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Mine dumps, wheeze, asthma, and rhinoconjunctivitis among adolescents in South Africa: any association?

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The study investigated the association between community proximity to mine dumps, and current wheeze, rhinoconjunctivitis, and asthma among adolescents. This study was conducted during May–November 2012 around five mine dumps in South Africa. Communities in close proximity to mine dumps had an increased likelihood of current wheeze OR 1.38 (95 % CI: 1.10–1.71), rhinoconjunctivitis OR 1.54 (95 % CI: 1.29–1.82), and a protective association with asthma OR 0.29 (95 % CI: 0.23–0.35). Factors associated with health outcomes included other indoor and outdoor pollution sources. Wheeze and rhinoconjunctivitis appear to be a public health problem in these communities. The findings of this study serve as a base for further detailed epidemiological studies for communities in close proximity to the mine dumps e.g. a planned birth cohort study.

Keywords: mine dumps; asthma; wheeze; rhinoconjunctivitis; adolescents; South Africa

Introduction

A recent review (Anandan et al. 2010) indicated that current wheeze, asthma, and rhinoconjunctivitis prevalence is increasing globally, including developing countries like South Africa (Zar et al. 2007). Various lifestyle risk factors have been associated with existing symptoms of asthma (i.e. wheeze) and rhinoconjunctivitis, such as diet (Corbo et al. 2008; Kim et al. 2009) lack of physical activity (Eijkemans et al. 2012), and active smoking (Polosa & Thomson 2012). Demographic factors such as sex (Kynyk et al. 2011), age (Kabir et al. 2005), and ethnicity (Hjern et al. 2000; Drake et al. 2008) have also been associated with existing symptoms of these health outcomes.

Evidence is also increasing that environmental factors, such as various air pollution sources, significantly increase the risk of existing symptoms of asthma (i.e. wheeze) and rhinoconjunctivitis (World Health Organization 2013). Environmental factors are beyond the control of the individual and therefore of great importance. Numerous studies in both developed and developing countries thus far investigated the following air pollution sources: environmental tobacco smoke (ETS) exposure at home or school (Tsai et al. 2010; Hedman et al. 2011), traffic (Gasana et al. 2012), and polluting fuel use for residential cooking/heating (De Bilderling et al. 2005; Koistinen et al. 2008; Brashier et al. 2012). Whether air pollution, lifestyle, and demographic factors actually are

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involved in the development of asthma and rhinoconjunctivitis is still being investigated (*The Global Asthma Report Asthma* 2011).

Mine dumps facilities are major generators of windblown dust and are one of the main sources of air pollution with potential adverse health implications for nearby residents (Ojelede et al. 2012). One of the biggest challenges facing mine industry is inadequate waste disposal. Mine dumps consist of crashed sand-like waste material which is generated by extraction and grinding methods of ground ore during mining (Saunders et al. 2009; Moreno et al. 2010). The material contains a complex mixture of metals, dust particles, or particulate matter that is released and transported to the surrounding communities by air, soil, or water contamination (Moreno et al. 2010). Exposed communities are of lower socioeconomic status, often elderly people and children (Ojelede et al. 2012). These communities comprise historically marginalized ethnic groups living in government-funded houses, informal settlements, and retirement homes (Wright et al. 2014). Epidemiological studies have shown that living near mine dumps is a major risk for exposure to particulate matter and metals such as cadmium, manganese, lead, and arsenic (Hu et al. 2007; Meza-Figueroa et al. 2009; Moreno et al. 2010). Children are particularly vulnerable because their respiratory system is still developing (Sacks et al. 2011). Higher prevalence of respiratory diseases was observed and correlated with toxic metals in the blood in people living near mining sites in Campos de Jales, Portugal as compared to a control group living 45 km in Vilar de Macada (Mayan et al. 2006).

Studies that have reported on the prevalence of asthma symptoms in South Africa applied the International Study of Asthma and Allergies in Childhood (ISAAC) protocol and a wide variability in the prevalence of asthma, wheeze, and rhinoconjunctivitis in residential areas situated near industries was observed (Wichmann et al. 2007; Zar et al. 2007; Shirinde et al. 2014). ISAAC is the largest worldwide collaborative respiratory research project that studies asthma and its symptoms among children (*The Global Asthma Report Asthma* 2011).

No studies have investigated whether exposure to dust from mine dumps or living in close proximity to mine dumps pose an increased risk for existing symptoms of asthma (i.e. wheeze) and rhinoconjunctivitis, whether this exposure is involved in the development of these health outcomes or there is effect modification between various air pollution sources, including mine dust.

This study is part of the bigger project initiated by Mine Health Safety Council of South Africa (MHSC) around communities located near mine dumps in Gauteng and North West provinces. This study is, to the best of our knowledge, the first study that investigated the prevalence, association between potential risk factors and wheeze and rhinoconjunctivitis among adolescents staying in communities situated near mine dumps in South Africa. The aim of the study was to investigate the prevalence, association between community proximity to mine dumps, and current wheeze, rhinoconjunctivitis, and asthma among adolescents. Effect modification between community proximity to mine dumps and other air pollution sources was also investigated i.e. type of fuel use for residential cooking/heating, frequency of truck traffic near homes, ETS exposure at home and school.

Methods

Study area and demographics

A cross-sectional epidemiological design was applied. Communities in urban areas living 1–2 km (exposed) and 5 km (unexposed) from pre-selected five mine dumps in

Gauteng and North West Provinces of South Africa were included in the study during May to November 2012. Table 1 lists the selected communities and Figure 1 shows the map of the study area. The socioeconomic and demographic profile of exposed and unexposed communities was similar.

The study focused on 13–14-year-old pupils who attended schools located in the 11 selected communities. The study participants were selected during school hours at their respective schools.

Exposed communities had 23 schools (primary and secondary) in total as identified by the investigators. Seven junior primary schools were excluded and 16 schools were contacted and invited to participate. Junior primary schools comprise pupils under the age of 12 with classes starting from grade zero to four and primary schools pupils from 5 to 15-year olds with classes begin from grade zero to seven. Four of the 16 schools declined and 12 schools participated in the study.

Fourteen schools, both primary and secondary in the unexposed area, were randomly selected to match the number of schools in exposed communities. Four schools declined and 10 schools participated in the questionnaire survey.

Twenty-two schools were included in the study, of which 13 were secondary and nine were primary schools. In each school, all eligible pupils who were 13–14 years old and who resided in one of the selected 11 communities were requested to participate. Each exposure group consisted of 3000 pupils that were invited to participate.

Exclusion criteria

Schools and pupils that did not grant permission prior to the start of the fieldwork, or showed lack of cooperation and pupils residing in communities other than the 11 selected communities (i.e. home and school communities not necessarily the same) were excluded from the study. Figure 2 shows a flowchart of the procedure followed to recruit study participants and the participation rate.

The institutional review boards of the participating schools approved the study protocol. Written informed consent was obtained from the parents and from all participants.

