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Original Article

Respiratory Hospital Admissions before and after Closure of a Major Industry in the Lower Hunter Region, Australia

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Abstract

Background: Many epidemiological studies reported significant associations between air pollution and respiratory hospital admissions. Proximity of industries to the residential areas may have considerable impacts on air quality and subsequently public health. This paper describes the indirect impacts of closing a large steel industry, Broken Hill Proprietary (BHP), in the Lower Hunter region, Australia.

Methods: The number of hospital admissions for a group of respiratory diseases including all respiratory disease, Chronic Obstructive Pulmonary Disease (COPD) and asthma were incorporated in this study. The study location comprised the entire Lower Hunter, Newcastle, as the closest location, and Port Stephens, as the most distant area to the industry. Two series of data set for 3.5 years before and after industry closure allowed a comparison of daily hospital admissions. Mixed Model was employed to calculate significant changes in the time series by month.

Results: While the rest of the disease categories decreased, COPD 65+ increased after BHP closure. All-age asthma in Newcastle showed the highest decrease whereas the least difference was observed for respiratory disease in Port Stephens. The decrease of admission rates was generally more significant in Newcastle, where the industry was operating, than in the other areas.

Conclusion: Inconsistent results challenged the publically viewed significant role of BHP closure on public health. The study expected consistent decreases of respiratory admissions after industry closure; however, the district results suggested some impacts on community health. Incompatible findings could be attributable to other factors that dominated the possible impacts of BHP closure.

Keywords: *Respiratory disease, Air pollution, Hospital admission, BHP steel works, Australia*

Introduction

The Lower Hunter region, which is situated on the southeast coast of Australia in New South Wales, consists of five Local Government Areas (LGA). Total population of the region is about 470000. As Fig. 1 shows, the study location surrounded by the coast to the east, and the reminder is bounded by higher terrain. The region which extends from 151º 15' to 152º 10' longitude east and from 32º 40' to 33º 05' latitude south, includes the LGAs of Newcastle, Lake Macquarie, Port Stephens, Maitland and Cessnock.

The study area is roughly contained within 45 kilometer radius of Newcastle CBD, where the major industry BHP Rod and Bar was operating. Newcastle, as the largest city of Lower Hunter, is the seventh most populated city in Australia and the second largest city of New South Wales. Until the late past century, the Hunter Region was known for air pollution caused by the local major chemical, steel making industries, and mining. The climate of region is best described as mainly under sub-tropical influence, which is generally warm in summer, mild in autumn and spring and cool in winter. The levels of air pollution are relatively low,

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so that, almost all the time, the pollutant concentrations have been reported within air-quality standards. The area has fully integrated industries, steel works, mining and rail and harbor activities. In October 1999, economic considerations led to the closure of the biggest local steel works industry, BHP Rod, and bar, located in Newcastle LGA near the coast. This industry was the principal source of SO_2, NO_2 and particulate matter. In the early 1990s, BHP was the source of around 30% of total particulate matter, 80% of total NO_x emissions and more than 90% of total SO_2 pollution in the industrial zone of inner Newcastle (1-2). The industry was thought to endanger public health by emitting pollutants in the air, although, there was no clear evidence.

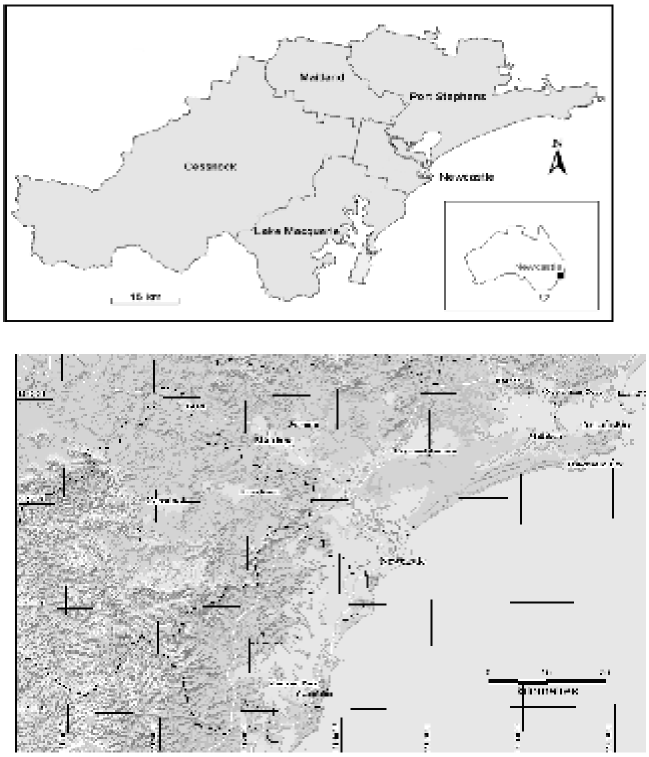


Fig. 1: The Study Location, the Lower Hunter Region in Australia
(**Source:** GIS Lab, School of Environmental and Life Science, Newcastle University, Australia)

This study investigated the role of BHP closure on public health on a local scale. The specific target was investigating the differences in the rate of a group of the diseases associated with air pollution before and after the closure of BHP in the region. The study period included 7 yr, 3.5 yr before and 3.5 yr after BHP closure (1/1/1996 to 30/06/1999 and 1/1/2001 to 30/06/2004). The time between 30/06/1999 and 1/1/2001 was considered as phase out of the industry. Choosing the same beginning and ending time of year allowed comparison of seasonal changes for the both periods of study.

