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Occupational respiratory health surveillance at Minara Resources, Murrin Murrin mine site

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Abstract

A respiratory health study of fly-in-fly-out workers potentially exposed to airborne contaminants, and a control group, was conducted at the Murrin Murrin mine site in Western Australia. Lung function was measured in terms of validated protocols (American Thoracic Society, 1995; Miller et al, 2005). The effect of length of service, as well as work area/department on lung function was established. Repeat lung function tests were conducted after approximately two years, in order to measure decrements over time. Furthermore, testing was conducted on a cohort of refinery workers prior to commencement and upon completion of their work period on-site (swing), in order to detect if there were decrements in lung function over this period. No significant decrements were detected in any of the work areas. Length of service was not related to a decrease in lung function however, effects of smoking were detected in the cohort.

Keywords: lung function, health surveillance, nickel, mixed exposures.

Background

The Minara Resources' Murrin Murrin nickel and cobalt mine site and refinery are located in a remote region of Western Australia (WA). Ongoing occupational hygiene sampling has been conducted at the site since Murrin Murrin commenced operations in 1999. A number of gases, aerosols and dusts associated with the process were identified, the most notable being hydrogen sulphide, ammonia, sulphur dioxide/trioxide, oxides of nitrogen, sulphur dust, nickel dust, cobalt dust, calcrete dust and *red dirt* (dust from the ground in this area). Mean exposures were generally found to be well below prescribed occupational exposure levels (Wing, 2005; Wing & Oosthuizen, 2007). Despite this, there was concern expressed by staff that, in combination, the various contaminants may present an additive or even a synergistic deleterious health effect (Oosthuizen & Cross, 2004). Subsequently Minara Resources commissioned a health surveillance study to establish the prevalence of respiratory symptoms and lung function among its workers. The purpose of this study was to establish if any work related respiratory health effects could be identified, to recommend interventions if deemed necessary, and to enable management to proactively ensure the protection of the workforce (Hendrick et al, 2002).

Methods

Traditionally, health risk assessments are based upon airborne concentrations of hazardous substances assessed independently. Such monitoring was conducted as a precursor to this study to determine the occupational exposures in each work area at Murrin Murrin and these were generally found to be compliant, (Oosthuizen & Cross, 2004). However, since workers are exposed to multiple agents that could impact upon respiratory health, it was hypothesised that:

– Exposure to multiple contaminants at low levels at Murrin Murrin could negatively impact on lung function and respiratory symptoms of exposed workers.
– Spirometry used in conjunction with a respiratory health questionnaire will detect respiratory impacts at an early stage.
– Early detection of respiratory disease will enable interventions that will improve long-term health outcomes.

A longitudinal cohort study (n=418; 99.5% of eligible subjects) was conducted in order to determine if working at Murrin Murrin impacts negatively on lung function and associated respiratory symptoms. A portable handheld spirometer (EasyOne Model 2001, ndd Medizintechnik AG, Zurich) was used to measure various lung function parameters. Catering staff who reside at the accommodation camp in the same geographical location 8 kilometres from the refinery constituted a control group (n=40). Furthermore, lung function data was compared to predicted normal values of a disease-free, non-smoking reference population which was computed into the spirometer (Zapletal, Paul, & Samànek, 1977) by the supplier NicheMedical, Leederville, WA.

The prevalence of respiratory symptoms was determined using the WA, Department of Mines and Petroleum (DMP) respiratory questionnaire (2010). Data regarding each individual's work history, respiratory symptoms, smoking status and history, and asthma status were collected.

Prior to commencing spirometry, each participant's height and weight was measured and entered into the instrument along with date of birth, ethnicity, gender, smoker and asthma status. Assessments were done as prescribed by the American Thoracic Society/European Respiratory Society protocol (American Thoracic Society, 1995; Miller et al, 2005). The study was conducted by a DMP "Approved Person" certified to conduct spirometry (Department of Mines and Petroleum, 2010).

Statistical assessments performed

The Statistical Package for the Social Sciences (IBM® SPSS® PASW Statistics 18, 2010) was used for data analysis. Confounding due to smoking status, being an asthmatic and pre-existing (non-work related) respiratory disorders (as determined by the questionnaire) was sequentially removed from the data set resulting in a *presumed healthy* subgroup of the original cohort.