Health outcomes

The study participants completed a self-administered questionnaire based on the ISAAC Phase I protocol (Asher et al. 1995). Data were collected using the English version of

Table 1. Eleven communities selected in the study, which are located in Gauteng and North West provinces, South Africa.

Mine dump facility name	Province located	Exposed communities[a]	Unexposed communities[b]
Durban Roodepoort Deep (DRD)	Gauteng	Braamfischerville	Dobsonville
Crown Gold Recoveries (CGR)	Gauteng	Diepkloof, Riverlea, and Noordgesig	Orlando East
East Rand Proprietary Mines (ERPM)	Gauteng	Reiger Park	Windmill Park
Ergo	Gauteng	Geluksdal	Windmill Park
Anglo Gold Ashanti (AGA)	North West	Stilfontein	Jouberton

[a]1–2 km from mine dumps.
[b]5 km or more from mine dumps.

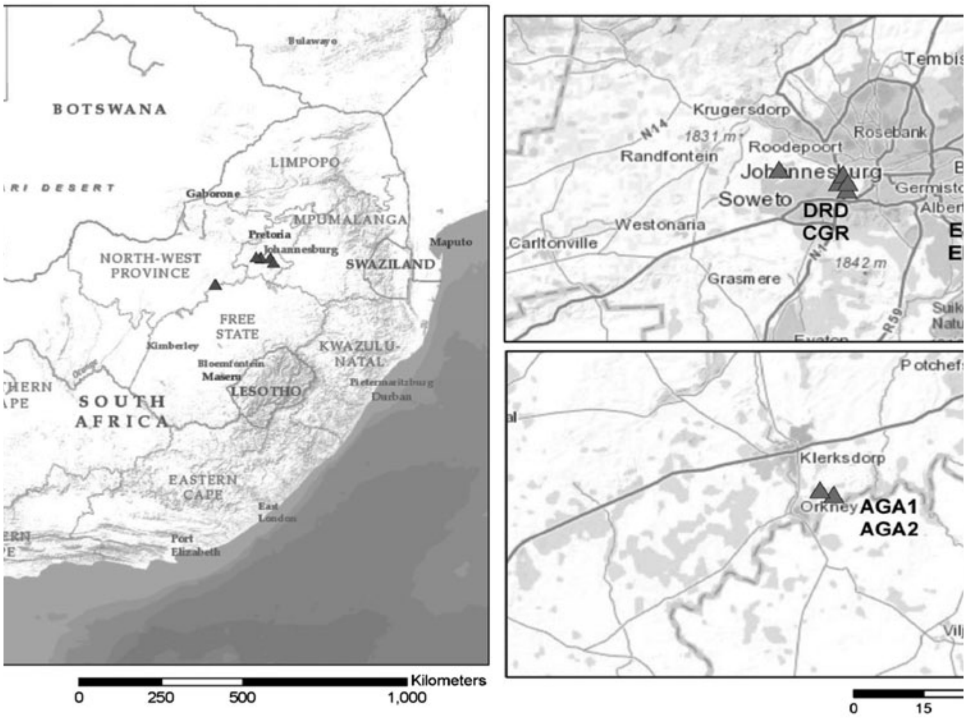


Figure 1. Location of mine dumps tailings in South Africa.

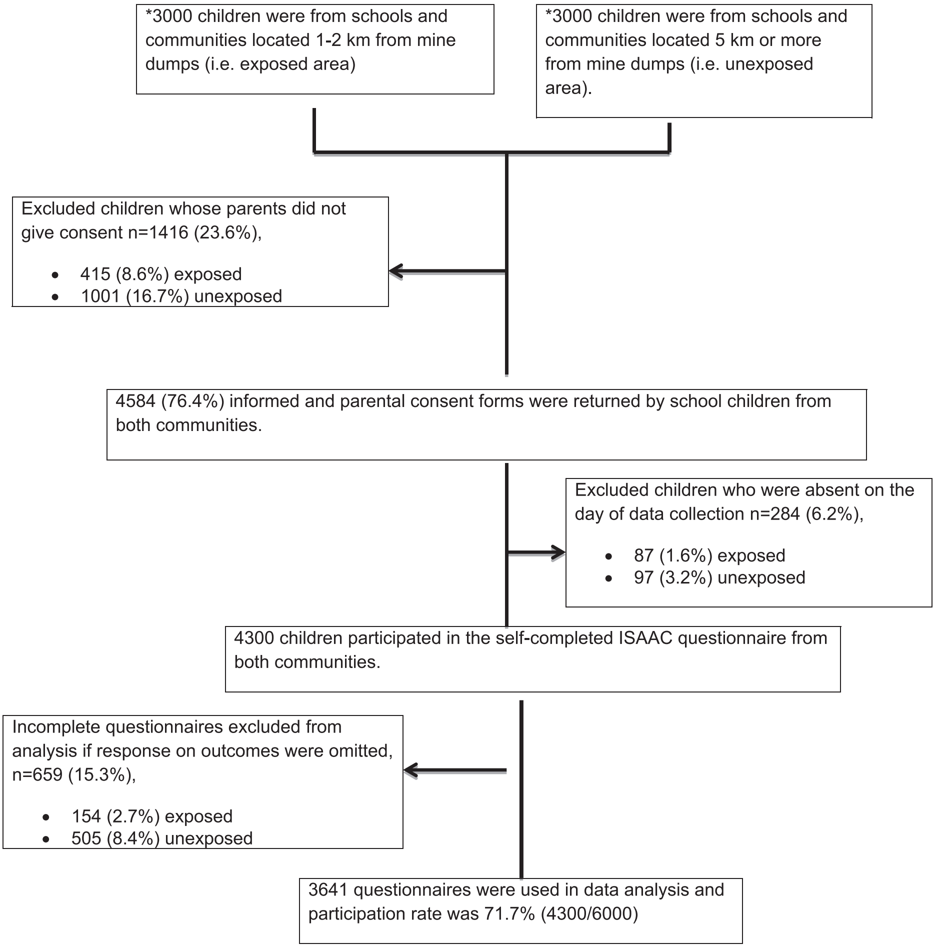
ISAAC written questionnaire composed of modules such as asthma and rhinitis, each comprising up to eight easily understood questions. The medium of instruction in all the schools that participated in the study was English.

According to the ISAAC Phase 1 protocol, current wheeze, asthma, and rhinoconjunctivitis symptoms were classified on the basis of positive answers to the following questions:

> Current wheeze: "Have you had wheeze or whistling in the chest at any time in the past 12 months?"
>
> Asthma: "Have you ever had asthma?"
>
> Rhinoconjunctivitis symptoms: "Have you ever had a problem with sneezing, or a runny, or blocked nose when you did not have a cold or flu?," "In the past 12 months have you ever had a problem with sneezing, or a runny, or blocked nose when you did not have a cold or flu?," and "In the past 12 months has this nose problem been accompanied by itchy-watery eyes?"