Materials and Methods

Data Collection and Manipulation

Data on daily hospital admission for respiratory diseases for Lower Hunter residents were obtained from the Centre for Clinical Epidemiology and Biostatistics (CCEB) at the University of Newcastle. We chose three age groups to examine, children (0-14 yr), the elderly (65+ yr), and all ages. For all respiratory diseases only all age group was considered. For COPD only 65+ yr group was examined, and the analysis was restricted to 0-14 yr and all age asthma admissions. Besides the entire Lower Hunter, the distribution of hospital admissions over the study period for Newcastle, as the closest LGA, and Port Stephens, as the most distant LGA to BHP (as the “control” site), are described to evaluate possible geographical impacts. The count of admissions for influenza and pneumonia was also included for modeling purposes, as a confounder. As other confounders, a combined three-station data set for temperature and relative humidity, were also obtained from the air quality monitoring stations operated by NSW Department of Environment and Climate Change (NSWDECC).

Statistical Analysis

Regarding the impacts of BHP closure, the analysis was applied for whole study area, Lower Hunter, the nearest LGA to industry, Newcastle; and the most distant LGA to BHP, Port Stephens. The statistical approach used to examine the difference of health variables before and after closing BHP utilized Mixed Model. Mixed model is a generalization of the standard linear model that examines statistical inferences along the data set. The model computes estimates of fixed effects and valid standard errors (3-4). Mixed Model is generally used in controlled experimental studies in which the measures of outcome are investigated before and after series of trials (5). This approach was used for the first time to investigate the indirect impacts of an industry on public health. In current study, the model compares the mean of each variable, health outcomes, over the same proportion of each pair of study period. In the model, each LGA was considered as an object, which experienced two different situations in two different periods, before and after BHP closure. BHP closure, as the central point in the trial, was hypothetically associated with these differences. The primary assumptions of underlying the analysis are that the data are normally distributed; the means of the data are linear in terms of parameters; and the variances and covariances of the data are different in terms of different sets of parameters (3), but show a matching structure (5). In longitudinal studies such as the current one, to increase the frequency of covariance parameters, repeated measures are taken on the same unit over time; and these repeated measurements are correlated or reveal variability that may change (3). To apply the model optimally, the unit of repeated measurements was created, as data must be similarly ordered for each subject. For this study the unit of repeated time was one month. As a result, each study period consisted of 42 units or months. Inspection of the data showed they were Guassian in distribution; consequently, their likelihood was maximised to estimate the model parameters. Therefore, Residual/ Restricted Maximum Likelihood (REML) was selected as estimation method for the covariance parameters. Compound Symmetry (CS) was preferred for covariance structure after comparing to the other structures including autoregressive (AR) and unstructured (UN) covariance. For this study, the benefits of the Mixed Model are its ability to directly compare and correlate pre- and post-BHP admission rates. It analyses the data in its original form, and handles between and within parameter effects similarly. While being computationally intensive, it was reasonably easy to use, and based on comparisons with other models, such Poisson Regression and General Linear Model (GLM), produced a better fit to the data set. The potential confounding factors of seasonal variation, day of week and public holidays, population, and viral epidemics were included in the model. To adjust for population, the rate of hospital admissions for each disease was considered in the analysis. The type of test was t-test for pair wise comparison adjustments with the $P= 0.05$ and 95% confidence interval. All analyses were conducted using SAS statistical software (3).

Results

Changes in disease admissions in the Lower Hunter Region

Number of respiratory admissions dropped from 23068 to 21277 after BHP closure. The same decreasing trend was observed for cool and warm seasons; however, the decrease of respiratory admissions was dramatically higher in cool season. Moreover, the counts of respiratory admissions were evidence for a strong seasonality, peaking in the cool season. Overall, the daily average number of respiratory admissions was 20 in winter and 14 in summer time. After closing BHP, the number of asthma admissions also had a significant decrease (about 35%); however, the decrease of childhood asthma was slightly lower. On the other hand, the other subcategory of respiratory disease, COPD 65+, showed a large increase (more than 30%). These vast changes of asthma and elderly COPD admissions may have been influenced by the modification of definition of diagnoses and ICDs, which is discussed in the next section.

Unlike for all respiratory admissions, both increase of COPD admissions and decrease of asthma admissions were considerably higher in the warm season. However, the number of hospital admissions was higher in cool season in both periods.

Changes in disease admissions in the Newcastle and Port Stephens

All respiratory disease admissions dropped in both LGAs after BHP closure; however, Newcastle showed significantly higher decrease. It decreased by about 12% in Newcastle and by 1% in the Port Stephens LGA. The decrease was more noticeable in cool season in Newcastle. All-age and childhood asthma admissions revealed extraordinary decreases in both LGAs after BHP closure. The decrease of all-age asthma in Newcastle, and children asthma in Port Stephens, appeared to be more considerable. In addition, the decrease rates were higher in summer time at both locations. After BHP closure, the number of admissions for elderly COPD in both locations, Newcastle and Port Stephens, increased; the increase was considerably greater in the Port Stephens LGA. Moreover, the difference of COPD admissions was higher in cool season at both LGAs. In general, the respiratory categories varied visibly season by season, and the number of admissions in all categories reached the minimum values in warm season.

Essentially, number of hospital admissions in these locations cannot be compared without considering their different populations. Therefore, by including the population factor, comparison of BHP impacts in terms of physical distance would be more reliable. Table 1 shows the daily rate of hospital admissions per a 100000 population of the Lower Hunter residents. The admission rate considers populations and their changes over time. Therefore, it controls the population factor and gives more precise and accurate comparable results by that occurrence of diseases can be compared in different periods. The hospital admission rate is calculated by using the following formula:

(Number of admissions[*]/Population[†]) x A constant number[‡]

As Table 1 reveals, in period 1996-99, on average, 4.02 patients were admitted to hospitals per a 100000 population in Lower Hunter per day. All-age asthma contributed around 18% to admission rate of all respiratory diseases. After BHP closure, with the exception of COPD, the rate of the other diseases decreased, while the greatest decrease was observed for the asthma and specifically for all-age asthma. In general, the admission rate of diseases showed consistency with the daily hospital admissions. Seasonal changes, which are more apparent in Table 1, were also similar to the changes described previously. Considering the fact that annual population growth rate in the Lower Hunter area was less than 1%, a large change would not be expected.