1. The influence of length of service at Murrin Murrin on lung function of a cohort of 418 workers was determined.
2. Lung function data for each work area/department were analysed (n=14) to determine if there were any statistically significant associations between lung function and work area.
3. Repeat lung function tests were conducted on a sample of the original study group (n=72) approximately two years after the initial study in order to determine if there were work related decrements over time.
4. Lung function tests for a cohort of fly-in-fly-out refinery workers (n=32) were conducted as they arrived at the Murrin Murrin site for the start of their two-week work period (swing) and again upon completion of the swing, in order to determine if there were any statistically significant decrements in lung function over a work period.

Results

The study population (n=418) consisted of 384 males and 34 females. The control group (n=40) consisted of 27 males and 13 females. The profiles of the two groups are compared in Table 1.

Table 1 Comparison of study and control group

	Study Group (n=418)	Control Group (n=40)
Male	92% (n=385)	68% (n=27)
Female	8% (n=33)	32% (n=13)
Mean Height (cm) & Standard Deviation & rRange	177 ±7.99 (155-200)	173 ±8.86 (155-195)
Mean Age (years) & Standard Deviation & Range	39 ±9.1 (19-67)	39 ± 12.7 (19-63)
Current Smokers	34% (n=144)	39% (n=16)
Ex-smokers	25% (n=104)	28% (n=11)
Non-smokers	41% (n=170)	33% (n=13)

There were a total of 26 individuals in the study population (6.2%) and 5 in the control population (12.5%) with abnormal spirometry results (ndd Medizintechnik AG, 2002; Johns & Pierce, 2003). All were due to non-work related respiratory disorders, each with a history of respiratory illness and/or smoking.

The effect of length of service on lung function for the presumed healthy non-smokers of the study group (32%) is represented in regression plots (Figures 1 and 2).

