From:	[redacted]
To:	Manston Airport
Subject:	Concerns about RSP DCO proposal and Student academic performance.
Date:	09 June 2019 16:50:37
Attachments:	Childhood Obesity.pdf Evidence of negative impact of External Noise and Air Pollutants on Academic achievement.pdf Pollution-Linked-to-Academic-Performance.pdf Academic performance and polluntants.pdf

To whom it may concern

I am writing to submit my grave concern for the students of Thanet from the potential pollution a freight hub would bring
I am a Secondary school teacher in the area and I am writing on behalf of myself and the 'Teachers against the Cargo hub 24/7 group'.

1. There was a fire at WestWood Cross last year and the pollution was so bad that the Pru school had to be closed for 3 months and the children in other schools, across Margate and Broadstairs had to be kept in at Break. And yet this proposal is suggesting that a higher level of pollution, every day is ok. I have included evidence of the determental effect both noise and air pollutants have on the academic behaviour of students. This in a area of already economic deprevation where the children's prospects have already been curtailed. Please do not let our students be further disadvantaged
2. You can't put double glazing on outdoor space. We also have really high levels of obesity here (page 16 of Childhood obsesity attachment evidence) - When looking at just obesity in isolation, Thanet (11%) and Dartford (11.1%) are the two worst districts in Kent and compare to a national prevalence of just 9%. We need to be encouraging children to have active play and use sports facilities in clean air. Not be kept in doors or risk lung pollution.
3. I just had a conversation with a friend who's son attends Chatham House, directly under the flight path in Ramsgate. She is concerned about his GCSEs being disrupted. Will they relocate the students to take their exams? She was asking. I said I dind't know. She got very anzious. That is Ramsgate. But as I have pointed out above, Air pollution will also affect Margate and Broadstairs as the wind blows.

Please do not let this happen to an already deprived area. These students already have low aspirations and achievement levels, lowering their academic achievements even further will be so costly for the whole area.

Kind regards
Ceri Diffley

KENT PUBLIC HEALTH OBSERVATORY

Thanet District Council

Child Health Profile

February 2016

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KENT PUBLIC HEALTH OBSERVATORY

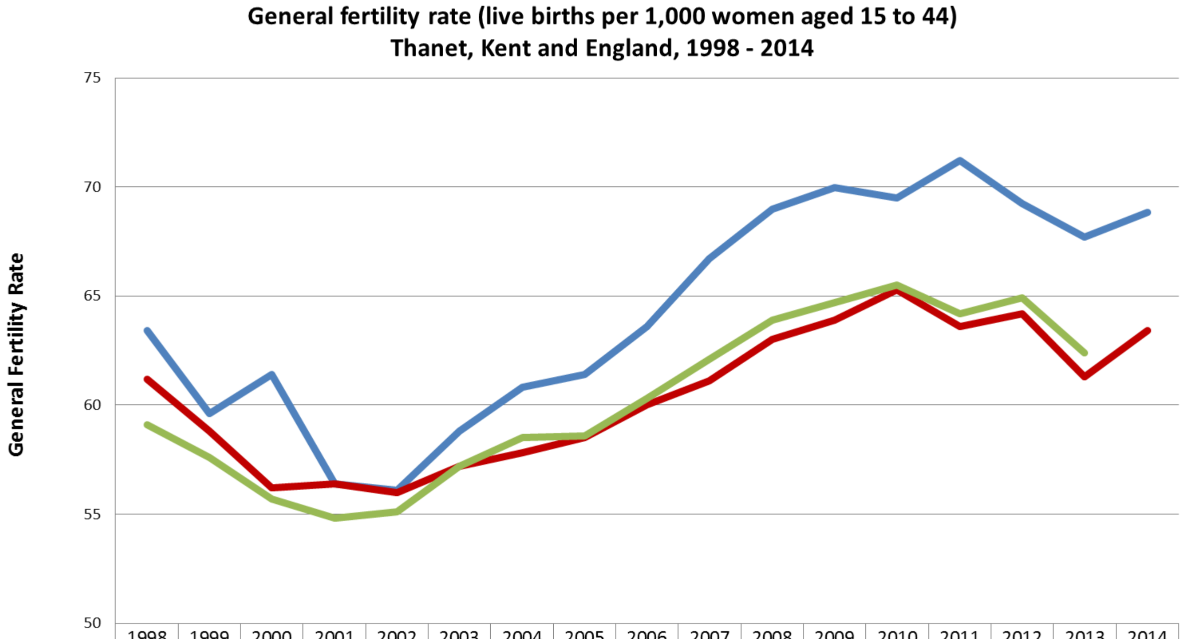
Contents

1. Maternity Indicators

1.1 General Fertility Rate

The General Fertility Rate (GFR) is the number of live births per 1,000 women aged 15-44 years. The recent trend in GFR across both Kent and Thanet shows an increasing rate up to 2009 since when recorded rates have fluctuated. The Thanet GFR has been consistently higher than the rate for Kent, which in turn is consistently a fraction lower than the national GFR.

Figure 1: Trend in General Fertility



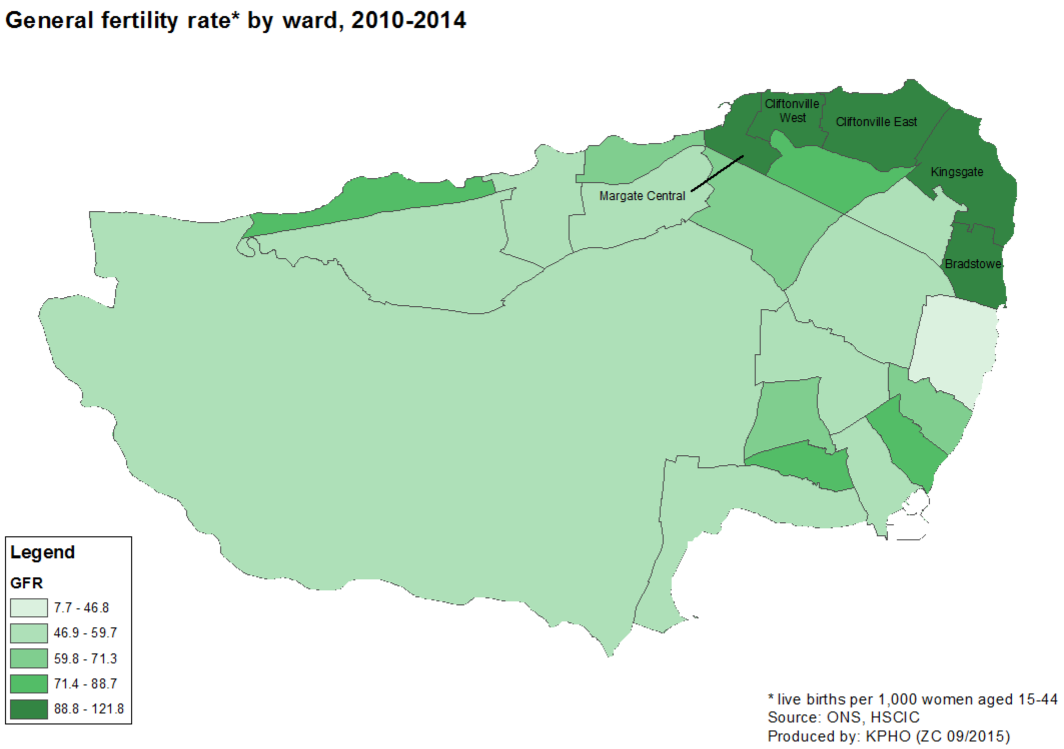
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Thanet	63.4	59.6	61.4	56.4	56.1	58.8	60.8	61.4	63.6	66.7	69.0	70.0	69.5	71.2	69.2	67.7	68.8
Kent	61.2	58.8	56.2	56.4	56.0	57.2	57.8	58.5	60.0	61.1	63.0	63.9	65.3	63.6	64.2	61.3	63.4
England	59.1	57.6	55.7	54.8	55.1	57.2	58.5	58.6	60.3	62.1	63.9	64.7	65.5	64.2	64.9	62.4	

Source: HSCIC

The number of births to Thanet resident mothers has also increased over recent years, with a high of 1,679 in 2012. The overall figure for 2014 was 1,606.

Within Thanet there is a wide variation in GFRs at electoral ward level. Due to relatively small numbers these rates are calculated for a five year rolling period. Figure 2 shows the spread of GFR across electoral wards and clearly shows that those rates are highest on the north-east coast. The GFR for those five highlighted wards is: Kingsgate (121.9), Cliftonville East (100.9), Cliftonville West (97.3), Bradstowe (91.7) and Margate Central (90.2).

Figure 2: General Fertility Rates - Ward level 2010-2014 (pooled data)



The electoral wards with the greatest number of births in 2014 are: Cliftonville West (199 births), Eastcliff (131), Dane Valley (124), Margate Central (122) and Central Harbour (100). It should also be noted that whilst Kingsgate had the highest GFR for Thanet electoral wards over the period 2010 – 2014, it also had the fewest number of total live births (just 15 in 2014)

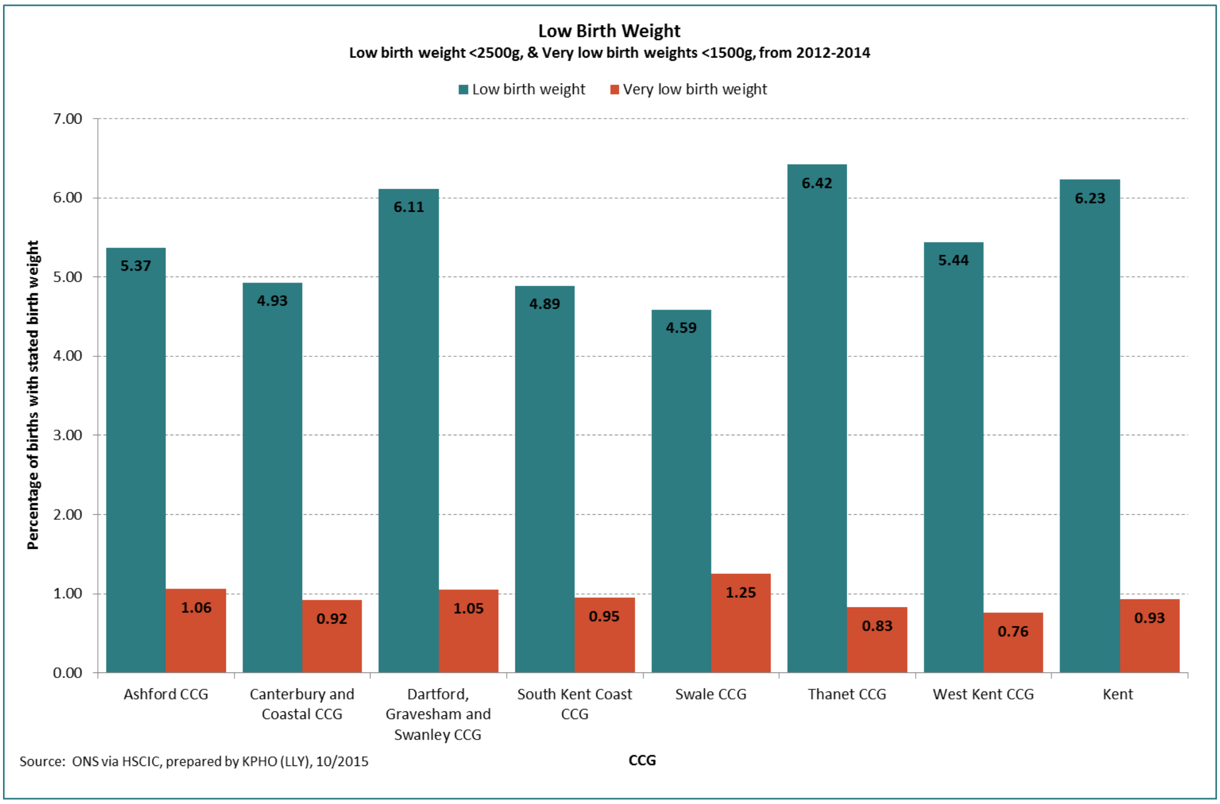
1.2 Low Birth Weights

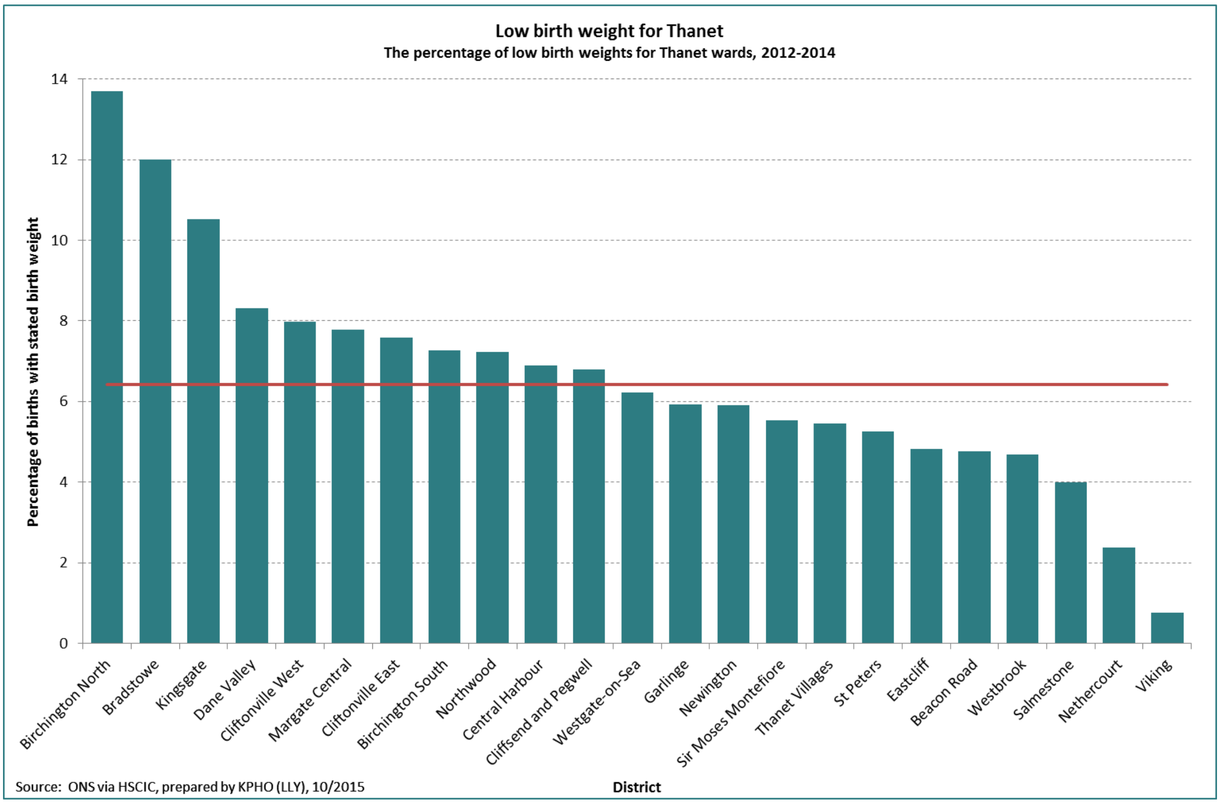
Low birth weight (LBW) is defined as a birth weight of a live born infant of less than 2,500 g (5 pounds 8 ounces) regardless of gestational age. Subcategories include very low birth weight (VLBW), which is less than 1500 g (3 pounds 5 ounces), and extremely low birth weight (ELBW), which is less than 1000 g (2 pounds 3 ounces). A normal weight at term is 2500–4200 g (5 pounds 8 ounces – 9 pounds 4 ounces).

Low birth weight is an indicator of the general health of newborns, and a key determinant of infant survival, health and development. Low birth weight infants are at a greater risk of dying during the first year of life, and of developing chronic health problems.

Thanet district/CCG area experienced the highest percentage of low birth weights across Kent for the period 2012 – 2014, although the Thanet percentage of very low birth weights was one of the lowest (Figure 3).

Figure 3: Low Birth Weight by Kent CCG 2012-2014 (pooled data)





1.3 Breastfeeding

Breast milk is the best form of nutrition for babies and can reduce their risk of developing infections. Breastfeeding delivers significant health benefits for both the mother and her baby.

Breastfeeding initiation is recorded by maternity services within each local acute trust and submitted to NHS England who then publishes the rates. The 2014/15 position for all mother's resident in Thanet was low at just 66.7%, this compares to 71.3 across Kent and 74.3 nationally. Sub district measures for breast feeding initiation are currently unavailable.

Breastfeeding continuation prevalence is measured at the 6-8 week check and this data is currently only available at a GP practice level for early 2015/16.

Table 1: Breastfeeding Continuation

Breastfeeding Continuation - Q1 2015/16 by Thanet CCG GP Practices

Practice	Number of Births	Coverage	Prevalence
G82020 - The Grange Medical Practice	37	91.9%	35.1%
G82046 - Summerhill Surgery	22	90.9%	4.5%
G82052 - The Limes Medical Centre	38	76.3%	28.9%
G82064 - Dashwood Medical Centre	29	93.1%	24.1%
G82066 - Northdown Surgery	35	88.6%	37.1%
G82079 - Westgate Surgery	15	80.0%	33.3%
G82105 - The Bethesda Medical Centre	54	90.7%	35.2%
G82107 - Minster Surgery	20	95.0%	40.0%
G82126 - East Cliff Practice	36	91.7%	47.2%
G82150 - Newington Road Surgery	24	83.3%	33.3%
G82210 - Osborne Road Surgery	4	50.0%	50.0%
G82219 - St Peters Surgery	14	92.9%	42.9%
G82649 - Union Row Surgery	11	63.6%	18.2%
G82650 - Mocketts Wood Surgery	19	84.2%	47.4%
G82666 - Birchington Medical Centre	19	100.0%	36.8%
G82769 - Cecil Square Surgery	5	20.0%	0.0%
G82796 - Broadstairs Medical Practice	11	90.9%	18.2%
G82810 - Garlinge Surgery	6	0.0%	0.0%
G82812 - Wickham Surgery	6	16.7%	0.0%
Thanet CCG	**405**	**32.1%**	**84.7%**
Kent	**4060**	**33.5%**	**70.7%**

Source: 6-8 week check, Child Health Information System

Whilst Table 1 (above) details the prevalence of breastfeeding at the 6-8 week check, it should be noted that where coverage is lower than 85%, the prevalence figure isn't an accurate reflection of the local prevalence. If more than 15% of your population isn't being measured then the prevalence should be viewed as inaccurate and not actively used.

Only about half of the Thanet practices currently exhibit prevalence greater than 85%. It is hoped that the recording and performance management of this indicator is enhanced under the new health visitor contract with public health.

1.4 Immunisations

Table 2 below details childhood immunisation uptake for the first 6 months of 2015/16, across all Thanet GP practices. Table is split by immunisations for 1yr, 2yr and 5yr olds.

It is generally recognised that achieving 95% uptake on childhood immunisation programmes gives population wide immunity. Whilst there is much variation in the levels of immunisation uptake across Thanet practices overall the CCG is generally in line with the Kent wide uptake.

MMR is one of the immunisations that has low uptake, in Thanet the booster 2^{nd} dose uptake is only 81% (and just 86% across the county).

Table 2: Uptake of Childhood Immunisation Q1 & Q2 2015/16 (pooled)

	12 months			24 months				
	DTaP.IPV.Hib uptake	MenC uptake	PCV uptake	DTaP.IPV .Hib uptake	MMR uptake	MenC.Infant uptake	Hib.MenC. Booster uptake	PCV.Booster uptake
G82020 - The Grange Medical Practice	93.4	97.4	93.4	96.0	98.7	96.0	98.7	29.3
G82046 - Summerhill Surgery	96.3	96.3	96.3	96.7	90.0	100.0	86.7	10.0
G82052 - The Limes Medical Centre	92.1	95.2	92.1	94.0	90.4	97.6	89.2	68.7
G82064 - Dashwood Medical Centre	90.9	92.7	90.9	93.2	86.4	96.6	88.1	35.6
G82066 - Northdown Surgery	69.2	80.8	71.8	98.3	93.3	98.3	93.3	71.7
G82079 - Westgate Surgery	94.2	96.2	94.2	98.0	89.8	93.9	89.8	67.3
G82105 - The Bethesda Medical Centre	87.4	93.7	87.4	88.4	83.2	93.7	80.0	61.1
G82107 - Minster Surgery	97.4	100.0	97.4	100.0	97.0	100.0	97.0	18.2
G82126 - East Cliff Practice	95.6	96.7	95.6	93.8	92.5	95.0	92.5	27.5
G82150 - Newington Road Surgery	97.5	100.0	97.5	90.0	82.0	96.0	82.0	36.0
G82210 - Osborne Road Surgery	100.0	100.0	100.0	100.0	100.0	100.0	100.0	80.0
G82219 - St Peters Surgery	86.7	93.3	86.7	100.0	100.0	100.0	100.0	76.9
G82649 - Union Row Surgery	100.0	100.0	100.0	96.7	100.0	100.0	100.0	66.7
G82650 - Mocketts Wood Surgery	89.3	96.4	92.9	94.4	94.4	100.0	100.0	63.9
G82666 - Birchington Medical Centre	66.7	87.9	66.7	91.3	87.0	95.7	82.6	73.9
G82769 - Cecil Square Surgery	91.7	100.0	91.7	92.9	100.0	100.0	92.9	64.3
G82796 - Broadstairs Medical Practice	60.0	92.0	52.0	81.5	92.6	81.5	81.5	37.0
G82810 - Garlinge Surgery	95.0	95.0	95.0	100.0	100.0	100.0	95.0	70.0
G82812 - Wickham Surgery	77.8	77.8	77.8	100.0	100.0	100.0	100.0	50.0
NHS THANET CCG	88.5	94.1	88.6	94.1	91.4	96.3	90.4	50.1
Kent	88.3	93.1	89.1	90.2	90.7	93.7	90.2	48.4

	5 years									
	DT.Pol. Primary uptake	DTaP.IPV. Booster uptake	Pertussis .Primary uptake	Hib.Infant uptake	MenC.Infant uptake	Hib.MenC .Booster uptake	MMR.1st .dose uptake	MMR.2nd. dose uptake	PCV.Infant uptake	PCV.Booster uptake
G82020 - The Grange Medical Practice	98.8	97.5	98.8	98.8	98.8	95.0	97.5	97.5	98.8	92.5
G82046 - Summerhill Surgery	94.3	91.4	94.3	94.3	94.3	88.6	94.3	91.4	94.3	88.6
G82052 - The Limes Medical Centre	88.4	86.0	88.4	88.4	83.7	83.7	91.9	87.2	87.2	83.7
G82064 - Dashwood Medical Centre	95.9	90.5	95.9	95.9	91.9	94.6	95.9	91.9	93.2	90.5
G82066 - Northdown Surgery	96.2	24.4	96.2	96.2	97.4	89.7	88.5	34.6	94.9	85.9
G82079 - Westgate Surgery	100.0	97.8	100.0	100.0	100.0	100.0	97.8	95.6	100.0	97.8
G82105 - The Bethesda Medical Centre	85.0	81.3	85.0	85.0	85.0	84.1	88.8	81.3	82.2	78.5
G82107 - Minster Surgery	90.9	66.7	90.9	90.9	90.9	90.9	93.9	66.7	90.9	90.9
G82126 - East Cliff Practice	94.7	93.3	94.7	94.7	97.3	93.3	96.0	90.7	94.7	93.3
G82150 - Newington Road Surgery	100.0	86.5	100.0	100.0	98.1	96.2	98.1	86.5	96.2	90.4
G82210 - Osborne Road Surgery	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
G82219 - St Peters Surgery	96.0	84.0	96.0	96.0	96.0	96.0	96.0	84.0	96.0	96.0
G82649 - Union Row Surgery	100.0	95.2	100.0	100.0	95.2	90.5	95.2	95.2	90.5	85.7
G82650 - Mocketts Wood Surgery	95.1	80.5	95.1	95.1	92.7	82.9	92.7	78.0	90.2	82.9
G82666 - Birchington Medical Centre	87.9	51.5	87.9	87.9	90.9	87.9	90.9	51.5	87.9	87.9
G82769 - Cecil Square Surgery	92.9	71.4	92.9	92.9	85.7	78.6	92.9	71.4	92.9	92.9
G82796 - Broadstairs Medical Practice	92.9	78.6	92.9	92.9	92.9	89.3	92.9	82.1	92.9	85.7
G82810 - Garlinge Surgery	100.0	88.5	100.0	100.0	100.0	100.0	100.0	88.5	100.0	100.0
G82812 - Wickham Surgery	83.3	83.3	83.3	83.3	83.3	83.3	83.3	83.3	83.3	83.3
NHS THANET CCG	93.7	80.3	93.7	93.7	92.9	90.4	93.6	81.1	92.2	88.3
Kent	95.2	85.8	95.3	95.3	94.5	92.6	94.6	85.9	94.2	90.2

< 85%
> 85% but < 95%
> 95%

Source: Child Health Information System (Unify2 submission)

1.4 Teenage Conceptions

Teenage conception rates are calculated nationally by the Teenage Conception Unit at the Office for National Statistics and released annually. At a district level conception rates are released for single year, the latest release is for 2013. Thanet has the highest district rate in Kent in 2013 at 35.6 per 1,000 females aged 15-17. Thanet has seen a substantial reduction in the teenage conception, from as high as 72.1 in 2001, and is now at its lowest point since the recording of teenage conception rates.

Electoral ward level rates are calculated using three years of conception information. For the period 2011-2013 there were 297 teenage conceptions across Thanet with the highest rates recorded in Cliftonville West (92.5 per 1,000 15-17yr olds), Nethercourt (71.9) and Dane Valley (58.9). Figure 5 (below) shows the all of the wards with high rates.

In the first six months of 2015 there were 55 births to teenage mothers across Thanet, 13 of these were resident in Cliftonville West.