Table 2 presents the comparable results of hospital admission rates in Newcastle and Port Stephens before and after the closure of BHP. Except for COPD, the admission rate of the other diagnoses dropped in both locations. However, the decrease of admission rates was most considerable in Newcastle. In Newcastle, the most seasonal variations were observed for the elderly COPD and all respiratory disease. Childhood asthma and all-age asthma presented the least seasonal fluctuations. In Port Stephens, seasonal variations were observed for all disease categories, while asthma groups showed the least seasonal differences.

Overall comparison of hospital admission rates in different locations revealed that the rate of all respiratory disease in the Lower Hunter area was barely higher than in Newcastle as well as in Port Stephens in the period 1996-99. After the closure of BHP, Newcastle showed the lowest, and Lower Hunter presented the highest rates of all respiratory admissions. The elderly COPD rate increased all over the whole study area, Newcastle and Port Stephens. However, it was higher in Lower Hunter area in both periods. All-age asthma rate was lower than the average level in Newcastle in period 1996-99. While it decreased in all locations after the closure of BHP, the decrease was less significant in Port Stephens. In contrast, the decrease of asthma was consistent with the Lower Hunter area. The rate of children asthma decreased after BHP closure. It was more significant for the Lower Hunter and Newcastle than for Port Stephens.

[*] In a given location for a given time period
[†] Averaged population of the location over the time period
[‡] Depends on the rate of disease, from 100 to millions

All respiratory disease

In spite of the fact that overall estimation of respiratory disease after closing BHP decreased by 11.7%, 14% and 10.4% in the Lower Hunter, Newcastle and Port Stephens, respectively, the statistical examination found all changes non-significant.

The result shows that the seasonal difference of respiratory disease estimations was not considerable, and an observable seasonal trend was seen for both periods; the lowest levels of estimations were found in the warm season; and the difference before and after BHP closure was only noticeable in the cool seasons. The difference of estimations of all respiratory disease in the whole study area before and after the closure of BHP was statistically significant in about 20% of time (10 mo).

Again, although, the estimation rate of all respiratory disease was found to be lower after BHP closure, the statistical analysis resulted in non-significant change in Newcastle as well as in Port Stephens. However, the decrease of respiratory rate after the closure of BHP was considerably higher in Newcastle than in the Port Stephens. It dropped by 14% in Newcastle, and 10.4% in Port Stephens. When compared to the Lower Hunter decrease (11.7%), the overall decrease of all respiratory rates was higher in Newcastle, and lower in Port Stephens. The findings show, while there was seasonal variation in study locations and periods, the difference was more noticeable in cool season in Newcastle. However, in Port Stephens, there was no apparent change in cool or warm seasons.

In addition, the decreasing trend of respiratory disease became less visible at the end of each study period in Port Stephens. Altogether, despite the non-significant change, the difference of respiratory admissions was significant in 10 mo in Newcastle. It was much lower in Port Stephens, with only 4 mo significantly different.

Elderly COPD

The change of estimations for elderly COPD admissions is presented in Table 3. As shown, in the Lower Hunter area, the estimations increased overall by 21.9% in the period 2001-04; therefore, the mixed model found the change significant.

Figure 2 shows the monthly estimations of COPD 65+ admissions before and after the closure of BHP in the Lower Hunter region. The estimations were higher almost all the time in the period 2001-04. Similar to all respiratory, the estimations of elderly COPD were visibly variable in different seasons of both periods, and the rate of admissions peaked in cool season. The results also revealed that the difference of COPD 65+ appeared to be consistent in both cool and warm seasons. However, it became less significant during the last year of study period.

Similar to Lower Hunter, admission rate of elderly COPD increased in other two locations, after BHP closure. The overall increase rate was 36.9% in Newcastle, and 31.5% in Port Stephens. The study, therefore, found the increases significant in both locations; however, it was more significant in Newcastle. Figure 3 shows the monthly admission rates of this category in the Newcastle and Port Stephens LGAs before and after the closure of BHP. As seen, the admission rates of the elderly COPD appeared mainly in the higher levels in period 2001-04 at both LGAs. Change rate of admissions for COPD 65+ after closing BHP was considerably higher at Newcastle and Port Stephens than its overall change in the Lower Hunter area.

All-age asthma

The rate of all-age asthma admissions in Lower Hunter appeared to be significantly different in the period before BHP closure. As Table 4 shows, the mixed model estimated that overall admission rate of asthma decreased by 36.7% in Lower Hunter, after the closure of BHP. The decrease was found to be statistically significant. The model also showed significant seasonal variation for asthma admissions, so that the maximum number of admissions was observed in the cool season. However, the seasonal trend is not as apparent in Figure 4 as other respiratory categories admissions.

The asthma estimations remained continuously in the lower levels in period 2001-04; and the difference of before and after the closure of BHP were significant in 25 mo. This was the largest proportion of time with significant distinction amongst all disease categories considered in the study. The time trend of admission rate of asthma also revealed that difference was apparently more significant at the beginning of both periods.

The admission rate for All-age asthma in Newcastle and Port Stephens roughly followed the same pattern as in the Lower Hunter area. After the closure of BHP, it decreased dramatically in both LGAs. However, the decrease was more noticeable in Newcastle. Overall asthma estimations declined by 39.9% in the Newcastle LGA, which was slightly higher than its average over the whole study location (36.7%). In Port Stephens, the decrease was a little lower than in the Lower Hunter. The mixed model found the change of asthma admission rate in Newcastle and Port Stephens significant.

As Figure 5 presents, the statistical analysis also found seasonal trend in both periods and locations; however, it was observable in Newcastle. The results also revealed that the difference of asthma rate was more significant in the cool season, and it became less significant at the end of study period. Although the analysis found the same significance for asthma decrease in Port Stephens and Newcastle (*P*= 0.0002), the difference of asthma admissions before and after BHP closure was statistically significant in 17 mo in Newcastle, whereas it was significant in only seven months in Port Stephens.