Main exposure factor

The exposure status of a community to mine dust was the main exposure factor. The exposure status was based on the distance between a community and a mine dump (Table 1).



*A sample size of 3000 is recommended by the ISAAC steering committee as it is deemed to be representative of children within the general population (Ellwood et al., 2005).

Figure 2. Recruitment procedure of study participants and participation rate.

Confounders

Potential confounding variables included other air pollution sources: active smoking by participants (yes/no), ETS exposure at home (yes/no), ETS exposure at school (yes/no), type of residential cooking/heating fuel (electricity, gas, paraffin, wood/coal), mode of transportation to school (walking, taxi/bus, car, combination), and the frequency of trucks passing near the residence (never, seldom, frequently through the day, almost all day). Additional confounders considered were: level of mother's education (primary school, secondary school, tertiary education), sex (female/male), vigorous physical activities (never/occasionally, 1 to 2 times/week, ≥ 3 times/week), hours spent watching television per day (<1, 1–3, 3–5, ≥5 h), frequency of dietary intake of 15 food items (rice, milk, pasta, meat, seafood, fruits, vegetables, pulses, cereal, butter, margarine, nuts, potatoes, eggs, fast food) (never/occasionally, once/twice per week, three or more times a week), type of house (brick, mud, corrugated iron, or combination), having running water inside the house (yes/no), and average travel time from home to hospital (15 min walk/5 min drive, 1h walk/15 min drive, ≥1 h walk/≥ 30 min drive).

Statistical analyses

Three data technicians entered the collected questionnaire data into a database set up in Epi Info version 3.5.3. Data were analyzed in Stata version 12. Prevalence of the health outcome and the proportion of air pollution sources under investigation and confounding variables were calculated by dividing the number of participants who responded affirmatively to a particular question by the number of questionnaires completed. Observations marked as "do not know", "not stated", or "other responses" were set as missing, but were included in the descriptive analyses. Therefore, each question had a slightly different sample size. All explanatory variables had some missing observations. A chi square test was applied to determine the relationship between community type (exposed/unexposed) and confounding variables. Crude and adjusted odds ratios (OR) and 95 % confidence intervals (CI) were calculated with univariate and multiple logistic regression analysis (LRA) to estimate the likelihood of having current wheeze, asthma, and rhinoconjunctivitis. Missing values were automatically excluded in each LRA model; therefore, each LRA model will have a different sample size. Air pollution source and confounding variables with $p < 0.20$ obtained in the univariate LRA were included in the multiple LRA. A p-value <0.05 in the multiple LRA was considered statistically significant (Gortmaker et al. 1994). The data were further stratified according to community type, exposed and unexposed to determine if the observed associations for the overall study population applied to the two community types separately. Effect modification between community type (exposed/unexposed) and the other air pollution source variables was investigated by including multiplicative terms in the multiple LRA models.

Results

From an original 4300, data from 3641 participants were included in the final statistical analysis (a participation rate of 71.7 %). The majority 2334 (77.8 %) of the study participants lived and attended school in the seven selected exposed communities, whereas 1307 (44.0 %) were from the four selected unexposed communities (Table 2). The use of paraffin or open fires for residential cooking/heating was more common in the exposed communities. The majority of participants from both the exposed and unexposed communities reported electricity as the main source of residential fuel for cooking/heating, engaged in vigorous physical activities more than once per week and spent more than 5 h watching television per week. Nearly a half of the participants in both the exposed and unexposed communities reported that their residences were located near roads where trucks were always passing. ETS exposure at home and at school was significantly more common among study participants from exposed communities.

The overall prevalence of current wheeze, asthma, and rhinoconjunctivitis was 675 (18.5 %), 596 (17.5 %), and 1060 (29.1 %), respectively (Table 3). The prevalence of current wheeze 429 (21.1 %) was significantly higher in the exposed than unexposed communities 183 (14.0 %). This trend was also observed for rhinoconjunctivitis. In contrast, asthma 238 (10.8 %) was significantly less prevalent in the exposed than unexposed communities 358 (29.6 %).

Table 2. Demographic characteristics and air pollution sources by type of community.

Characteristic	Community		
	Exposed[a] (n = 2334)	Unexposed[b] (n = 1307)	p-value[c]
Sex			
Female	1125 (49.5)	620 (50.0)	0.766
Male	1147 (50.5)	619 (50.0)	
Missing	62	68	
Residential cooking/heating fuel type			
Electricity	1926 (88.0)	1084 (93.0)	<0.001
Gas	64 (2.9)	29 (2.5)	
Paraffin	95 (4.3)	44 (3.8)	
Open fires	105 (4.8)	8 (0.7)	
Missing	144	142	
Frequency of trucks passing near residence on weekdays			
Never	340 (14.8)	216 (17.4)	0.138
Seldom	478 (20.9)	245 (19.7)	
Frequently	332 (14.5)	159 (12.9)	
Always	1140 (49.8)	621 (50.0)	
Missing	44	66	
ETS exposure at home in the past 30 days			
Yes	572 (25.0)	127 (10.2)	<0.001
No	1712 (75.0)	1115 (89.8)	
Missing	50	65	
ETS exposure at school in the 30 days			
Yes	1058 (55.4)	435 (41.2)	<0.001
No	851 (44.5)	620 (58.8)	
Missing	425	252	
Vigorous physical activities per week			
Never	706 (31.0)	382 (30.7)	0.189
Once or twice per week	935 (41.1)	546 (43.9)	
Three or more times per week	634 (27.9)	316 (25.4)	
Missing	59	63	
Hours spent watching television per week			
Less than 1 h	319 (13.8)	179 (14.3)	< 0.001
1 h but less than 3 h	445 (19.3)	177 (14.2)	
3 h but less than 5 h	527 (22.9)	228 (18.2)	
5 h or more	1014 (44.0)	666 (53.3)	
Missing	29	57	

Note: Figures in parentheses are percentages.
[a]Exposed: communities located 1–2 km from mine dumps.
[b]Unexposed: communities located 5 km or more from mine dumps.
[c]p-values of the χ^2 test.

Supplementary tables 1–3 summarize the results from the univariate LRA of all 11 study communities and by community type (exposed/unexposed).

Table 4 summarizes the results from the multiple LRA of all 11 study communities. Living in exposed communities significantly increased the likelihood of having current wheeze (38 %) and rhinoconjunctivitis (54 %). In contrast, those living in the exposed

Table 3. Prevalence of current wheeze, asthma, and rhinoconjunctivitis.