Figure 4: District level teenage conception rates - 2013

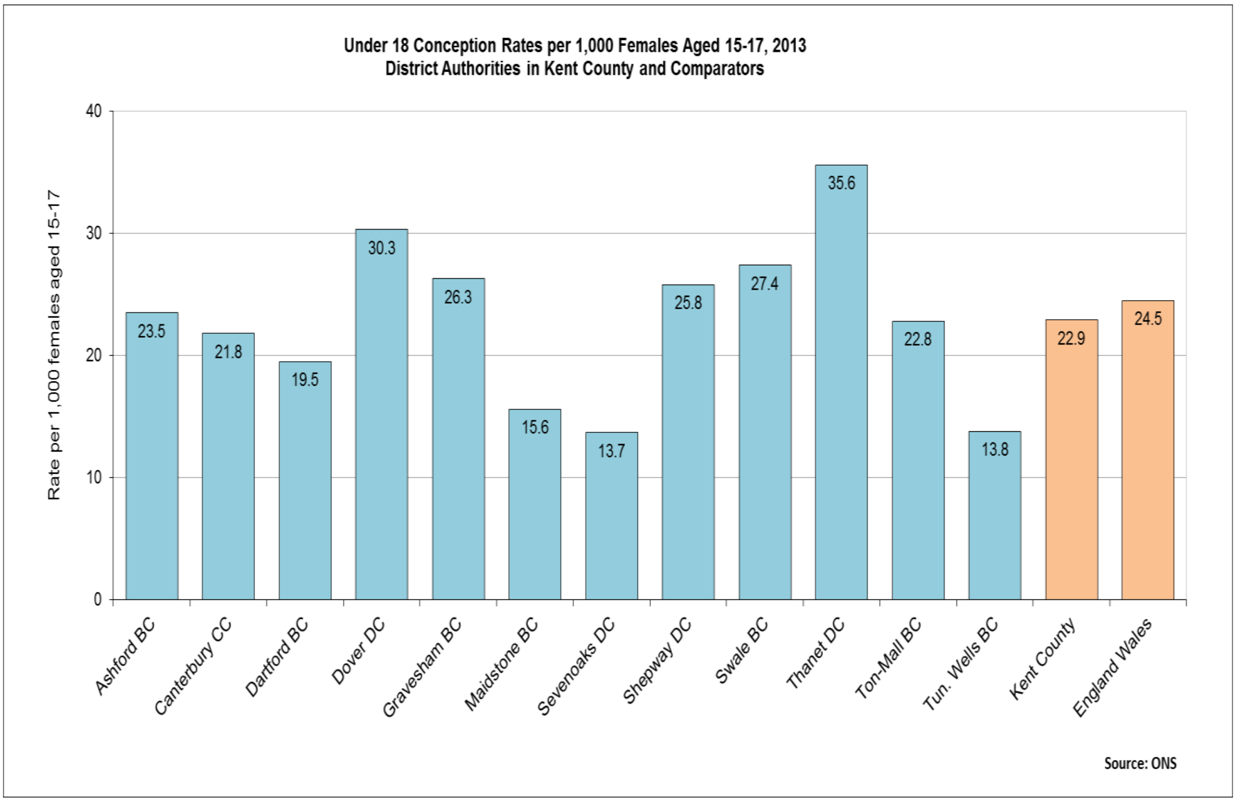
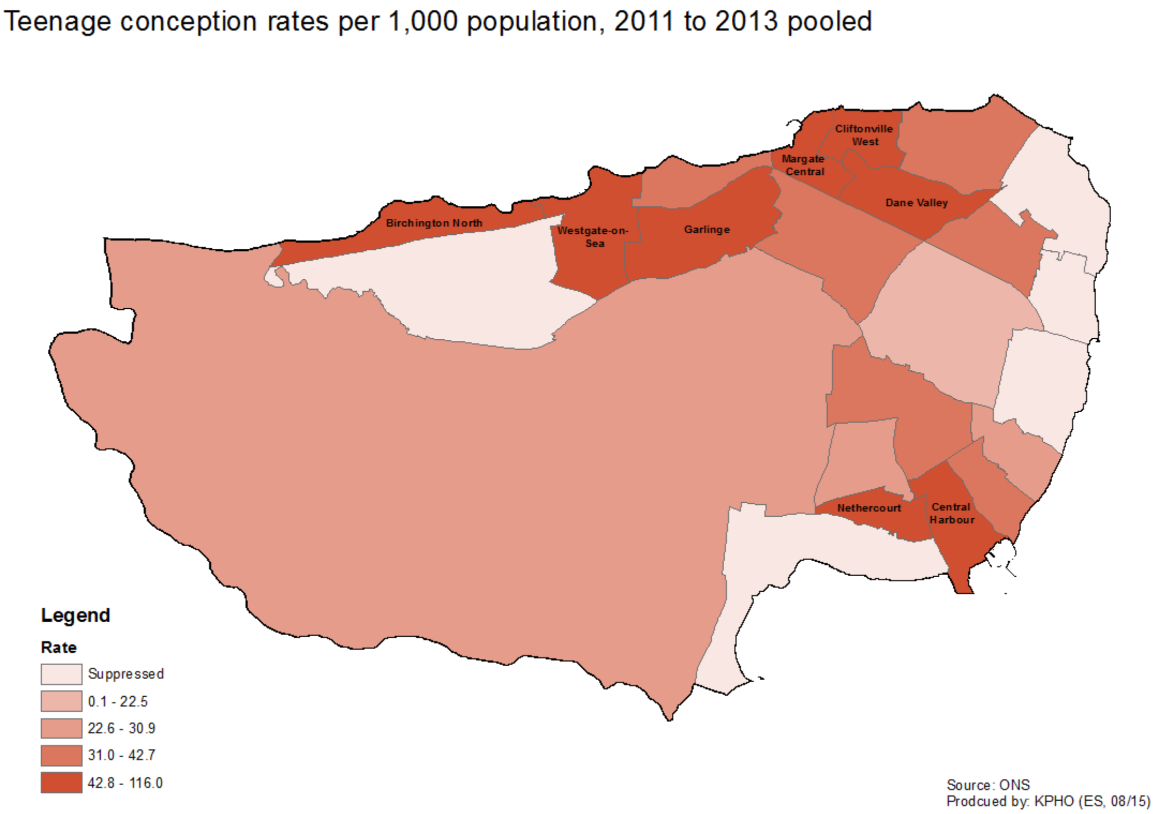
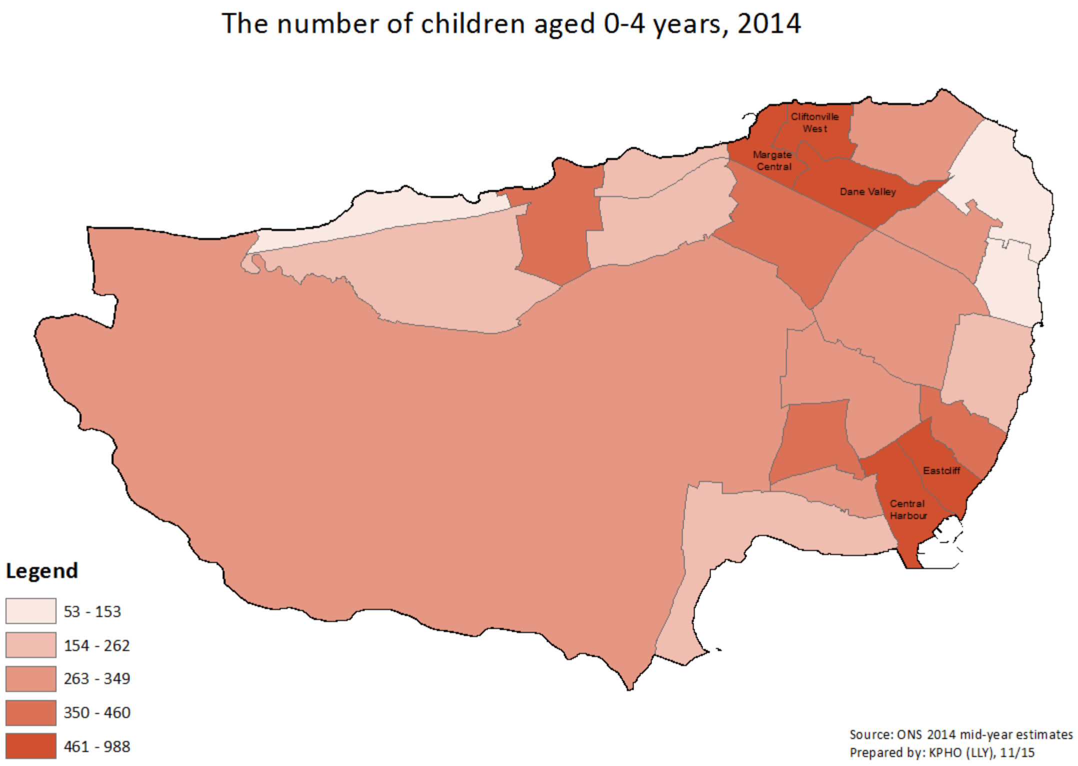


Figure 5: Ward level teenage conception rates - 2011-2013 (pooled data)



2.1 0-4s & 0-19s population distribution

Figure 6: Distribution of resident 0-4 yr olds in Thanet 2014



The distribution of young children across Kent is mainly centred around Margate and Ramsgate with the highest numbers found in Cliftonville West (950), Dane Valley (747) and Eastcliff (710).

Similarly the distribution for the 0-19 age group is also centred on the two main towns.

There are a total estimated number of 33,056 resident 0-19 year olds in Thanet in 2014, of which 8,385 are aged 0-4 years.

Figure 7: Distribution of resident 0-19 yr olds in Thanet 2014

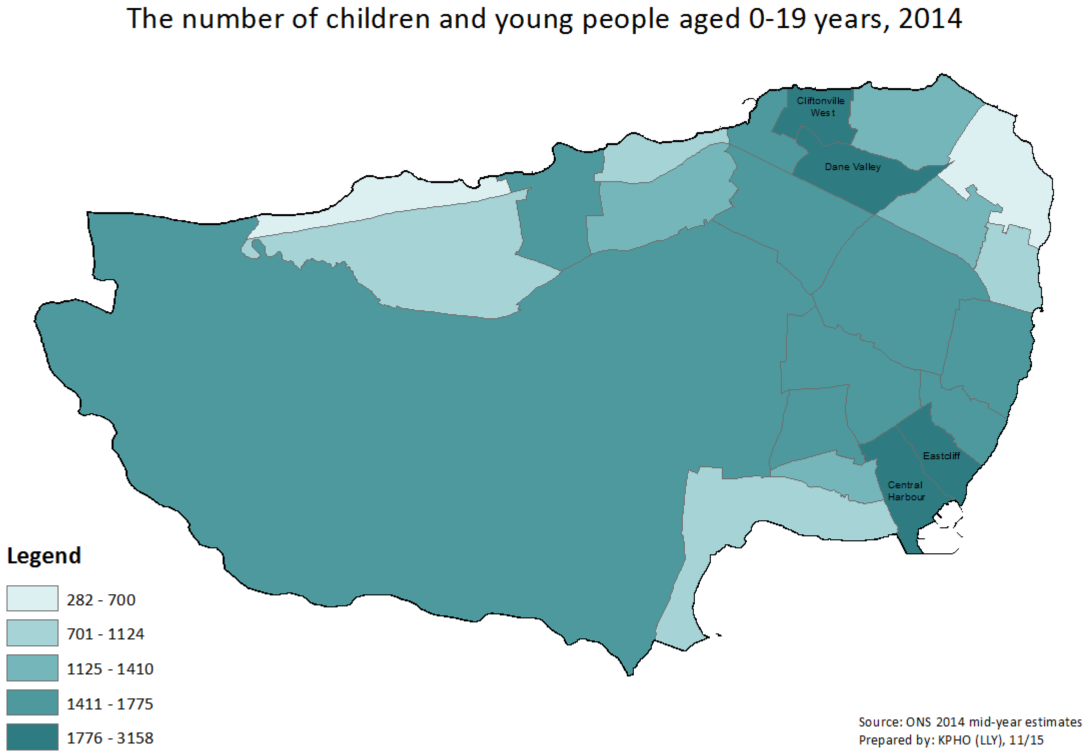


Table 3: Number of resident children and young people in Thanet 2014

The estimated number of resident children by Thanet electoral wards

Ward Name	0-4	0-19
Cliftonville West	950	3049
Dane Valley	747	2516
Eastcliff	710	2389
Central Harbour	566	2076
Margate Central	534	1648
Newington	423	1646
Salmestone	413	1559
Westgate-on-Sea	389	1484
Sir Moses Montefiore	381	1416
Northwood	316	1546
Beacon Road	314	1324
Thanet Villages	299	1467
St Peters	288	1523
Nethercourt	277	1135
Cliftonville East	269	1155
Birchington South	261	1093
Viking	255	1462
Garlinge	247	1185
Westbrook	205	900
Cliffsend & Pegwell	199	839
Bradstowe	149	727
Birchington North	124	492
Kingsgate	69	425

Source: ONS

2.2 Projecting the children and young people's population

The 8,385 0-4 year olds in Thanet is set to rise by 1.7% over the next 5 years. This is one of the smallest 0-4 population growths for 0-4 year olds in Kent.

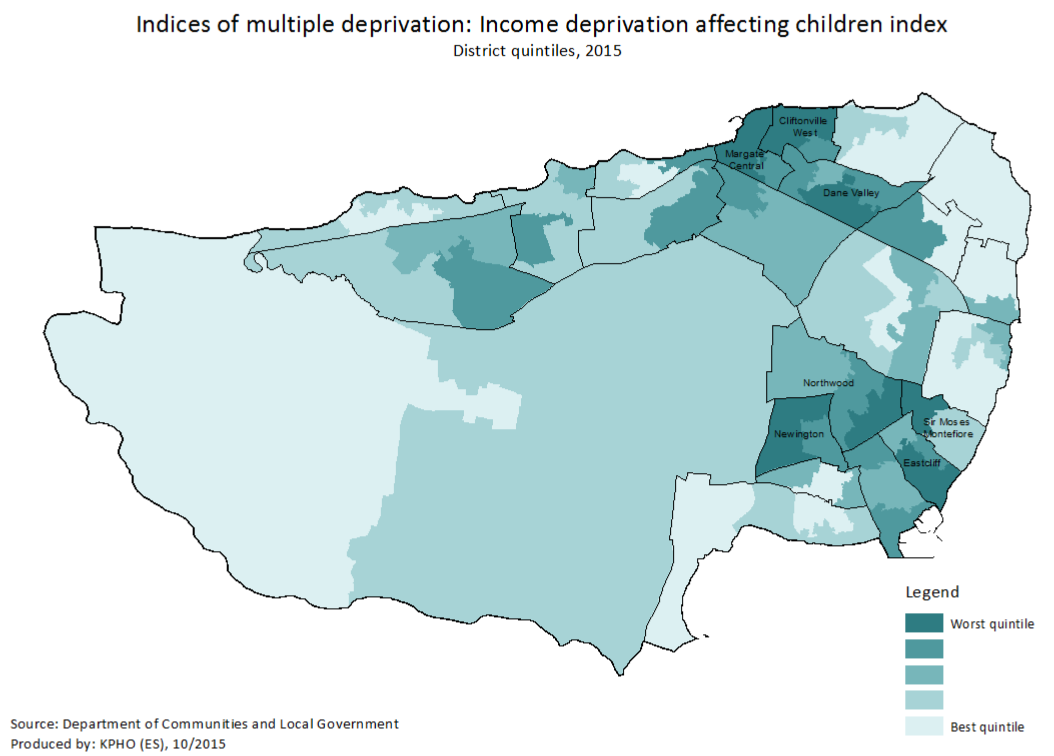
The 0-19 population is also set to rise over the next 5 years, this growth is predicted to rise by 3% which will equate to an extra 1,000 young people by the end of 2020.

2.3 Childhood poverty

Childhood poverty is measured using a sub-domain of the Income domain in the Indices of Multiple Deprivation called 'Income Deprivation Affecting Children Index' (IDACI).

This indicator measures the percentage of children who live in income deprived households (those in receipt of benefits) by Lower Super Output Area (LSOA) which are geographical small geographical areas comprising of approximately 1,500 population.

Figure 8: Income Deprivation Affecting Children Index



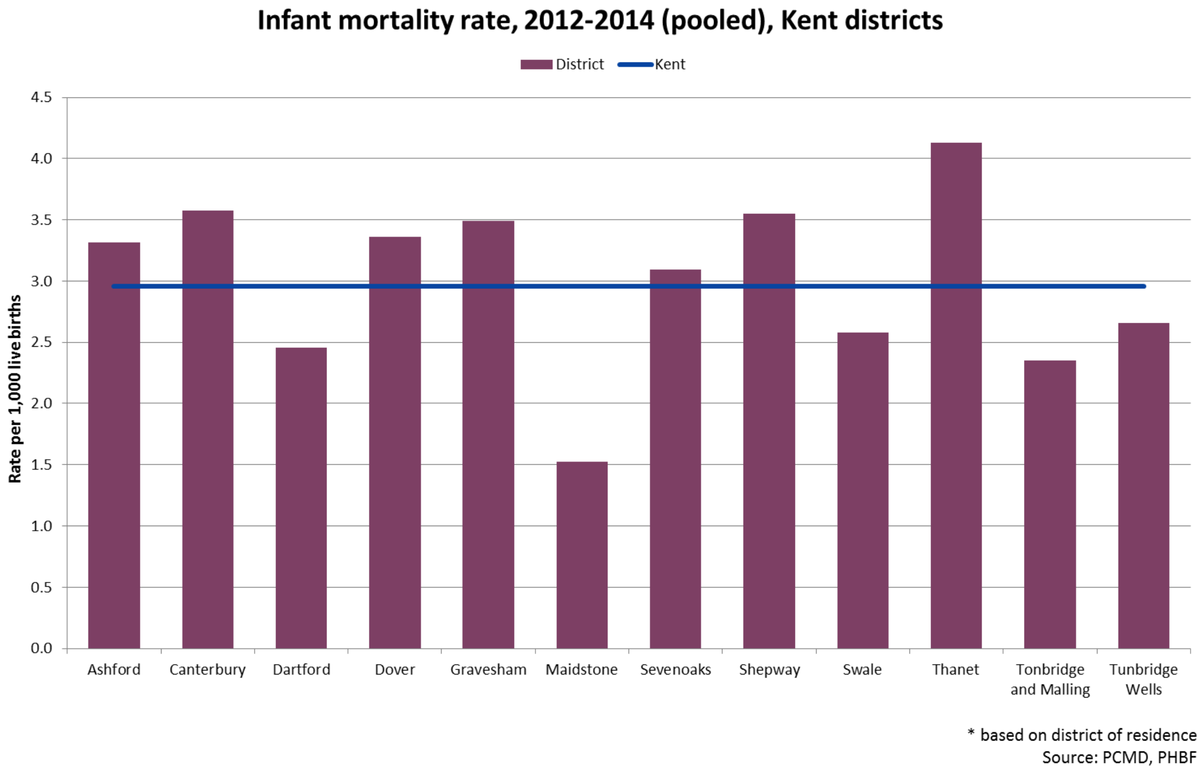
Electoral wards with relatively high levels of child poverty include Margate Central and Cliftonville West, where many of the LSOAs have more than 50% of children living in income deprived households. These particular areas are among the poorest in Kent.

Other wards with relatively high levels of child poverty include Dane Valley, Northwood, Newington and Eastcliff.

2.4 Infant Mortality

Infant mortality is defined as the death of a child less than one year of age. It is measured as infant mortality rate (IMR), which is the number of deaths of children under one year of age per 1000 live births.

Figure 9: Infant Mortality Rate (IMR)



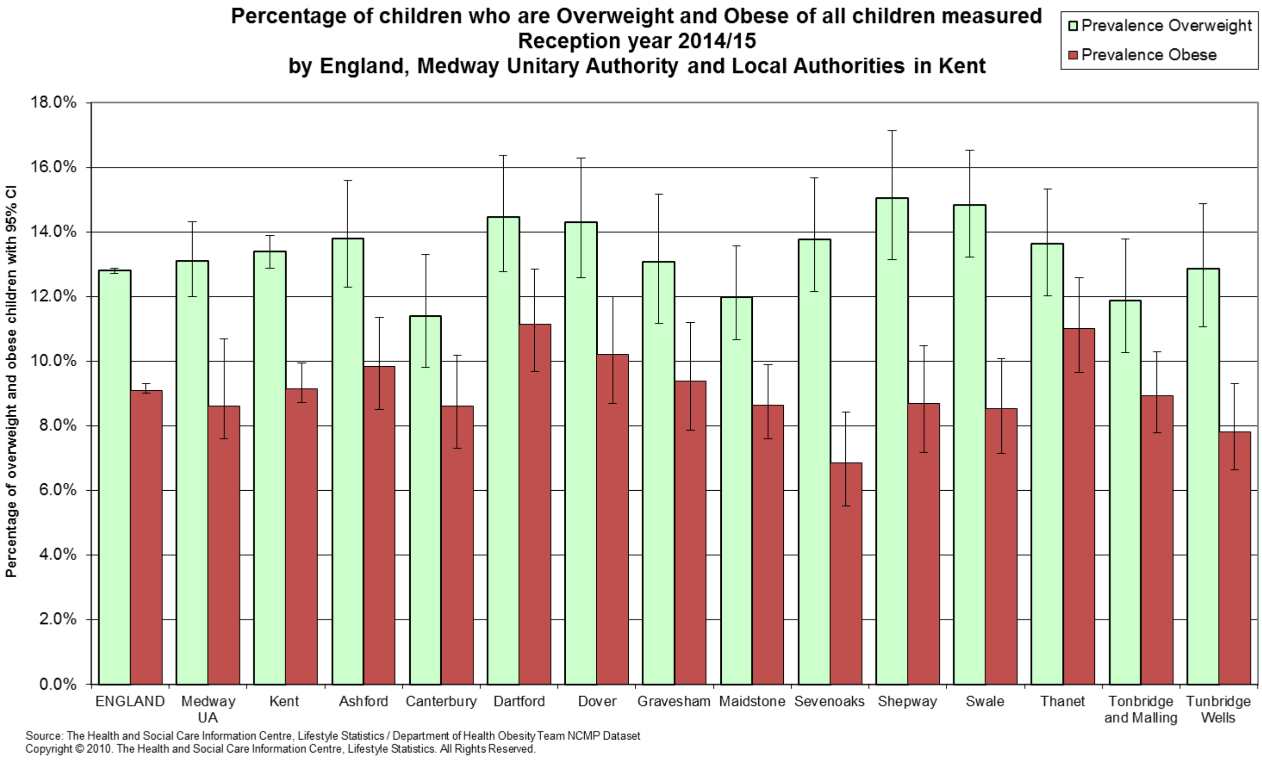
Thanet has the highest IMR for all districts in Kent for the period 2012-2014, other districts with high rates in Kent are Canterbury and Shepway. Lowest rates are found in Maidstone. The most common cause of death for infants is 'Sudden Infant Death Syndrome" (approximately 33% of all deaths in this age category) which is often related to extreme prematurity.

3. Childhood lifestyles

3.1 National Child Measurement Programme

3.1.1 Reception Year

Figure 10: Percentage of reception year children recorded with exces weight - School Year 2014/15



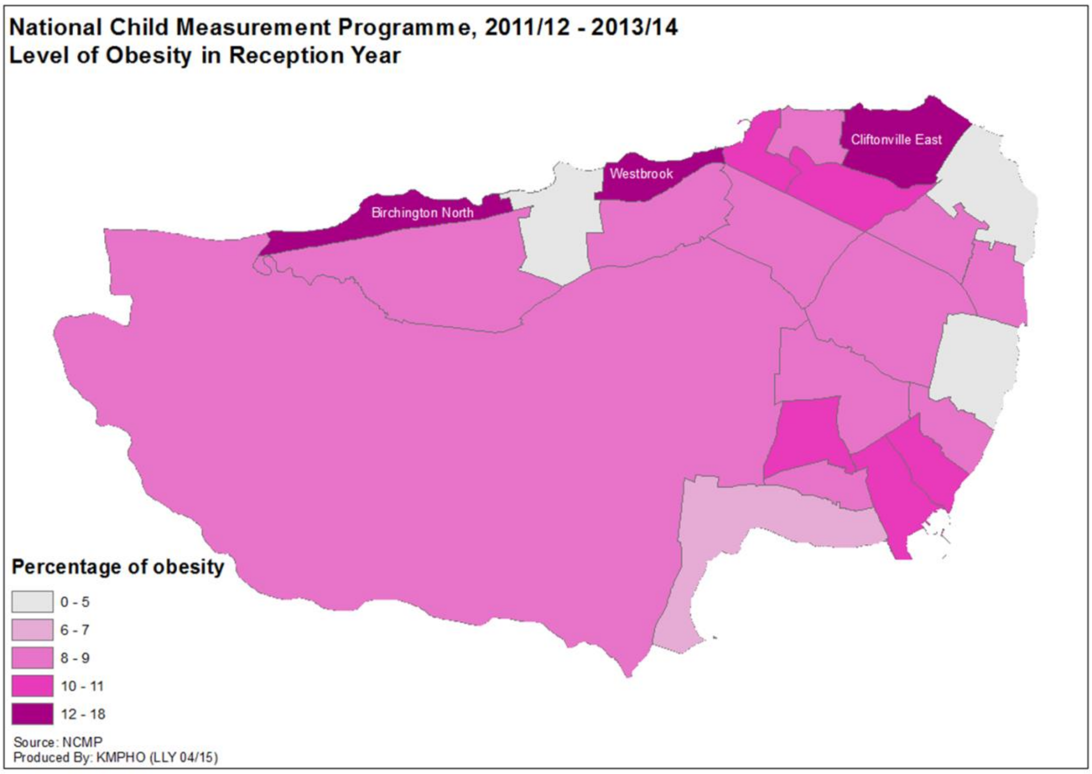
Levels of excess weight in reception year children have remained at between 21% and 23% since the programme began in 2006/07. In Thanet the levels have always been slightly higher at 22% to 24%. In the information shown in figure 10 Thanet has the third highest percentage of reception year children with excess weight at 24.6% (Dartford 25.6% and Dover 24.5%).

When looking at just obesity in isolation, Thanet (11%) and Dartford (11.1%) are the two worst districts in Kent and compare to a national prevalence of just 9%.

There are three electoral wards: Birchington North, Westbrook and Cliftonville East in Thanet, where more than 12% of the resident children were recorded as obese in their reception year. The wards of Westgate, Kingsgate and Viking have a rate of less than 5% for the three years 2011/12 to 2013/14

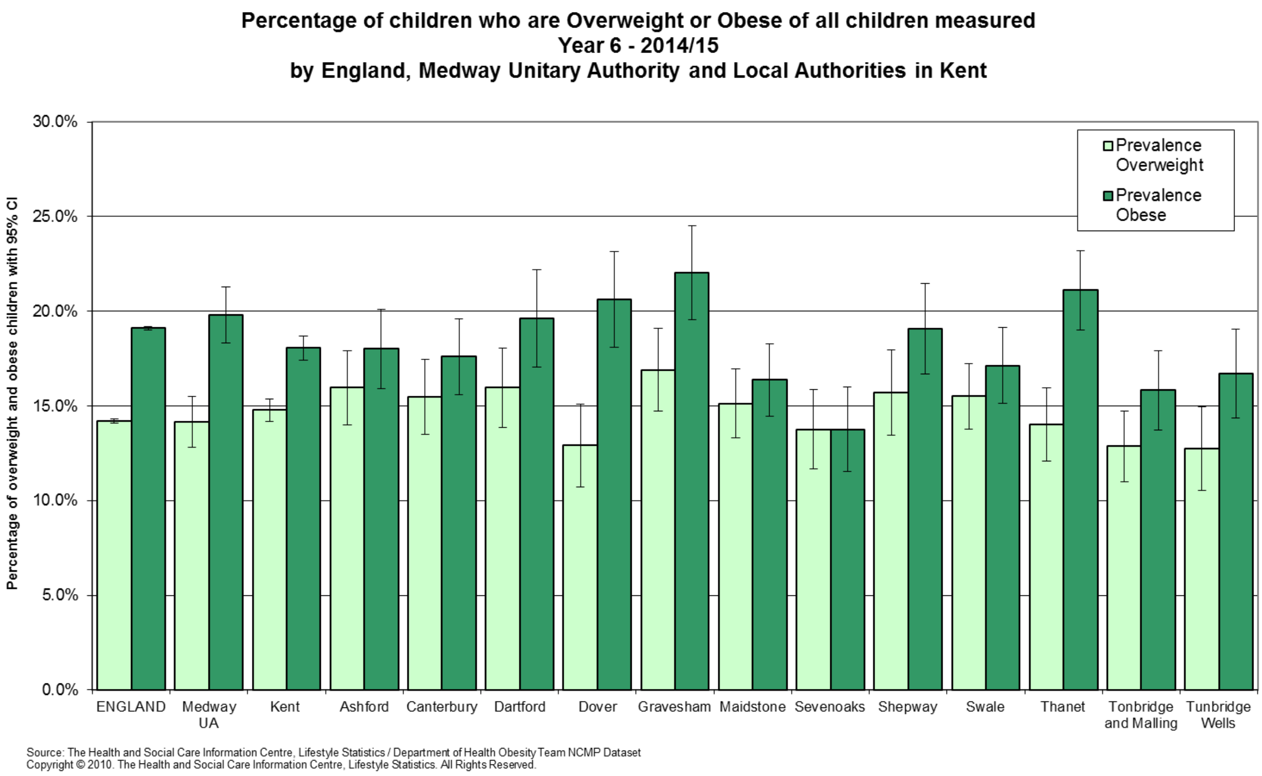
NOTE: At the time of writing the ward level 2014/15 NCMP data hadn't been released.