Childhood asthma

Consistent with all-age asthma, the estimations of childhood asthma admission were found to be significantly different before and after BHP closure. As Table 5 shows, the statistical analysis estimated that overall admission rate of children asthma in Lower Hunter decreased around 30% after closing BHP.

Though the time trend did not show a clear seasonal variation in Lower Hunter (Fig. 6), the model resulted in a significant seasonal trend. Furthermore, overall childhood asthma rate was at the maximum levels in the cool seasons. The line graph also shows that approaching the closure of BHP, the admission rate of childhood asthma generally declined, while there was no particular trend for period 2001-04. Therefore, the difference of asthma 0-14 estimations was more significant at the beginning of study period.

Again, similar to all-age asthma, the levels of children asthma estimations were mostly higher before BHP closure. However, the results showed the difference was statistically significant only in 12 mo of study period. More than 90% of significant times were in common with all-age asthma.

Similarly, the change of asthma 0-14 was found to be significant before and after the closure of BHP in both LGAs of Newcastle and Port Stephens. The results of mixed model estimated that asthma among children decreased by 34.2% in Newcastle, and by 36.6% in Port Stephens in period 2001-04. Both changes were slightly greater than the average decrease in the Lower Hunter area (30.3%). Even though, the time trend in Figure 7 does not show an apparent seasonal variation, particularly for the period 2001-04, the model found statistically seasonal difference for childhood asthma admissions. The difference of estimations was significant in nine months in Newcastle, and in five months in Port Stephens. All months with the significant changes were in common with all-age asthma at both locations.

In summary, of the diseases considered in the analysis, only COPD 65+ increased after BHP closure, while the rest of disease categories decreased. Figure 8 compares the overall estimations of diseases in the whole study area (Lower Hunter), Newcastle and Port Stephens. As shown, all respiratory disease and childhood asthma decreased roughly in the same way in all locations. The decrease of all-age asthma and increase of COPD were more apparent in Newcastle. In comparison, except for childhood asthma, the differences of disease incidences in before and after BHP closure were more significant in Newcastle than in Port Stephens and Lower Hunter. The highest decrease of disease incidences was found for all-age asthma in Newcastle, and the least difference was observed for respiratory disease in Port Stephens. Overall, the change incidence of diseases was more significant in Newcastle than in Port Stephens.

Table 1: Mean daily admissions per a 100000 population of Lower Hunter, before and after BHP Closure

Disease	1996-99			2001-04		
	Whole Period	Cool Season [a]	Warm Season [b]	Whole Period	Cool Season [a]	Warm Season [b]
Respiratory	4.02	4.73	3.31	3.54	4.18	3.01
COPD 65+	3.11	3.72	2.50	3.76	4.48	3.18
Asthma	0.71	0.77	0.65	0.44	0.52	0.39
Asthma 0-14	1.76	1.77	1.76	1.22	1.34	1.13

[a] April – September [b] October - March

Table 2: Mean daily admissions per a 100000 population, Newcastle and Port Stephens, Before and after BHP Closure

LGA	Disease	1996-99			2001-04		
		Whole Period	Cool Season [a]	Warm Season [b]	Whole Period	Cool Season [a]	Warm Season [b]
Newcastle	Respiratory	3.91	4.63	3.20	3.34	3.91	2.87
	COPD 65+	2.76	3.27	2.27	3.77	4.31	3.33
	Asthma	0.70	0.76	0.65	0.42	0.49	0.36
	Asthma 0-14	2.18	2.18	2.18	1.43	1.59	1.30
Port Stephens	Respiratory	3.81	4.38	3.25	3.41	4.10	2.86
	COPD 65+	3.08	3.40	2.76	4.11	4.85	3.50
	Asthma	0.68	0.68	0.69	0.43	0.55	0.32
	Asthma 0-14	1.58	1.48	1.68	0.97	1.14	0.83

[a] April – September [b] October – March

Table 3: Difference of estimations of COPD 65+ admission rate*, before and after BHP closure

Location	1996-99	2001-04	Difference	*P* Value
Lower Hunter	2.961	3.608	+21.9%	0.001
Newcastle	2.671	3.656	+36.9%	<0.0001
Port Stephens	3.243	4.264	+31.5%	0.0003