	Community		
	Exposed[a]	Unexposed[b]	Total
Current wheeze			
Yes	492 (21.1)	183 (14.0)	675 (18.5)
No	1842 (78.9)	1124 (86.0)	2966 (81.5)
Missing	–	–	–
Total	2334 (64.1)	1307 (35.9)	3641 (100)
Asthma			
Yes	238 (10.8)	358 (29.6)	596 (17.5)
No	1962 (89.2)	851 (70.4)	2813 (82.5)
Missing	134	98	232
Total	2200 (64.5)	1209 (35.5)	3409 (100)
Rhinoconjunctivitis			
Yes	768 (32.9)	292 (22.3)	1060 (29.1)
No	1566 (67.1)	1015 (77.7)	2581 (70.9)
Missing	–	–	–
Total	2334 (64.1)	1307 (35.9)	3641 (100)

Note: Figures in parentheses are percentages.
[a]Exposed: communities located 1–2 km from mine dumps.
[b]Unexposed: communities located 5 km or more from mine dumps.

communities had a significant protective association with asthma (OR = 0.29; 95 % CI: 0.23–0.35). Males were less likely than females to have asthma (OR = 0.73; 95 % CI: 0.59–0.90) or rhinoconjunctivitis (OR = 0.60; 95 % CI: 0.51–0.71). Using polluting fuels, such as open fires for residential cooking/heating had a significant detrimental association with current wheeze (OR = 1.98; 95 % CI: 1.73–2.33) and a dose–response was observed for this factor. None of the other two health outcomes were significantly associated with the fuel use variable. Those participants who lived near roads where trucks were always passing were 53 and 32 % more likely to have wheeze and rhinoconjunctivitis, respectively. Truck traffic was not significantly associated with asthma. ETS exposure at home had a significant detrimental association with current wheeze (OR = 1.33; 95 % CI: 1.08–1.63) and rhinoconjunctivitis (OR = 1.23; 95 % CI: 1.04–1.46), but not with asthma. ETS exposure at school significantly increased the likelihood of asthma (63 %), but not for current wheeze or rhinoconjunctivitis. Engaging in vigorous physical activities once or more per week had a significant detrimental association with all three health outcomes. More than 5 h spent indoors watching television had a significant protective association with asthma (OR = 0.73; 95 % CI: 0.53–0.99), but a significant detrimental association with rhinoconjunctivitis (OR = 1.52; 95 % CI: 1.18–1.75). Effect modification between community type (exposed/unexposed) and the other air pollution source variables was investigated. No significant effect modification was observed (results not shown).

Tables 5 and 6 show results from multiple LRA stratified by community type (exposed/unexposed). In exposed communities, gas frequently used for residential cooking/heating was associated with asthma (OR = 2.20; 95 % CI: 1.02–4.70). Engaging in vigorous physical activities was consistently associated with current wheeze, asthma, and rhinoconjunctivitis in exposed compared to unexposed communities. More than 5 h spent indoors watching television had a significant protective association with asthma (OR = 0.49; 95 % CI: 0.27–0.89), but a significant association with current

Table 4. Prevalence, adjusted odds ratios of wheeze, asthma, and rhinoconjunctivitis in all 11 study communities.

Characteristics	Current wheeze *n* (%)	Adjusted OR[a] (95% CI)	*p*-value	Asthma *n* (%)	Adjusted OR[b] (95% CI)	*p*-value	Rhinoconjunctivitis *n* (%)	Adjusted OR[c] (95% CI)	*p*-value
Community									
Unexposed*	183 (14.0)	1		358 (29.6)	1		292 (22.3)	1	
Exposed	492 (21.1)	**1.38 (1.10–1.71)**	**0.004**	238 (10.8)	**0.29 (0.23–0.35)**	**<0.001**	768 (32.9)	**1.54 (1.29–1.82)**	**<0.001**
Sex									
Female*	339 (9.7)	1		314 (9.4)	1		609 (17.4)	1	
Male	321 (9.1)	–		265 (7.9)	**0.73 (0.59–0.90)**	**0.004**	437 (12.5)	**0.60 (0.51–0.71)**	**<0.001**
Residential heating/cooking fuel type									
Electricity*	574 (17.1)	1		447 (14.0)	1		933 (27.8)	1	
Gas	12 (0.4)	0.48 (0.23–1.02)	0.057	18 (0.6)	–		21 (0.6)	–	
Paraffin	31 (0.9)	1.25 (0.78–1.99)	0.351	19 (0.6)	–		47 (1.4)	–	
Open fire	29 (0.9)	**1.98 (1.73–2.33)**	**0.004**	6 (0.2)	–		36 (1.1)	–	
Frequency of trucks passing near residence on weekdays									
Never*	90 (2.6)	1		89 (2.6)	1		121 (3.4)	1	
Seldom	144 (4.1)	0.96 (0.68–1.35)	0.813	95 (2.8)	–		216 (6.1)	1.25 (0.95–1.66)	0.105
Frequently	110 (3.1)	1.25 (0.77–1.99)	0.448	85 (2.5)	–		150 (4.3)	1.26 (0.93–1.71)	0.130
Always	320 (9.1)	**1.53 (1.28–1.97)**	**0.003**	317 (9.4)	–		564 (16.0)	**1.32 (1.07–1.75)**	**0.012**
ETS exposure at home in the past 30 days									
No*	228 (7.2)	1		234 (7.7)	1		392 (12.3)	1	
Yes	365 (11.5)	**1.33 (1.08–1.63)**	**0.006**	294 (9.7)	–		547 (17.2)	**1.23 (1.04–1.46)**	**0.020**
ETS exposure at school									
No*	259 (8.7)	1		199 (7.0)	1		437 (14.7)	1	
Yes	300 (10.1)	**1.63 (1.26–2.11)**	**0.030**	265 (9.4)	**1.77 (1.43–2.20)**	**<0.001**	462 (15.6)	–	
Vigorous physical activities per week									
Never*	150 (4.3)	1		146 (4.4)	1		268 (7.6)	1	
Once or twice per week	290 (8.2)	**1.37 (1.10–1.71)**	**0.014**	245 (7.3)	1.29 (0.99–1.68)	0.059	483 (13.7)	**1.51(1.25–1.83)**	**<0.001**
Three or more times per week	226 (6.4)	**1.61(1.29–2.20)**	**<0.001**	200 (6.0)	**2.02 (1.52–2.67)**	**<0.001**	299 (8.5)	**1.54 (1.24–1.91)**	**<0.001**

(*Continued*)

Table 4. (*Continued*).