Figure 11: Reception year obesity levels by electoral wards in Thanet



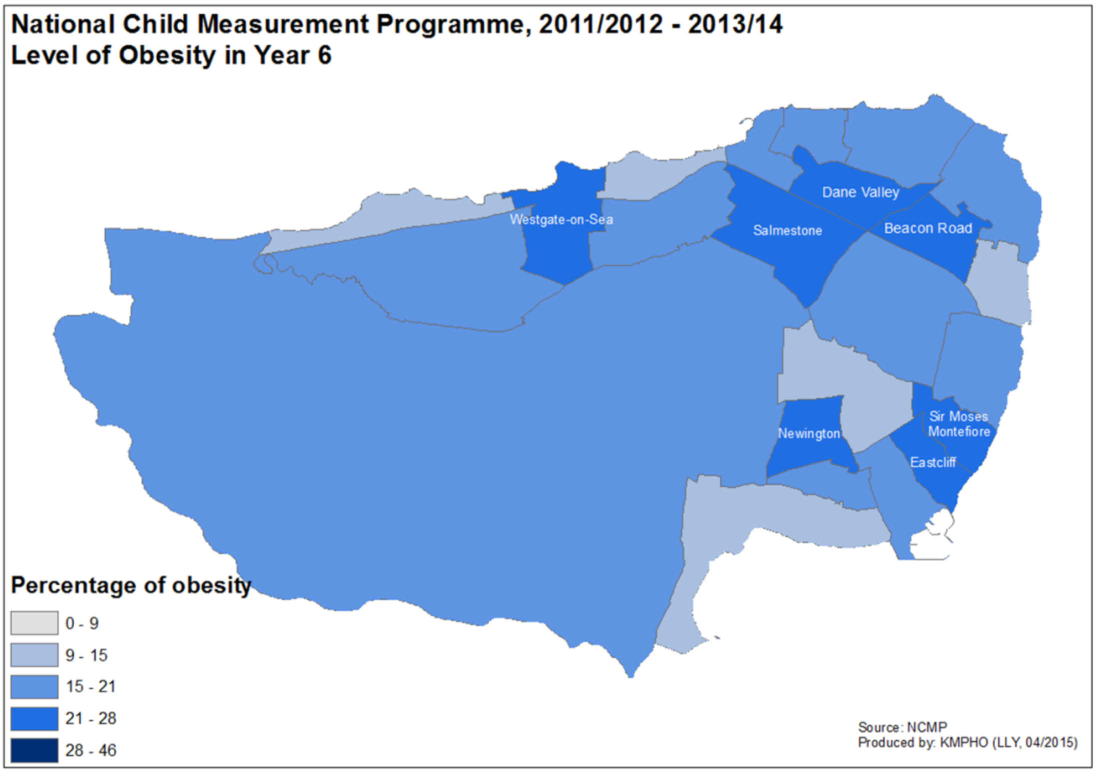
3.1.2 Year Six

Figure 12: Percentage of year 6 children recorded with excess weight - School Year 2014/15



Excess weight in year 6 children across Kent has risen from around 30% in 2007/08 to almost 33% in 2014/15. The three districts with the highest prevalence for year 6 children are Dartford 38.9%, Gravesham 35.6% and Thanet 35.1% .

Figure 13:Year 6 obesity levels by electoral ward in Thanet



Thanet District is recorded as the second highest Kent district when looking at obesity prevalence with 21%, compared to around 19% nationally and 18% across Kent.

Locally there were 7 electoral wards where the three year pooled prevalence (2011/12 to 2013/14) was greater than 21%: Westgate, Salmestone, Dane Valley, Beacon Road, Sir Moses Montifiore, Eastcliff and Newington.

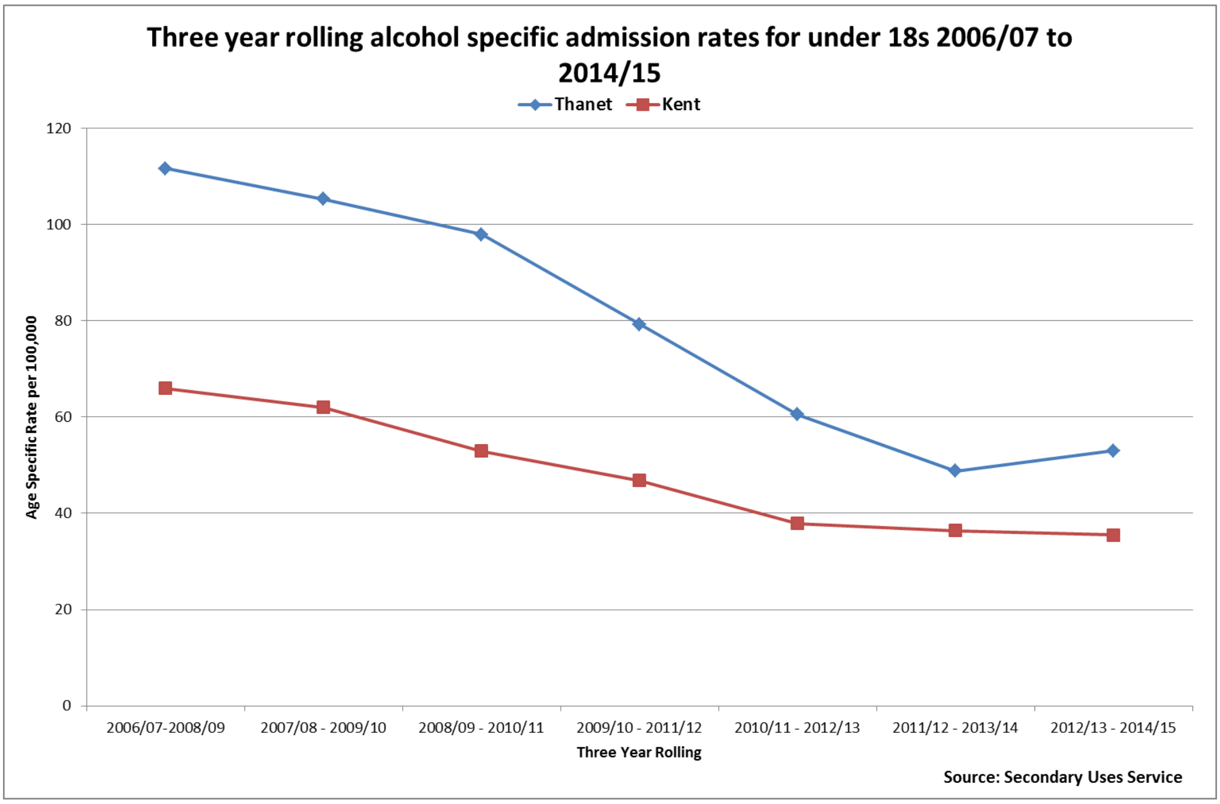
NOTE: At the time of writing the ward level 2014/15 NCMP data hadn't been released.

3.2 Under age alcohol

Admissions to hospital for alcohol specific conditions are recorded nationally for under 18s. The alcohol specific conditions that are used to monitor this indicator are detailed in the following document www.lape.org.uk/downloads/Lape_guidance_and_methods.pdf

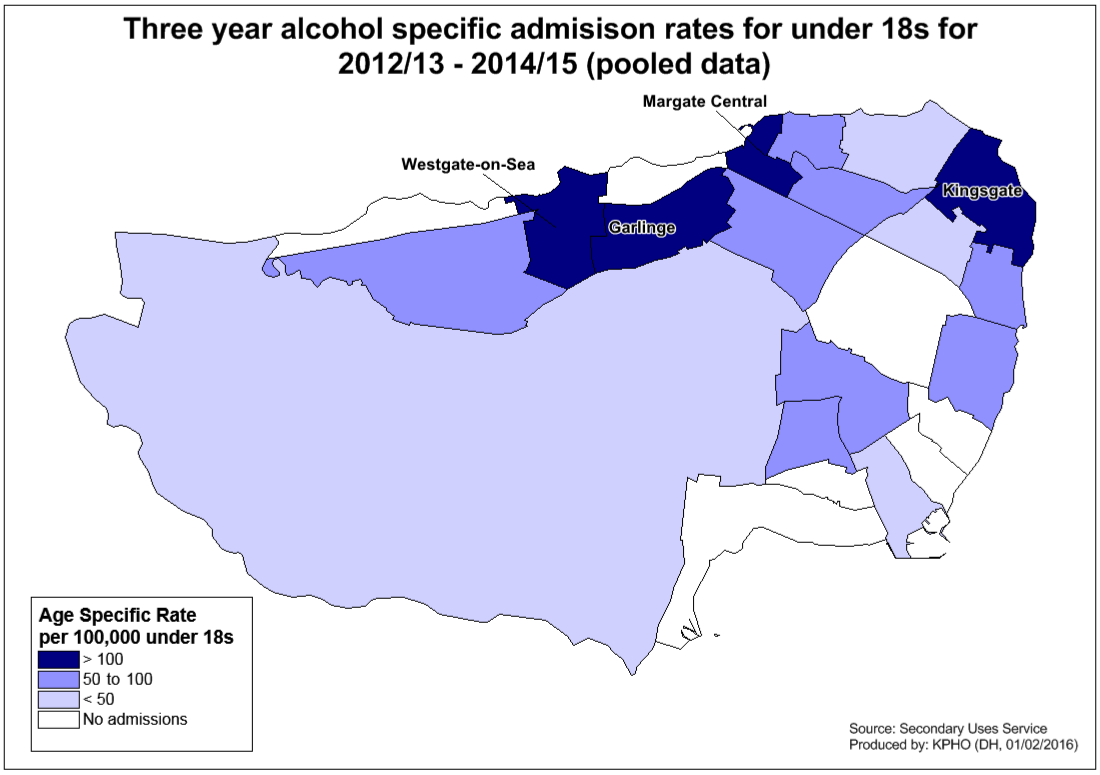
Admission rates for alcohol specific conditions for children aged under 18 has been steadily reducing over recent years. The rate for Thanet residents is higher than the Kent rate and the second highest rate of all districts in the county. Only Canterbury has a consistently higher rate.

Figure 14: Trend in alcohol specific admissions for under 18s



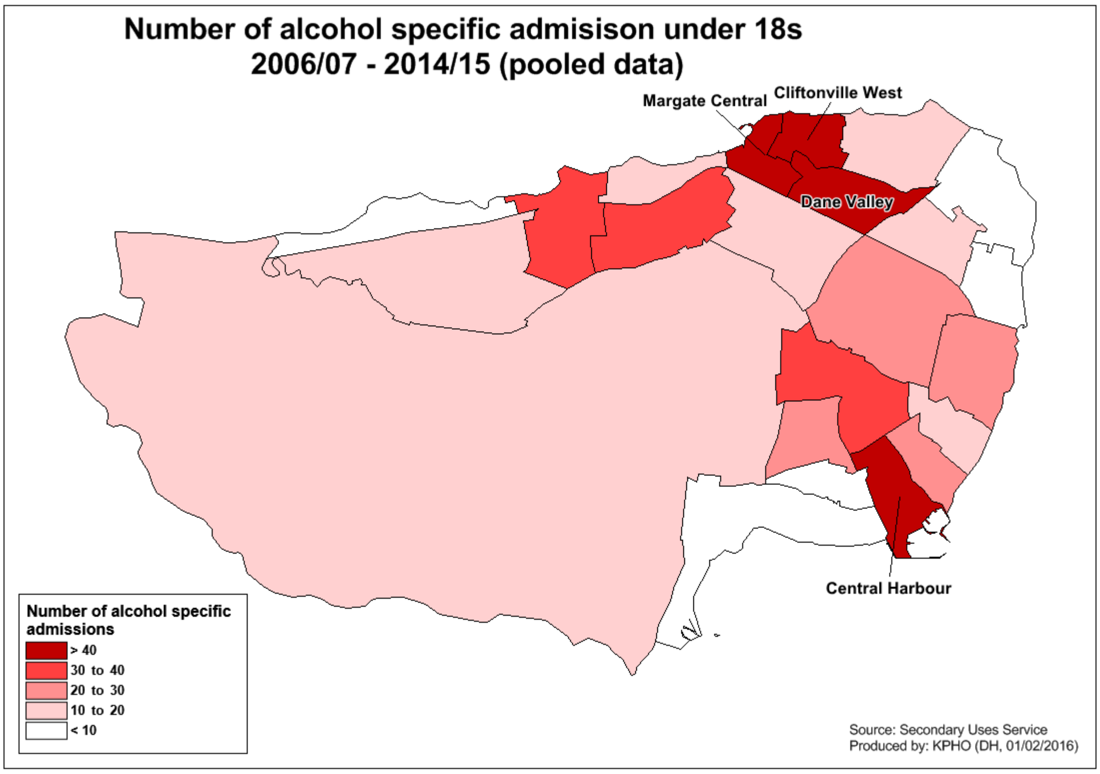
Locally the highest rates of admissions are found in Westgate (147 per 100,000), Garlinge (140), Margate Central (137) and Kingsgate (137) see figure 15.

Figure 15: Under 18 alcohol specific admission rates



However, as the actual numbers involved over a three year period are relatively small it is more helpful to look at the total number of admissions over a longer time period. Figure 16 shows the nine years of admission numbers by electoral ward. Four electoral wards have in excess of 40 admissions over that period:- Margate Central (47), Cliftonville West (53), Dane Valley (45) and Central Harbour (41).

Figure 16: The number of alcohol specific admissions



4. Hospital Admissions and Attendances

4.1 Elective and Emergency Care

4.1.1 Elective Admissions

The rate of elective admissions, for those aged under 18, over the period 2006/07 to 2014/15 is shown for Thanet and Kent in figure 17. The trend in the rate has been steadily increasing over this time period with Thanet consistently higher than Kent. In 2014/15 the rate in Thanet was the fourth highest behind Shepway, Gravesham and Dover.

A breakdown of reason for the elective admissions in the last three years of the trend is shown in table 4. Diseases of oral cavity, salivary glands and jaws form the largest single reason accounting for just over 11% of all elective admissions for this age group.

Figure 17: Trends in under 18 elective admission rates

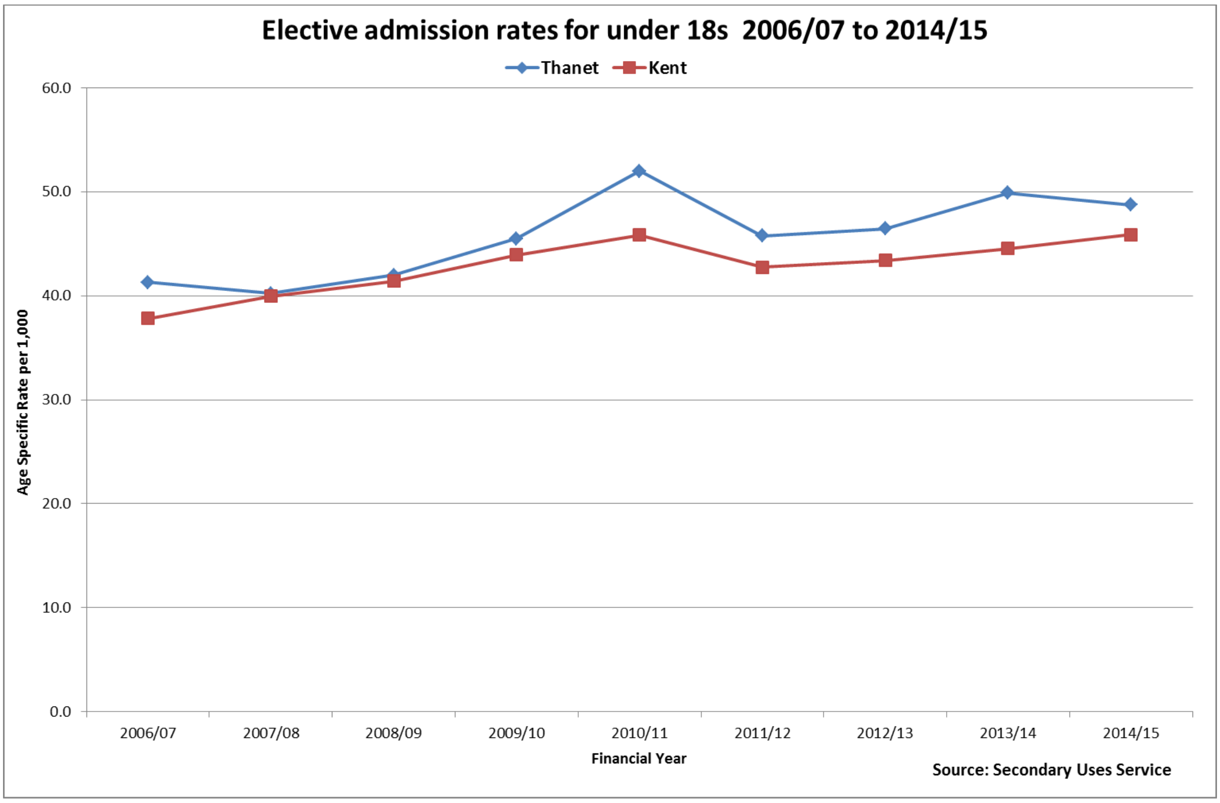


Table 4: Primary reason for elective admission - Under 18s

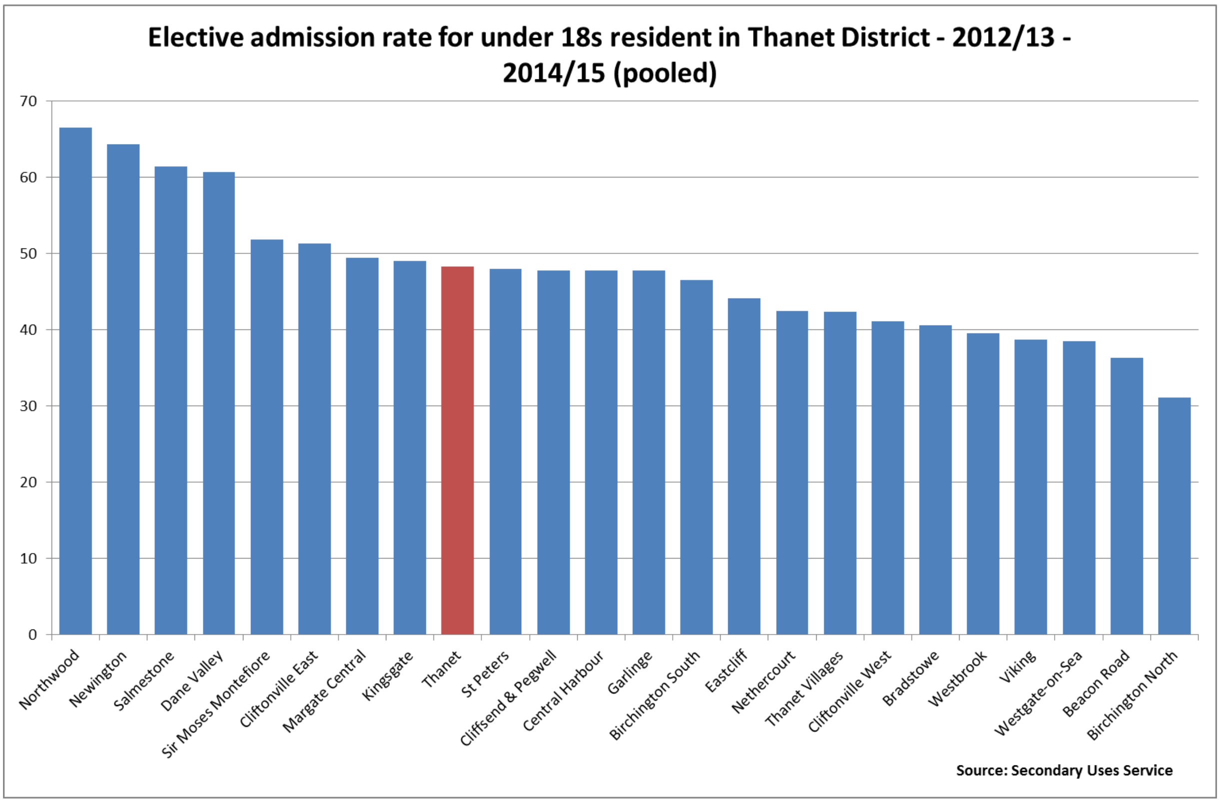
Primary reason for elective admission for under 18s resident in Thanet - 2012/13 - 2014/15 (pooled data)

Primary Condition	Number of Admissions
Diseases of oral cavity, salivary glands and jaws	479
Diseases of middle ear and mastoid	262
Acute upper respiratory infections	204
Malignant neoplasms, stated or presumed to be primary, of lymphoid, haematopoietic and related tissue	201
Other congenital malformations of the digestive system	179
Diseases of male genital organs	176
Other diseases of upper respiratory tract	154
Persons encountering health services for examination and investigation	135
Persons encountering health services for specific procedures and health care	114
Congenital malformations of genital organs	110
Benign neoplasms	105
Congenital malformations and deformations of the musculoskeletal system	102
Systemic connective tissue disorders	101
Arthropathies	99
Symptoms and signs involving the circulatory and respiratory systems	81
Other diseases of intestines	74
General symptoms and signs	72
Malignant neoplasm of mesothelial and soft tissue	66
Hernia	66
Congenital malformations of the circulatory system	60
All other conditions	1451

Source: Secondary Uses Service

Locally the highest elective admission rate over the last three years is recorded in Northwood, Newington, Salmestone and Dane Valley areas.

Figure 18: Elective admission rates for under 18s by electoral ward



4.1.2 Emergency Admissions

The rate of emergency admissions, for those aged under 18, over the period 2006/07 to 2014/15 is shown for Thanet and Kent in figure 17. Whilst the trend in the rate remained fairly constant over this time period, with Thanet consistently higher than Kent, there has been a sharp rise in the rate for 2014/15 reflected across Kent. In 2014/15 the rate in Thanet was the second highest behind Dartford.

A breakdown of reason for the emergency admissions in the last three years of the trend is shown in table 5. Acute respiratory infections (upper and lower) account for just over 17.5% of all emergency admissions for this age group.

Figure 19: Trends in under 18 emergency admission rates

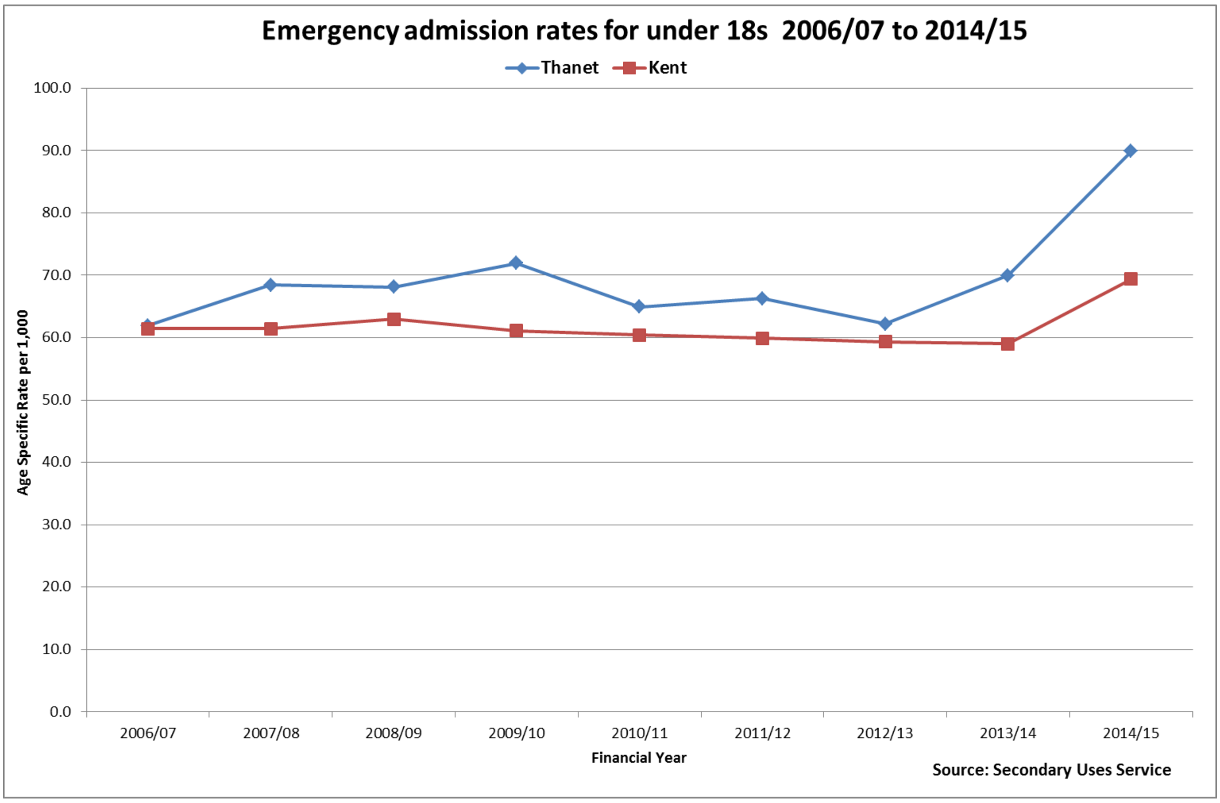


Table 5: Primary reason for elective admission - Under 18s

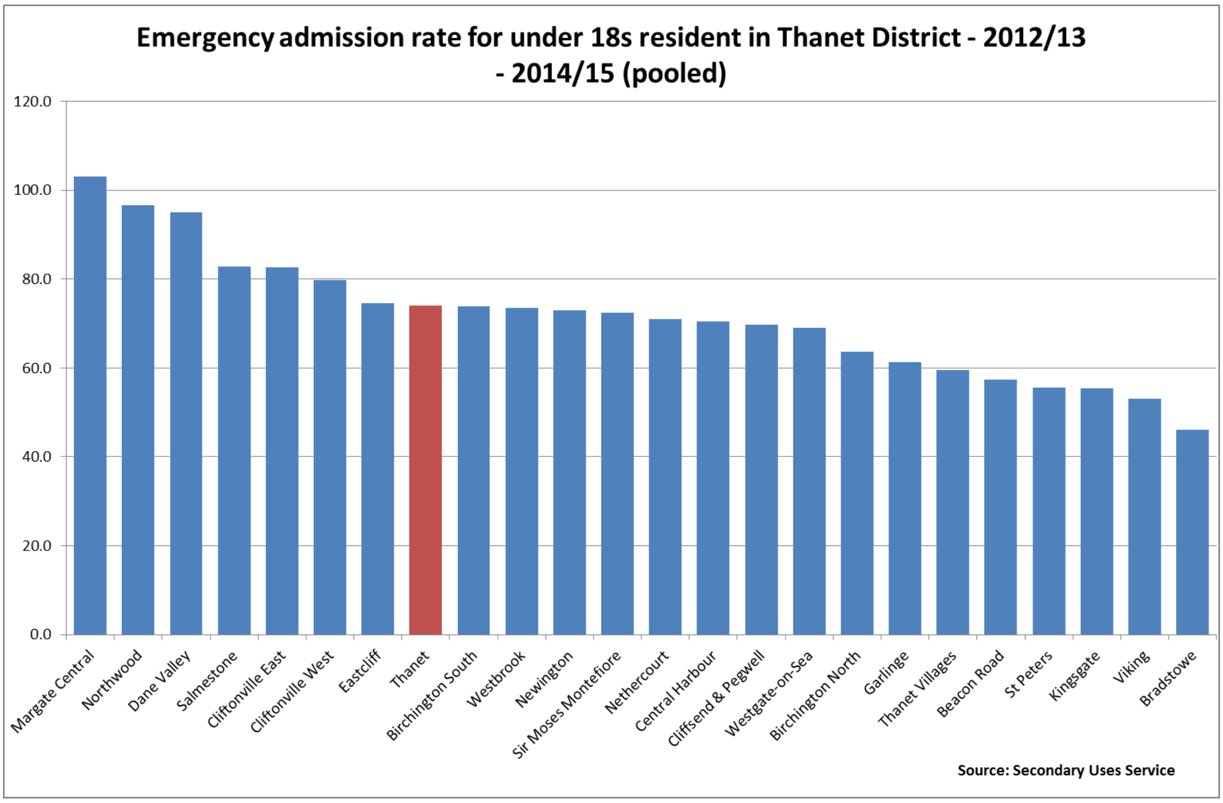
Primary reason for emergency admission for under 18s resident in Thanet - 2012/13 - 2014/15 (pooled data)

Primary Condition	Number of Admissions
Acute upper respiratory infections	702
Other acute lower respiratory infections	450
General symptoms and signs	426
Other viral diseases	398
Intestinal infectious diseases	339
Symptoms and signs involving the digestive system and abdomen	298
Injuries to the head	252
Chronic lower respiratory diseases	184
Symptoms and signs involving the circulatory and respiratory systems	170
Poisoning by drugs, medicaments and biological substances	155
Other diseases of intestines	150
Haemorrhagic and haematological disorders of fetus and newborn	127
Diseases of appendix	124
Injuries to the elbow and forearm	123
Episodic and paroxysmal disorders	104
Other disorders originating in the perinatal period	103
Diseases of oesophagus, stomach and duodenum	102
Symptoms and signs involving the skin and subcutaneous tissue	96
Diabetes mellitus	91
Influenza and pneumonia	87
All other conditions	2092

Source: Secondary Uses Service

Locally the highest emergency admission rate over the last three years is recorded in Margate Central, Northwood, Dane Valley and Salmestone areas.