* Mean daily admissions for a 100,000 population

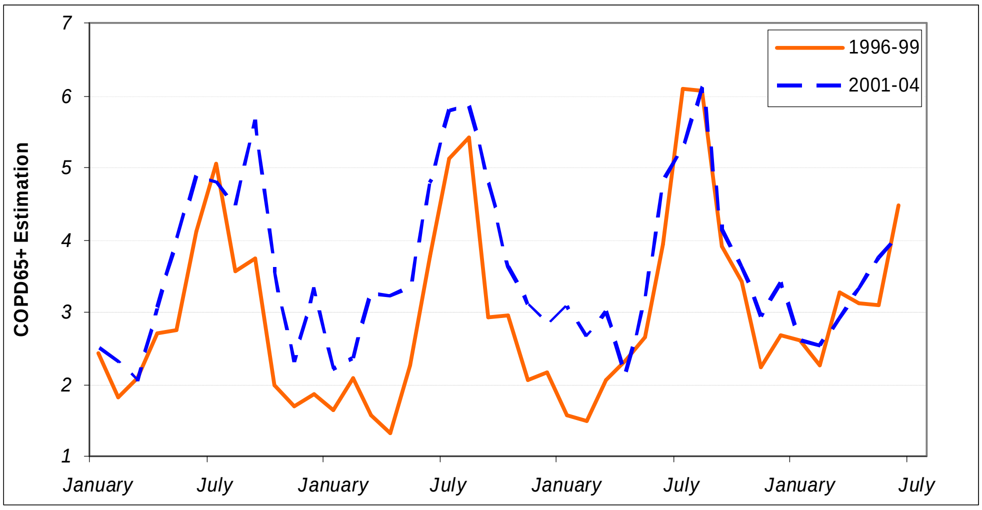
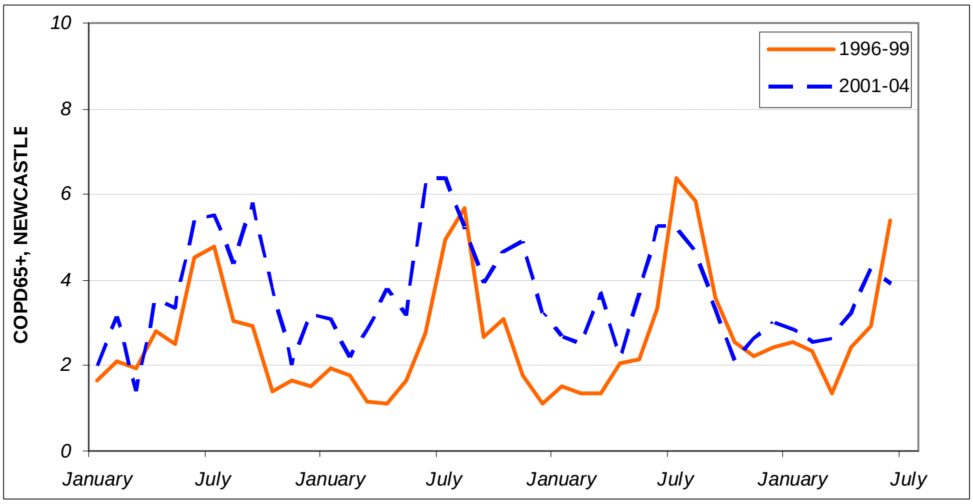


Fig. 2: Comparison of COPD 65+ estimations in Lower Hunter, before and after BHP closure



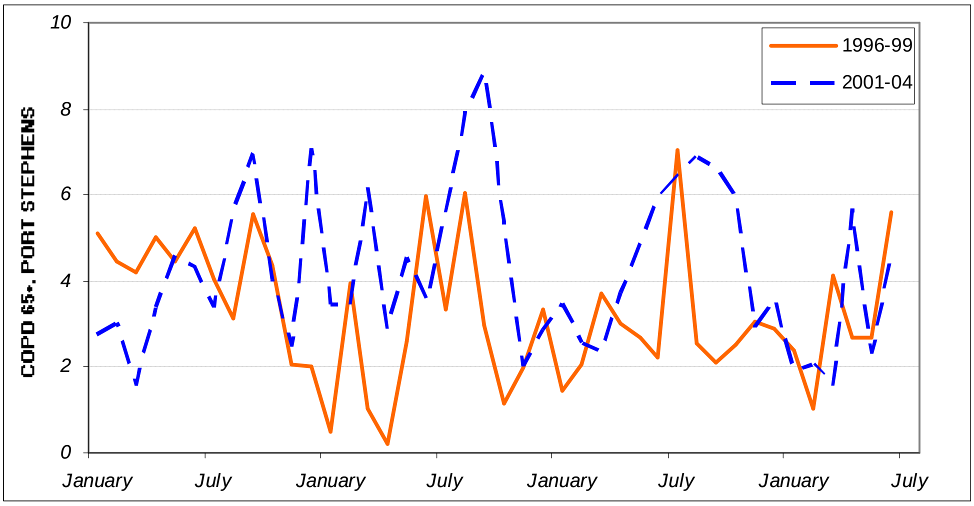


Fig. 3: Comparison of COPD 65+ estimations in Newcastle and Port Stephens, before and after BHP closure

Table 4: Difference of estimations of asthma admission rate*, before and after BHP closure

Location	1996-99	2001-04	Difference	*P* Value
Lower Hunter	0.723	0.458	-36.7%	<0.0001
Newcastle	0.714	0.429	-39.9%	0.0002
Port Stephens	0.750	0.488	-34.9%	0.0002