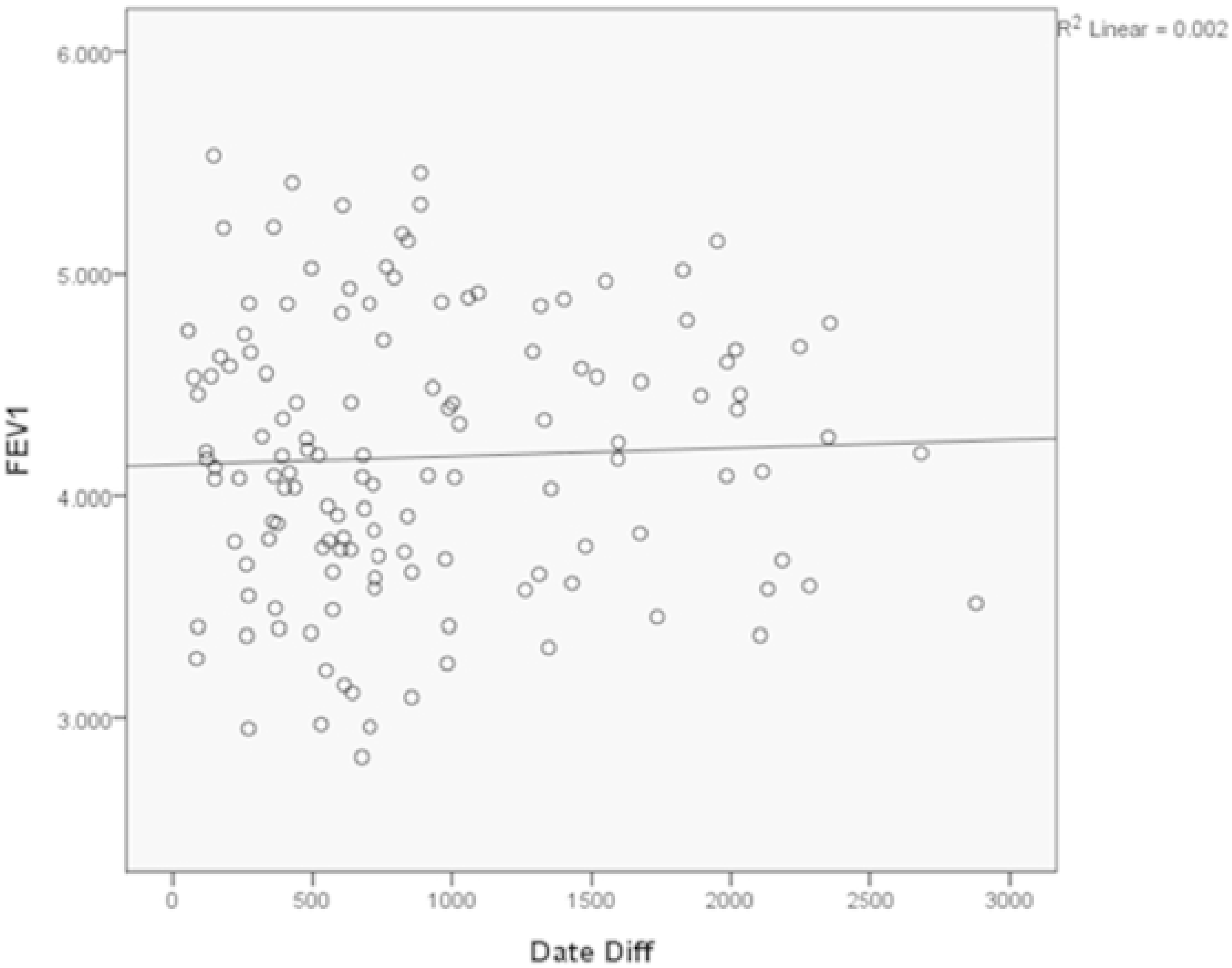

Figure 1: Scatter plot showing the relationship of FEV_1 (litres) and length of service (Date Diff — days) for the presumed healthy non-smoker subgroup of the original cohort (n=134) (R^2= 0.002) (r=0.04).