Figure 20: Emergency admission rates for under 18s by electoral ward



4.2 Deliberate and Unintentional Injury

The recent trend in admissions for deliberate and unintentional injury for children aged under 18 are shown in figure 21. Whilst the rate across Thanet and Kent is falling, it is still higher in Thanet (the second highest district behind Dartford).

Locally the highest admission rate for deliberate and unintentional injury over the last three years is recorded in Margate Central, Northwood, Dane Valley and Newington areas.

Figure 21: Trends in admissions for deliberate and unintentional injury - under 18s

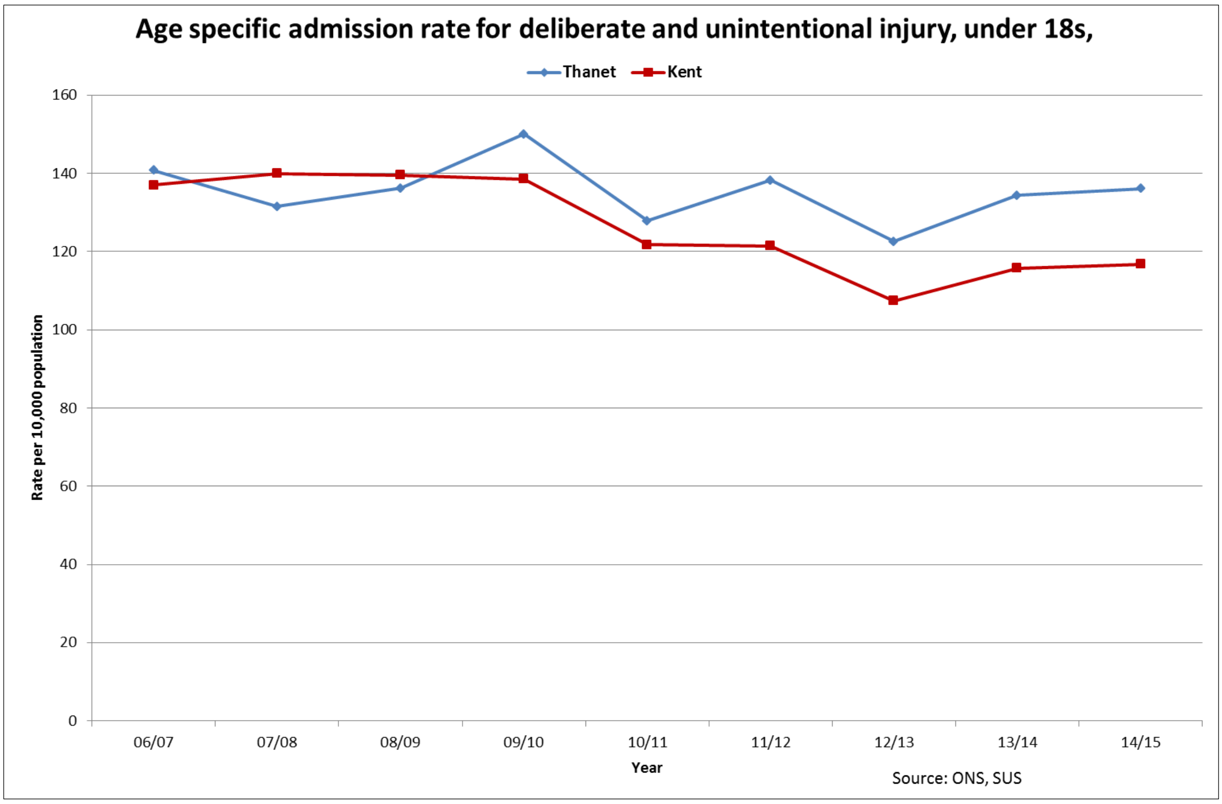
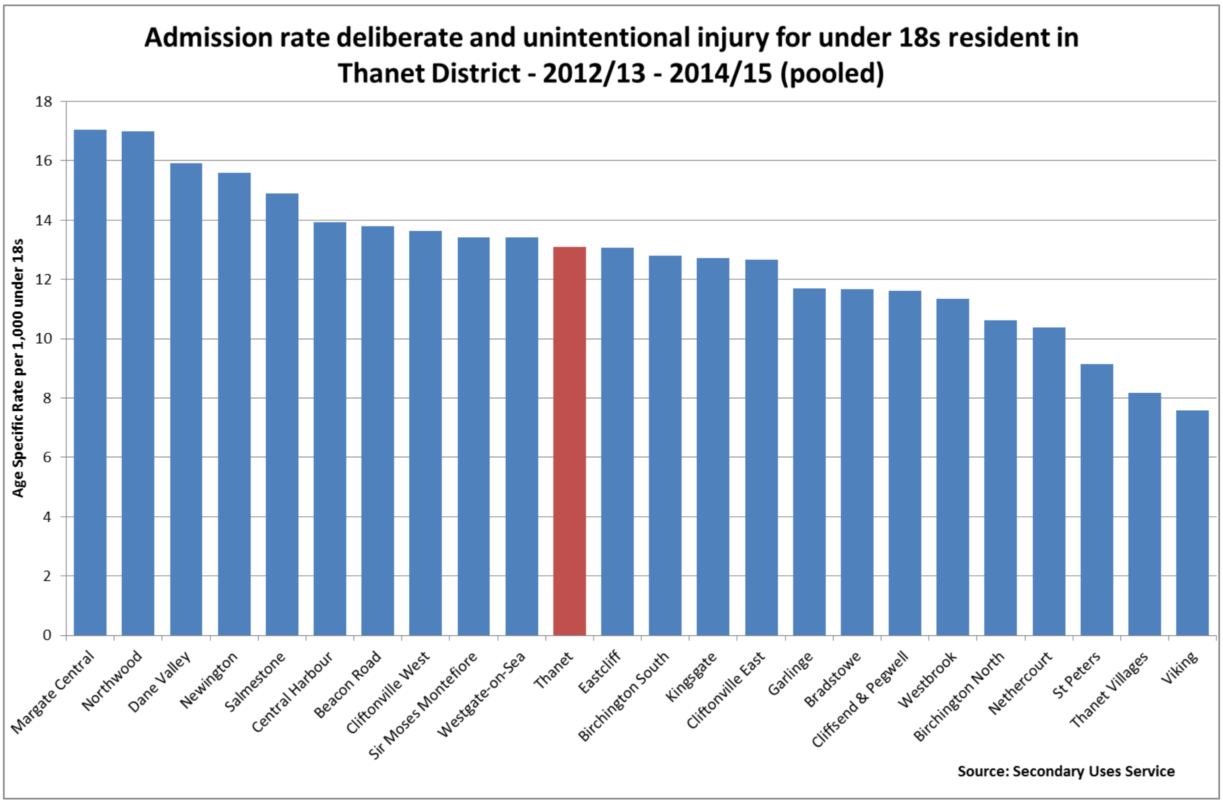


Figure 22: Admissions for deliberate and unintentional injury



Tables 6 and 7 (below) detail the type of injuries, and causes of those injuries, that were most common within age groups 0-4, 5-9, 10-14 and 15-17. The pattern of injuries and causes across Thanet are no different than those for Kent generally.

Table 6: Most common injuries for children admitted for deliberate and unintentional injury

Admissions to hospital for deliberate and unintentional injury in children aged 0-17 years - Top 5 injuries by age group

Under 18

Injury	%
Head injury	25%
Poisoning by drugs, medicaments and biological substances	14%
Other complications	12%
Injuries to elbow/forearm	11%
Injuries to knee and lower leg	6%

Aged 10-14

Injury	%
Injuries to elbow/forearm	24%
Poisoning by drugs, medicaments and biological substances	22%
Other complications	14%
Head injury	12%
Injuries to knee and lower leg	7%

Under 5

Injury	%
Head injury	46%
Complications of healthcare	8%
Poisoning by drugs, medicaments and biological substances	8%
Other complications	6%
Foreign body entering through a natural orifice	4%

Aged 15-17

Injury	%
Poisoning by drugs, medicaments and biological substances	25%
Other complications	12%
Head injury	12%
Injuries to wrist and hand	10%
Injuries to knee and lower leg	9%

Aged 5-9

Injury	%
Injuries to elbow/forearm	22%
Other complications	21%
Head injury	13%
Injuries to knee and lower leg	7%
Injuries to upper arm	7%

The most common injury for under 18s is 'head injury', although this tends to be in the younger age groups, 'poisoning by drugs, medicaments and biological substances' is more common in the older age groups, especially the 15-17 year group.

Table 7: Most common causes of deliberate and unintentional injury

Admissions to hospital for deliberate and unintentional injury in children aged 0-17 years - top 5 causes by age group

Under 18

Cause	%
Fall	30%
Exposure to inanimate mechanical forces	14%
Complications of medical and surgical care	12%
Accidental poisoning	9%
Intentional self poisoning	8%

Aged 10-14

Cause	%
Fall	25%
Intentional self poisoning	16%
Exposure to inanimate mechanical forces	14%
Complications of medical and surgical care	13%
Transport accident	8%

Under 5

Cause	%
Fall	38%
Accidental poisoning	14%
Complications of medical and surgical care	12%
Accidental exposure to unspecified factors	12%
Exposure to inanimate mechanical forces	11%

Aged 15-17

Cause	%
Intentional self poisoning	21%
Exposure to inanimate mechanical forces	16%
Fall	14%
Transport accident	9%
Complications of medical and surgical care	8%

Aged 5-9

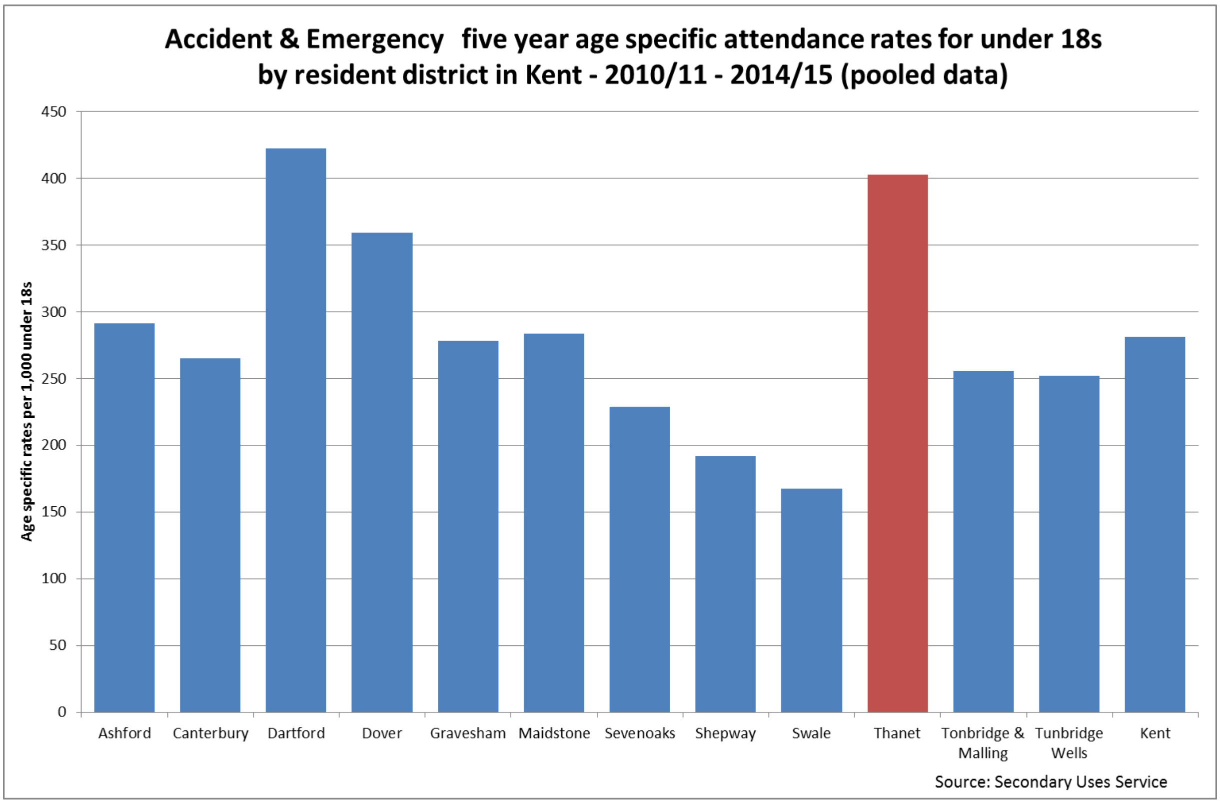
Cause	%
Fall	42%
Complications of medical and surgical care	16%
Exposure to inanimate mechanical forces	15%
Transport accident	9%
Exposure to animate mechanical forces	6%

The most common cause on injury in the younger age groups is for a 'fall' of some type. In the older age groups it is 'intentional self-poisoning'.

4.3 Accident & Emergency Attendances

The number of attendances to accident and emergency departments by Thanet resident children, aged under 18, are the highest in Kent for the five year period 2010/11 to 2014/15. However the rate of attendance is the second highest district in Kent, behind Dartford.

Figure 23: A&E attendance rates by district

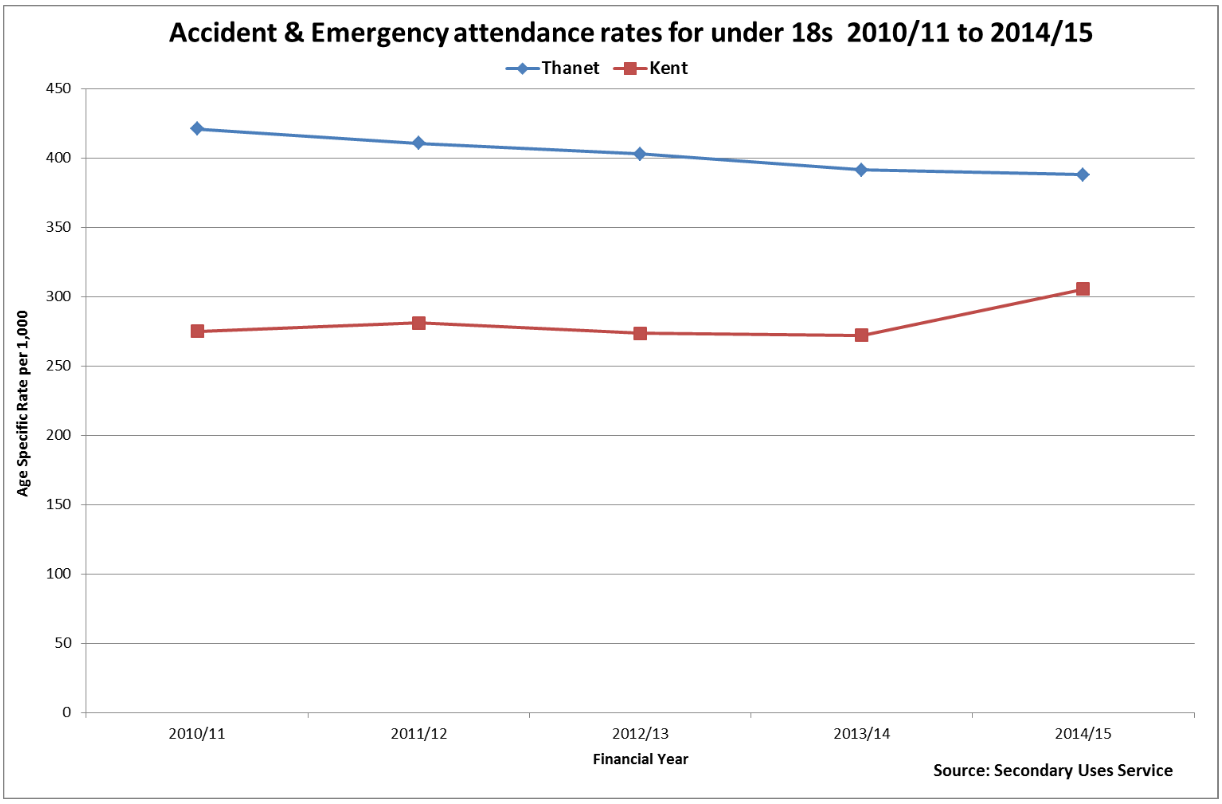


The number of attendances, by Thanet resident under 18s, across this five year period is 59,139 or 11,827 per year or slightly more than 32 per day.

The trend in accident & emergency attendances by Thanet resident under 18s has been steadily falling over the five year period 2010/11 to 2014/15. This is in contrast to the rate across Kent, which has seen a sharp rise in 2014/15.

The Kent level rise is a reflection of data collation rather than an increased number of attendances. Early in 2014/15 a number of Minor Injury Units (MIU) also started to submit their attendance data to the Secondary Uses System (the national systems for collating hospital activity data) which has resulted in an apparent rise in rates. With no MIU based in Thanet, this extra data collation has not affected the Thanet attendance figures in the same way.

Figure 24: A&E attendance rate trend



Accident and emergency attendances by electoral ward of residence are shown in figures 25 (numbers) and 26 (rates).

High numbers of attendances are from Cliftonville West and Dane Valley, where both areas saw more than 5,000 attendances in the five year period. Lowest number of attendances were from Kingsgate and Birchington North (< 1,000).

High age specific rates of attendances were recorded for Cliftonville West, Margate Central, Dane Valley, Newington and Salmestone. Low attendance rates for Bradstowe and Viking wards.

Figure 25: Number of accident & emergency attendances for under 18s

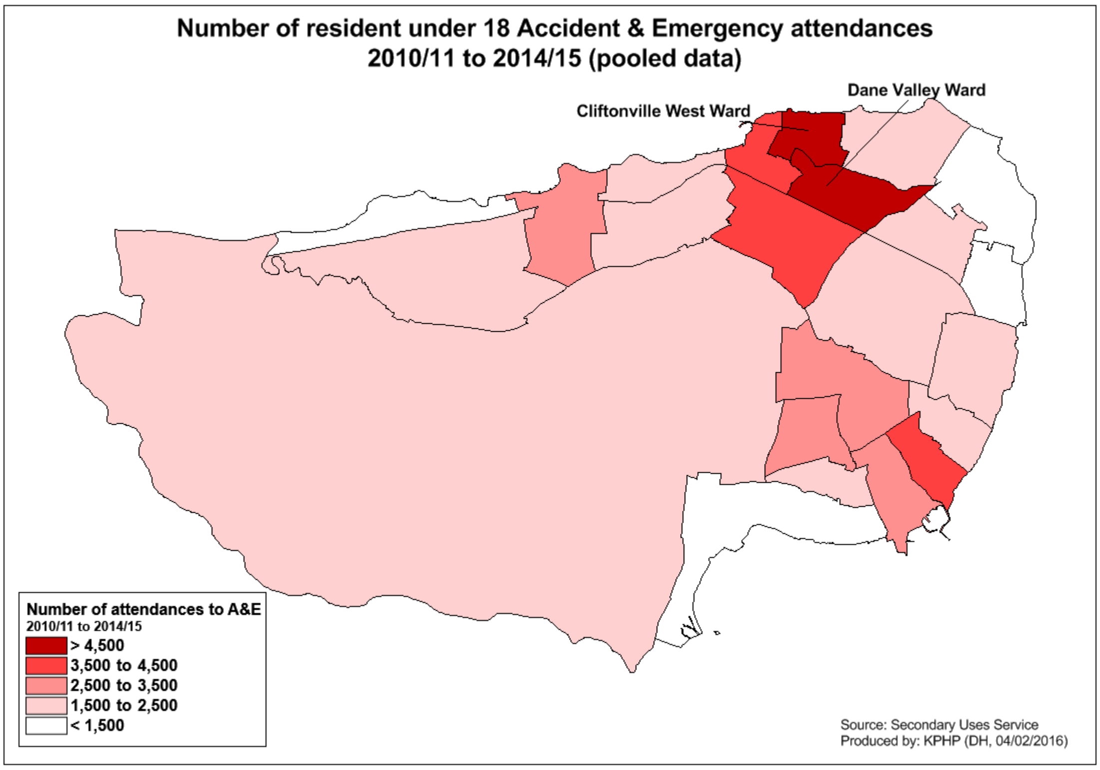
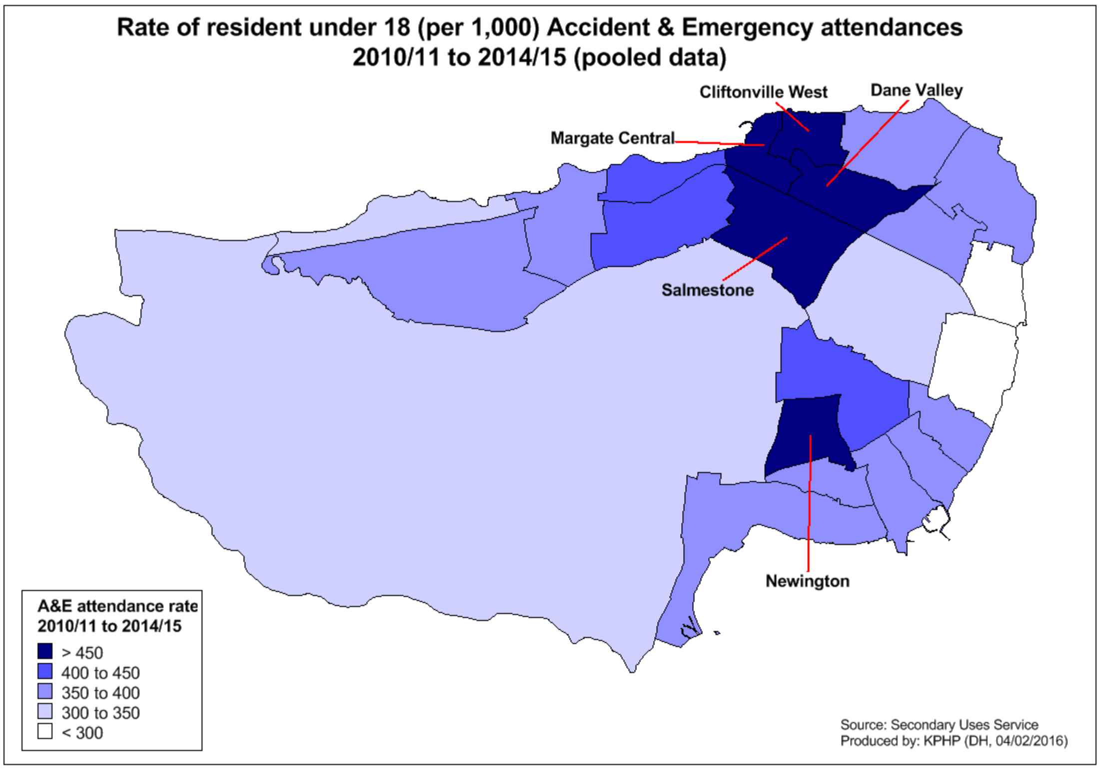


Figure 26: Age specific rate of attendance, per 1,000 under 18s



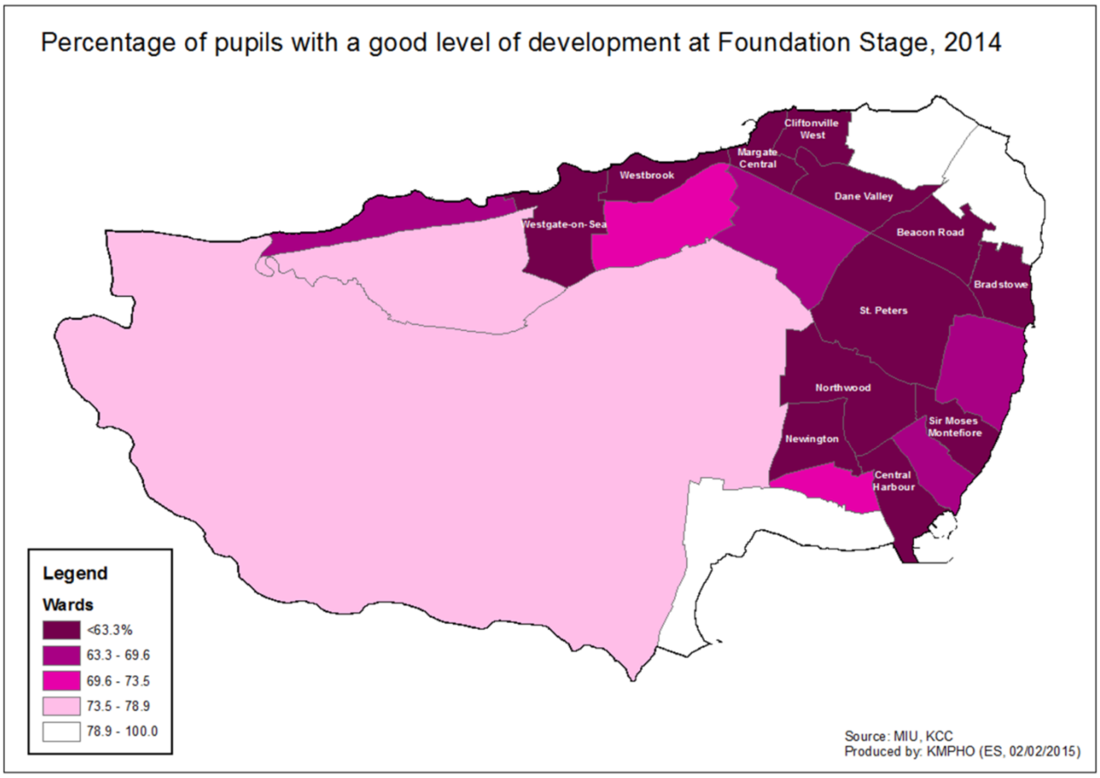
5. Education

4.1 Good level of development

Children are defined as having reached a good level of development at the end of the Early Year Foundation Stage (EYFS) if they achieve at least the expected level in: the early learning goals in the prime areas of learning (personal, social and emotional development; physical development; and communication and language) and; the early learning goals in the specific areas of mathematics and literacy.

The overall percentage for Thanet is 60%, this compares to 66% nationally and 72% across Kent. There are a significant number of electoral wards in Thanet that fall below 60%

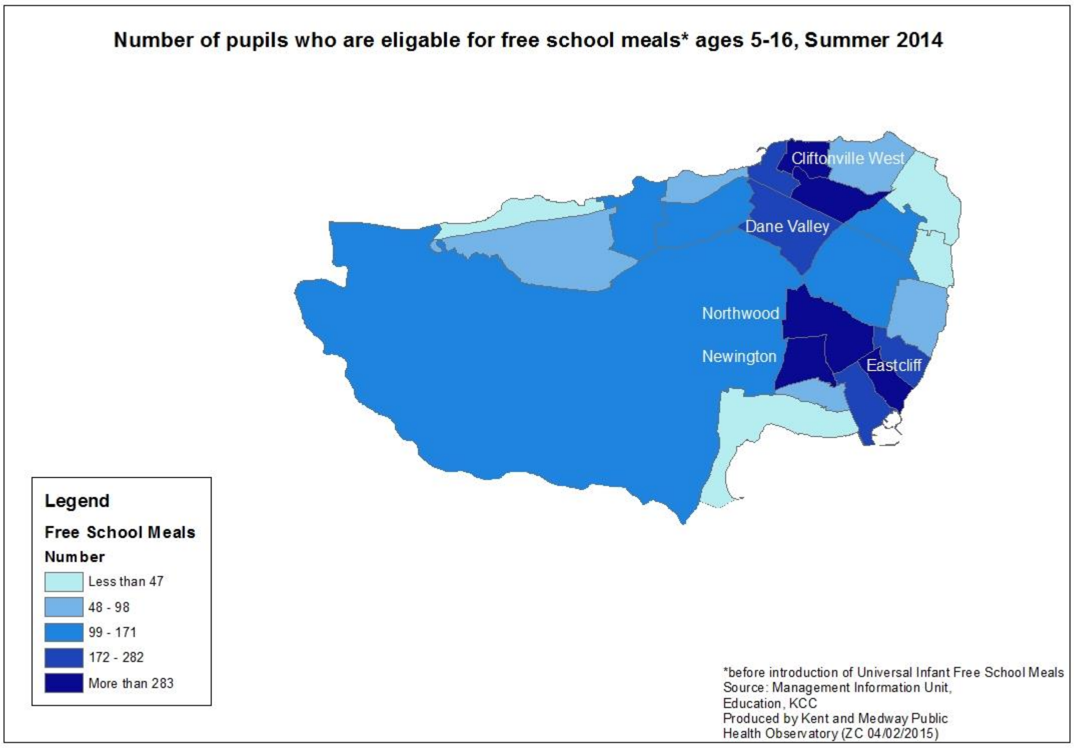
Figure 27: Good level of development



4.2 Free school meals eligibility

There are slightly more than 4,100 children eligible for free schools meals who are resident in Thanet. The largest proportion (a little over 50%) of these pupils are resident in Cliftonville West, Dane Park, Northwood, Eastcliff and Newington.