* Mean daily admissions for a 100,000 population

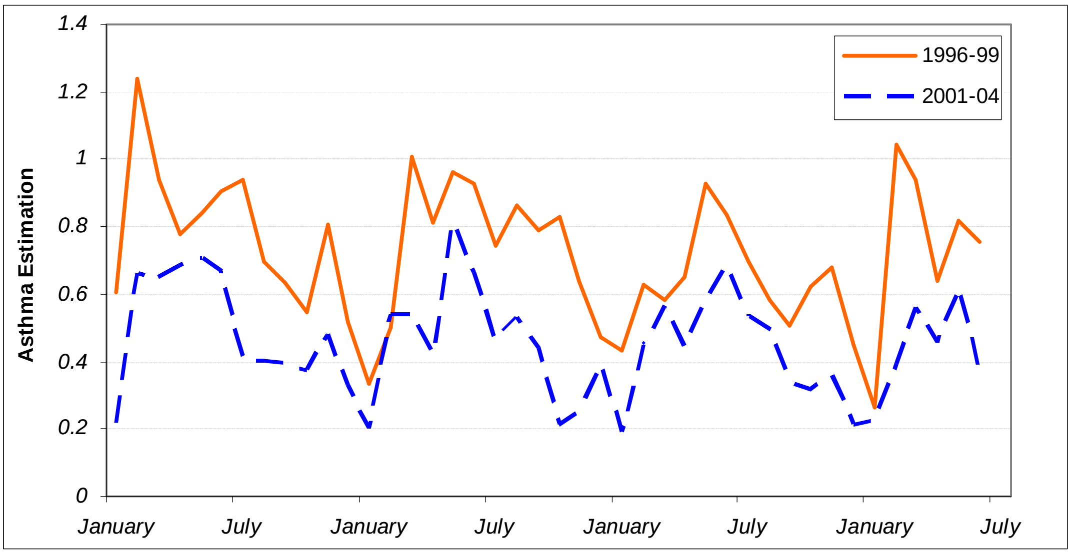
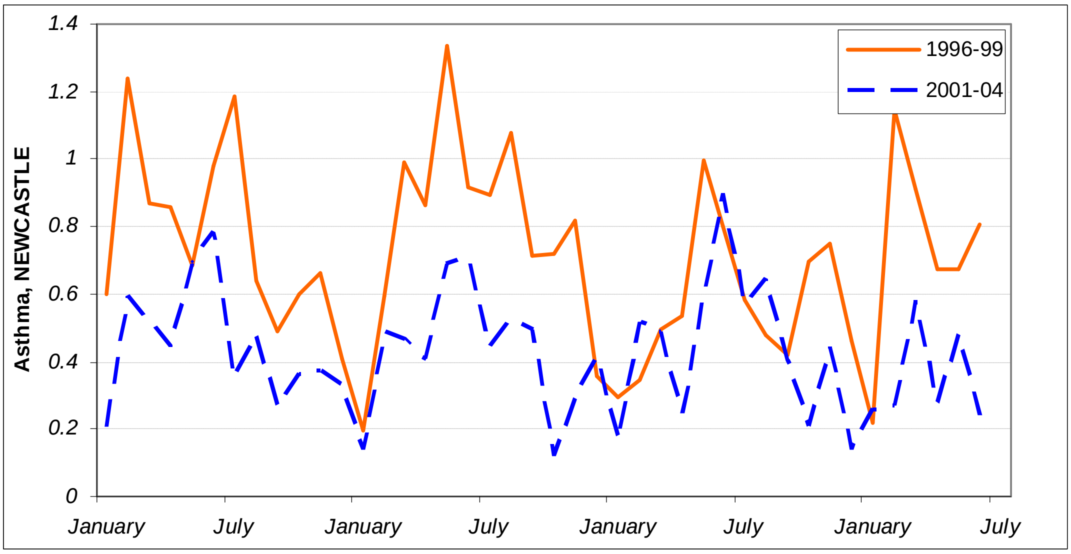


Fig. 4: Comparison of all-age asthma estimations in Lower Hunter, before and after BHP closure



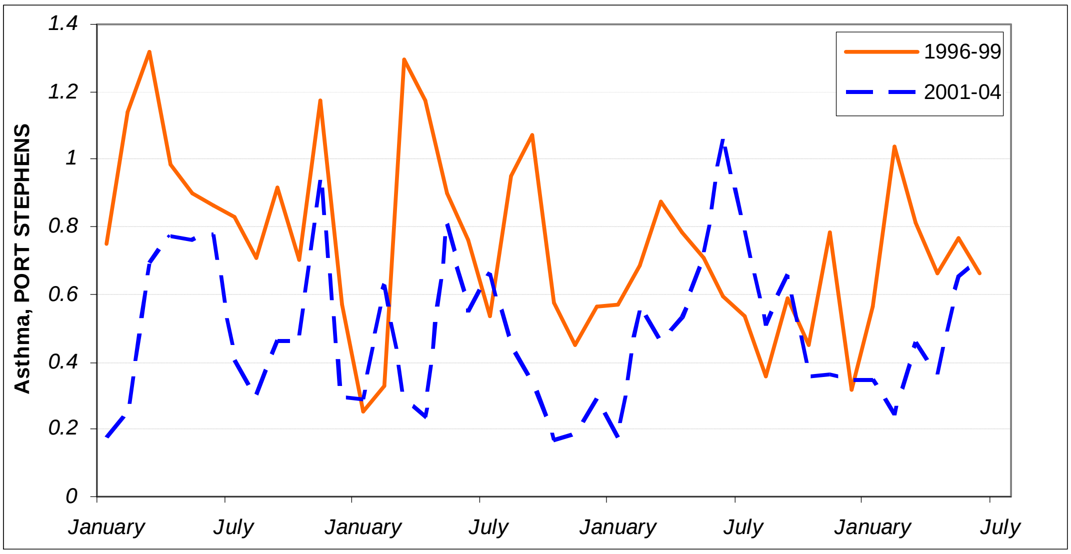


Fig. 5: Comparison of all-age asthma estimations in Newcastle and Port Stephens, before and after BHP closure

Table 5: Difference of estimations of children asthma admission rate*, before and after BHP closure

Location	1996-99	2001-04	Difference	*P* Value
Lower Hunter	1.795	1.252	-30.3%	0.004
Newcastle	2.199	1.450	-34.1%	0.0031
Port Stephens	1.652	1.048	-36.6%	0.0008

Mean daily admissions for a 100,000 population

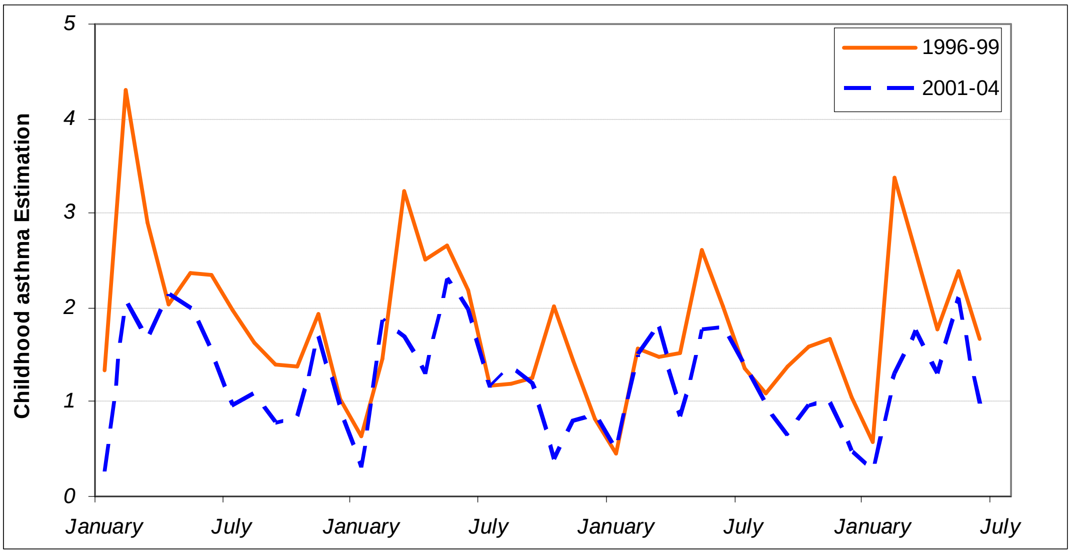


Fig. 6: Comparison of childhood asthma estimations in Lower Hunter, before and after BHP closure

