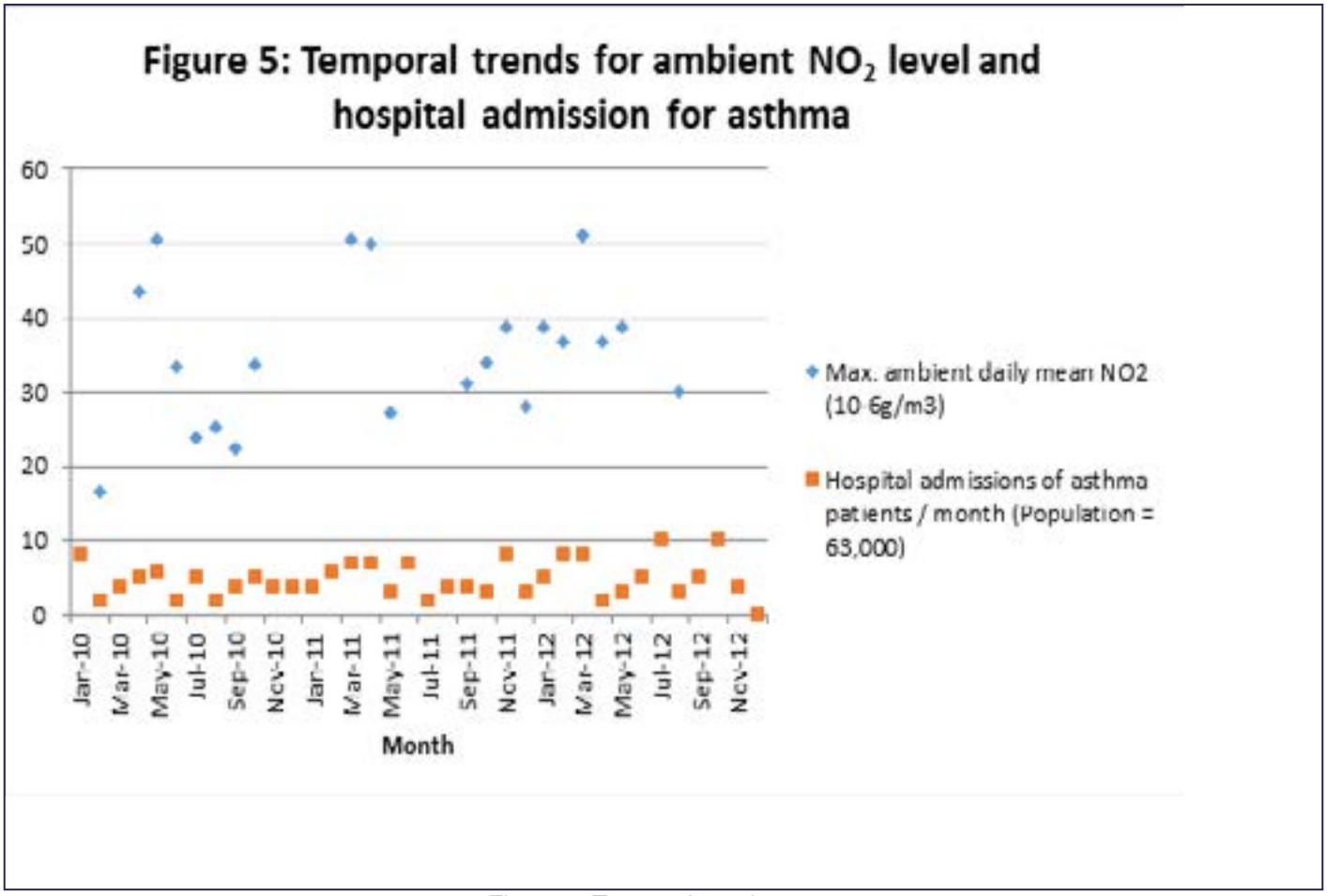

Figure 5: Temporal trends.