Figure 28: Number of children eligible for free school meals

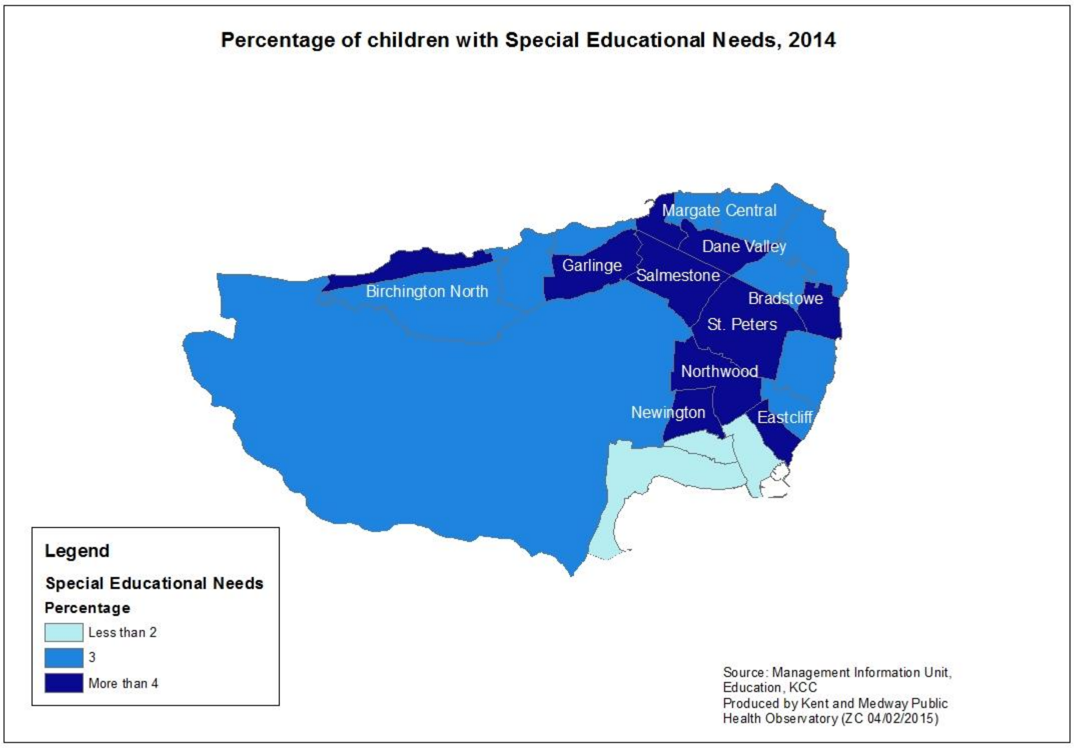


4.3 Special Educational Need

Special educational needs are defined as the educational requirements of pupils or students suffering from any of a wide range of physical disabilities, medical conditions, intellectual difficulties, or emotional problems, including deafness, blindness, dyslexia, learning difficulties, and behavioural problems.

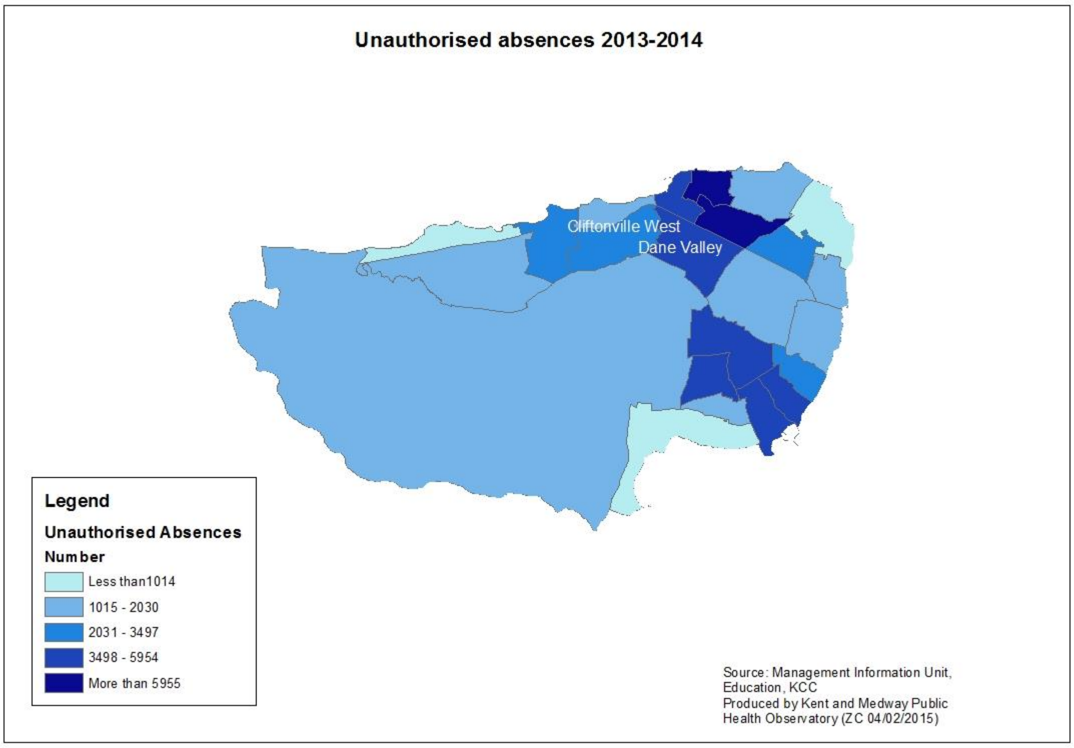
Across Thanet there are approximately 3% of pupils who have a special educational need, this relates to around 640 children. Locally that percentage can climb to as high as 4.8% from Garlinge and 4.5 from Newington.

Figure 29: Special educational needs in Thanet



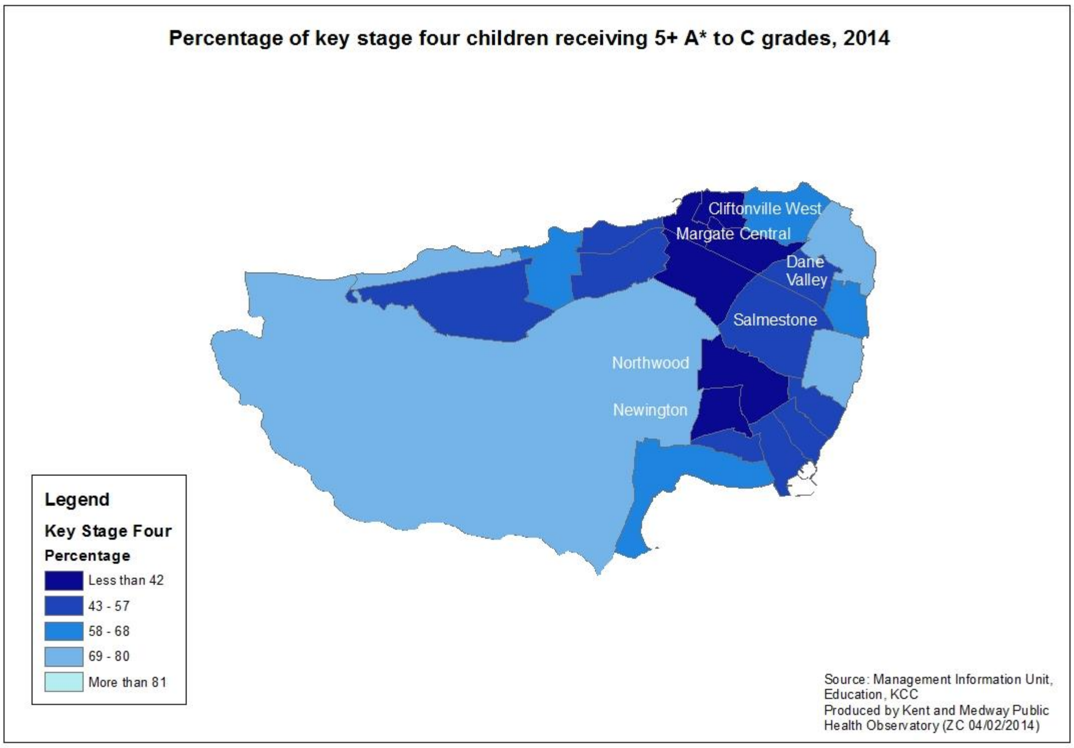
4.4 Unauthorised Absences

Figure 30: Unauthorised Absences



Of the 13,500 unauthorised absences across Thanet in the school year, approximately 7,800 (58%) were from Cliftonville West.

4.5 Key Stage Four



43% of students entered for KS4 achieved five or more GCSE grades A*-C, there was considerable variation across the district. In Birchington North 71% of pupils achieved the required standard where as in Newington only 23% achieved.

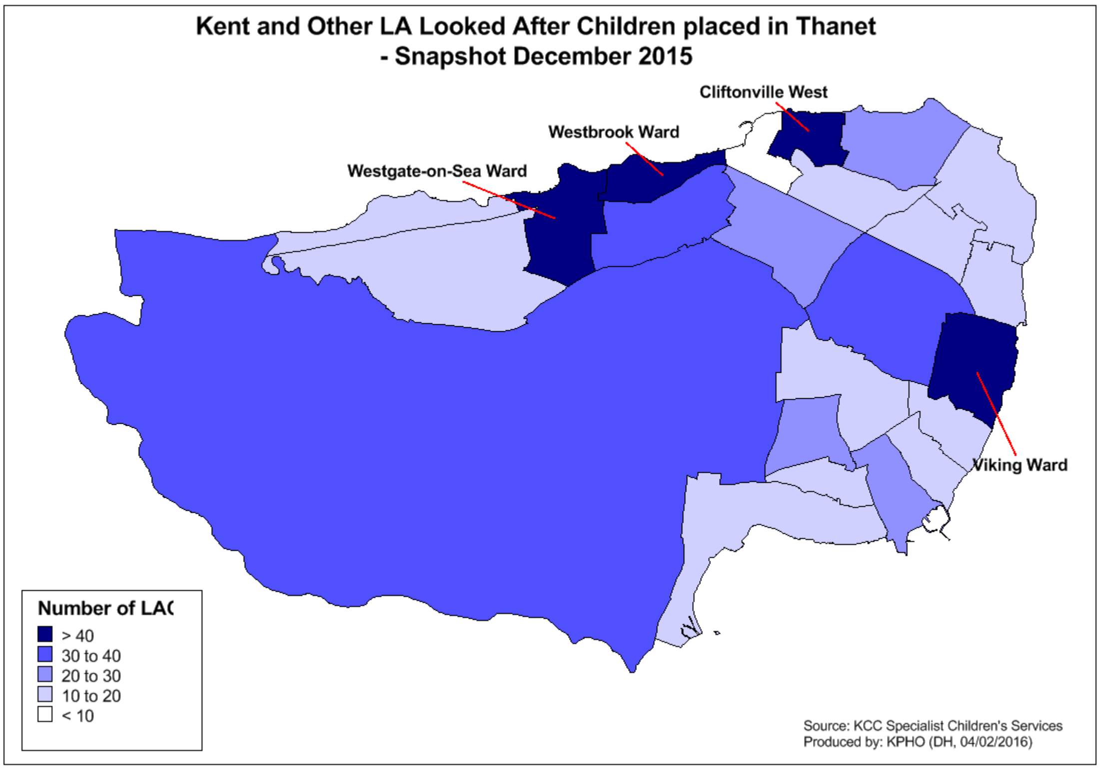
5. Social Care

5.1 Looked After Children

A snapshot taken at the end of 2015 listed 579 looked after children who had been placed in Thanet – 350 by Kent and 229 by other authorities.

Electoral wards with the greatest number of placements are Westgate-on-Sea, Westbrook, Cliftonville West and Viking.

Figure 31: Looked after children placed in Thanet by Kent and Other Local Authorities - December 2015



5.2 Child Protection

The number of children on the child protection register across Kent at the end of 2015 is shown in table 8. There were 133 children, resident in Thanet, who were on the register in December 2015. Proportionately Thanet, Swale and Shepway have the highest number of children.

Table 8: Number of children on child protection register

Children Aged 0-17 (inclusive) Subject to Kent CP Plan (snapshot as at 31/12/2015)

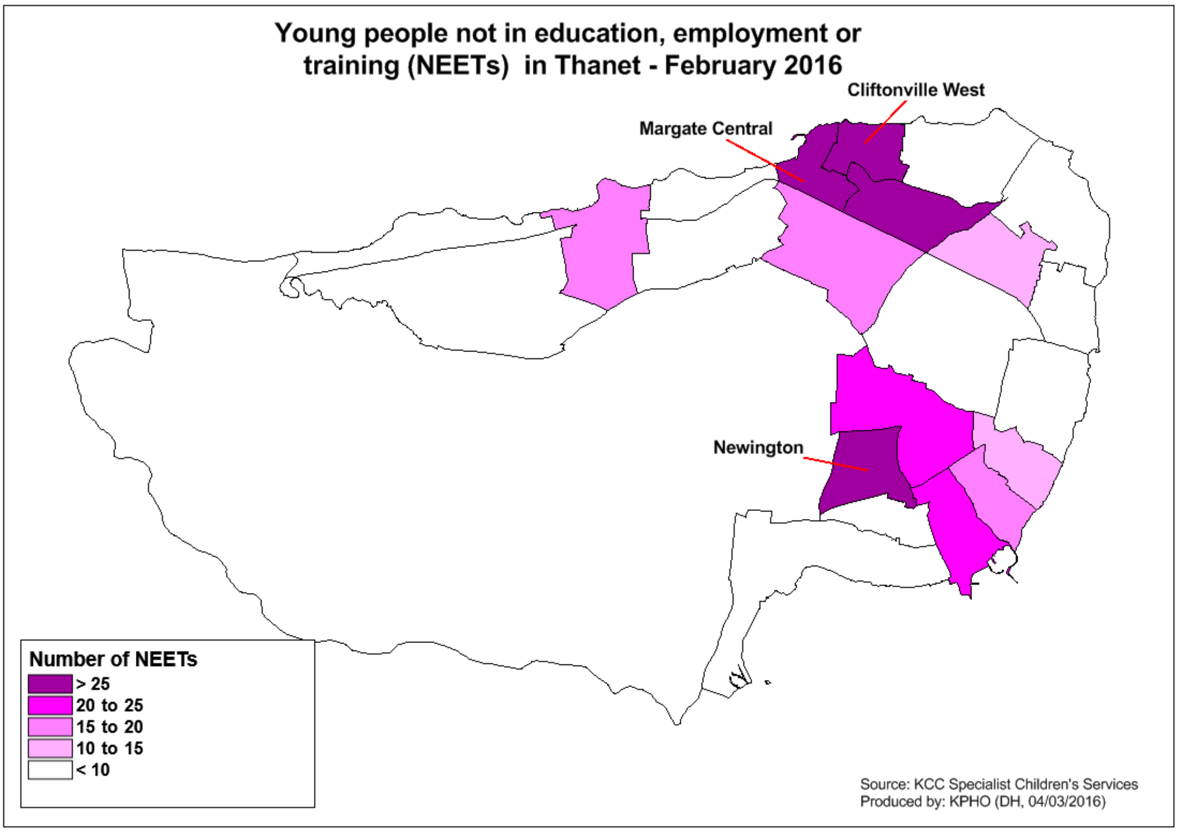
District Living In	Number of Children
Ashford	98
Canterbury	97
Dartford	48
Dover	67
Gravesham	86
Maidstone	66
Sevenoaks	31
Shepway	117
Swale	154
Thanet	133
Tonbridge and Malling	43
Tunbridge Wells	25
OLA (incl Medway)	19
Not Recorded	29
Grand Total	**1013**

Children Services:, Kent County Council

5.3 Not in Education, Employment and Training (NEETs)

A 'NEET' is a young person who is not in education, employment or training. The total number of NEETs in Thanet in February 2016 is 336, Clitonville West recorded the highest number of NEETs with 64. Newington and Margate Central also have relatively high numbers with 28 and 25 respectively.

Figure 32: Young People - Not in Education, Employment or Training (NEETs)



Format: Abstract

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J Acoust Soc Am. 2008 Jan;123(1):133-44. doi: 10.1121/1.2812596.

The effects of environmental and classroom noise on the academic attainments of primary school children.

Shield BM[1], Dockrell JE.

Author information

Abstract

While at school children are exposed to various types of noise including external, environmental noise and noise generated within the classroom. Previous research has shown that noise has detrimental effects upon children's performance at school, including reduced memory, motivation, and reading ability. In England and Wales, children's academic performance is assessed using standardized tests of literacy, mathematics, and science. A study has been conducted to examine the impact, if any, of chronic exposure to external and internal noise on the test results of children

aged 7 and 11 in London (UK) primary schools. External noise was found to have a significant negative impact upon performance, the effect being greater for the older children. The analysis suggested that children are particularly affected by the noise of individual external events. Test scores were also affected by internal classroom noise, background levels being significantly related to test results. Negative relationships between performance and noise levels were maintained when the data were corrected for socio-economic factors relating to social deprivation, language, and special educational needs. Linear regression analysis has been used to estimate the maximum levels of external and internal noise which allow the schools surveyed to achieve required standards of literacy and numeracy.

PMID: 18177145 DOI: 10.1121/1.2812596

[Indexed for MEDLINE]

https://healthyschoolscampaign.org/education/air-pollution-how-it-affects-student-health-and-academic-performance-6583/

Air Pollution: How It Affects Student Health and Academic Performance

- June 6, 2011

By Austin Sears, HSC Communications Intern

Today, many environmental issues are front and center in our minds. Recycling bins are almost as common as trash cans and reusable shopping bags have become increasingly popular. However, there is one issue that we can't see and often gets pushed to the back of our minds: air pollution and its effects on our health. And while air pollution undoubtedly affects us all, children are particularly vulnerable and suffer disproportionately from the impact of dirty air.

A recent article published by Health Affairs draws attention to air pollution and its link to student health and academic performance. The study focused on public schools, the levels of pollution in the areas surrounding them and how these factors affect students. The findings showed that many schools in Michigan were located in places with high levels of air pollution coming from industrial sources. The study also found that while 44 percent of white students in the state were affected, 82 percent of African American students and 62 percent of Latino students were affected, results that show that children of color are more at risk than other students.

Here are some more of the study's findings:

"…schools located in areas with the highest pollution levels also had the lowest attendance rates (a potential indicator of poor health) and the highest

proportions of students failing to meet the state's educational testing standards.

A recent survey of Michigan school superintendents verified that land availability and cost are a major consideration in school siting decisions. When the superintendents were asked to rank various considerations in school boards' decisions about where to locate new schools, the two most important considerations were the availability of land and whether the school district already owned the land.

Half of the states, including Michigan, do not require any evaluation of the environmental quality of areas under consideration as sites for new schools, nor do they prohibit siting new industrial facilities and highways near existing schools. This makes it likely that new schools will be built in undesirable locations to keep the cost of land acquisition down."

One of the most significant points that Health Affairs highlights is the vulnerability of our children. Children have little to no say in where they live, and even less say in where they attend school. Parents often cannot afford to move to a different city or send their children to a different school, so it is up to our leaders in government to address site analysis and make changes to ensure that both schools already in use and schools that will be built in the future will be safe for our children. Pollution causes a number of adverse health effects, including childhood asthma, and this study shows that pollution affects children in Latino and African American communities more than their peers.

We know it's not possible to pick up and move your school to a cleaner location; so as a concerned parent, what can you do? While there are not panaceas, there are a few things you can do.

First, while it's hard for one school to affect outdoor air pollution, you can have an impact on your indoor environment and make sure the air inside your school is as clean as possible. Consider developing a school indoor environmental quality (IEQ) team to address issues. Many free tools are available to help establish IEQ teams, such as the EPA's Tools for Schools Action Kit. Working with other parents, teachers, students and administrators, we can take action to limit pesticide use, green the cleaning programs, or improve ventilation within the school building.

Second, let's get proactive on school siting. Work in your community or your state to make sure there are siting guidelines that will limit the exposures that can happen with a highly polluted site. Visit the Child Proofing Our Communities guidelines for school siting recommendations.

Finally, if your school district is going to build a new school, get involved and make sure your community understands the importance of school siting. Let your voice be heard and educate school boards, principals, teachers and anyone else that will listen about siting and the effects that it can have on your children.

Together, we can take action to ensure that our nation's schools are healthy and safe.

By Paul Mohai, Byoung-Suk Kweon, Sangyun Lee, and Kerry Ard

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HEALTH AFFAIRS 30,
NO. 5 (2011): 852–862

Air Pollution Around Schools Is Linked To Poorer Student Health And Academic Performance

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Kerry Ard is a graduate student in sociology and environmental policy at the University of Michigan.

ABSTRACT Exposing children to environmental pollutants during important times of physiological development can lead to long-lasting health problems, dysfunction, and disease. The location of children's schools can increase their exposure. We examined the extent of air pollution from industrial sources around public schools in Michigan to find out whether air pollution jeopardizes children's health and academic success. We found that schools located in areas with the highest air pollution levels had the lowest attendance rates—a potential indicator of poor health—and the highest proportions of students who failed to meet state educational testing standards. Michigan and many other states currently do not require officials considering a site for a new school to analyze its environmental quality. Our results show that such requirements are needed. For schools already in existence, we recommend that their environmental quality should be investigated and improved if necessary.

There are more than fifty-three million schoolchildren and more than 135,000 public and private schools in the United States.[1] Are these schools safe and healthy places for children to grow, play, and learn? Or are we exposing children to unhealthy pollution?

Children are known to be more vulnerable than adults to the effects of pollution. Exposure to environmental pollutants during important times of physiological development can lead to long-lasting health problems, dysfunction, and disease.[2] Children's lung functioning is not yet fully developed.[3–5] Compared to adults, they breathe in greater levels of polluted air relative to their weight and spend more time outside when air pollution levels are the highest.[5] And because of differences in metabolism, mouthing behavior—such as the tendency to put their hands and objects in their mouths—and respiratory rates, children are often exposed to higher levels of lead, arsenic, pesticides, and other pollutants.[4] Moreover, children have little or no choice about where they live or go to school.

Childhood is a critical period for brain formation. Researchers have shown that children exposed to air pollution perform worse on cognitive functioning tests[6] and have impaired neurological function[7–9] and lower IQ scores[10] compared with other children. Also, children exposed to high levels of nitrogen dioxide—a common air pollutant generated by the burning of fossil fuels—have been found to have "decreases of 6.71, 7.37 and 8.61 points in quantitative, working memory and gross motor areas, respectively."[11]

Similarly, children with high levels of exposure to nitrogen dioxide and particles 10 micrometers or less in the air—a standard used by the Environmental Protection Agency (EPA) to measure air quality—perform significantly worse on neurobehavioral tests, even after confounding variables are controlled for.[6] In one example of this kind of test, to measure line discrimination, the subject is instructed to hit the space bar on a computer keyboard within a second after seeing a long line, when being presented with long and short lines. And children with high levels of estimated exposure to black carbon—tiny particles released into the air by diesel exhaust, for example—have a decreased ability to perform well on both verbal and nonverbal intelligence and memory assessments, such as the Kaufman Brief Intelligence Test and the Wide Range Assessment of Memory and Learning.[10]

A large and growing body of evidence shows that pollution burdens fall disproportionately on low-income and racial or ethnic minority communities.[12–15] There is little evidence of disproportionate pollution burdens on children in these groups. However, a recent study by Manuel Pastor and his colleagues[16] found that California students in these categories were disproportionately exposed to high levels of respiratory risks from outdoor air pollution. Furthermore, the authors found that such exposure was associated with lower performance on standardized tests, even after controlling for important confounding variables such as school size, suburban—as opposed to urban or rural—location, and demographics of the student body.

The risks of air pollution around public schools were highlighted in a series of articles in *USA Today*.[17] The series provided estimates of air pollution from industrial sources for more than 125,000 schools in the United States, using data from the EPA. Schools were ranked based on the estimated pollution burdens around them. The *USA Today* analysis prompted the EPA to conduct a study of its own, and it selected sixty-four schools nationwide (two were in Michigan, where we conducted our study) for air quality monitoring, the results of which have been posted online by the agency.[18] However, neither *USA Today* nor the EPA examined the links between air pollution, health, and academic performance. Nor did they examine demographic disparities related to pollution burdens around schools.

School siting policies should protect children from their vulnerability to environmental pollution. However, many states do not have any school siting policies.[19] According to a 2006 survey, only fourteen states prohibit or severely restrict school districts from siting schools on or near sources of pollution or hazards that might pose a risk to children's health.[20] Twenty-one states have policies suggesting that officials "avoid" siting schools on or near specified man-made or natural environmental hazards, or "consider" those hazards when selecting school sites.

In November 2010 the EPA released a draft of voluntary school siting guidelines.[1] The draft guidelines recommend an initial assessment of air quality around a potential school site using existing data, such as the agency's air quality monitoring data or data from its National Air Toxics Assessment.[21] Although the guidelines do not propose maintaining minimum distances between schools and highways, factories, airports, rail lines, or other potential environmental hazards, they do recommend mitigating the effects of such hazards by using noise barriers, vegetation, or buildings. The agency says that "the guidelines are intended to assist communities and community members in making the best possible school siting decisions."[1] However, one critic has expressed concern that the voluntary guidelines might not be strong enough and could be ignored by many school districts.[22]

Children's health and well-being are viewed by many as top priorities in American society, but links between air pollution and children's school performance and health have received little attention and are not well understood. Our study started with three questions: Do public schools tend to be located in areas of less or more air pollution, compared to average or median levels for the state, the metropolitan area, and the school district? Are disparities in pollution burdens related to the demographic characteristics of the student body? And are levels of air pollution linked to student performance and health?

Study Data And Methods

We examined air pollution concentrations from industrial sources within one, two, and three kilometers of the 3,660 public elementary, middle, junior high, or high schools in Michigan. We based our estimates of air pollution deposition from industrial sources on the EPA's Risk-Screening Environmental Indicator geographic microdata.[23] The data set is modeled from emissions data in the EPA's Toxic Release Inventory to estimate pollution burdens in cells on a one-kilometer grid covering most of the continental United States (see "Data and Methods" in the online Appendix for a more detailed discussion).[24]

As a school performance measure, we used the 2007 Michigan Educational Assessment Program scores, a standardized test that all third to ninth graders in Michigan public schools are required to take.[25] More specifically, we used the percentage of students not meeting the state standards for English and math because, unlike other subjects, English and math are consistently tested from third to eighth grades (see "Data and Methods" in the online Appendix for a more detailed discussion).[24]

We downloaded information about school

demographics from the website of Michigan's Center for Educational Performance and Information.[26] This information included the number of students in each school, school expenditures, the racial and ethnic makeup of the school, and the number of students eligible for the free lunch program. We obtained address information and attendance rates for the schools from the Michigan Department of Education. We used ArcView geographic information system software, version 3.3, to digitally map the locations of the 3,660 schools.

We overlaid the school locations with the EPA's geographic microdata and estimated the total air pollution concentrations within one, two, and three kilometers of each school. Because these distances produce circular areas, and the EPA microdata pollution estimates are available only for one-kilometer squares, we used so-called areal apportionment to estimate pollution concentrations within the circular areas around the schools. That is, we determined the percentage of the area of a circle located within a microdata grid cell and multiplied this percentage by the pollution value for the cell. After the pollution estimates for all grid cells intersected by the circle were weighted by their respective percentages, we summed these weighted values over all of the grid cells to produce pollution estimates for the circular areas.

