Environmentally-related health impact assessment of coal seam gas development activities in Queensland, Australia

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Introduction

Queensland, Australia has been rapidly developing its coal seam gas (CSG) resources over the past decade. CSG forms the basis for the expanding liquefied natural gas industry in Australia (1). Likewise, in recent years, the energy sector in the United States has undergone a significant transformation due to the exploitation of shale gas resources (2). While these two types of unconventional natural gas are often seen as similar, health implications from studies based on shale gas cannot be translated directly to the CSG context because of several differences including geological formations, processes, and regulatory frameworks (3, 4).

However, a common concern is the potential human health impact that would result from exposure to environmental media, such as water, air, and soil, that could be contaminated during gas development activities (1). There is also the potential for psychosocial stress and related health impacts (5). The two main stages of unconventional natural gas development are well development and production (6), and the activities conducted during the well development stage (e.g., construction, pad preparation, well drilling and completion) would present the most environmental change. Therefore, it is likely that this stage presents the greatest likelihood for exposures related to unconventional natural gas development (e.g., to VOCs, diesel exhaust).

While a number of studies have examined environmental health impacts associated with unconventional natural gas development, few methodologically rigorous studies have examined CSG-associated impacts, particularly those within Australia (7). Another important shortcoming in developing the knowledge about environmental health impact is the lack of research using comparative areas such as impacted versus non-impacted areas (8-10). The aim of this research was to explore environmentally-related health impacts (ERHIs) associated with CSG development in Queensland, Australia. The objective of this study was to use an assessment framework to explore health outcomes data across three study areas. This was to determine if hospitalisation rates increased over time in the primary environmental setting compared to two comparative settings.

Methods

Framework design

Several frameworks were examined to determine which would: support the assessment of health, environmental, and social data; allow for assessment of CSG impacts over time to present; and indicate future health risk from CSG development, but not necessarily require prediction of future impacts. Ultimately, the integrated environmental health impact assessment (IEHIA) framework proposed by Briggs (11) was adapted to form the basis for this study due to its flexibility, scope, and method of assessment. The IEHIA framework is policy-driven and uses various scenarios to compare and assess health impacts associated with environmentally-related policies (12). The use of this framework as the foundation for this study allowed for comparative capability within the ERHI assessment so that environmental, as well as health conditions, in a CSG setting could be compared to two alternative environmental settings. Figure 1 shows the broader study framework. This paper focuses on the objective health outcomes component of the assessment.

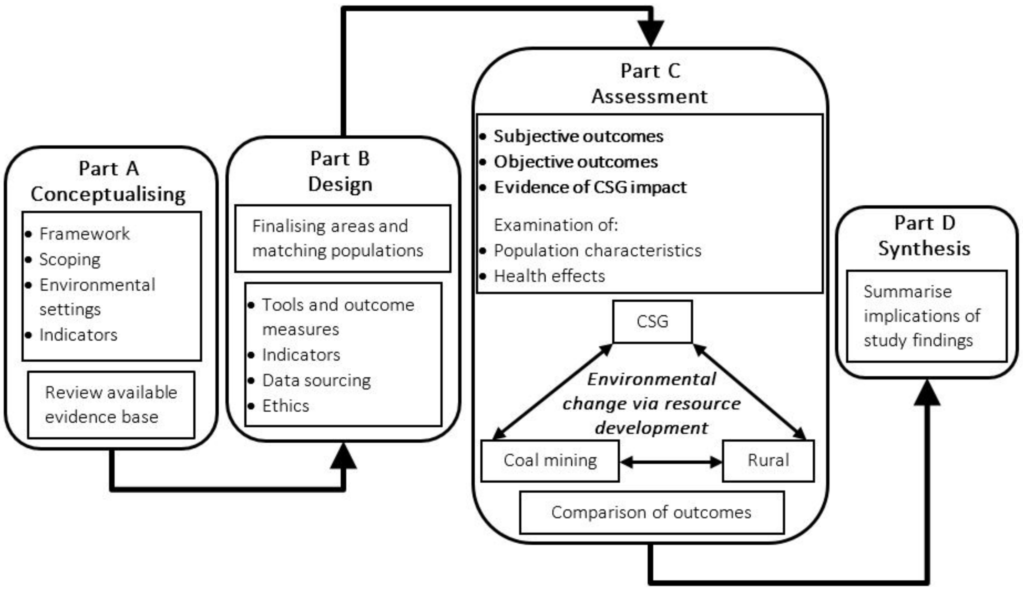

Figure 1. The environmentally-related health impact (ERHI) assessment framework, based on the integrated environmental health impact assessment (IEHIA) framework. Note: CSG = coal seam gas.