Characteristics	Current wheeze *n* (%)	Adjusted OR[a] (95% CI)	*p*-value	Asthma *n* (%)	Adjusted OR[b] (95% CI)	*p*-value	Rhinoconjunctivitis *n* (%)	Adjusted OR[c] (95% CI)	*p*-value
Hours spent watching television per week									
Less than 1 h*	83 (2.3)	1		104 (3.1)	1		119 (3.4)	1	
1 h but less than 3 h	114 (3.2)	–		95 (2.8)	0.76 (0.52–1.10)	0.151	169 (4.8)	1.26 (0.93–1.70)	0.133
3 h but less than 5 h	121 (3.4)	–		103 (3.0)	**0.59 (0.41–0.85)**	**0.005**	221 (6.2)	1.31(0.99–1.75)	0.063
5 h or more	355 (10.0)	–		291 (8.6)	**0.73 (0.53–0.99)**	**0.046**	545 (15.3)	**1.52 (1.18–1.75)**	**0.001**

*Reference category.
[a]Model adjusted for all the variables in this table, except sex.
[b]Model adjusted for all the variables in this table, except ETS exposure at home/ frequency of trucks passing near residences.
[c]Model adjusted for all the variables in this table and having pets in and around the house, but not adjusted for residential heating/cooking fuel type and ETS at school.

wheeze (OR = 1.70; 95 % CI: 1.17–1.82) and rhinoconjunctivitis (OR = 1.69; 95 % CI: 1.18–1.75) in exposed communities, whereas a significant protective effect was observed for wheeze (OR = 0.41; 95 % CI: 0.22–0.77) in unexposed communities.

Discussion

The results of this study suggest that there is a high prevalence of current wheeze and rhinoconjunctivitis in the seven exposed communities (i.e. 1–2 km from mine dumps). A recent report from different centers in African countries that participated in the ISAAC Phase III reported considerable variations in the prevalence of current wheeze (4.0–21.5 %) and rhinoconjunctivitis (7.2–27.3 %) (Ait-Khaled et al. 2007). The prevalence of current wheeze reported in this study support findings in the ISAAC Phase III for African countries. The prevalence of asthma in exposed communities was consistent with earlier studies conducted in South Africa, i.e. between 10 and 13 % (Burr et al. 1994; Ehrlich et al. 1995; Nriagu et al. 1999; Obihara et al. 2005). However, high prevalence of current wheeze and rhinoconjunctivitis was observed as compared to other studies conducted in the industrialized cities of Cape Town (20.3 and 20.7 %) (Zar et al. 2007) and Polokwane (18.0 and 16.9 %) (Wichmann et al. 2007). The 12-month prevalence of wheeze and rhinoconjunctivitis over lifetime prevalence was used as previous studies had shown that this definition is less susceptible to recall bias.

The proximity of a community to mine dumps, residential heating/cooking fuel type, truck traffic frequency, and ETS exposure at home and school is all surrogate measures for indoor and outdoor exposure to criteria air pollutants and other pollutants. Criteria air pollutants include particulate matter with an aerodynamic diameter smaller than 10 µm (PM_{10}), $PM_{2.5}$, nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ground-level ozone (O_3), carbon dioxide (CO), and lead. Mine dump facilities are major sources of windblown dust and smaller PM, e.g. PM_{10}. The mine dust and smaller PM are released and transported to the surrounding communities by air, soil, or water contamination (Moreno et al. 2010; Ojelede et al. 2012). Mine dumps contain a complex mixture of metals such as cadmium, manganese, gold, arsenic, selenium, lead (Hu et al. 2007; Jasso-Pineda et al. 2012). In this study, residing in an exposed community was significantly associated with an increased risk of current wheeze and rhinoconjunctivitis among adolescents. A worldwide analysis of ISAAC Phase 1 data of adolescents showed that the urban background PM_{10} has little or no association with current wheeze and rhinoconjunctivitis (Anderson et al. 2010). These findings are in contrast to those of this study; this may be due to the difference in concentration and chemical composition of PM_{10} and the study setting. Residential developments in some of the selected communities are now at the foot of the mine dumps (Ojelede et al. 2012), and therefore, increasing human exposure from the eroded particulate matter of mine dumps (Annegarn 2006).

The results of this study showed increased risk of current wheeze due to the use of open fires for residential heating/cooking. Due to various socioeconomic reasons and high unemployment rate in South Africa, many households use paraffin and open fires as alternative sources of energy as they are more affordable than electricity (Schwebel & Swart 2009). A global analysis of ISAAC data of 13–14-year olds showed a positive association between current wheeze and use of open fires for cooking (Wong et al. 2013). In our study, a stronger association was observed than that of the ISAAC global analysis.

The association between air pollution derived from truck traffic, asthma, current wheeze, and rhinoconjunctivitis is not novel (Guo et al. 1999; Janssen et al. 2003;

Table 5. Prevalence, adjusted odds ratios of wheeze, asthma, and rhinoconjunctivitis in exposed communities.

Characteristics	Current wheeze *n* (%)	Adjusted OR[a] (95% CI)	*p*-value	Asthma *n* (%)	Adjusted OR[b] (95% CI)	*p*-value	Rhinoconjunctivitis *n* (%)	Adjusted OR[c] (95% CI)	*p*-value
Sex									
Female*	242 (10.7)	1		123 (5.7)	1		435 (19.2)	1	
Male	237 (10.4)	–		107 (5.0)	**0.71 (0.50–0.99)**	**0.048**	333 (14.1)	**0.60 (0.51–0.73)**	**<0.001**
Residential heating/cooking fuel type									
Electricity*	413 (18.9)	1		170 (8.2)	1		673 (30.7)	1	
Gas	9 (0.4)	–		12 (0.6)	**2.20 (1.02–4.70)**	**0.044**	14 (0.6)	–	
Paraffin	22 (1.0)	–		9 (0.4)	1.20 (0.53–2.72)	0.667	29 (1.3)	–	
Open fires	29 (1.3)	–		4 (0.2)	0.49 (0.17–1.37)	0.172	33 (1.5)	–	
Frequency of trucks passing near residence on weekdays									
Never*	56 (2.5)	1		34 (1.6)	1		86 (3.8)	1	
Seldom	108 (4.7)	–		52 (2.4)	–		137 (6.0)	1.09 (0.79–1.66)	0.580
Frequently	75 (3.3)	–		32 (1.5)	–		114 (5.0)	1.35 (0.96–1.71)	0.088
Always	244 (10.7)	–		115 (5.3)	–		423 (18.5)	**1.56 (1.17–1.75)**	**0.002**
ETS exposure at home in the past 30 days									
No*	148 (7.3)	1		86 (4.5)	1		272 (13.4)	1	
Yes	270 (13.3)	**1.44 (1.15–1.81)**	**0.002**	126 (6.6)	–		388 (19.2)	–	
ETS exposure at school									
No*	161 (8.4)	1		69 (3.8)	1		272 (14.3)	1	
Yes	242 (12.7)	–		122 (6.7)	**1.43 (1.01–2.02)**	**0.042**	374 (19.6)	–	
Vigorous physical activities per week									
Never*	101 (4.4)	1		46 (2.1)	1		204 (9.0)	1	
Once or twice per week	204 (9.0)	**1.59 (1.20–2.10)**	**0.001**	96 (4.4)	1.49 (0.95–2.33)	0.059	326 (14.3)	**1.35 (1.05–1.61)**	**0.017**
Three or more times per week	178 (7.8)	**2.25 (1.67–3.03)**	**<0.001**	94 (4.4)	**2.60 (1.65–2.67)**	**<0.001**	228 (10.0)	**1.49 (1.17–1.91)**	**0.001**
Hours spent watching television per week									
Less than 1 h*	50 (2.2)	1		42 (1.9)	1		82 (3.6)	1	
1 h but less than 3 h	81 (3.5)	1.22 (0.80–1.84)	0.355	41 (1.9)	0.78 (0.44–1.40)	0.151	123 (5.3)	1.11 (0.79–1.56)	0.545
3 h but less than 5 h	101 (4.4)	1.21 (0.81–.81)	0.355	44 (2.0)	**0. 49 (0.27–0.89)**	**0.020**	171 (7.4)	1.35 (0.98–1.87)	0.071
5 h or more	259 (11.2)	**1.70 (1.17–1.82)**	**0.005**	110 (5.0)	0. 84 (0.51–1.38)	0.487	388 (16.8)	**1.69 (1.18–1.75)**	**0.001**