The section discusses the NO2 data for 2010-2012 and the hospital admissions data for the same period. The 2015 data was used to validate the predictive outcomes from the 2010-2012 research data. Annual mean air pollution data from Guernsey clearly indicate that the areas of heavy traffic flow and therefore vehicle emissions are significant contributors to NO2 levels in those areas where traffic jams in the morning and evening frequently occurred (Cameron, 2014). For this research the best correlation is found between the maximum daily mean ambient concentration of NO2 during a month at the heavily trafficked Bulwer Avenue site on the Island and the monthly hospital admissions of asthmatics on the Island (see Figure 5). This suggests an agreement with the indication in the literature that there was an exacerbation of symptoms when asthmatics were exposed to NO2.

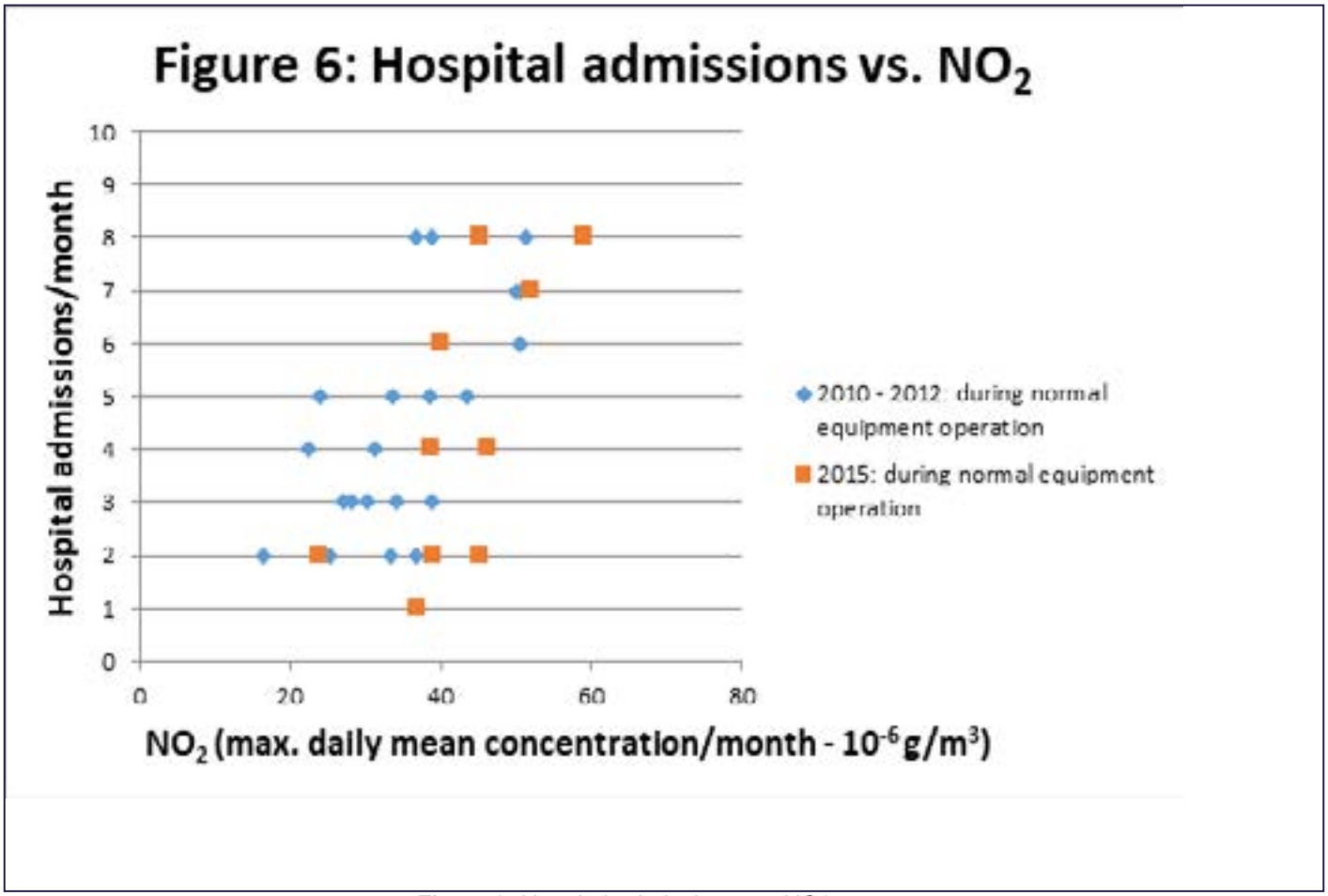

Figure 6: Hospital admissions vs. NO2.