We determined the pollution concentrations at varying distances to see how robust the results of our analyses would be. We found that the results obtained at the varying distances were very consistent with each other. Because of space limitations, we thus report only the results of our analyses using the distance of two kilometers from the schools. This distance (approximately 1.2 miles) also serves as a proxy for the area that children are required to walk to school in most states—as opposed to being eligible for school buses—which exposes them to the pollution in this area.

Study Results

Exhibit 1 displays the 155,140 grid cells in Michigan sorted into deciles based on their estimated total air pollution concentration. The green areas have the lowest concentrations, while the red areas have the highest. Although the EPA's microdata are not designed to provide thresholds of health risk, they can be used to assess relative risk. Thus, people living in the areas with the lowest concentrations are at lower potential risk, compared to people in areas with the highest concentrations, of diseases associated with air pollution.

As Exhibit 1 indicates, although several places in Michigan's Upper Peninsula fall in the tenth, or most polluted, decile, most of the cells in this decile are in the lower part of Michigan, where the state's population is also concentrated. Exhibit 1 also indicates the locations of the public schools in Michigan for which Michigan Educational Assessment Program English and math scores are available. Because high schools do not consistently test for English and math, only elementary and middle schools are included. We provide a more detailed discussion about the links between pollution levels and performance on the standardized tests below.

LINKS BETWEEN SCHOOL LOCATIONS AND AIR POLLUTION In our analyses we first addressed the question of whether schools tend to be located in the less or more polluted areas of a particular region. Because more than 33 percent (1,221) of all public schools in Michigan are in the Detroit metropolitan area (Macomb, Oakland, and Wayne Counties), we began by comparing the median pollution levels around the schools in the metropolitan area with the median pollution levels in the metropolitan area as a whole (Exhibit 2).

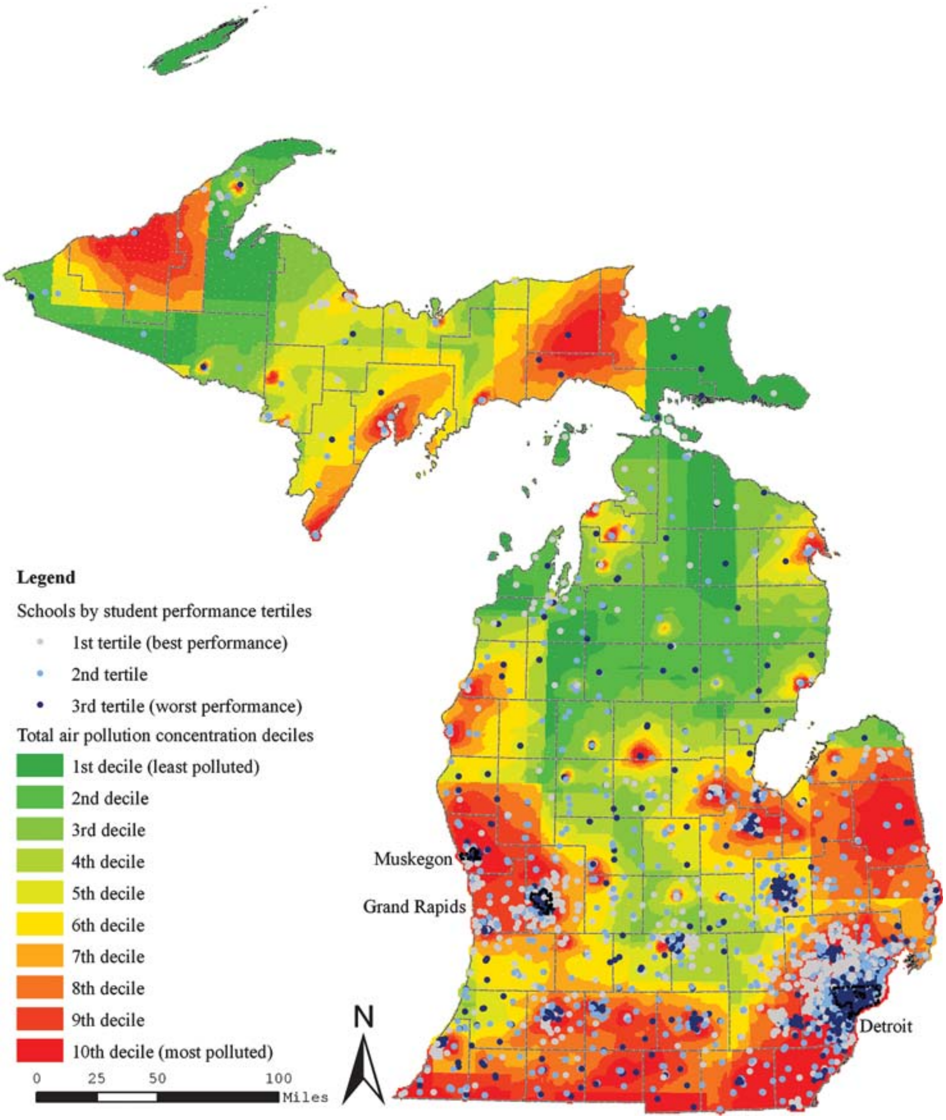
We found that the median air pollution concentrations of the areas within two kilometers of the schools in the metropolitan area were greater than the concentrations in the one-kilometer squares in the metropolitan area as a whole for every year from 1999 to 2006. Likewise, the median air pollution concentrations of the areas within two kilometers of the schools in the City of Detroit were higher than the concentrations in the one-kilometer squares in the city for the entire period.

Next we examined the distribution of all 3,660 schools in the state. We found that 62.5 percent of them were located in grid cells in the ninth and tenth deciles—the 20 percent of the cells with the greatest pollution from industrial sources (Exhibit 3). Almost half of the state's schools (48.4 percent) were in grid cells in the tenth decile. In addition, 67.3 percent of all schoolchildren in the state attended schools in the two most polluted deciles; more than half (53.0 percent) were in schools in the top decile.

We further found that the majority of schools in the two most polluted deciles were located in the more polluted parts of their respective school districts, thus further compounding the pollution burdens for students attending those schools. Specifically, 326 of the 514 schools in the ninth decile were in the more polluted parts of their school districts, as were 1,623 of the 1,773 schools in the tenth decile (Exhibit 3). Overall, 2,328 of the 3,660 public schools in Michigan, or 63.6 percent, were located in the

EXHIBIT 1

Deciles Of Total Air Pollution Concentrations From Industrial Sources In Michigan, With School Locations, By Student Performance Tertiles



SOURCE Authors' analysis of geographic microdata for 2006 from Note 23 in text. **NOTES** Only locations of elementary and middle schools are shown. Schools are sorted into three groups (tertiles) based on the percentage of students (grades 3–8 combined) who do not meet the Michigan Educational Assessment Program standards for English. The schools in the first tertile ("best performance") have the lowest percentage of students failing to meet the standards. For more details about the values of air pollution, see the Appendix (see Note 24 in text).

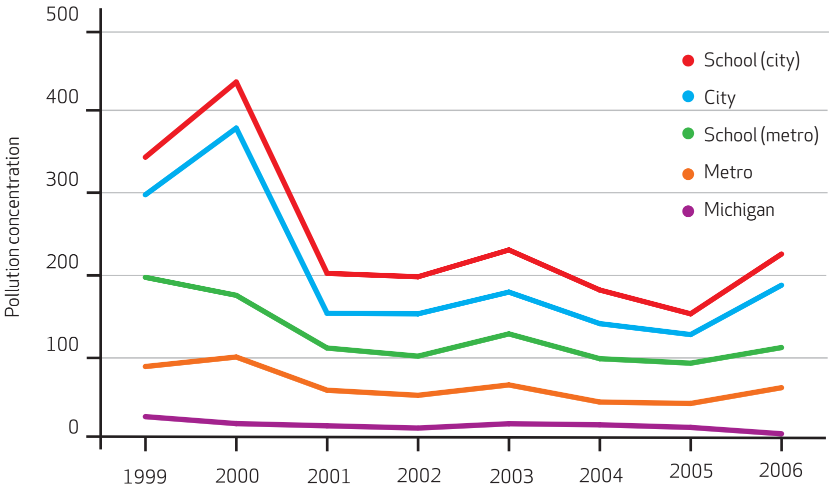
more polluted parts of their districts.

AIR POLLUTION AND SCHOOL DEMOGRAPHICS The demographics of the schools' student bodies followed a similar pattern. We found that 44.4 percent of all white schoolchildren in the state attended schools located in grid cells in the 10th (most polluted) decile, but 81.5 percent of all African American schoolchildren and 62.1 percent of all Hispanic schoolchildren did so. In those schools, 62.2 percent of all students were enrolled in the free lunch program, our chief socioeconomic indicator (Exhibit 3).

AIR POLLUTION, HEALTH, AND ACADEMIC PERFORMANCE Are air pollution burdens around schools linked to student health and performance? Although we cannot conclusively establish cause and effect linkages from our macrolevel analysis, we can nevertheless examine associations and rule out obvious confounding variables, such as school demographics, school expenditures, and locations (suburban versus urban or rural) of schools.[16] And we can deter-

EXHIBIT 2

Median Total Air Pollution Concentrations Within Two Kilometers Of Schools And In Larger Areas, 1999–2006



SOURCE Authors' analysis of geographic microdata for 1999–2006 from Note 23 in text. **NOTES** Metro is the Detroit metropolitan area. City is the City of Detroit. Schools (metro) is areas within two kilometers of schools in the Detroit metropolitan area. Schools (city) is areas within two kilometers of schools in the City of Detroit. Median air pollution concentration values for Michigan, the Detroit metropolitan area, and the City of Detroit are for the one-kilometer squares in the respective areas. Median air pollution concentration values for schools in the Detroit metropolitan area and the City of Detroit are for the circular areas within two kilometers of the schools in those locations.

mine how robust the associations are, and whether they warrant concern.

▸ **CHEMICALS IN THE AIR:** We found that 95 percent of the estimated total air pollution concentrations around the schools came from twelve chemicals: diisocyanates, manganese, sulfuric acid, nickel, chlorine, chromium, trimethylbenzene, hydrochloric acid, molybdenum trioxide, lead, cobalt, and glycol ethers. The chemicals are listed in order, with diisocyanates contributing the most to pollution, and glycol ethers the least. These chemicals come from a variety of sources, including the motor vehicle, steel, and chemical industries; power plants; the manufacturers of rubber and plastic products; and the manufacturers of wood products. The chemicals are suspected of producing a wide variety of health effects, including increased risk of respiratory, cardiovascular, developmental, and neurological disorders, as well as cancer.[27]

Some of the chemicals, such as lead and manganese, may have direct effects on brain functioning and hence children's ability to perform well in school.[28] However, chemicals that have other health effects, including carcinogens and those that increase the risk of respiratory disorders, may also result in absences from school and otherwise impair students' ability to perform well.

▸ **SCHOOL ATTENDANCE RATES:** Because direct measures of health at the level of the individual school are not available in Michigan, we used school attendance rates as a proxy for health outcomes. We found that attendance rates were lower in schools with greater concentrations of pollution around them. This relationship was not linear, so we sorted the schools into quintiles based on the total estimated air pollution concentration within two kilometers. Although attendance rates did not vary appreciably for schools in the first three quintiles, we found statistically significant decreases in these rates for schools in the fourth and fifth quintiles. This was true even after we controlled for confounding variables, such as the rural, suburban, or urban location of the school; average expenditure per student; size of the student body; student-teacher ratio; and percentage of students enrolled in the free lunch program (see Appendix Exhibit 1).[24]

▸ **STUDENT PERFORMANCE IN ENGLISH AND MATH:** Our next step was to determine whether a relationship existed between pollution levels around the schools and the percentage of students who failed to meet the Michigan Educational Assessment Program standards for English and math. We first examined the overall pattern between pollution levels around the schools and the percentages of students failing to meet the state standards. As with attendance rates, we found that this relationship was not linear, so again we looked at quintiles of schools based on the total estimated air pollution concentration within two kilometers.

We first examined performance on the English tests. For each grade level for the schools in each quintile of pollution, we determined the average percentage of students who failed to meet the standards. As Exhibit 4 shows, there was no appreciable difference in the average percentages of students failing to meet the standards for English among the schools in the first, second, and third quintiles. However, there were distinct increases in these percentages for schools in the fourth and fifth quintiles. This was true for every grade level. We next examined performance on the math tests and obtained nearly identical results (Exhibit 5).

We investigated whether these patterns were statistically significant and whether they persisted after we controlled for school attendance rates and school locations, expenditures, and demographics. We used ordinary least squares regression, with the percentages of students in a school failing to meet the state standards in English and in math as the dependent variables and dummy variables representing each of the five quintiles of air pollution concentration around the schools as the independent variables.

EXHIBIT 3

School Demographics By Deciles Of Total Air Pollution Concentrations

	Schools[a]	Students: All[a]	White[a]	African American[a]	Hispanic[a]	In free lunch program[a]	Proportion of schools with higher concentrations than their districts[b]
DECILE 1							
Number	65	16,754	13,228	170	129	5,732	0/65
Percent	1.78	1.03	1.14	0.05	0.17	1.19	0.00
DECILE 2							
Number	78	23,118	21,793	193	405	7,043	8/78
Percent	2.13	1.42	1.88	0.06	0.53	1.46	10.26
DECILE 3							
Number	95	32,269	30,354	337	537	9,441	11/95
Percent	2.60	1.98	2.61	0.10	0.71	1.96	11.58
DECILE 4							
Number	147	50,165	46,124	1,173	1,370	11,666	26/147
Percent	4.02	3.08	3.97	0.36	1.81	2.43	17.69
DECILE 5							
Number	182	71,208	63,349	2,074	3,274	15,978	35/182
Percent	4.97	4.37	5.45	0.64	4.32	3.32	19.23
DECILE 6							
Number	233	100,045	89,117	4,064	3,921	21,319	95/233
Percent	6.37	6.14	7.67	1.26	5.18	4.43	40.77
DECILE 7							
Number	268	109,229	87,444	14,545	3,946	28,470	84/268
Percent	7.32	6.70	7.53	4.51	5.21	5.92	31.34
DECILE 8							
Number	305	129,906	113,023	8,315	4,700	30,525	120/305
Percent	8.33	7.97	9.73	2.58	6.21	6.35	39.34
DECILE 9							
Number	514	233,399	181,574	28,641	10,413	51,645	326/514
Percent	14.04	14.32	15.63	8.89	13.75	10.74	63.42
DECILE 10							
Number	1,773	863,629	515,839	262,685	47,046	298,984	1,623/1,773
Percent	48.44	52.99	44.40	81.53	62.11	62.18	91.54
TOTAL							
Number	3,660	1,629,722	1,161,845	322,197	75,741	480,803	2,328/3,660 (63.60%)

SOURCE Authors' analysis of geographic microdata for 2006 from Note 23 in text and school demographic data for 2007 from Note 25 in text. [a]Percentage of the total in the respective column. [b]Percentage of the total number of schools in the decile (row).

We found that air pollution concentrations are statistically significant predictors of student performance, even after controlling for confounding variables. The results of this analysis are presented in the Appendix.[24]

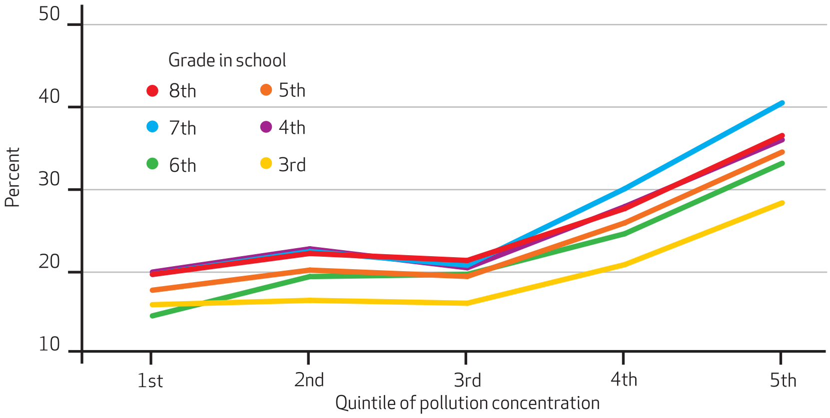
ROBUSTNESS OF FINDINGS Space limitations do not allow us to display the results here, but we found nearly identical patterns when we analyzed the 2005 National Air Toxic Assessment data.[21] This data set includes air pollution estimates from multiple sources. In addition to the major industrial sources in the EPA's Risk-Screening Environmental Indicator microdata—which refer to square kilometers rather than entire census tracts, and which were thus more suitable for our purposes—the National Air Toxic Assessments include minor industrial sources and on-road mobile sources, such as cars, trucks, and buses, as well as nonroad mobile sources, such as airplanes, tractors, and lawn mowers. We also found very similar patterns when we analyzed actual distances from schools to major industrial facilities and major highways.

Conclusions And Policy Implications

Our findings show that schools in Michigan were disproportionately located in places with high levels of air pollution from industrial sources, whether the basis of comparison was the median level for the state or the school's metropolitan area or school district. Fewer than half of the

EXHIBIT 4

Average Percentage Of Students Not Meeting Michigan Educational Assessment Program Standards In English, By Quintile Of Total Air Pollution Concentration



SOURCE Authors' analysis of geographic microdata for 2006 from Note 23 in text and Michigan Educational Assessment Program scores for 2007 from Note 25 in text. **NOTE** For each quintile, the average percent of students not meeting the test-score standard is based on the average percentage across all schools in the quintile.

white students in the state (44 percent)—but substantial majorities of African American students (82 percent), Hispanic students (62 percent), and students enrolled in the free lunch program (62 percent)—attended schools in the most polluted (by industrial sources) 10 percent of the state.

Furthermore, schools located in areas with the highest pollution levels also had the lowest attendance rates (a potential indicator of poor health) and the highest proportions of students failing to meet the state's educational testing standards. These associations remained statistically significant even when we controlled for important confounding variables such as schools' locations (urban, suburban, or rural), spending per student, and school socioeconomic characteristics. Because of the lack of available data, we could not control for all possible confounding variables. Future studies should include variables such as parental education levels; language and cultural differences; and crowding, natural versus artificial light, and ventilation in the classroom, which might influence children's school performance as well.

What explains these patterns, and what should be done about them? Because little attention to date has been given to the environmental quality of where schools are located, it is difficult to pinpoint all of the possible causes of the patterns we found. The large amount of land that a school requires and the costs of land acquisition probably mean that officials searching for new school locations focus on areas where property values are low, which may be near polluting industrial facilities, major highways, and other potentially hazardous sites.[29]

A recent survey of Michigan school superintendents verified the fact that land availability and cost are a major consideration in school siting decisions. When the superintendents were asked to rank various considerations in school boards' decisions about where to locate new schools, the two most important considerations were the availability of land and whether the school district already owned the land.[30]

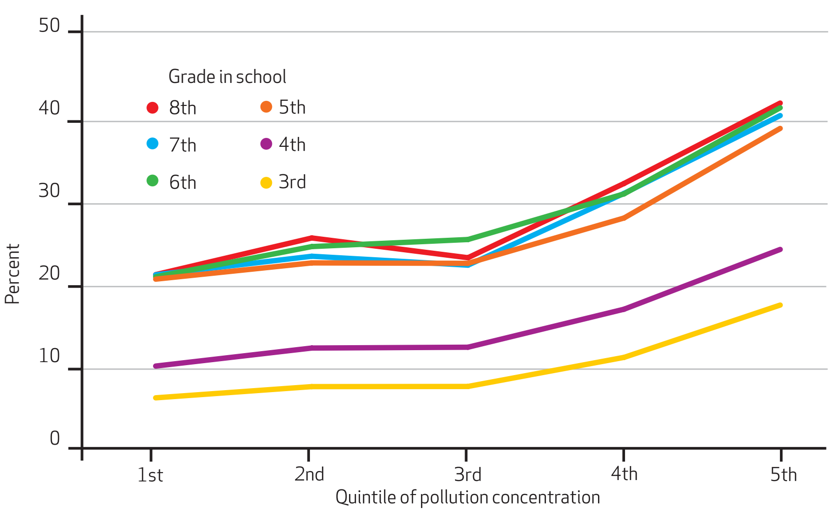
Half of the states, including Michigan, do not require any evaluation of the environmental quality of areas under consideration as sites for new schools, nor do they prohibit siting new industrial facilities and highways near existing schools. This makes it likely that new schools will be built in undesirable locations to keep the cost of land acquisition down.

Our findings underscore the need to expand the concept of environmental justice to include children as a vulnerable population. They are required to attend school and have little or no say in where they live or go to school, which makes them particularly dependent on governmental policies to protect them from harm. Moreover, as our findings show, children of color are disproportionately at risk.

There is a need for proactive school policies that will protect children from exposure to unhealthy levels of air pollution and other environmental hazards. To achieve that goal, we make

EXHIBIT 5

Average Percentage Of Students Not Meeting Michigan Educational Assessment Program Standards In Math, By Quintile Of Total Air Pollution Concentration



SOURCE Authors' analysis of geographic microdata for 2006 from Note 23 in text and Michigan Educational Assessment Program scores for 2007 from Note 25 in text. **NOTE** For each quintile, the average percent of students not meeting the test-score standard is based on the average percentage across all schools in the quintile.

four policy recommendations, which we discuss in turn: site analysis, minimum distance requirements, environmental mitigation, and multilevel cooperation.

ANALYZE POTENTIAL SCHOOL SITES Our first policy recommendation is that potential school sites be thoroughly analyzed. The analysis should include testing the quality of the soil, water, and air; inventorying nearby sources of pollution, such as highways, industrial facilities, power plants, and airports; investigating previous and current uses of the land; and studying the local climate—that is, characteristics such as usual wind direction and wind tunnels—topography, and other physical aspects of the site.

The quality of the environment around existing schools should also be evaluated, and steps taken to address unsafe conditions.

REQUIRE MINIMUM DISTANCES BETWEEN SCHOOLS AND POLLUTION SOURCES Second, policies need to be enacted that insist on a minimum distance between sources of pollution and school locations. The locations of existing schools need to be taken into account when considering new highways, industrial facilities, and other potential sources of contamination. Currently, only seven states (California, Florida, Indiana, Kentucky, Mississippi, Utah, and West Virginia) prohibit locating schools near sources of pollution such as factories, plants, stables, mills, and stockyards. Six of the seven states do not mandate any specific distance. Only Indiana specifies a minimum distance: 500 feet from a school to a source of pollution, a distance too small to completely protect children from environmental hazards. Even though no previous research indicates what is a safe distance, pollution levels generally decrease with greater distance from the sources of the pollution.[31,32]

ADOPT POLICIES TO REDUCE EXPOSURE Third, environmental mitigation policies should be adopted, to reduce children's potential exposure to pollution. It may be particularly important to implement mitigation approaches in urban settings where land is scarce, and where sites for schools away from sources of pollution are difficult to find. California and Florida allow schools to be built on previously polluted sites if the pollution has been cleaned up and removed, and children attending the school will not be exposed to contaminants.

Improving indoor air quality and minimizing the infiltration of air pollution into school buildings are other mitigations that may reduce exposure to contaminants. The EPA created its voluntary Indoor Air Quality Tools for Schools Program[33] to improve indoor air quality for children. The program provides an action kit that describes best practices (such as painting with organic compounds that are not very volatile), industrial guidelines (cleaning carpets according to manufacturers' guidelines), sample policies (banning bus idling), and a sample management plan. Jerome Paulson and Claire Barnett recommend regulating indoor air quality for schools with standards that are "appropriate to children's higher respiration rate[, which] enhances vulnerability to toxins."[34]

These efforts should improve the current environmental conditions of schools, but they should not be used as a way to make up for poor school siting decisions.

ENSURE COOPERATION AMONG AGENCIES Finally, oversight and enforcement at the national, state, and local levels are needed to ensure better school environments. Until the EPA's recent draft voluntary school guidelines,[1] the federal government had little involvement in school siting policy. And although the guidelines address a wide range of issues, because the guidelines are voluntary, they may be ignored. Nevertheless, state and local agencies interested in creating healthier schools can benefit from the EPA's scientific knowledge, technical expertise, and environmental data.

State environmental agencies already cooperate with the EPA in regulating the redevelopment of brownfields—properties that contain or may contain some hazardous substance whose presence affects any future use of the properties. And brownfield redevelopment and school siting have been linked. Alison Cohen reports that because of the problem of land availability, brownfields are often considered as viable sites for schools.[35] However, building schools in previous brownfields requires great caution. The standards for cleaning brownfields up are not necessarily high enough; Michigan lowered its standards in 2000, for example.[36] Thus, state environmental agencies should develop stringent standards for cleaning up brownfields intended as school sites.

All relevant national, state, and local stakeholders—including school administrators and health officials, parents, teachers, industry and community leaders, public health professionals, environmental scientists, and educational policy makers—need to work together to develop policies that will ensure safe learning environments for schoolchildren. In states such as Michigan, school districts are mainly responsible for deciding where to build new schools.[30] However, previous cooperation between the EPA and state agencies demonstrates that different levels of government can work together on these issues. Indeed, they must, if we are to protect the health and enhance the learning environment of the nation's children. ■

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In their article in *Health Affairs* this month, Paul Mohai and coauthors recommend a checklist of considerations for use in the siting of schools to avoid exposing children to health-threatening pollution.

A professor in the School of Natural Resources and Environment at the University of Michigan, Mohai has long worked in the field of environmental justice. Yet he was surprised at the overwhelming number of Michigan schools that were near environmental hazards. The best explanation, he says, is that school systems often look for large parcels of land that are available cheaply—and land near industrial sites usually fits that bill. Unfortunately, he observes, at least twenty states "have no policy whatsoever in terms of taking into consideration environmental hazards when siting schools."

Mohai, who is also a faculty associate at the Institute for Social Research at the University of Michigan, was an early and major contributor to quantitative research examining the disproportionate environmental burdens in communities where residents are largely from racial or ethnic minority groups or of low income. His current research involves studies at the national level that examine the role environmental factors play in accounting for racial and socioeconomic disparities in health and student performance.

Mohai has a master of science degree in forest science and statistics from the State University of New York, Syracuse, and a doctorate in natural resource policy and sociology of natural resources from Pennsylvania State University.

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Byoung-Suk Kweon is a research investigator at the Institute for Social Research and an adjunct assistant professor in the School of Natural Resources and Environment at the University of Michigan. For the past ten years, she has been conducting research on environmental risks around public schools and their consequences. She has a master's degree in landscape architecture from Cornell University and a doctorate in natural resources and environmental sciences from the University of Illinois, Urbana-Champaign.

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Sangyun Lee is a postdoctoral research fellow in the School of Natural Resources and Environment at the University of Michigan. He has a master's degree in urban and environmental planning from the University of Virginia and a doctorate in environmental policy and behavior from the University of Michigan. His research interests include environmental justice, sustainable development, environmental policy and planning, and urban inequality.

Kerry Ard is a graduate student in sociology and environmental policy at the University of Michigan.

Kerry Ard is a doctoral student in sociology and environmental policy at the University of Michigan. The School of Natural Resources and Environment recently honored her with a Justin W. Leonard Award, which is given to students with superior academic credentials who are judged to have the greatest promise for leadership in the wise use of natural resources through the integration of natural and social sciences.

Air Pollution and Academic Performance: Evidence from California Schools

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ABSTRACT

Air pollution has been associated with a number of detrimental health effects for children. Another potentially substantive, but previously unappreciated, effect of air pollution on children is diminished academic performance, presumably resulting in reduced human capital accumulation and reduced future earnings. In this paper we investigate the relationship between outdoor air pollution levels and standardized state test scores of California public school children. To do this we combine individual family data and community pollution data from the Children's Health Study (CHS), a longitudinal respiratory health study of Southern California school children, with publicly available information on California standardized test scores by grade, school, and year. We find that a 10% decrease in outdoor PM_{10}, $PM_{2.5}$, or NO_2 would raise math test scores by 0.15%, 0.34%, or 0.18%, while a 10% decrease in outdoor $PM_{2.5}$ increases reading scores by 0.21%. To put these effects in perspective, if it were possible to reduce $PM_{2.5}$ by 10% for low-income students but not for high-income students, the gap in math test scores between high- and low-income 8th grade students would fall by nearly one thirtieth.