*Reference category.
[a]Model adjusted for all the variables in this table, except sex.
[b]Model adjusted for all the variables in this table, except adjusted for residential heating/cooking fuel type and ETS at school.
[c]Model adjusted for all the variables in this table except ETS at school.

Table 6. Prevalence, adjusted odds ratios of wheeze, asthma, and rhinoconjunctivitis in unexposed communities.

Characteristics	Current wheeze %	Adjusted OR[a] (95% CI)	*p*-value	Asthma %	Adjusted OR[b] (95% CI)	*p*-value	Rhinoconjunctivitis %	Adjusted OR[c] (95% CI)	*p*-value
Sex									
Female*	97 (7.8)	1		191 (16.0)	1		174 (14.0)	1	
Male	86 (6.8)	–		158 (13.3)	–		117 (9.4)	**0.56 (0.42–0.76)**	**<0.001**
Residential heating/cooking fuel type									
Electricity*	161 (13.8)	1		277 (24.6)	1		260 (22.3)	1	
Gas	3 (0.3)	0.67 (0.20–2.28)	0.528	6 (0.5)	–		7 (0.6)	–	
Paraffin	9 (0.8)	1.53 (0.71–3.29)	0.280	10 (0.9)	–		18 (1.6)	–	
Open fires	0 (0.0)	–	–	2 (0.2)	–		3 (0.3)	–	
Frequency of trucks passing near residence on weekdays									
Never*	34 (2.7)	1		55 (4.6)	1		35 (2.8)	1	
Seldom	36 (2.9)	–		43 (3.6)	0.64 (0.37–1.08)	0.095	79 (6.4)	–	
Frequently	35 (2.8)	–		53 (4.4)	**1.70 (1.02–2.82)**	**0.043**	36 (2.9)	–	
Always	76 (6.1)	–		202 (16.9)	1.33 (0.88–2.00)	0.171	141 (11.4)	–	
ETS exposure at home in the past 30 days									
No*	80 (6.9)	1		148 (13.3)	1		120 (10.4)	1	
Yes	95 (8.2)	–		168 (15.1)	–		159 (13.8)	–	
ETS exposure at school									
No*	98 (9.3)	1		130 (12.8)	1		165 (15.6)	1	
Yes	58 (5.5)	–		143 (14.1)	**1.87 (1.39–2.49)**	**<0.001**	88 (8.3)	**0.70 (0.52–0.94)**	**<0.001**
Vigorous physical activities per week									
Never*	49 (3.9)	1		100 (8.4)	1		64 (5.1)	1	
Once or twice per week	86 (6.9)	–		149 (12.5)	1.16 (0.82–1.65)	0.392	157 (12.6)	**1.77 (1.25–2.51)**	**0.001**
Three or more times per week	48 (3.9)	–		106 (8.9)	**1.62 (1.11–2.39)**	**0.013**	71 (5.7)	1.47 (0.97–2.20)	0.065
Hours spent watching television per week									
Less than 1 h*	33 (2.6)	1		62 (5.2)	1		37 (3.0)	1	
1 h but less than 3 h	33 (2.6)	1.07 (0.62–1.87)	0.807	54 (4.5)	0.84 (0.49–1.43)	0.521	46 (3.7)	–	
3 h but less than 5 h	20 (1.6)	**0.41 (0.22–0.77)**	**0.005**	59 (4.9)	0.67 (0.40–1.11)	0.119	50 (4.0)	–	
5 h or more	96 (7.7)	0.81 (0.52–1.28)	0.280	181 (15.1)	0.67 (0.44–1.01)	0.058	157 (12.6)	–	

*Reference category.
[a]Model adjusted for all the variables in this table, except sex, ETS exposure at home, ETS exposure at school, vigorous physical activity per week.
[b]Model adjusted for all the variables in this table, except frequency of trucks passing near residences.
[c]Model adjusted for all the variables in this table, but not adjusted for, except ETS exposure at home.

Brunekreef et al. 2009; Anderson et al. 2010; McConnell et al. 2010). People living in close proximity to busy roads are most adversely affected (Gonzalez-Barcala et al. 2013). A strong association between truck traffic frequency and current wheeze was observed in this study.

A recent systematic review of 79 prospective studies found that pre- or postnatal ETS was associated with increased risk of wheezing and rhinoconjunctivitis (Burke et al. 2012), our study supports this association. A large number of adolescents reported ETS exposure at schools, which indicated that smoking habits are common in South African public schools. Hence, health promotion programs to reduce smoking at schools should be strengthened; programs that will not only improve knowledge of the dangers of smoking, but also change the attitude toward smoking.

Individual exposure to pollutants depends on the amount of concentration in the exposed environment, duration, and time pattern of exposure (Furtaw 2001). A significant association was observed between those who engaged in vigorous physical activities more than once per week, and current wheeze, asthma, and rhinoconjunctivitis. During exercise, a higher quantity of air inhaled is observed and consequently higher internal dose of air pollution. It is surprising that hours spent indoors watching television had a significant protective effect for asthma, but was a risk factor for rhinoconjunctivitis. Children with asthma are generally less active than their non-asthmatic counterparts (Williams et al. 2008) and may consequently spend more time indoors and be less exposed to outdoor air pollution.

A possible mechanism to explain the observed detrimental associations between wheeze and the community exposure status and the other indoor or outdoor air pollution sources is that the emitted criteria pollutants may cause air way mucosal damage, disabled mucociliary clearance, enhanced penetration and the access of inhaled allergens to the cells of the immune system, and airway sensitization; thus, resulting in airway inflammation (D'Amato et al. 2002; Yang & Omaye 2009).