Environmental settings and study areas

The primary environmental setting was CSG and the two comparative environmental settings were coal mining (CM) and rural/agricultural (RA). All three geographic areas were rural, and the primary land use activity was historically agriculture. Two of the three areas changed over time due to resource development (CSG development and coal mining). Figure 2 shows the study areas and CSG well locations. Due to the availability of data, the study areas were classified by larger aggregations of state sub-regions.

Data

Yearly estimated resident population data were obtained for each study area (1995-2011). Hospital admissions data (by study area and calendar year) were obtained from the Queensland Hospital Admitted Patient Data Collection to calculate hospitalisation rates. Data were obtained on admissions to any Queensland hospital for any *resident* of one of the study areas (i.e., non-residents, such as fly-in, fly-out workers, were not included). The primary variable of interest was the primary diagnosis code, as indicated by International Classification of Diseases (ICD) codes. All codes were categorised according to the ICD-10-Australian Modification version. Covariate data, acquired from the Australian Bureau of Statistics for each Census year over the study period, were aggregated to the CSG, CM, and RA areas. These included: proportion Australian-born, proportion Indigenous, proportion employed full-time, proportion in white-collar occupations, median household income, and mean household size.

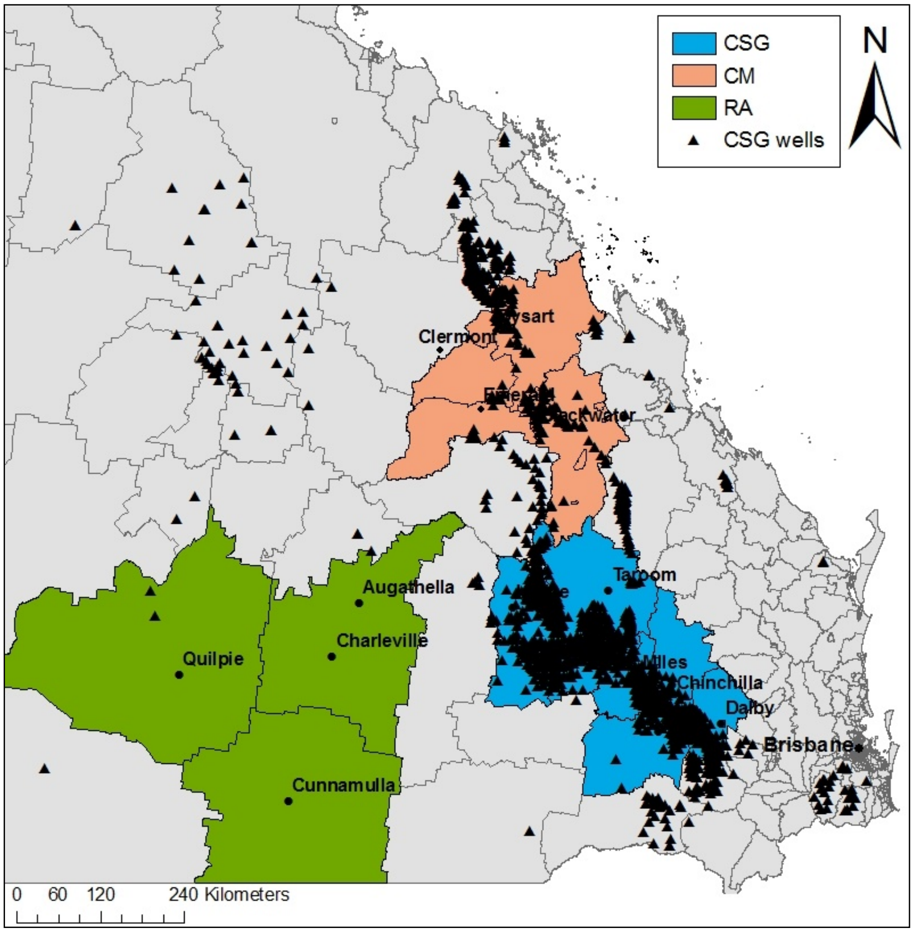

Figure 2. The three environmental settings and the geographic study areas, along with CSG well locations at time of site selection (2011). Note: CSG = coal seam gas; CM = coal mining; and RA = rural/agricultural.