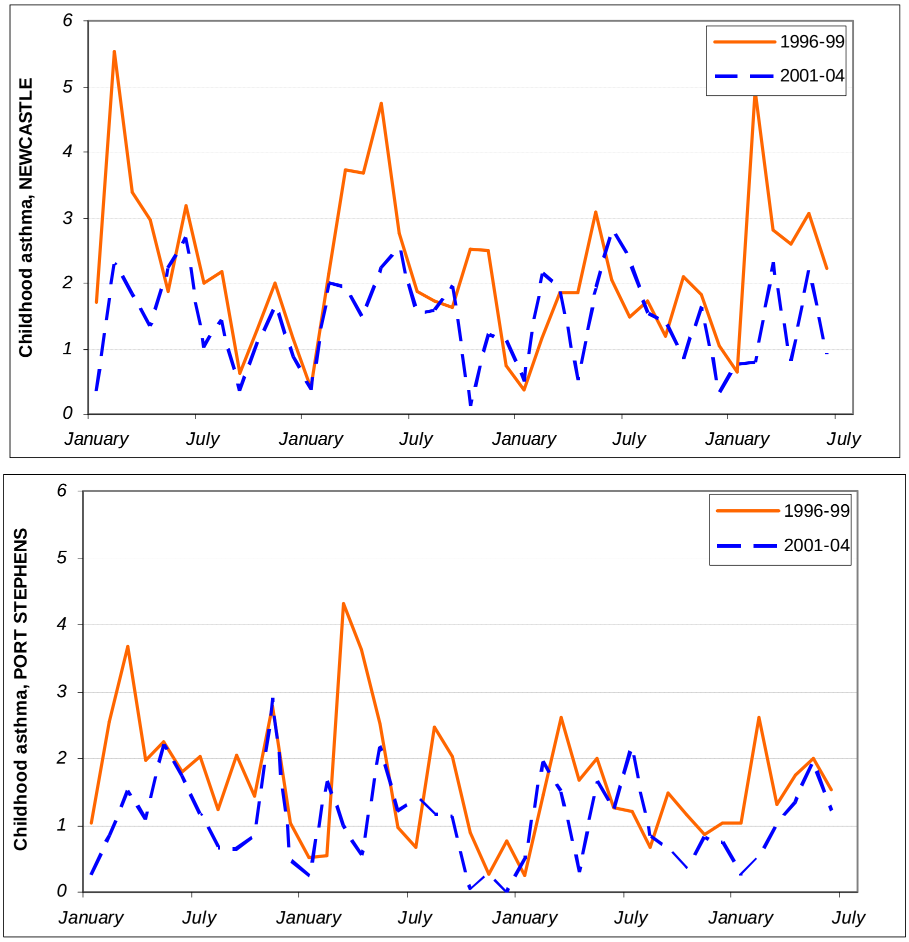


Fig. 7: Comparison of childhood asthma estimations in Newcastle and Port Stephens, before and after BHP closure

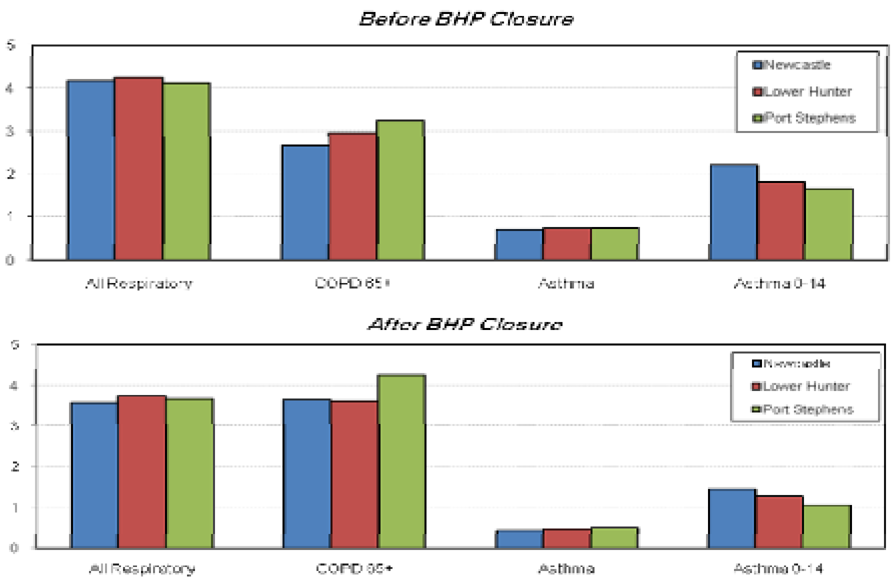


Fig. 8: Change of admission estimations of disease, before and after BHP closure

Discussion

Changes in overall disease admission rate in the periods before and after closing BHP are apparently indirect indicators of impacts of the closure of BHP. The diagnoses categories, as health outcomes of air pollution, should ideally be consistent with expected decreasing trend of pollutants released from the industry. Moreover, epidemiological studies are not commonly able to investigate the cause-effects; they only determine the significance of relationships between possible causes and effects. However, in this study, it can reasonably be hypothesized that the potential health effects were at least partially due to the pollutants emitted from the industry (they are multi-causes diseases). However, diverse cause and effect relationships could not be determined in Lower Hunter.