This study has a few limitations. First, the findings are based on self-reported answers from a questionnaire. Self-reported answers may lead to misclassification of the disease and exposure status, which may result in spurious statistical significant associations. For example, children with asthma might have underestimated how often they engage in vigorous physical activities, while overestimation could have occurred without asthma. Second, no quantitative air pollution exposure assessment was conducted. Third, frequency of trucks passing near homes on weekdays maybe misclassified as on weekdays participants are at school. Fourth, the differential participation rate between exposed and unexposed communities is of concern and may well have introduced selection bias, which is likely to overestimate the prevalence estimates derived from our cross-sectional study and also bias the association in either direction. Fifth, no data on possible reasons for declining to take part were collected from parents who did not give consent. Sixth, data on the video questionnaire, which were believed to be more specific for asthma, were not included in the analysis, as the questionnaire could not be completed in some schools, due to logistical problems such as unavailability of electricity, challenges of moving audio–visual equipment from class to class, or lack of a suitable venue where the children could watch the video. Lastly, we did not collect data on how access to healthcare varies between exposed and unexposed communities.

The strength of our study is that an international validated ISAAC questionnaire was used to study the symptoms of wheeze, asthma, and rhinoconjunctivitis. The findings of this study serve as a base for further detailed epidemiological studies for communities in close proximity to the mine dumps e.g. a planned birth cohort study.

Conclusions

A high prevalence of wheeze (a symptom of asthma), and rhinoconjunctivitis among adolescents in communities located near mine dumps was observed. Detrimental associations between these health outcomes and community proximity to mine dumps, open fire cooking, frequency of truck traffic, ETS, and physical activeness were noted. In the era when disease such as asthma is rapidly rising to be leading burden globally and with developments at the base of mine dumps in some communities, the increasing population in these areas will potentially add to the burden of non-communicable diseases in South Africa.

Ethical considerations

Ethical approval (Number: 235/2011) was obtained from the Research Ethics Committee of the Faculty of Health Sciences, University of Pretoria, Gauteng Department of Education (Number: D2012/79) and North West Department of Education (Number: 23-04-2012). School principals and governing bodies were approached and gave their consent for the study. Parents or guardians of participants were sent a letter explaining the details and nature of the study. The parents or guardians of the participants granted consent. Data collectors were instructed to keep all information confidential. Anonymity was maintained and the names of the participants were not recorded.

List of abbreviations

CI: Confidence Intervals; ETS: Environmental Tobacco Smoke; ISAAC: International Study of Asthma and Allergies in Childhood; LRA: Logistic Regression Analysis; AGA: Anglo Gold Ashanti; CGR: Crown Gold Recoveries; DRD: Durban Roodepoort Deep; ERPM: East Rand Proprietary Mines; NRF: National Research Fund; DAAD: Deutscher Akademischer Austausch Dienst.

Supplementary material

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Conflict of interest

Authors report no conflict of interest.

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References

Ait-Khaled N, Odhiambo J, Pearce N, Adjoh KS, Maesano IA, Benhabyles B, Bouhayad Z, et al. 2007. Prevalence of symptoms of asthma, rhinitis and eczema in 13- to 14-year-old children in Africa: the International Study of Asthma and Allergies in Childhood Phase III. Allergy. 62:247–258.

Anandan C, Nurmatov U, van Schayck OCP, Sheikh A. 2010. Is the prevalence of asthma declining? Systematic review of epidemiological studies Allergy. 65:152–167.

Anderson HR, Ruggles R, Pandey KD, Kapetanakis V, Brunekreef B, Lai CKW, Strachan DP, et al. 2010. Ambient particulate pollution and the world-wide prevalence of asthma, rhinoconjunctivitis and eczema in children: phase One of the International Study of Asthma and Allergies in Childhood (ISAAC). Occup Environ Med. 67:293–300.

Annegarn HJ. 2006. Implications of the new Air quality Act for the residential built environment. Environ Manage. 1:18–21.

Asher MI, Keil U, Anderson HR, Beasley R, Crane J, Martinez F, Mitchell EA, et al. 1995. International study of asthma and allergies in childhood (ISAAC): rationale and methods. Eur Respir J. 8:483–491.

Brashier B, Londhe J, Madas S, Vincent V, Salvi S. 2012. Prevalence of self-reported respiratory symptoms, asthma and chronic bronchitis in slum area of a rapidly developing Indian City. Open J Respir Dis. 2:73–81.

Brunekreef B, Stewart AW, Anderson HR, Lai CKW, Strachan DP, Pearce N. 2009. Self-reported truck traffic on the street of residence and symptoms of asthma and allergic disease: a global relationship in ISAAC phase 3. Environ Health Perspect. 117:1791–1798.

Burke H, Leonardi-Bee J, Hashim A, Pine-Abata H, Chen Y, Cook DG, Britton JR, et al. 2012. Prenatal and passive smoke exposure and incidence of asthma and wheeze: systematic review and meta-analysis. Pediatrics. 129:735–744.

Burr ML, Limb ES, Andrae S, Barry DM, Nagel F. 1994. Childhood asthma in four countries: a comparative survey. Int J Epidemiol. 23:341–347.

Corbo GM, Forastiere F, De Sario M, Brunetti L, Bonci E, Bugiani M, Chellini E, et al. 2008. Wheeze and asthma in children: associations with body mass index, sports, television viewing, and diet. Epidemiology. 19:747–755.

D'Amato G, Liccardi G, D'Amato M, Cazzola M. 2002. Outdoor air pollution, climatic changes and allergic bronchial asthma. Eur Respir J. 20:763–776.

De Bilderling G, Chauhan AJ, Jeffs JAR, Withers N, Johnston SL, Holgate ST, Clough JB. 2005. Gas cooking and smoking habits and the risk of childhood and adolescent wheeze. Am J of Epidemiol. 162:513–522.

Drake KA, Galanter JM, Burchard EG. 2008. Race, ethnicity and social class and the complex etiologies of asthma. Pharmacogenomics. 9:453–462.

Ehrlich RI, Toit D, Jordaan E, Volmink JA, Weinberg EG, Zwarenstein M. 1995. Prevalence and reliability of asthma symptoms in primary school children in Cape town. Int J Epidemiol. 24:1138–1146.

Eijkemans M, Mommers M, Draaisma JMT, Thijs C, Prins MH. 2012. Physical activity and asthma: a systematic review and meta-analysis. PloS One. 7:1–11.

Ellwood P, Asher MI, Beasley R, Clayton TO, Stewart AW. 2005. The International Study of Asthma and Allergies in Childhood (ISAAC): phase three rationale and methods. Int J Tuberc Lung Dis. 9:10–16.

Furtaw EJ. 2001. An overview of human exposure modeling activities at the USEPA's National Exposure Research Laboratory. Toxicol Ind Health. 17:302–314.

Gasana J, Dillikar D, Mendy A, Forno E, Ramos Vieira E. 2012. Motor vehicle air pollution and asthma in children: a meta-analysis. Environ Res. 117:36–45.

Gonzalez-Barcala FJ, Pertega S, Garnelo L, Castro TP, Sampedro M, Lastres JS, San Jose Gonzalez MA, et al. 2013. Truck traffic related air pollution associated with asthma symptoms in young boys: a cross-sectional study. Public Health. 127:275–281.