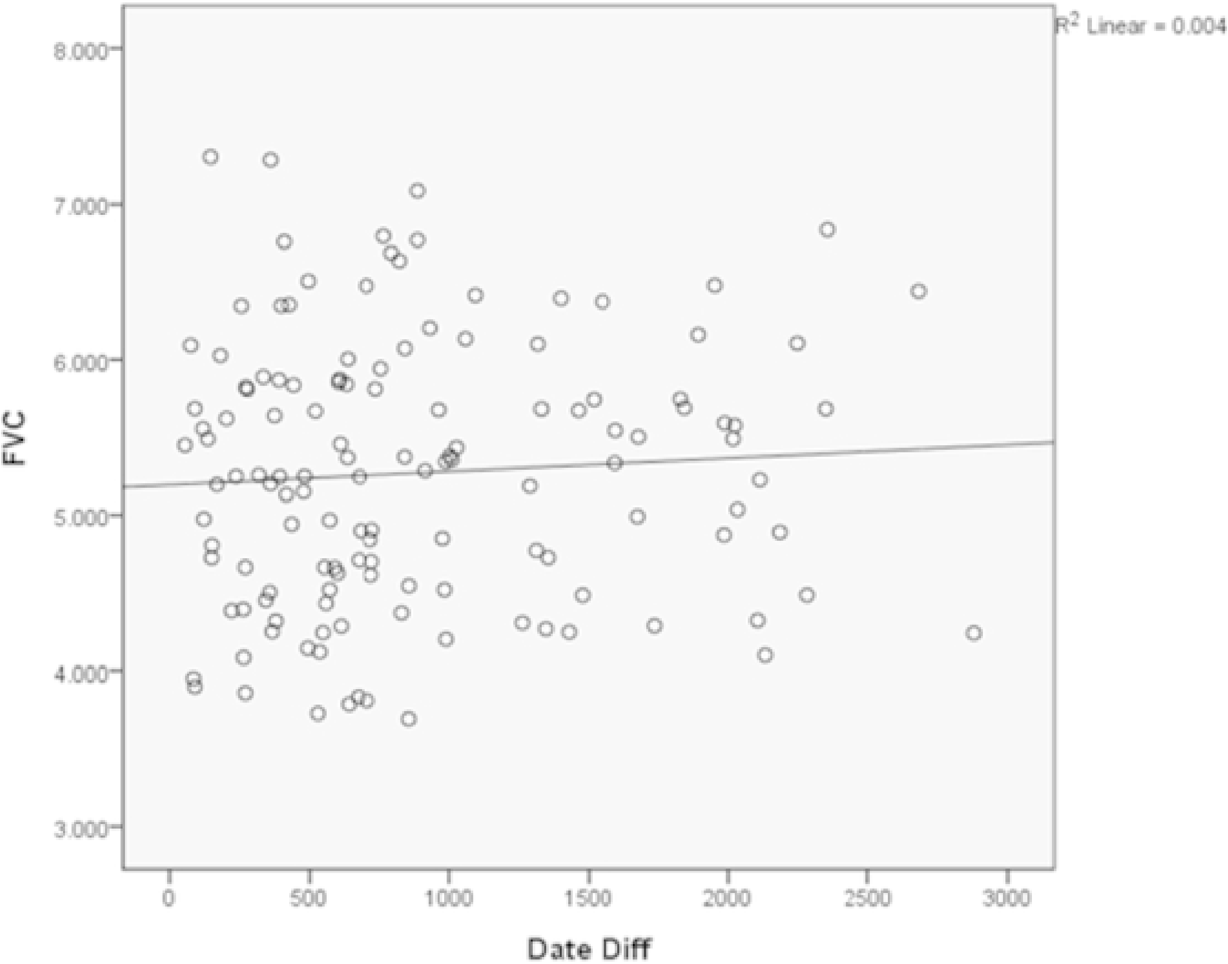

Figure 2: Scatter plot showing the relationship of FVC (litres) and length of service (Date Diff — days) for the presumed healthy non-smoker subgroup of the original cohort (n=134) (R^2=0.004) (r=0.07).

The effect of length of service and FEV_1 for the non-smokers and smokers in the study group is presented in Figures 3 and 4.