All respiratory disease

The study found around 12% overall decrease of admission rate of all respiratory disease in the Lower Hunter area after the closure of BHP. The decrease of respiratory disease in the period 2001-04 varied in different LGAs. As a result, it was 14% in Newcastle, the closest LGA to BHP, and about 10% in the Port Stephens LGA, which, as the most distant location to the industry, was considered as the control LGA. Although not all these changes were statistically significant in the analytical model, it can be alleged that decrease in admission rate of this disease in immediate surrounding area to industry was higher than the average decrease in the whole study location, as well as the relatively remote area, the Port Stephens LGA. Given the fact that many studies reported statistically significant links between pollutants and respiratory diseases (6-11), the LGA results imply that the levels of pollutants in air closer to BHP were higher than in the more distant area.

COPD 65+

Unlike the other disease categories examined in this study, admission rate of elderly COPD increased considerably after the closure of BHP. Again, inconsistently, the greatest increase rate was observed in Newcastle, about 37%, much higher than in whole study area. The increase rate in the Lower Hunter region was around 22% and it was more than 30% in the Port Stephens LGA after the closure of BHP. The unexpected growth of incidence of COPD 65+ may have been due to the modification of codes and definition of diagnoses in International Classification of Disease (ICD) which was carried out in 1999 (12). The study used definitions of ICD-9th and ICD-10th revisions for the periods before and after BHP closure, respectively. Since asthma is classified as a subcategory of COPD, the new definition for asthma in the 10th revision of ICD led to a significant decrease of asthma and subsequently noticeable increase of COPD. (As asthma is a major public concern in Australia, in this study, it was excluded from COPD category and examined as a separate group.) Table 6 compares the codes and definitions used for asthma in the periods before (ICD-9) and after (ICD-10) the closure of BHP industry.

Table 6: Comparison of ICD codes for asthma in 9th and 10th Revision

ICD-9	*ICD-10*
493 Asthma	J45 Asthma
493.0 Extrinsic asthma	Excludes: acute severe asthma (J46)
493.1 Intrinsic asthma	chronic asthmatic (obstructive) bronchitis (J44.-)
493.2 Chronic obstructive asthma	chronic obstructive asthma (J44.-)
Asthma with chronic obstructive pulmonary disease [COPD]	J45.0 Predominantly allergic asthma
Chronic asthmatic bronchitis	J45.1 Nonallergic asthma

Source: WHO, 2006 (12) & ICD9, 2007 (13)

In the period 1996-99, chronic obstructive asthma, code 493.2 (underlined), was included in the asthma, whereas, in period 2001-04, it was excluded from the asthma category and integrated into COPD category. As well, chronic asthmatic bronchitis (italicized) was considered as asthma before the closure of BHP, whereas it was excluded and added to COPD category afterwards.

Ignoring the uncertainties caused by the new ICD codes, the increase of elderly COPD could be related to the increase of PM_{10} levels after the closure of BHP reported by Sajjadi and Bridgman (14). On one hand, some epidemiological studies (15) found significant associations between increased particulate matter and COPD. On the other hand, significant relationships were reported between the other pollutants levels, NO_2 and SO_2, and COPD (9, 11). Since PM_{10} concentrations increased and NO_2 and SO_2 levels decreased after the closure of BHP (14), the increase of incidence of elderly COPD might be associated with factors other than air pollution. However, any discussion and evaluation for COPD, as well as asthma trend, would lead to an error of interpretation before overcoming the problems related to the disease classification discussed previously.

Asthma

Of the disease categories considered in this study, admission rate of all-age asthma showed the most decrease after the closure of BHP. All-age asthma dropped significantly by about 40%, 35% and 37% in Newcastle, Port Stephens and the Lower Hunter, respectively, after the closure of BHP. Almost the same change was observed for childhood asthma. The considerable decrease of asthma admission rate in the study area can be explained by the same reason stated for increase of elderly COPD discussed already. What is more, a number of studies reported significant changes in counts of hospital admissions for changes in air pollution levels (8-11). Therefore, partial decrease of asthma admissions related to decrease of pollutants levels must be acknowledged, as the decrease rate was higher in the Newcastle LGA.

Presumably, the results for COPD and asthma would be different if they were examined together as one category. By that, the impacts of different codes and definitions would be resolved.

In summary, the inconsistent results of this study identified complications relating to the impacts of BHP closure on public health in the Lower Hunter region. BHP steel works was the major source of PM, NO_2 and SO_2. Therefore, the study would expect consistent decreases of the diseases associated with these pollutants after closure of the industry. Increase of admission rate of elderly COPD after the closure of BHP was not consistent with the decrease of the other diseases. On the other hand, in specified locations, the overall decrease of disease rates in before and after BHP closure were more noticeable in Newcastle than in Port Stephens and the Lower Hunter. In other words, LGA results suggest some BHP impacts on public health. Inconsistent results might be attributable to the change of source of pollutants, dominantly traffic related, which is consistent with worldwide studies. Moreover, the closure of BHP was a continuing process, which started in the early 1980s (16); therefore, emitted pollutants may have reduced over time. In other words, in reality, it is not possible to determine a clear period for operating and closure of industry, and subsequently, for the impacts of industry closure. Accordingly, a number of growing small sources in the study area could negate the possible impacts of BHP closure. What is more, a conceptual shift in structure as well as moving between the two ICD codes needs especial medical expertise. This study had to acknowledge the possible interference related to the different codes and definitions for asthma and COPD in two disease classifications. Employing the Mixed Model for investigating the impacts of BHP closure was a new experiment that was applied for the first time in this study. Despite the reasonable outputs, applying the Mixed Model in such studies should be further evaluated in future studies. Moreover, other factors such as BMI, smoking status, rainfall, wind speed, and particularly wind direction are other important confounders, which should be, included in future studies.

Ethical Considerations

Ethical issues including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc. have been completely observed by the authors.

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