Gortmaker SL, Hosmer DW, Lemeshow S. 1994. Applied logistic regression. 2nd ed. New York (NY): Wiley.

Guo YL, Lin YC, Sung FC, Huang SL, Ko YC, Lai JS, Su HJ, et al. 1999. Climate, traffic-related air pollutants, and asthma prevalence in middle-school children in Taiwan. Environ Health Perspect. 107:1001–1006.

Hedman L, Bjerg A, Sundberg S, Forsberg B, Rönmark E. 2011. Both environmental tobacco smoke and personal smoking is related to asthma and wheeze in teenagers. Thorax. 66:20–25.
Hjern A, Haglund B, Hedlin G. 2000. Ethnicity, childhood environment and atopic disorder. Clin Exp Allergy. 30:521–528.
Hu H, Shine J, Wright RO. 2007. The challenge posed to children's health by mixtures of toxic waste: the tar creek superfund site as a case-study. Pediatric Clin North Am. 54:155–175.
Janssen NAH, Brunekreef B, van Vliet P, Aarts F, Meliefste K, Harssema H, Fischer P. 2003. The relationship between air pollution from heavy traffic and allergic sensitization, bronchial hyperresponsiveness, and respiratory symptoms in Dutch schoolchildren. Environ Health Perspect. 111:1512–1518.
Jasso-Pineda Y, Díaz-Barriga F, Calderón J, Yáñez L, Carrizales L, Pérez-Maldonado IN. 2012. DNA damage and decreased DNA repair in peripheral blood mononuclear cells in individuals exposed to arsenic and lead in a mining site. Biol Trace Elem Res. 146:141–149.
Kabir ML, Rahman F, Hassan MQ, Ahamed F, Mridha MA. 2005. Asthma, atopic eczema and allergic rhino-conjunctivitis in school children. Mymensingh Med J. 14:41–45.
Kim JH, Ellwood PE, Asher MI. 2009. Diet and asthma: looking back, moving forward. Respir Res. 10:1–7.
Koistinen K, Kotzias D, Kephalopoulos S, Schlitt C, Carrer P, Jantunen M, Kirchner S. 2008. The INDEX project: executive summary of a European Union project on indoor air pollutants. Allergy. 63:810–819.
Kynyk JA, Mastronarde JG, McCallister JW. 2011. Asthma, the sex difference. Curr Opin Pulm Med. 17:6–11.
Mayan ON, Gomes MJ, Henriques A, Silva S, Begonha A. 2006. Health survey among people living near an abandoned mine. A case study: Jales Mine, Portugal. Environ Monit Assess. 123:31–40.
McConnell R, Islam T, Shankardass K, Jerrett M, Lurmann F, Gilliland F, Gauderman J. 2010. Childhood incident asthma and traffic-related air pollution at home and school. Environ Health Perspect. 118:1021–1026.
Meza-Figueroa D, Maier RM, de la O-Villanueva M, Gómez-Alvarez A, Moreno-Zazueta A, Rivera J, et al. 2009. The impact of unconfined mine tailings in residential areas from a mining town in a semi-arid environment: Nacozari, Sonora, Mexico. Chemosphere. 77:140–147.
Moreno ME, Acosta-Saavedra LC, Meza-Figueroa D, Vera E, Cebrian ME, Ostrosky-Wegman P, Calderon-Aranda ES. 2010. Biomonitoring of metal in children living in a mine tailings zone in Southern Mexico: a pilot study. Int J Hyg Environ Health. 213:252–258.
Nriagu J, Robins T, Gary L, Liggans G, Davila R, Supuwood K, Harvey C, et al. 1999. Prevalence of asthma and respiratory symptoms in south-central Durban, South Africa. Eur J Epidemiol. 15:747–755.
Obihara CC, Marais BJ, Gie RP, Potter P, Bateman ED, Lombard CJ, Beyers N, et al. 2005. The association of prolonged breastfeeding and allergic disease in poor urban children. Eur Respir J. 25:970–977.
Ojelede ME, Annegarn HJ, Kneen MA. 2012. Evaluation of Aeolian emissions from gold mine tailings on the Witwatersrand. Aeolian Res. 3:477–486.
Polosa R, Thomson NC. 2012. Smoking and asthma: dangerous liaisons. Eur Respir J. 41:133–146.
Sacks JD, Stanek LW, Luben TJ, Johns DO, Buckley BJ, Brown JS, Ross M. 2011. Particulate matter-induced health effects: who is susceptible? Environ Health Perspect. 119:446–454.
Saunders JR, Knopper LD, Yagminas A, Koch I, Reimer KJ. 2009. Use of biomarkers to show sub-cellular effects in meadow voles (*Microtus pennsylvanicus*) living on an abandoned gold mine site. Sci Total Environ. 407:5548–5554.
Schwebel DC, Swart D. 2009. Preventing paraffin-related injury. J Inj Violence Res. 1:3–5.
Shirinde J, Wichmann J, Voyi K. 2014. Association between wheeze and selected air pollution sources in an air pollution priority area in South Africa: a cross-sectional study. Environ Health. 13:1–12.
The International Union Against Tuberculosis and Lung Disease. 2011. The global asthma report asthma. www.globalasthmareport.org.
Tsai CH, Huang JH, Hwang BF, Lee YL. 2010. Household environmental tobacco smoke and risks of asthma, wheeze and bronchitic symptoms among children in Taiwan. Respir Res. 11:1–10.

World Health Organization. 2013. Review of evidence on health aspects of air pollution – REVIHAAP Project. http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/airquality/publications/2013/review-of-evidence-on-health-aspects-of-air-pollution-revihaap-project-finaltechnical-report

Wichmann J, Wolvaardt JE, Maritz C, Voyi KVV. 2007. Household conditions, eczema symptoms and rhinitis symptoms: relationship with wheeze and severe wheeze in adolescents living in the Polokwane Area, South Africa. J Asthma. 44:659–666.

Williams B, Powell A, Hoskins G, Neville R. 2008. Exploring and explaining low participation in physical activity among children and young people with asthma: a review. Family Pract. 9:1–11.

Wong GW, Brunekreef B, Ellwood P, Anderson HR, Asher MI, Crane J, Lai CK. 2013. Cooking fuels and prevalence of asthma: a global analysis of phase three of the International Study of Asthma and Allergies in Childhood (ISAAC). Lancet Respir Med. 1:386–394.

Wright CY, Matooane M, Oosthuizen MA, Phala N. 2014. Risk perceptions of dust and its impacts among communities living in a mining area of the Witwatersrand, South Africa. Clean Air J. 24:22–27.

Yang W, Omaye ST. 2009. Air pollutants, oxidative stress and human health. Mutat Res. 674:45–54.

Zar HJ, Ehrlich RI, Workman L, Weinberg EG. 2007. The changing prevalence of asthma, allergic rhinitis and atopic eczema in African adolescents from 1995 to 2002. Pediatr Allergy Immunol. 18:560–565.