Analyses

The objective of the analyses was to determine if hospitalisation rates increased in the CSG area over time compared to rates in the CM and/or RA areas. Hospitalisation rates per 1000 persons were calculated for each calendar year (1995-2011) for each area. Crude all-cause rates were calculated for each area (all-cause admissions and 19 ICD chapters), and direct age-standardised rates were calculated using the 2001 Australian population (13). Negative binomial regression models were used to model counts, offset by the log of the population to account for underlying changes in the population, and time was a continuous variable. After estimating unadjusted models, models were adjusted for sex, age, and the previously described covariates. The models provided rate ratios (RR; 95% CI) to describe increases over time. This study did not weigh costs and benefits as the intent was to explore adverse impacts.

Results

There was a total of 459 549 hospital admissions over the study period. The CSG, CM, and RA areas made up 51.9%, 35.8%, and 12.3% of admissions, respectively. Table 1 shows estimates from the unadjusted and adjusted regression models. Rate ratios greater than 1.00 indicate an increase in the hospitalisation rate over time relative to the reference area. Of key interest were the ICD chapters where increases in admission rates were observed for the CSG area compared to the CM *and* RA areas.

Table 1. Rate ratios (RR) and 95% confidence interval (CI) for unadjusted and adjusted[a] models for all-age hospitalisation rates in the coal seam gas, coal mining, and rural/agricultural areas, 1995-2011.[b]

	CSG vs CM	CSG vs RA	CM vs RA
Unadjusted			
All-cause	1.01 (1.00-1.01)	1.01 (1.01-1.02)	1.00 (1.00-1.01)
Infectious disease	1.02 (0.99-1.04)	1.03 (1.00-1.06)	1.02 (0.98-1.05)
Neoplasms	1.03 (1.01-1.04)	1.01 (0.99-1.03)	0.98 (0.97-1.00)
Blood/immune	1.08 (1.05-1.12)	1.05 (1.01-1.09)	0.97 (0.94-1.01)
Nervous system	1.01 (1.00-1.03)	1.04 (1.02-1.06)	1.02 (1.00-1.04)
Eye	1.04 (1.02-1.06)	1.04 (1.02-1.06)	1.00 (0.98-1.03)
Ear	1.04 (1.01-1.06)	1.03 (1.00-1.05)	0.99 (0.96-1.02)
Respiratory	1.00 (0.99-1.01)	1.01 (1.00-1.03)	1.02 (1.01-1.03)
Skin	1.06 (1.04-1.08)	0.98 (0.96-1.00)	0.93 (0.91-0.95)
Musculoskeletal	1.01 (1.00-1.02)	0.99 (0.98-1.01)	0.98 (0.97-1.00)
Genitourinary	1.01 (1.00-1.02)	1.02 (1.01-1.03)	1.01 (0.99-1.02)
Injuries	1.02 (1.00-1.04)	0.99 (0.98-1.01)	0.97 (0.96-0.99)
Adjusted			
Neoplasms	1.01 (0.96-1.07)	1.09 (1.02-1.16)	1.07 (1.00-1.15)
Blood/immune	1.08 (0.97-1.20)	1.14 (1.02-1.27)	1.05 (0.92-1.20)
Congenital	1.10 (1.02-1.19)	1.00 (0.92-1.09)	0.91 (0.92-1.00)

[a] Models were adjusted for: age, sex, proportion Australian-born, Indigenous, employed full-time, and in white-collar occupations, median household income, and mean household size.
[b] CSG = coal seam gas; CM = coal mining; and RA = rural/agricultural. RRs describe relative increases in hospitalisation rates in a given area compared to the reference area.