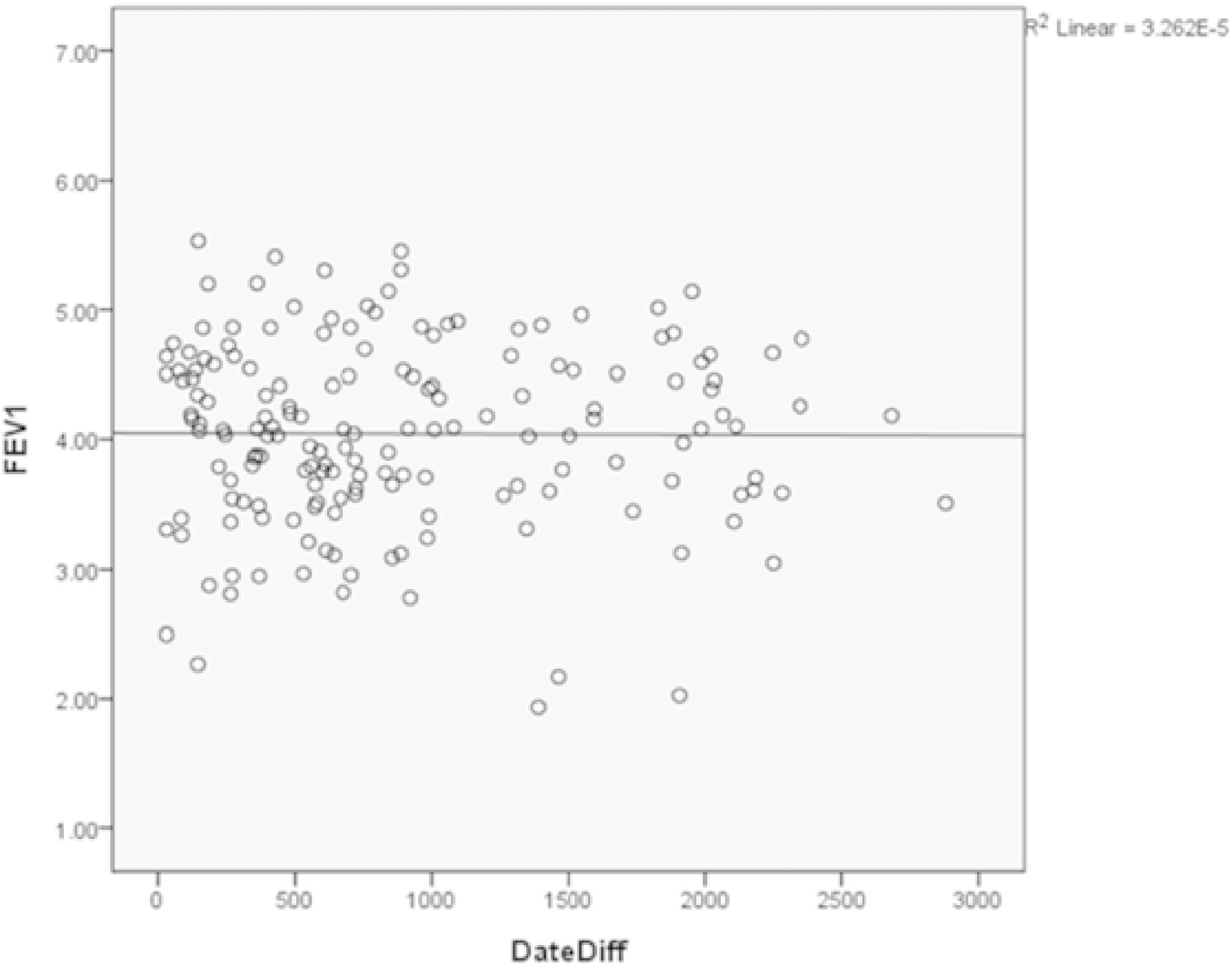

Figure 3: Scatter plot showing the relationship of FEV_1 (litres) and length of service (DateDiff – days) for the Non-Smoking subgroup (n=174) (R^2=3.262E-5) (r=0.01).

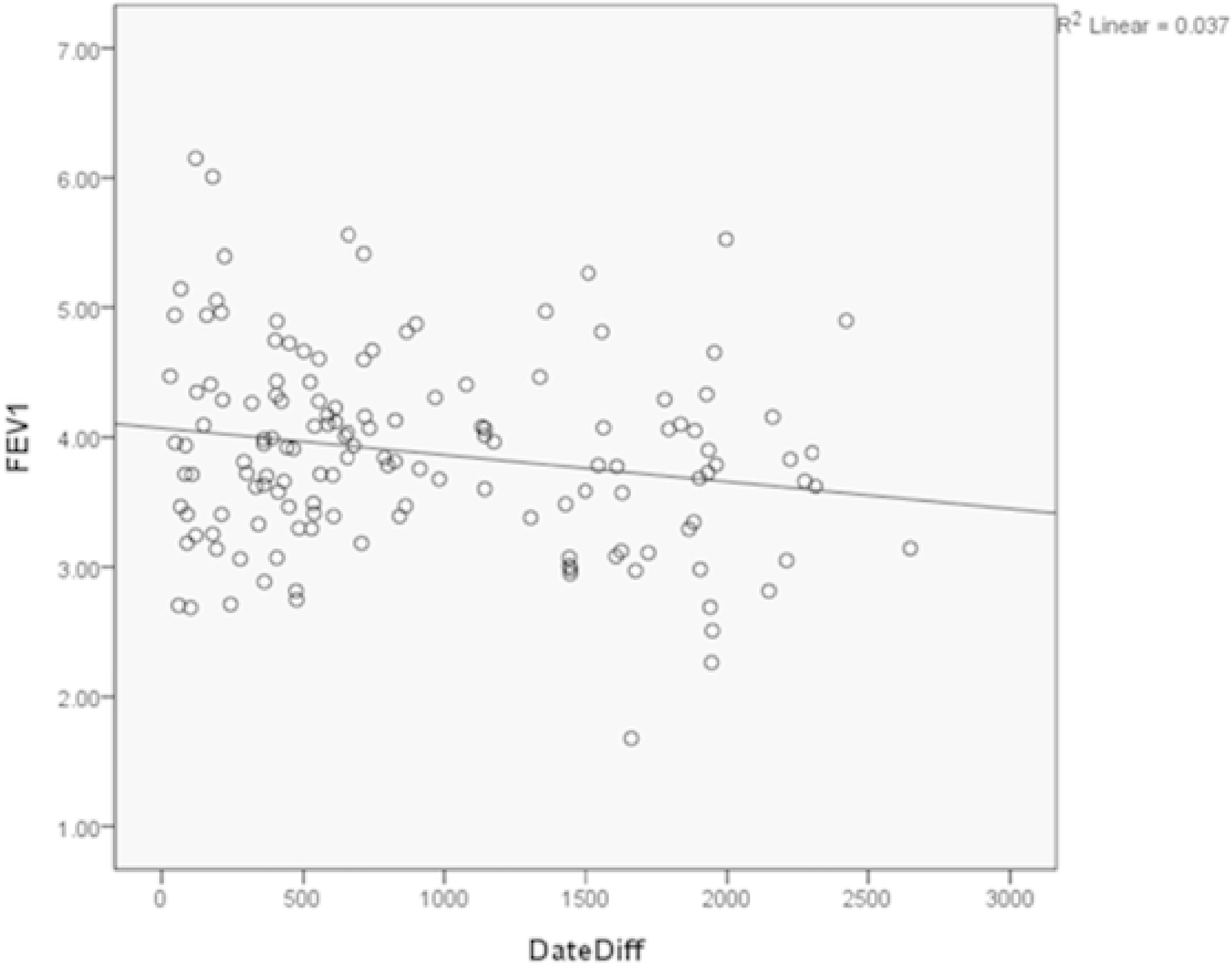

Figure 4: Scatter plot showing the relationship of FEV_1 (litres) and length of service (DateDiff – days) for the smoker subgroup (n=143) (R^2=0.037) (r=-0.19).