Figure 6 (above) shows a direct relationship between the independent and dependent variables for the 2010 – 2012 data analysed; maximum daily mean ambient concentration of NO2 during a month at the heavily trafficked Bulwer Avenue site on the Island and monthly hospital admissions of asthmatics on the Island respectively. The superimposition of the 2015 data on the same graph validates the existence of this relationship. The scatter on the graph suggests there might be other variables that affect this relationship. In light of this and the evidence in the literature that asthmatic episodes are exacerbated during the winter months (Price, 2007; Wark et al, 2006), the winter data (November – March) were separated from the summer data (April – October).

This analysis resulted in very strong direct regression relationships between maximum daily mean ambient concentration of NO2 during a month at the heavily trafficked Bulwer Avenue site on the Island and monthly hospital admissions of asthmatics on the Island (Figures 7 and 8). The regression relationships are as stated on Figures 7 and 8 (over) for both the original 2010 – 2012 research data and the 2015 data used for validation. Both sets of data compare very well and there is a suggestion that higher number of hospital admissions per the population is predicted during the winter months than during the summer months for the same value of maximum daily mean ambient concentration of NO2 during a month at the heavily trafficked Bulwer Avenue site on the Island.

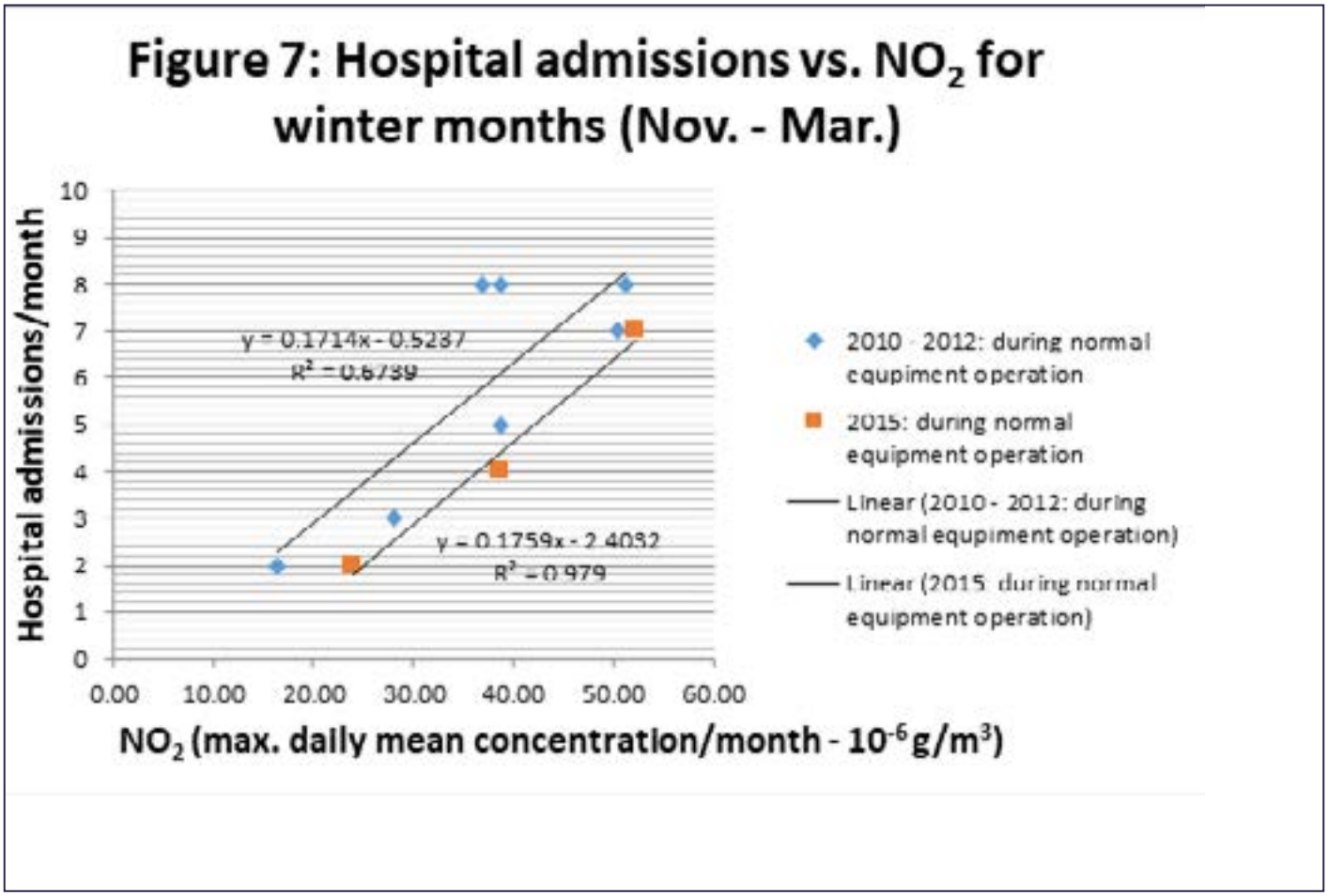

Figure 7: Hospital admissions vs. NO2 for winter months.