1. Introduction

Air pollution has been associated with a number of detrimental health effects for children. One of the main findings of the recent medical, epidemiological and economics literature is that pollution has a positive and significant effect on asthma exacerbation. Pollution has also been associated with new onset asthma (McConnell et al. 2002), as well as other respiratory diseases, lower lung function, hay fever (Gauderman et al. 2001, McConnell et al. 2003) and infant mortality (Chay and Greenstone 2003a, 2003b, Currie and Neidell 2005). Another potentially substantive, but previously unappreciated, effect of air pollution on children is diminished academic performance, presumably resulting in reduced human capital accumulation and reduced future earnings.

There are four mechanisms by which pollution could affect academic performance: (i) school absenteeism due to illness caused by pollution; (ii) attention problems in school due to illness caused by pollution; (iii) fatigue when doing homework due to illness caused by pollution; and (iv) a direct negative effect of pollution on brain development. Earlier research (Gilliland et al. 2001, Ransom and Pope 1992, and Currie et al. 2007) established a statistically significant relationship between pollution and school absenteeism and thus relate to mechanism (i) above. Furthermore, there is evidence that children with asthma tend to have more behavioral problems in school than children who do not have asthma (Butz et al. 1995, Bussing et al. 1995, Halterman 2006), which provides support for mechanism ii) above. We do not know of any available evidence on mechanism iii) above. Recent neuropathological, epidemiological, and brain imaging literature suggests that air pollution may be harmful to the development of the brain and may affect cognitive ability (Calderón-Garcidueñas et al. 2008ab; Suglia et al. 2008; Wang et al. 2009), which supports mechanism (iv) above.

Since neurological effects, absenteeism, behavioral problems, and fatigue are directly caused by pollution (or associated with diseases that are exacerbated or caused by pollution) and since they have also been linked to poor academic performance, a natural question that arises is "what is the direct effect of pollution on academic performance?" This measured effect will incorporate mechanisms i) - iv) above. To our knowledge, there has been no published work on this subject, although there is a small related literature on the effect of asthma on school readiness, learning disabilities and academic performance. For example, Halterman et al. (2001) found that kindergarten-age children with asthma with limitation had lower scores than non-asthmatic kindergarten-age children in reported school readiness skills in Rochester, New York during 1998.[1] Further, Fowler, Davenport and Garg (1992) found that, after controlling for demographic factors, asthmatic children in grades 1-12 were more likely to have a learning disability than non-asthmatics. Finally, as we describe in more detail below, Currie et al. (2009) matched several data sources for young adults in Manitoba, Canada and found some limited evidence that current asthma affected current achievement, but that past asthma (conditional on current asthma status) had no effect on current performance.

In this paper, we fill this gap by investigating the relationship between outdoor air pollution levels and standardized state test scores of California public school children. To do this we combine individual family data and community pollution data from the Children's Health Study (CHS), a longitudinal respiratory health study of Southern California school children (Peters et al. 1999), with publicly available information on California standardized test scores and school characteristics by grade, school, and year. An additional benefit to our study is that our data set contains information on $PM_{2.5}$ (a marker for fine particulate matter) while many of the studies discussed in the literature review do not have data on $PM_{2.5}$.[2] Indeed below we find that $PM_{2.5}$ exposure has much stronger

[1] A child was considered to have asthma with limitation compared to without limitation if the parent described any ongoing health conditions that limited the child's activity.
[2] $PM_{2.5}$ represents the portion of the particle size distribution whose mean diameter is 2.5 micrometers or less.

effects on test scores than the other pollution measures that we investigate.[3] In our analysis we use school, and (in some cases) year, fixed-effects to account for unobserved factors that may be correlated with test scores and air pollution. Our study differs from Currie et al. (2009) by using U.S. data, considering the effect of air pollution (as opposed to asthma) on school performance, using different pollution measures, and using a different measure of school performance. Thus we provide an important compliment to the Currie et al. (2009) Canadian evidence, since the effect of air pollution in our case (or asthma in their case) on school performance may differ substantially across the two countries, given the presence of universal health care in Canada, which would be expected to provide more equal access to controller medications for respiratory illness.

The paper proceeds as follows. Section 2 discusses the related economic and epidemiological literature. We describe the data in Section 3 and discuss our empirical strategy in Section 4. We evaluate the effect of outdoor air pollution on academic performance by using a school fixed effects model. We find that a richer specification that includes year dummies is appropriate since omitting these dummies appears to lead to omitted variable bias. We present our results in Section 5. We find that higher levels of $PM_{2.5}$ (a marker for fine particulate matter), PM_{10} (a marker for coarse particulate matter), and NO_2 consistently lower math scores, while higher levels of $PM_{2.5}$ consistently reduce reading test scores. However, the magnitude of this effect is reduced by including year dummies, and a comparison of the results with and without year dummy variables suggests that year dummies are indeed necessary for obtaining consistent estimates. Specifically, when we include year dummies, we find that a 10% decrease in PM_{10}, $PM_{2.5}$, or NO_2 would raise math test scores by 0.11%, 0.14%, or 0.12%, while a 10% decrease in $PM_{2.5}$ increases reading scores by 0.21%. To put these effects in perspective and to gain some intuition on the potential importance of these effects, note that if it were possible to decrease $PM_{2.5}$ by 10% for low-income, but not high-income, students, the 10% gap

[3] On the other hand, note that we do not have data on community carbon monoxide levels, which related studies have found to be important.

in math test scores between high- and low-income 8th grade students would be reduced by a little less than one-thirtieth.[4] To reduce the gap in reading scores by the same amount, one would need to reduce $PM_{2.5}$ by 14%.

Exposure to particulate matter has been shown to have several negative health outcomes (Peng et al. 2005; Perera et al. 2009; Pope and Dockery 2006;; Russell and Brunekreef 2009; Stieb, Judek, and Burnett 2002; and, Suglia et al. 2008) which present important costs to society of pollution. Given the strong relationship between academic performance and future labor income, and a strong relationship between measures of ability and earnings conditional on schooling (see e.g., Neal and Johnson 1996), our results suggest a heretofore unappreciated additional cost of air pollution in terms of reduced future earnings. Moreover, given that more highly polluted areas tend to have lower-cost rentals and thus attract more low-income households, we might expect that decreasing $PM_{2.5}$ would disproportionately benefit low-income households. Thus to the extent one puts a positive weight on a more equitable distribution of income, a reduction in pollution also implies additional social benefits by decreasing inequality. We conclude the paper in Section 6 and discuss possible limitations of our study.

2. Literature Review

As noted above, we know of no papers on the effect of pollution on academic performance, although there is epidemiological and neuropathological research suggesting that pollution affects brain development and intelligence quotient (IQ), and there is a strong relationship between measures of ability and academic performance. The literature most relevant to our paper focuses on the related issues of: (i) does pollution affect brain development and cognition?; (ii) does air

[4] In 2007, the average eighth grade NAEP math score (at the national level) is 291 for high-income students and 263 for low-income students (Barton and Coley 2009). Therefore, the ratio of high to low-income students is 1.106, resulting in a 10.6% difference between high and low-income students. The reading scores are 271 and 248 for high and low-income students respectively, resulting in a 9.3% difference.

pollution increase school absenteeism?; (iii) does an asthmatic child have more behavioral problems than a non-asthmatic child?; (iv) do absenteeism and behavioral problems affect academic performance?; and (v) does an asthmatic child have lower academic performance than a non-asthmatic child? Research area (i) is very relevant given the well established relationship between measures of ability and school performance (Cameron and Heckman 2001; Lochner and Belley 2007; Murnane, Willett, and Levy 1995). Research areas (ii) and (iv) provide evidence of how pollution may affect academic performance through absenteeism while (iii) and (iv) relate to how pollution may affect it through behavioral problems. Research area (v) complements our findings since asthma may be caused by, and is certainly exacerbated by, pollution. Note that we will not be able to trace out the different paths by which pollution can affect test scores; on the other hand the presence of many paths does raise the issue of whether, estimated asthma effects on performance may be including other paths by which pollution affects performance.

2.1 Air Pollution and Brain Development

Epidemiologic, neuropathological, and brain imaging studies provide evidence of a negative relationship between ambient air pollution and with lower brain development conditional on observable demographic factors, and since we have not seen this issue discussed in the economics literature, we now spend some time describing existing research in this area. For example, among 202 children who were approximately 10 years old in Boston, Massachusetts, higher levels of black carbon (a marker for traffic particles) was associated with decreased cognitive function across assessments of verbal and nonverbal intelligence and memory constructs (Suglia et al. 2008). The authors estimated exposure to black carbon for each participant's current residence and controlled for age, gender, mother's education, and language spoken at home.

In a prospective study of a birth cohort of 249 children whose mothers lived in Harlem and the South Bronx during pregnancy, Perera et al. (2009) investigated the effect of polycyclic aromatic hydrocarbons (PAHs) on a child's IQ.[5] Motor vehicles are a major source of PAH in Harlem and south Bronx. PAH levels were measured through personal monitoring of the mothers in their third trimester of pregnancy and IQ was evaluated using the Wechsler Preschool and Primary Scale of Intelligence-revised. Researchers found that children with prenatal exposure to high levels of PAHs had full scale and verbal IQ scores at age 5 years that were 4.31 and 4.67 points lower, respectively than those of less exposed children. In a cross-sectional study in Quanzhou, China, the performance in multiple neurobehavioral function tests was lower in children of 8-10 years old who came from a school located in a high traffic exhausts pollution area, as compared to those studying in the other school located in a clear air area (Wang et al. 2009). The schools were chosen based on traffic density and air pollution monitoring data and the authors controlled for, among other things, father's education, age, sex, birth weight, and second-hand smoke.

Calderón-Garcidueñas et al. (2008a, 2008b) led a series of clinical, neuropathological, and neuroimaging studies on clinically healthy and neurocognitively intact children and adolescents who were growing up either in Mexico City (a place with high ambient air pollution) or in other areas with substantially cleaner air. In Calderón-Garcidueñas et al. (2008a), the authors found that among the forty-seven subjects who died suddenly, accumulations of amyloid β42 (a marker of neurodegenerative disease) in the prefrontal brain region and disruption of the blood-brain-barrier both were found in those who were lifetime residents in Mexico City (n=35), but not in the comparison group (n=12).[6] In another study, Calderón-Garcidueñas et al. 2008b found that children from Mexico City exhibited significant deficits in a combination of fluid and crystallized

[5] Polycyclic aromatic hydrocarbons are formed by incomplete combustion of fossil fuels, among other organic material. Prenatal exposure to PAH has been linked with adverse immune, metabolic, and neurological functions and reduced birth weight.

[6] The comparison group consisted of residents of Tlaxcala and Veracruz.

cognition tasks, as compared to other children from Polotitlán, a city with much lower pollution levels. Fluid cognition is supported by working memory, while crystallized cognition is supported by long-term memory. The fifty-five subjects from Mexico City and the eighteen subjects from Polotitlán were from middle-class families where their mothers had similar average years of formal schooling groups. Brain MRI-measured hyperintense white matter lesions were substantially increased (56.5%) in children from Mexico City (vs. 7.6% in the control city). The white matter lesions may affect cognitive dysfunction and the particulate matter may contribute to the neuroinflammation.

2.2 Pollution and Absenteeism

There are several studies in the economics and epidemiological literature on how pollution affects absenteeism, so we only present the findings of a few here. The first paper in the economics literature is Ransom and Pope (1992), who investigated how PM_{10} affected absenteeism in the Utah Valley between 1985 and 1990. This location and time period provided a "natural experiment" because a steel mill, which was the major polluter in the valley, shut down. They controlled for temperature, snowfall, day of week, month of school year, and days preceding and following holidays and extended weekends. Regression results suggested that "an increase in 28-day moving average PM_{10} equal to 100 micrograms/m3 was associated with an increase in the absence rate equal to approximately two percentage points (p. 210)." [7] This is approximately equal to a 40% increase over the average.

The second paper in the economics literature is Currie et al. (2007), which used the Texas Schools Project, a longitudinal administrative data set on student absenteeism in Texas. They aggregated pollution data from the Texas Commission on Environmental Quality into 6 week time

[7] They do not control for individual covariates in their analysis.

blocks to merge with the administrative absenteeism data. They used school-by-year, school-by-time block, and time block-by-year fixed effects to control for many unobserved characteristics of schools, years and time blocks that would be correlated with test scores and pollution. They identified the effect of pollution by the variation across years within the same six week block for each school. The pollution variables were a set of dummy variables that indicated for each pollutant, whether the maximum was between: (i) 25-50% of the threshold; (ii) 50-75% of the threshold; (iii) 75-100% of the threshold; or (iv) greater than 100% of the threshold. (The omitted category was 0-25% of the threshold.) Their main finding was that maximum CO in the six week period has a positive and significant effect on school absences when it was between 75-100% of the air quality standards threshold and when it exceeded the standard. Ozone was not statistically significant in most specifications, but they did find a statistically significant increase in absences associated with PM_{10} levels between 50-75% of the EPA threshold. They were not able to investigate $PM_{2.5}$ since it was not available for their study period.

In the epidemiological literature, Gilliland et al. (2001) also used the CHS data (but a different approach) as our present study, to evaluate the effect of pollution on absenteeism. They studied a cohort of 2,081 4th grade students who resided in 12 southern California communities. They tracked the students' absences for the first 6 months of 1996 and followed up with the students' parents to determine if the absence was illness-related or not, and if so, whether it was an upper-respiratory, lower-respiratory, or gastro-intestinal illness. The type of illness was determined by the symptoms described during the phone interview. Using daily pollution from monitors located near the schools, the authors used within-school variation in pollution over the six month period to determine its effect on average daily absences due to respiratory illness. They found that ozone had a statistically significant effect on both upper respiratory and lower respiratory illness rates.

2.3 Asthma and Attention Problems

While there is no work to our knowledge on how air pollution affects behavioral problems, there is related work on the association between asthma and attention or behavioral problems. Since asthma is thought either to be exacerbated or caused by pollution, this literature is relevant for our purposes. First, Butz et al. (1995) obtained demographic, asthma symptom and psychosocial information on children in kindergarten through eighth grade in 42 schools in Baltimore, Maryland. Asthma symptoms were divided into low, medium and high levels, while a child was considered to have behavior problems if she scored higher than a given threshold score in a survey comprised of standardized psychosocial questions. Using logistic regressions and controlling for demographic characteristics, the authors concluded that the parents who reported that their children had higher levels of asthma symptoms were twice as likely to report a behavioral problem as compared to parents who reported lower levels of asthma symptoms.

Bussing et al. (1995) first used responses to the 1988 National Health Interview Survey on Child Health to categorize children into those that suffered from asthma alone, those who suffered from asthma combined with other chronic conditions, those who suffered from other chronic conditions alone or those who had no chronic (including asthmatic) conditions. They then combined this information with the Behavior Problem Index constructed from psychosocial questions in the survey. Using logistic regressions, the authors found that children with severe asthma alone were nearly three times as likely to have severe behavioral problems as children without a chronic condition.

Halterman et al. (2006) investigated the relationship between behavioral problems and asthma symptoms for a cohort of 1,619 inner-city students in Rochester, New York. The parents of these kindergarten-age children were surveyed about their children's health and behavior. The authors found that children with persistent asthma scored worse on peer interactions and task orientation, and were more likely to exhibit shy and anxious behaviors compared to non-asthmatic children.[8]

2.4 Absenteeism and Behavioral Problems on Academic performance

Behavioral problems, including truancy and absenteeism, have been associated with dropping out (Bachman, Green, & Wirtanen, 1971; Segal 2008). Specifically, Segal (2008) used the National Educational Longitudinal Study of 1998 to evaluate how behavioral problems affect academic performance by employing a multinomial logit model to control for race, socioeconomic status, family background, and test scores. She found that maladaptive behavior in the eighth grade was associated with a decrease in the probability that the student graduated from college and an increase in the probability that the student dropped out of high school.

Much of the absenteeism research has focused on performance in postsecondary education. Marburger (2001) showed that students who were absent from class were 9 to 14% more likely to write an incorrect answer to a question related to material covered on the day of their absence than were students who were present.[9] In a more recent article, Marburger (2006) compared the performance of students who attended a college class with a mandatory attendance policy and one without the attendance policy. He found that the attendance policy increased performance by up to 2% on exams.

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[8] According to the National Heart, Blood and Lung Institute of the National Institutes of Health, asthma is considered persistent if the patient experiences symptoms more than two days per week, limitation in activities, some nighttime awakenings or use of short acting $beta_2$ agonists combined with either more than two exacerbations requiring oral steroids or more than four wheezing episodes longer lasting than a day per year. For additional information, see pg. 72 of the "Expert Panel Report 3 (EPR3): Guidelines for the Diagnosis and Management of Asthma" available at http://www.nhlbi.nih.gov/guidelines/asthma/04_sec3_comp.pdf.

[9] See also Durden and Ellis (1995) and Romer (1993), cited by Marburger (2001).

2.5 Asthma and Academic performance

As noted above, there is a small literature on the relationship between asthma and academic performance. Fowler, Davenport and Garg (1992) analyzed data for 10,362 children in first through twelfth grade from the 1988 United States National Health Interview Survey. They determined that children with asthma were more likely to have a learning disability than children who did not have asthma. In addition, among households with incomes below $20,000, asthmatic children were twice as likely to fail a grade as those without asthma, but among higher income families, asthmatic children had only a slightly higher failure rate than non-asthmatic children.[10] Second, Halterman et al. (2001) compared the parent-reported development skills of asthmatic children to non-asthmatic children in Rochester, New York in 1998. After controlling for insurance, education of the care-giver, gender, and pre-kindergarten education, the authors found that asthmatic kindergarten-aged children scored lower in school readiness skills (one category of reported development skills), than their non-asthmatic peers.

Finally, Currie et al. (2009), matched school administrative data, social assistance records, and health records for young adults in Manitoba, Canada born between 1979 and 1987. They investigated whether having been treated for asthma, among other childhood diseases, at various ages (0-3, 4-8, 9-13, 14-18) affected (i) performance on a literacy exam, (ii) whether the students enrolled in a college preparatory math class, (iii) whether they were in the twelfth grade by age 17, and (iv) whether they used social assistance. The authors employed a mother fixed-effect to control for fixed family characteristics, and found (at the 10% level) that (a) asthma at ages 9 to 13 had a significant negative effect on taking a college preparatory math class and (b) asthma at ages 14 to 18 sometimes had a negative effect on the literacy score in the 12th grade. They found no effect of earlier asthma, conditional on current asthma, on their outcomes of interest.

[10] This suggests the possibility of heterogeneous asthma effects by socioeconomic status, but we felt we did not have sufficient data to explore this possibility in our analysis.

3. Our Data

We combine several data sources to evaluate the effect of pollution on academic performance. Long-term outdoor air pollution data and family background information come from the Children's Health Study (CHS) described above. Fourth, seventh, and tenth-grade students were originally recruited into the CHS in 1993 from twelve Southern California communities with differing air pollution profiles, and a number of health measurements were collected each school year until high school graduation. Upon graduation of the respective sub-groups from the twelfth grade, additional students (2,081 fourth graders in the 1995/96 school year, and 5,603 kindergarten and first grade students in the 2002/2003 school year) were enrolled into the study. Further, the CHS data set also contains information about community-level air pollution over the study period. Participating schools were selected for inclusion in the data set on the basis of: (i) location in a community of interest with differing pollution profiles; (ii) a sufficient population of study-aged children; (iii) a preponderance of children attending school from the immediate neighborhood; (iv) demographic similarity with other potential and participating community school sites; (v) the absence of localized air pollution sources such as close proximity to factories or freeways; (vi) proximal location to a fixed-site air monitoring station and (vii) the approval of the respective school district to proceed.

We are only able to use part of the CHS data since California test scores were not available until 1998, and then only for grades 2-11. As a result, from the CHS we investigated Cohort C and D students (fourth-graders in 1993 and 1996, respectively) for the years 1998-2002, as well as Cohort E students (kindergarteners and first-graders in 2002) for the years 2004 and 2005.[11] Participants completed annual questionnaires on demographic characteristics, family smoking behavior, and medical history. Annual medical history questionnaires contained questions on

[11] Since Cohort D ends in 2004 when the students graduate from high school, and the standardized test changed in 2003, we did not use the 2003 data.

respiratory symptoms and illnesses while most of the demographic data was only collected at each subject's enrollment into the study.

Continuously operating outdoor air pollution monitoring stations were placed in each of the CHS participating communities. Commercially available and USEPA-approved instrumentation was used to measure ozone (O_3), particulate matter with a diameter of less than 10 microns (PM_{10}), nitrogen dioxide (NO_2), and carbon monoxide (CO) at these locations. A two-week integrated sampler was developed for the CHS study and used to continuously measure particulate matter with a diameter of less than 2.5 microns ($PM_{2.5}$), acid vapors, and PM chemical constituents. For the current study, we focus on annual community averages of NO_2, O_3, PM_{10}, and $PM_{2.5}$, because they have been shown in previous studies to have negative effects on health and school absences and were measured consistently throughout the study period. Unlike the papers on absenteeism, our use of the CHS allows us to investigate $PM_{2.5}$. Currie et al. (2007) found that CO was associated with school absenteeism, but unfortunately, CO is unavailable for several periods in several CHS towns.

PM_{10} (often considered a marker of coarse particles) and $PM_{2.5,}$ (often considered a marker for fine particles) can be emitted directly from primary sources (such as combustion or vehicle exhaust or from entrained road or construction dust) or can be formed through a series of secondary photochemical reactions of airborne gaseous compounds and particulate matter. Particle diameter has been shown to be related to physical deposition in the lungs, with smaller particles generally thought to be of greater health concern.[12] PM_{10} and $PM_{2.5}$ have been associated with: mortality (Peng et al. 2005; Stieb, Judek, and Burnett 2002): pulmonary disease (Pope and Dockery 2006); allergic immune responses (Russell and Brunekreef 2009); asthma (Yu et al. 2000); lung development (Gauderman et al. 2004) and an increased incidence of cardiovascular disease (Grahame and Schlesinger 2007). NO_2 is a by-product of combustion exhaust (from vehicles,

[12] See "Particulate Matter" at http://www.epa.gov/particles/basic.html/.

boilers, or any combustion source). Gauderman et al. (2005) found that the incidence of asthma and wheezing in *all* children is associated with higher outdoor NO_2, while Shima and Adachi (2000) only obtained this result for female schoolchildren. Finally, Gauderman et al. (2004) found a negative association between NO_2 and lung development.

Ozone is formed in outdoor air when sunlight provides sufficient photochemical energy to drive reactions of oxygen with a number of gaseous pollutants.[13] McConnell et al. (2002) demonstrated that children who lived in high ozone areas and play sports outdoors were more likely to be diagnosed with asthma during the study period than those who did not play sports, while in the low ozone areas there was no difference in asthma rates between children who played sports and those who did not. Their result supports the hypothesis that the extra exposure to ozone in the high ozone areas causes either the onset of asthma or the earlier onset of asthma.

From the CHS data we construct average demographic information at the grade-school-year level for the CHS students, and then use these averages as proxies for averages of the demographic variables for *all* students in the grade at that school. Next we merge this data from CHS with publically available test score data, as well as other publically available information on the characteristics of the school at the school-year level (e.g., the percent of students receiving a free lunch, and the pupil-teacher ratio) and at the grade-school-year level (e.g., racial breakdown of the class).[14] We use the demographic data from CHS, as well as the publically available school data, to minimize bias in our pollution effects arising from time-changing omitted variables at the grade-school level, which may be correlated with pollution and not captured by the school and year dummies.

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[13] Environmental Protection Agency, 1999."Smog—Who Does It Hurt? What You Need to Know About Ozone and Your Health."EPA-452/K-99-001 Available at http://www.epa.gov/airnow//health/smog.pdf .

[14] These additional data are from the California Department of Education.

Finally, we include data on the unemployment rate in each city in each year from the California Employment Development Departments' local area unemployment data.[15] We include the unemployment rate to control for several factors. Increased unemployment may create added stress for students through an increased probability that a parent will become unemployed, which could lower test scores. In addition, unemployment reduces family income, which again could lower test scores.

Our outcome measures are the math and reading comprehension scores at the grade-school-year level. After 1998, California school districts were required to test all students in the second through eleventh grades. The scores from 1998-2002 are from the Stanford Achievement Test, ninth edition (Stanford 9) administered each spring in California. The Stanford 9 is a multiple-choice test where scores are based on comparisons to a national sample of students. The test scores are adjusted so that mean scaled scores across years for a cohort (e.g., fifth grade in 1999 to sixth grade in 2000) are comparable. Starting in 2003, the State Board of Education replaced the Stanford 9 exam with the California Achievement Tests, Sixth Edition Survey (CAT/6). Like the Stanford 9, the CAT/6 is a national norm-referenced achievement test, but it is shorter in length than the Stanford 9.[16] Thus for 2004 and 2005 we use test scores from the CAT/6 and include a dummy variable for when this test was used. We focus on the reading comprehension and mathematics portions of the exam. Reading comprehension is part of the Language Arts section of the CAT/6, but was its own section of the Stanford 9. Reading comprehension scores, however, were reported separately from the rest of Language Arts in CAT/6, and thus we have these scores for our entire sample period.

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[15] Since the unemployment rate for Lake Gregory was not available, the unemployment rate for Crestline was used there instead. In the CHS, study students were enrolled and studied from both these adjacent communities and combined as one community.

[16] We use the CAT/6 instead of the (also publicly available) California Standardized Test (CST) because the norm-referencing of the CAT/6 is most similar to the Stanford 9.

4. Empirical Specification

Our basic model is

$$(1)\quad T_{gstl} = \beta_1 P_{st} + \beta_2 X_{gst} + \beta_3 Z_{gst} + \beta_4 U_{st} + f_s + \gamma Y_{cat} + \varepsilon_{gstl},$$

where T_{gstl} represents the respective California Standards test scores in grade *g* at school s in year t for test l. Further, in (1) P_{st} represents various measures of pollution for school s in year t,[17] X_{gst} denotes time-changing family background characteristics of the students by grade from CHS (i.e. not available from public data), Z_{gst} denotes time-changing school characteristics from publicly available data, U_{st} denotes the city unemployment rate in year t, f_s denotes a school fixed effect, Y_{cat} is a dummy variable for the new test used in 2004 and 2005 and ε_{gstl} is an error term assumed to be correlated across schools in the same community for all time periods.[18] In our second specification we use a full set of year dummies denoted by Y_t in year *t:*

$$(2)\quad T_{gstl} = \beta_1 P_{st} + \beta_2 X_{gst} + \beta_3 Z_{gst} + \beta_4 U_{st} + f_s + \delta_t Y_t + \varepsilon_{gstl}.$$

The school fixed effect is used to address, at least partially, the concern that a spurious correlation between pollution and achievement might exist due to a tendency for low-income Americans to locate in highly polluted areas because of lower rents; on average, student test score achievement increases with parental income (Duncan et al. 1994, Hanushek 1992; and Korenman 1995). However, the school fixed effect only takes care of sorting based on time-constant factors, and will not control for time-varying factors that affect residential location decisions. Thus, in (2) we

[17] The data collection process required that we assume that pollution was the same for all schools in a given community in a given year.

[18] As noted above some of the school characteristics included in Z_{gst} are only reported at the school level. To keep the subscripts manageable, we do not distinguish these in the equations.

use dummies for each year to capture unobserved sample-wide effects in each year.[19] Of course, neither school nor time dummies capture unobserved time-changing factors at the grade-school-year level, which motivates our use of grade-school-year data.

As noted above, we focus on the impact of annual average community pollution measures NO_2, O_3, $PM_{10,}$ and $PM_{2.5}$ based on previous research findings and data availability. Thus we are we are identifying the effect of pollution on school test scores by the variation in community pollution over time. Previous work has shown that NO_2, PM_{10} and $PM_{2.5}$ are highly inter-correlated, while ozone is much less correlated with these pollution measures – the correlation rates for the pollution measures are presented in Table 1 and these results confirm the previous findings. Given these high correlations, one might suspect that it would be difficult to separately identify the effect of a given pollution variable, holding the others constant, and, indeed, that is what we found. Thus, we present results for pollution by entering the variables one at a time, but for completeness we also include the results using all pollutants simultaneously as explanatory variables. We do not focus on the latter results since we would expect that the correlation structure in the pollution variables would create a multicollinearity problem that will make it difficult to identify specific coefficients.