In the unadjusted models, hospitalisation rates due to any cause increased by 1% over the study period in the CSG area compared to the CM *and* RA areas; however, this association was attenuated after adjustment for key sociodemographic covariates (14). Prior to adjustment, base models showed several ICD chapters where there were significant increases over time in the CSG area compared to both study areas. These included blood/immune diseases, eye diseases, and genitourinary diseases. Eye and genitourinary diseases associations weakened after adjusting for covariates. However, adjusted models showed significant increases in blood/immune hospitalisation rates in the CSG area compared only to the RA area, with the CSG area rates increasing by 14% over time (14).

After adjusting for a number of covariates, three ICD chapters, including neoplasms, blood/immune diseases, and congenital-related outcomes, showed significant increases in admission rates in the CSG area compared to the CM *or* RA areas. While results from the unadjusted models were not significant, results from the adjusted models showed there was a 10% increase in congenital-related admissions in the CSG area over time compared to the CM area, with rates decreasing 9% over time in the CM area compared to the RA area. No ICD chapters showed significant increases in the CSG area compared to *both* study areas over time for adjusted models.

Discussion

Adjusting for key covariates weakened many of the relationships noted in the unadjusted models presented here. While not significant in the unadjusted models, congenital-related admission rates showed significant increases over time in the CSG area compared to the CM area in adjusted models. There are few studies against which to compare these results; in particular, few, if any, studies have examined CSG and/or unconventional natural gas-related health impacts in Australia.

Two natural gas-related studies have broadly examined hospitalisation data in the United States: one examined admissions in a county with higher levels of gas development (i.e., Garfield County) compared to surrounding counties (15), the other examined admissions in conjunction with number and density of gas wells (16). Coons & Walker (15) noted that cancer incidence was similar across all counties. Conversely, Jemielita et al. (16) found a positive association between the number and density of wells and oncology prevalence rates. The blood/immune-related findings are in contrast to the findings presented for Garfield County (14), where admissions in the red cell/clotting diagnostic-related grouping decreased over time (15). While a review of chemicals used in natural gas operations found that 46% of chemicals can affect the cardiovascular system and blood (17), there are few studies that examined these outcomes in-depth in relation to community health. Detailed environmental data were not available for this study; therefore, the three area groupings served as proxies for unmeasured environmental exposures.

Other studies focused solely on birth outcomes such as small for gestational age (18-20). The adjusted model results presented here showed an increase in congenital-related admissions in the CSG area compared to the CM area. Many of the birth outcomes that have been previously studied fall under the perinatal-related ICD chapter (i.e., low APGAR scores, small for gestational age), which is distinct from the congenital ICD chapter. In the current study, perinatal-related admissions did not increase significantly over time (unadjusted or adjusted models) in the CSG area compared to the two study areas.

Several limitations are associated with this study, including the necessity for broad study area groupings due to confidentiality concerns, particularly in the RA area. Another limitation is the ecologic approach and ecological adjustments for sociodemographic factors. Rates of hospitalisation are likely to be underestimated. Additionally, relatively few hospital presentations occurred for some of the ICD chapters during the study period, limiting interpretation of results. While the inclusion of individual-level environmental data would be useful, this was lacking due to availability.

This research was exploratory in nature and presented one component of the larger ERHI assessment. This is the first study of its kind in Australia and the preliminary results are intended to guide further research. Assuming sufficient sample sizes, additional research should examine sub-chapters within specific ICD chapters. Data should also be examined in conjunction with data on CSG wells and potential mechanisms of effect should be investigated further to determine if such outcomes could result from exposures related to CSG development. Ideally, higher resolution data should be used rather than broad study area groupings, and data, such as general practitioner data, should be linked with environmental monitoring data.

Conclusion

The findings suggest a significant increase for some admission rates, classified by ICD diagnoses, in the CSG area compared to the CM and/or RA areas over time. After adjusting for key sociodemographic covariates, the CSG area showed statistically significant increases over time for neoplasms and blood/immune-related admission rates (all-ages) compared to the RA area and for congenital-related rates compared to the CM area. This preliminary research is exploratory in nature and is intended to guide future research. Future work should include analysis of sub-chapters, given sufficient sample sizes, as well as analysis of CSG admissions data alongside CSG well numbers data.

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