There was a significant difference in FEV_1 between non-smokers and smokers with length of service (p=0.05).

A dependent (paired samples) t-test was conducted to compare measured and predicted FEV_1 values for the never-smoker subgroup in each work area (Table 2).

Table 2 Dependent t-test, comparing measured and predicted FEV1 for non-smokers stratified by work area.

			95% Confidence Limits		
Work Area	**Mean**	**Standard Deviation**	**Lower**	**Upper**	**Sig.(2–tailed)**
Administration	-.060	.527	-.300	.180	.608
Mining Production	.102	.506	-.129	.332	.368
Mining Geologists	-.205	.393	-.830	.421	.374
Mining Maintenance	-.037	.386	-.650	.577	.862
Ore Leach Production	.140	.360	-.089	.369	.206
Ore Leach Maintenance	.012	.404	-.259	.283	.923

Refinery Production	-.063	.413	-.268	.142	.526
Refinery Maintenance	-.046	.421	-.279	.187	.679
Utilities Production	-.227	.623	-.748	.293	.336
Utilities Maintenance	.007	.572	-.522	.536	.974
Laboratory	.255	.508	-.135	.646	.170
Warehouse	.644	.479	-.118	1.405	.075
General Maintenance	.208	.369	-.040	.456	.092
Electrical Maintenance	.202	.208	.028	.377	.029*

Note. *p=0.05

A significant difference (p=0.05) was observed for the electrical maintenance work area. This indicated a better overall FEV_1 for the electrical maintenance workgroup compared to their equivalent predicted values (Zapletal, et al, 1977). No other differences were observed for any other work groups (p=0.05).

Repeat lung function tests (n=72) were conducted on a subgroup of 25 non-smokers/non-asthmatics, 43 smokers and 4 asthmatics. Five of the individuals had known non-work related respiratory disorders. Time intervals from the initial to the follow-up spirometry ranged from 173 days to 845 days, these data are summarised in Table 3.

Table 3 Change in lung function over time, with sequential removal of confounders

	Number of Individuals (n)	Lung Function Parameter	Mean ± Standard Deviation (litres)	Range (litres)	Mean Time Period± Standard Deviation (days)	Overall Mean Change (ml/year)
All Subjects	72	FEV_1	-0.036±0.21	-0.54 to 0.39	623±198	-21
	72	FVC	-0.007±0.33	-0.74 to 0.79	623±198	-4
Smokers/ Asthmatics	47	FEV_1	-0.068±0.22	-0.54 to 0.39	616±192	-40
	47	FVC	-0.003±0.35	-0.74 to 0.79	616±192	-2
Non-Smokers/Non-Asthmatics	25	FEV_1	0.024±0.17	-0.33 to 0.39	637±211	+14
	25	FVC	-0.013±0.29	-0.60 to 0.40	637±211	-7
Presumed Healthy, Non-Smokers	24	FEV_1	0.033±0.17	-0.33 to 0.39	633±215	+19
	24	FVC	<0.001±0.29	-0.60 to 0.40	633±215	0

Lung function tests for a cohort (n=32) of fly-in-fly-out refinery workers were conducted as they arrived on site at the start of their 14-day work cycle (swing) and the tests were repeated upon their departure from site at the end of the swing; these data are presented in Table 4.

Table 4 Cross-Swing Change in Lung Function (FEV1 and FVC)

	Range (Litres)	Mean (Litres)	Standard Deviation	P
FEV_1	-0.58 to +0.52	-0.03	0.25	>0.05
FVC	-0.72 to + 0.95	+0.01	0.35	>0.05

There was no significant difference (p=0.05) between the FEV1 and FVC values for the 35 individuals across a swing.

Validity and Reliability

As well as calibrating regularly during each batch of testing using a certified three litre syringe as per the ATS/ERS recommended standard (American Thoracic Society, 1995; Miller et al, 2005), the lung function of the trained researcher was measured 41 times throughout the investigation to act as a biological control, for calibration purposes and to demonstrate internal validity (Figure 5).