In terms of the individual level data, we calculate the means for students in the CHS data in year t at school s for grade g, for the following variables: the responding parent's education; the fraction of children whose parents smoked;[20] the fraction of children who had public health insurance; and the fraction of children who had no health insurance.[21] We divide parental education into dummy variables for those who graduated from high school, attended some college, graduated from college, and attended graduate school (with the control group being those who had less than a

[19] The year dummies eliminate the need to use the test change dummy since it is perfectly collinear with the year dummies.
[20] For Cohorts C and D, parental smoking is equal to one if the person who completed the questionnaire smoked. For Cohort E, parental smoking is equal to one if the mother or the father smoked.
[21] In making this calculation, we need to ignore the possibility of a student failing a grade.

high school degree).[22] As noted above, we use these variables to minimize omitted-variable-bias in the pollution coefficient estimates.[23]

We use the following variables available through the California Department of Education (CDE) at the school-year level: pupil-teacher ratio, the percent of staff that have masters or doctoral degrees and the percent of students who received free lunches for each school s in year t as well as the ethnic breakdown of students in each grade g at school s in year t. Finally, we include a dummy variable for years after the change in the test (when we do not use year dummies) and the community unemployment rate as conditioning variables. Further, in *some specifications* we use year dummy variables. By controlling for school demographics and quality from the CDE and CHS data, published community unemployment rates, as well as school dummies and year dummies (in our most general specifications), we believe that we control for many of the potentially confounding factors in our analysis.

Our data set consists of 229 grade-school-year observations covering 88 schools. Summary statistics for the grade-school-year observations are presented in Table 2. Considering variables from the CHS data set, about 65% of the students in each grade had private insurance, 21% had Medicaid, and the remaining 14% did not have insurance. Moreover, about 13% of the parents reported that they smoked, and 16% of the subjects came from a single-parent household. Further, 16% of parents had less than a high school degree, 20% had a high school degree, 42% had some college, 11% had a college degree, and 11% had more than a college degree. In terms of the publicly available information on schools, about 29% of students received a free lunch, about 45% of teachers had an MA or PhD, and the average pupil-teacher ratio was around 20:1. Moreover, 8% of the students self-reported being Black, 56% reported being White non-Hispanic, and 36% reported

[22] These variables are only measured at the base year, but will change over time in a given grade and school as students progress through the school.
[23] Given that they will being noisy estimates of the true values for the grade-school-year observation, the coefficients on these variables will be inconsistent because of measurement error.

being Hispanic.[24] We note that the minimum and maximum statistics indicate a wide range in all of these variables across grade-school-year observations. Since we would expect most or all of these variables to affect school test scores, and it is plausible that some or all of them might affect location decisions and thus exposure to pollution, we believe it is crucial to control for such factors.

4. Empirical Results

We first consider the case where we omit a full set of year dummies. For this case we have placed the results for the math test scores in Table 3A and the results for reading scores in Table 3B. In each set of results we cluster the standard errors by city to allow for arbitrary forms of heteroskedacticity and dependence across observations on schools in a given community at a point in time as well as over time.

Considering the results for the math scores in Table 3A, in column (1) we include all four pollution measures simultaneously. A Wald test indicates that the estimated pollution coefficients are jointly significant[25], and all except the coefficient for O_3 have the expected negative signs. However, $PM_{2.5}$ is the only pollution measure in column (1) that is individually statistically significant at standard confidence levels, indicating that the multicollinearity issue, as suggested by the high correlations in Table 1, is indeed a problem. Next, we enter the pollution measures individually in columns (2) - (5) of Table 3A. We find that when used as the only pollution measure, PM_{10}, $PM_{2.5}$, and NO_2 are statistically significant; the coefficient on O_3 continues to have an unexpected positive sign, but is far from attaining statistical significance.

To assess the magnitude of the effects implied by the coefficients, note first that a one-standard-deviation increase in PM_{10}, $PM_{2.5}$, or NO_2 would decrease test scores by 8.99, 26.72, or

[24] We group students who self-reported as Asian, Pacific Islander, Native American or other in the White non-Hispanic category.
[25] We use a Wald test since the error terms are assumed to not be independent or homoskedastic; an F-Test for the joint significance would be inappropriate since the errors are not assumed independent or homoskedastic.

18.45 points, respectively, out of 999 possible points.[26] The standard deviation in $PM_{2.5}$ is 5.88 μg/m3. and the annual average concentration of $PM_{2.5}$ in the South Coast Air Basin dropped by approximately 11 μg/m3 between 1999 and 2006. The standard deviations for PM_{10} and NO_2 are 12.27 and 9.14, respectively. For this same time period and location, the (statewide) annual average for concentrations of PM_{10} and NO_2 dropped by about 22 μg/mg and 19 ppb respectively.[27] For those less familiar with the units used for pollution measures, we also calculate the relevant elasticities and find that a 1% increase in PM_{10}, $PM_{2.5}$, or NO_2 would decrease math test scores by 0.036%, 0.088%, or 0.059%, respectively.

Our results for the reading scores (when we do not use a full set of year dummies) appear in columns (1) - (5) of Table 3B. In column (1), we again include all four pollution measures. As in the case of the math scores, $PM_{2.5}$ is the only pollution measure that is individually statistically significant. A Wald test indicates that the four pollution measures are jointly significant at the 10 percent level, and the coefficient on O_3 has an unexpected positive sign, but is very insignificant. In columns (2) - (5), we show the results of entering the pollution measures individually, and again as in the case of the math scores, all the pollution variables, except O_3, have the expected sign. However, in contrast to our results for the math scores, only $PM_{2.5}$ is statistically significant. In terms of the size of the $PM_{2.5}$ coefficient, a one-standard-deviation increase in $PM_{2.5}$ would decrease reading test scores by 4.26 points and a 1% increase in $PM_{2.5}$ would decrease reading test scores by 0.014%. Note that the effect of an increase in $PM_{2.5}$ on math scores is over six times as large as the effect of the same increase on reading scores.

We next consider the case when we include time dummies. We have placed the results for math and reading scores in Tables 4A and 4B, respectively. In column (1) of Table 4A, we again

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[26] The CAT/6 is on a scale of 0 to 999 while the Stanford 9 was on a scale of 200 to 900. Therefore we subtracted 200 from the Stanford 9 scores and multiplied the remaining number by 1.427.

[27] For additional statistics on the trends, see chapters 3 and 4 of The California Almanac of Emissions and Air Quality– 2009 edition.

enter the pollution variables simultaneously. As in the case in column (1) of Table 3A, the Wald test indicates that the pollution coefficients are still jointly significant, only O_3 has an unexpected positive sign, and only $PM_{2.5}$ is individually statistically significant. When we enter the pollutants separately in columns (2) - (5), again as in Table 3A, $PM_{2.5}$, PM_{10} and NO_2 are individually significant with the expected signs, while O_3 has an unexpected positive sign but remains insignificant. Thus the results in Tables 3A and 4A are qualitatively very similar; however, they are not quantitatively similar, as now a one-standard-deviation increase in $PM_{2.5}$, PM_{10} or NO_2 would decrease test scores by 3.89, 10.23, or 5.53 points, respectively. In terms of elasticities, a 1% increase in PM_{10}, $PM_{2.5}$, or NO_2 would decrease math test scores by 0.015%, 0.034%, or 0.018%, respectively. Note that these estimated impacts are substantially smaller than those implied by Table 3A, but the largest effect is still associated with $PM_{2.5}$, illustrating the importance of having data on $PM_{2.5}$ for studying this problem. These effects are still substantial, especially for $PM_{2.5}$. For example a reasonable estimate of the difference in math test scores between high-income and low-income eighth graders is only about 10% (Barton and Coley 2009). To gain some intuition on the importance of these effects, our results imply that if it were possible to decrease $PM_{2.5}$ by 10% for low-income, but not high-income children, nearly one-thirtieth of this difference in eight grade math scores between the groups would be eliminated.

In Table 4B we show the effects of including year dummies in our specification for reading scores. Again column (1) shows the results of entering all four pollution measures simultaneously; similarly to column (1) of Table 3B, $PM_{2.5}$ is statistically significant with the appropriate sign. Among the remaining pollution variables, PM_{10} has the expected sign but NO_2 and O_3 do not. In this case the pollution variables are not jointly significant at standard test levels. As in table 3B, when we enter the pollution variables separately, $PM_{2.5}$ is the only individual pollutant that has a statistically significant coefficient with the expected sign. $PM_{10,}$ $NO_{2,}$ and O_3 are statistically insignificant, and the PM_{10} coefficient continues to have the expected negative sign while O_3 does not. However, now NO_2 also has an unexpected positive sign. Thus the only qualitative difference between Tables 3B and 4B is the positive (but still insignificant) coefficient on NO_2. Now a one-standard-deviation increase in $PM_{2.5}$ is predicted to decrease test scores by 6.51 points; in terms of elasticity, a 1% increase in $PM_{2.5}$ would change reading test scores by -0.021%. Given that a reasonable estimated difference in reading scores between high and low income eighth grade students is 9.3%, to reduce this gap by one-thirtieth one would need to reduce $PM_{2.5}$ by about 14% for low income, but not high income, students. Given these results, we conclude that results for reading test scores change quantitatively, but not qualitatively, when we use a full set of year dummies.

Of course one must choose whether to focus on the quantitative results generated from the specification that excludes a full set of year dummies or the specification that includes them. The benefit of including a full set of year dummies is that it allows one to control for the possibility of general unobserved time effects in test scores that are potentially correlated with pollution measures and not captured by our control variables. The potential cost of using year dummies is that if they are not needed, one is losing efficiency in terms of obtaining bigger standard errors. In other words, if we do not need a full set of year dummies, we would expect the coefficients to not change much between Tables 3A and 4A, and between Tables 3B and 4B, but that the standard errors should be larger in Tables 4A and 4B. However, this is not what happens. While the estimates without time dummies are qualitatively similar to those with time dummies, we see a considerable change between the coefficients in Table 3A and 3B and the respective entries in Tables 4A and 4B; moreover the standard errors with time dummies are often smaller than the respective standard errors without time dummies.[28] From these results it seems clear that the time dummy variables are indeed picking up unobserved factors correlated with the pollution measures and test scores, in spite of the fact that we have a large number of time changing control variables.

5. Conclusion

In this study, we examine the effects of four common and nationally-regulated outdoor air pollutants (PM_{10}, $PM_{2.5}$, NO_2 and O_3) on math and reading test scores. After controlling for a large number of possibly confounding factors using demographic variables, school dummies, and year dummies, we find that higher levels of $PM_{2.5}$ (a marker for fine particulate matter), PM_{10} (a marker for coarse particulate matter), and NO_2 consistently lower math scores, with $PM_{2.5}$ having the largest effect. Further, we find that higher levels of $PM_{2.5}$ consistently reduce reading test scores.

The results suggest a sizable effect of pollution on academic performance, which provides evidence of another avenue by which pollution is harmful. Not only is it bad for children's health, but it also impacts negatively on students' performance in school and their ability in general, which we would expect to reduce future labor earnings. Since lower socioeconomic households tend to reside in more highly polluted areas, our results suggest that a decrease in pollution will result in a decrease in inequality, everything else held equal. This effect will be accentuated by Fowler, Davenport and Garg (1992)'s finding that asthma has worse consequences for low income children than for high income children. Our results also identify some important methodological points. If quantitative effects, rather than qualitative effects, are of interest, it is important to include a full set of year dummies. Second, having monitoring data for $PM_{2.5}$ is crucial to our analysis; without it, we would have underestimated the effect of pollution on test scores.

[28] One could formally test whether, e.g., the coefficients in Table 3A and the respective coefficients in Table 4A are statistically different. One cannot use the formula in Hausman (1978) since neither set of estimates is efficient, but one could use the bootstrap to calculate appropriate standard errors for the difference in the coefficients. We do not follow this path since, *a priori,* there seems to be no reason to use the coefficients obtained without a full set of time dummies.

Of course, there are several limitations to our study that we should mention. First, while we control for a large number of possibly confounding factors, there is always the possibility that our results are biased by remaining unobserved factors correlated with pollution and test scores. Second, we assumed that pollution levels were the same at each school within a given community, since we used data from the regional air monitoring station located within that respective community. However, in most communities, there can be substantial variability in local pollution levels due to proximity to busy roadways, local sources, local topology, and meteorological factors. Thus it would clearly be desirable to obtain pollution levels by school. Third, it would be preferable to link individual test scores to individual factors, but given current confidentiality restrictions, it does not seem feasible to obtain such disaggregated data. A final limitation of our study is the lack of data on CO. Since other studies have found CO to have adverse health effects and be linked to absenteeism, it is an important pollutant to study the effect of CO when controlling for $PM_{2.5}$ and vice-versa.

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Table 1: Correlation across Pollution Variables

	PM_{10}	$PM_{2.5}$	O_3	NO_2
PM_{10}	1			
$PM_{2.5}$	0.88	1		
O_3	0.28	0.25	1	
NO_2	0.65	0.83	0.09	1

Table 2: Descriptive Statistics by Grade-School-Year

Variable	Mean	Std. Dev.	Min	Max
A. Student and School Dummy Variables:				
Parent's Education (%):				
< high school graduate	16.47	14.44	0.00	66.13
high school graduate	19.77	8.68	0.00	60.00
some college	41.63	12.21	11.43	70.00
college graduate	11.21	7.29	0.00	32.53
graduate school	10.92	8.06	0.00	30.36
Parent smokes (%)	13.28	6.60	0.00	36.36
Insurance (%):				
no insurance	13.76	10.05	0.00	58.33
medicaid	21.02	15.96	0.00	72.73
private insurance	65.22	16.66	18.18	96.00
Grade Characteristics (%):				
hispanic	36.30	22.30	6.00	95.92
black	7.51	8.16	0.00	38.76
white	56.18	23.16	30.52	90.32
School Characteristics:				
students who receive a free lunch (%)	28.67	18.98	0.00	93.12
staff with a MA or PHD (%)	45.39	14.43	0.00	79.00
pupil-teacher ratio	20.55	5.41	7.45	43.44
B. Community Characteristic:				
Unemployment rate	5.81	1.84	2.60	9.70
C. Pollution:				
PM_{10}	31.98	12.27	12.01	78.25
$PM_{2.5}$	12.70	5.88	4.72	28.85
NO_2	19.20	9.14	2.69	39.46
O_3	53.38	11.28	32.41	78.26
D. Test Scores:				
Mathematics mean scaled score	659.20	53.08	536.00	739.97
Reading mean scaled score	665.01	43.61	570.30	739.12

Note: Descriptive statistics are for the 229 grade-school-year observations.

Table 3A: The Effect of Pollution on Mathematics Test Scores
School Fixed Effects

	(1)	(2)	(3)	(4)	(5)
Pollution:					
PM_{10}	-0.329	-0.733[d]			
	(0.28)	(0.34)			
$PM_{2.5}$	-4.050[c]		-4.546[c]		
	(0.87)		(0.98)		
NO_2	-0.841			-2.018[c]	
	(0.77)			(0.67)	
O_3	0.363				0.269
	(0.45)				(0.38)
Wald Statistic for Joint Significance[a]	40.07				
Personal Characteristics:					
Age	14.33[c]	17.19[c]	14.13[c]	17.62[c]	18.01[c]
	(1.17)	(0.98)	(1.31)	(1.45)	(1.40)
Parent's Education (%):					
high school graduate	0.438	0.303	0.355	0.163	0.215
	(0.31)	(0.34)	(0.30)	(0.32)	(0.38)
some college	0.772[c]	0.558[d]	0.761[c]	0.427	0.407
	(0.23)	(0.25)	(0.25)	(0.28)	(0.27)
college graduate	0.590[d]	0.292	0.594[e]	0.227	0.237
	(0.26)	(0.25)	(0.31)	(0.27)	(0.26)
graduate school	-0.102	-0.446	-0.101	-0.401	-0.587
	(0.42)	(0.43)	(0.45)	(0.42)	(0.45)
Parent smokes (%)	-0.299	-0.202	-0.283	-0.170	-0.282
	(0.39)	(0.38)	(0.41)	(0.35)	(0.38)
Insurance (%):					
medicaid	-0.092	-0.113	-0.078	-0.112	-0.122
	(0.11)	(0.13)	(0.12)	(0.11)	(0.14)
no insurance	-0.178	-0.279	-0.183	-0.047	-0.176
	(0.17)	(0.16)	(0.18)	(0.21)	(0.17)
School Characteristics:					
free lunch (%)	-0.358	-0.370	-0.306	-0.105	-0.163
	(0.42)	(0.47)	(0.39)	(0.41)	(0.44)
pupil-teacher ratio	0.366	0.537[e]	0.386	0.433	0.481
	(0.32)	(0.29)	(0.32)	(0.35)	(0.31)
staff w/MA or PhD (%)	0.001	0.000	0.000	0.001	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Grade Characteristics (%):					
hispanic	0.348	0.393	0.376	0.370	0.375
	(0.25)	(0.29)	(0.26)	(0.25)	(0.28)
black	0.203	0.251	0.224	0.210	0.222
	(0.25)	(0.30)	(0.29)	(0.33)	(0.33)
Unemployment Rate	-7.491[c]	-6.915[c]	-6.879[c]	-5.853[c]	-6.058[c]
	(1.72)	(1.63)	(1.94)	(1.60)	(1.54)
Test Change	-39.79[c]	-16.45[d]	-40.70[c]	-28.04[c]	-17.59[d]
	(8.63)	(7.71)	(7.22)	(7.17)	(6.51)
Constant	547.358[c]	482.753[c]	545.510[c]	485.359[c]	433.687[c]
	(56.31)	(40.37)	(44.07)	(44.94)	(60.73)
School Dummies	Y	Y	Y	Y	Y
Year Dummies	N	N	N	N	N
Observations	216	222	220	226	229
Number of Schools	88	88	88	88	88

Notes:

a. The critical values of the Wald test statistic at the .05 and .10 levels are 9.488 and 7.779, respectively.

b. Robust standard errors in parentheses.

c. $p<0.01$. d. $p<0.05$. e. $p<0.10$.

Table 3B: The Effect of Pollution on Reading Test Scores
School Fixed Effects

	(1)	(2)	(3)	(4)	(5)
Pollution:					
PM_{10}	-0.188	-0.232			
	(0.16)	(0.14)			
$PM_{2.5}$	-0.473		-0.725[d]		
	(0.44)		(0.33)		
NO_2	-0.162			-0.414	
	(0.35)			(0.32)	
O_3	0.142				0.191
	(0.21)				(0.17)
Wald Statistic for Joint Significance[a]	9.09				
Personal Characteristics:					
Age	13.16[c]	13.32[c]	12.83[c]	13.35[c]	13.52[c]
	(0.77)	(0.58)	(0.77)	(0.61)	(0.59)
Parent's Education (%):					
high school graduate	0.277[d]	0.219[e]	0.239[d]	0.201[d]	0.199[e]
	(0.10)	(0.12)	(0.11)	(0.09)	(0.11)
some college	0.355[c]	0.290[d]	0.345[d]	0.277[d]	0.231[c]
	(0.11)	(0.13)	(0.12)	(0.12)	(0.12)
college graduate	0.270	0.228	0.292	0.190	0.200
	(0.23)	(0.23)	(0.22)	(0.22)	(0.20)
graduate school	-0.050	-0.117	-0.038	-0.071	-0.160
	(0.29)	(0.24)	(0.29)	(0.26)	(0.24)
Parent smokes (%)	-0.215	-0.187	-0.221	-0.186	-0.220
	(0.13)	(0.14)	(0.16)	(0.14)	(0.13)
Insurance (%):					
medicaid	-0.154[d]	-0.162[d]	-0.148[d]	-0.156[d]	-0.168[d]
	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)
no insurance	-0.252[e]	-0.255[e]	-0.232	-0.205	-0.212
	(0.14)	(0.14)	(0.14)	(0.12)	(0.12)
School Characteristics:					
free lunch (%)	-0.745[c]	-0.796[c]	-0.711[c]	-0.680[c]	-0.703[c]
	(0.22)	(0.22)	(0.22)	(0.22)	(0.22)
pupil-teacher ratio	0.392	0.404	0.372	0.373	0.381
	(0.25)	(0.24)	(0.23)	(0.25)	(0.24)
staff w/MA or PhD (%)	-0.001	-0.001	-0.001	-0.001	-0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Grade Characteristics (%):					
hispanic	-0.054	-0.051	-0.060	-0.074	-0.073
	(0.10)	(0.10)	(0.09)	(0.10)	(0.11)
black	0.179	0.157	0.174	0.157	0.146
	(0.23)	(0.23)	(0.23)	(0.21)	(0.20)
Unemployment Rate	-1.771[d]	-1.556[d]	-1.522[d]	-1.287[e]	-1.405[d]
	(0.72)	(0.69)	(0.70)	(0.73)	(0.65)
Test Change	-8.462[e]	-5.754	-10.388[c]	-8.219[d]	-5.631
	(4.49)	(3.77)	(3.40)	(3.55)	(3.55)
Constant	527.523[c]	530.574[C]	533.761[c]	528.385[c]	511.351[c]
	(22.33)	(15.92)	(18.89)	(19.16)	(20.76)
School Dummies	Y	Y	Y	Y	Y
Year Dummies	N	N	N	N	N
Observations	216	222	220	226	229
Number of Schools	88	88	88	88	88

Notes:
a. The critical values of the Wald test statistic at the .05 and .10 levels are 9.488 and 7.779, respectively.
b. Robust standard errors in parentheses.
c. $p<0.01$. d. $p<0.05$. e. $p<0.10$.

Table 4A: The Effect of Pollution on Mathematics Test Scores
School and Year Fixed Effects

	(1)	(2)	(3)	(4)	(5)
Pollution:					
PM_{10}	-0.147	-0.317[d]			
	(0.13)	(0.11)			
$PM_{2.5}$	-1.648[d]		-1.741[d]		
	(0.57)		(0.69)		
NO_2	-0.430			-0.605[e]	
	(0.34)			(0.34)	
O_3	0.171				0.215
	(0.17)				(0.18)
Wald Statistic for Joint Significance[a]	13.100				
Personal Characteristics:					
Age	-8.905[e]	-2.057	-11.31[e]	-8.297[e]	-3.004
	(4.95)	(5.41)	(6.22)	(4.65)	(5.90)
Parent's Education (%):					
high school graduate	0.168	0.128	0.105	0.089	0.120
	(0.10)	(0.08)	(0.09)	(0.08)	(0.09)
some college	0.180	0.149	0.121	0.071	0.096
	(0.12)	(0.14)	(0.13)	(0.15)	(0.16)
college graduate	0.081	-0.016	0.059	-0.015	-0.019
	(0.16)	(0.17)	(0.17)	(0.18)	(0.18)
graduate school	0.119	0.085	0.132	0.036	0.041
	(0.25)	(0.27)	(0.26)	(0.24)	(0.25)
Parent smokes (%)	-0.140	-0.078	-0.125	-0.085	-0.105
	(0.10)	(0.08)	(0.09)	(0.07)	(0.08)
Insurance (%):					
medicaid	-0.070	-0.076	-0.060	-0.070	-0.072
	(0.06)	(0.06)	(0.06)	(0.05)	(0.05)
no insurance	-0.004	-0.023	0.049	0.041	0.048
	(0.12)	(0.12)	(0.11)	(0.11)	(0.12)
School Characteristics:					
free lunch (%)	-0.639[d]	-0.636[d]	-0.623[d]	-0.635[d]	-0.560[d]
	(0.26)	(0.22)	(0.25)	(0.22)	(0.20)
pupil-teacher ratio	0.135	0.120	0.135	0.116	0.118
	(0.19)	(0.19)	(0.19)	(0.20)	(0.21)
staff w/MA or PhD (%)	0.000	0.000	0.000	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Grade Characteristics (%):					
hispanic	-0.009	-0.061	-0.042	-0.073	-0.090
	(0.15)	(0.16)	(0.13)	(0.15)	(0.16)
black	-0.026	-0.113	-0.065	-0.133	-0.157
	(0.12)	(0.16)	(0.12)	(0.13)	(0.14)
Unemployment Rate	-0.566	-1.663	-0.618	-1.581	-2.116[e]
	(1.30)	(1.12)	(1.34)	(1.22)	(1.09)
Constant	828.147[c]	735.885[c]	862.827[c]	824.568[c]	730.871[c]
	(71.83)	(73.77)	(81.73)	(59.21)	(83.43)
School Dummies	Y	Y	Y	Y	Y
Year Dummies	Y	Y	Y	Y	Y
Observations	216	222	220	226	229
Number of Schools	88	88	88	88	88

Notes:
a. The critical values of the Wald test statistic at the .05 and .10 levels are 9.488 and 7.779, respectively.
b. Robust standard errors in parentheses.
c. $p<0.01$. d. $p<0.05$. e. $p<0.10$.

Table 4B: The Effect of Pollution on Reading Test Scores
School and Year Fixed Effects

	(1)	(2)	(3)	(4)	(5)
Pollution:					
PM_{10}	-0.116	-0.125			
	(0.13)	(0.14)			
$PM_{2.5}$	-1.012[e]		-1.107[d]		
	(0.54)		(0.51)		
NO_2	0.307			0.207	
	(0.23)			(0.28)	
O_3	0.124				0.149
	(0.17)				(0.13)
Wald Statistic for Joint Significance[a]	7.026				
Personal Characteristics:					
Age	-3.979	-1.179	-3.714	-2.739	-0.508
	(6.79)	(4.76)	(6.03)	(6.83)	(4.57)
Parent's Education (%):					
high school graduate	0.194[e]	0.142	0.168	0.132	0.139
	(0.09)	(0.10)	(0.10)	(0.09)	(0.09)
some college	0.236	0.170	0.225	0.159	0.136
	(0.16)	(0.17)	(0.16)	(0.16)	(0.17)
college graduate	0.161	0.111	0.168	0.073	0.089
	(0.29)	(0.30)	(0.28)	(0.28)	(0.27)
graduate school	0.149	0.073	0.148	0.097	0.043
	(0.27)	(0.25)	(0.27)	(0.26)	(0.24)
Parent smokes (%)	-0.162	-0.141	-0.159	-0.137	-0.160
	(0.12)	(0.11)	(0.13)	(0.11)	(0.10)
Insurance (%):					
medicaid	-0.127[d]	-0.140[d]	-0.127[d]	-0.133[d]	-0.145[d]
	(0.06)	(0.06)	(0.05)	(0.05)	(0.06)
no insurance	-0.113	-0.106	-0.091	-0.085	-0.076
	(0.10)	(0.10)	(0.09)	(0.10)	(0.09)
School Characteristics:					
free lunch (%)	-0.700[c]	-0.739[c]	-0.690[c]	-0.696[c]	-0.690[c]
	(0.22)	(0.21)	(0.22)	(0.22)	(0.20)
pupil-teacher ratio	0.471	0.443	0.459	0.441	0.438
	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)
staff w/MA or PhD (%)	-0.001	-0.001	-0.001	-0.002	-0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Grade Characteristics (%):					
hispanic	-0.102	-0.127	-0.106	-0.156	-0.152
	(0.17)	(0.17)	(0.16)	(0.16)	(0.17)
black	0.153	0.095	0.157	0.074	0.080
	(0.21)	(0.23)	(0.22)	(0.22)	(0.22)
Unemployment Rate	-0.051	-0.154	0.195	-0.344	-0.229
	(1.42)	(1.38)	(1.46)	(1.17)	(1.23)
Constant	739.962[c]	711.704[c]	746.793[C]	727.118[C]	692.839[C]
	(84.37)	(62.33)	(78.78)	(85.48)	(61.80)
School Dummies	Y	Y	Y	Y	Y
Year Dummies	Y	Y	Y	Y	Y
Observations	216	222	220	226	229
Number of Schools	88	88	88	88	88

Notes:
a. The critical values of the Wald test statistic at the .05 and .10 levels are 9.488 and 7.779, respectively.
b. Robust standard errors in parentheses.
c. p<0.01. d. p<0.05. e. p<0.10.