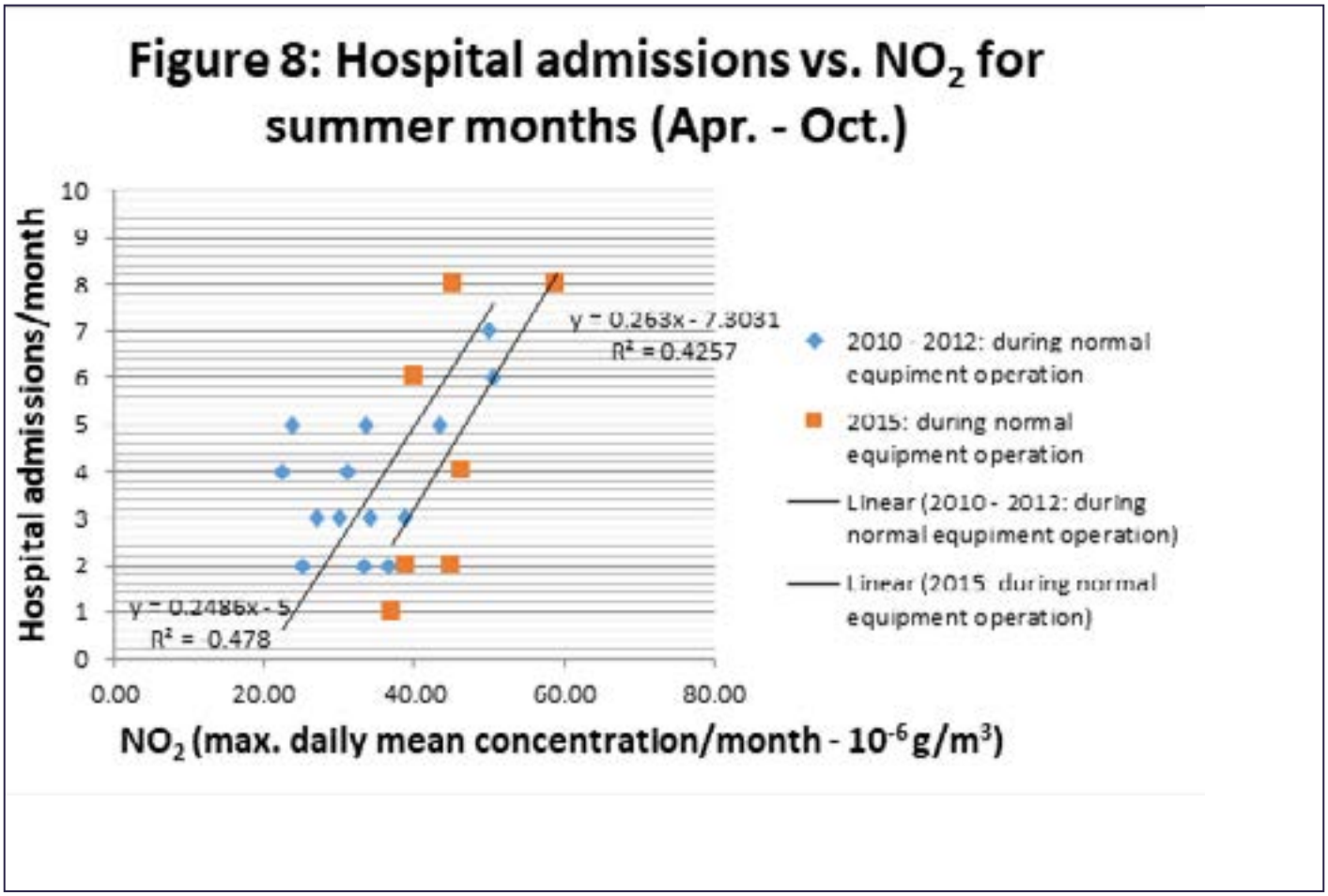

Figure 8: Hospital admissions vs. NO2 for summer months.

The results obtained in this research study suggest that if maximum daily mean ambient concentration of NO2 during a month at a heavily trafficked site in an urban area can be predicted, then a relationship can be established between this variable and the monthly hospital admissions of asthmatics in the area and the relationship can be used to establish, predict, and manage the health outcomes of asthmatics in the area, by being better prepared for the predicted number of admissions.

Conclusions

This research project was aimed at contributing to the evidence base and understanding about pre-existing asthmatics and the impacts on their health and wellbeing and exacerbations from environmental stressors.

The assessment of NO2 was selected specifically for the various studies because it was the only ambient pollutant in Guernsey that exceeded the NAQS standards.

The aim of this research was to examine whether ambient air quality is a good proxy for impacts on the health of asthmatics by examination of temporal variations in hospital admissions in Guernsey, for patients with asthma during 2012-2015 in comparison with ambient air quality data for NO2.

The research outlined in this manuscript was aimed at assessing the nature of influences from air pollution on the health of asthmatics in Guernsey, with specific interest in variation in ambient NO2 concentrations. Studies undertaken over a number of years by researchers including Hasselblad et al (1992), Tunnicliffe et al (1994), Linaker et al, (2000), Chauhan et al, (2003), Price, (2007), have indicated that variation in NO2 concentrations have an impact on the health and wellbeing of asthmatics and admissions to hospital.

The analysis and evaluation of the research data for this manuscript presented new and unique information which contributed to a better understanding of the local situation and the evidence base. The research showed that there was an increase in monthly hospital admissions for asthmatics, on the Island of Guernsey, when maximum daily mean ambient concentration of NO2 during a month at a heavily trafficked site on the Island increased.

The regression relationships between the monthly hospital admissions for asthmatics, on the Island of Guernsey, and the maximum daily mean ambient concentration of NO2 during a month at a heavily trafficked site on the Island for both the original 2010 – 2012 research data and the 2015 data used for validation compare very well. The results suggest that higher number of hospital admissions per the population is predicted during the winter months than during the summer months for the same value of maximum daily mean ambient concentration of NO2 during a month at the heavily trafficked Bulwer Avenue site on the Island.

The results obtained in this research study can be used to establish, predict, and manage the health outcomes of asthmatics in the area.

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References available on request.

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