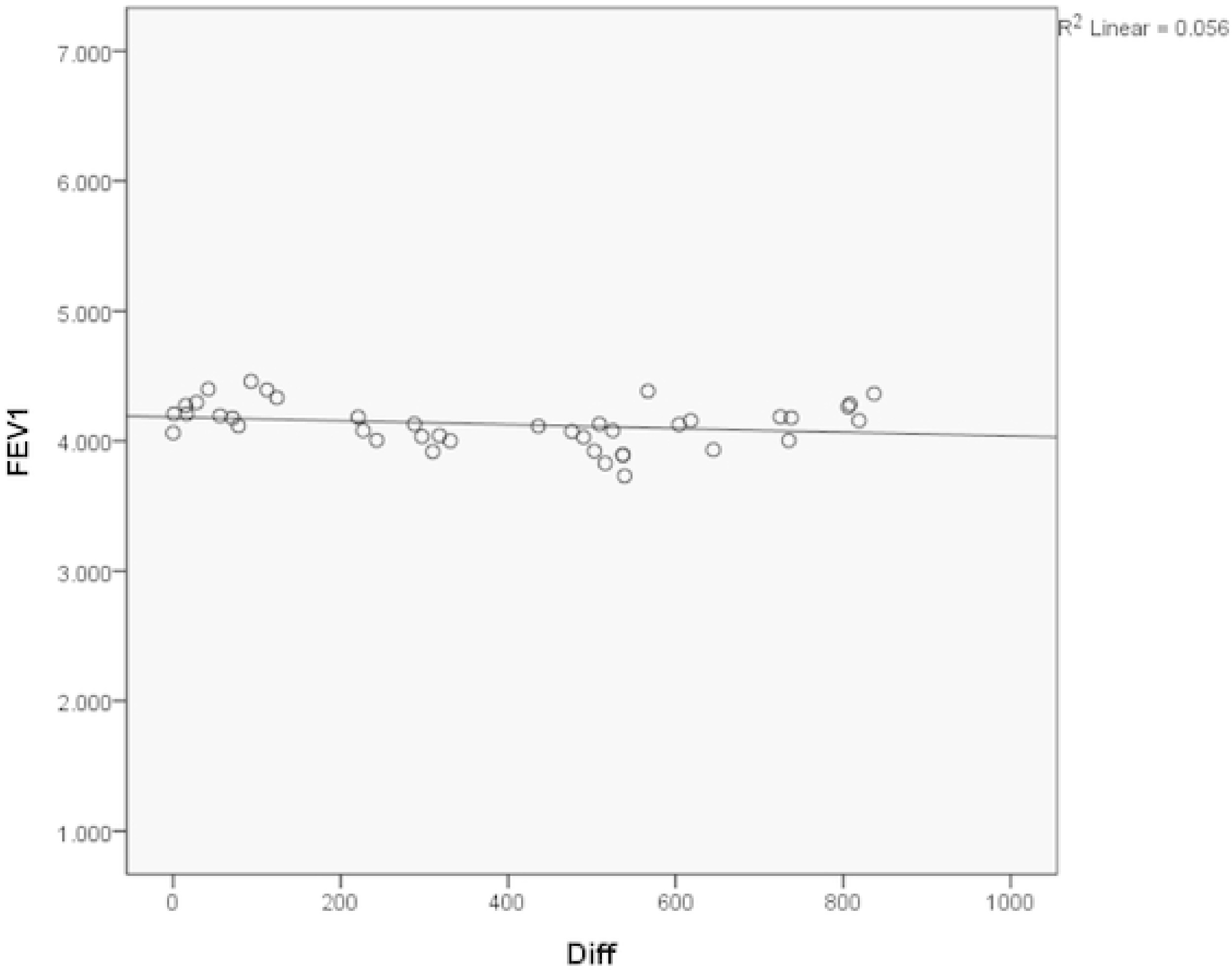

Figure 5: Scatter plot showing the FEV_1 (litres) of the researcher, measured at various time intervals [Diff] (days) over the study period. (R^2=0.056) (r=-0.237) (p=0.05).

Pack years (Connolly & Alpert, 2008; National Cancer Institute, n.d.) were used to assess the effect of smoking on FEV_1 for the ever smokers of both the study and control groups (Figures 6 and 7). The R^2 values and r values are given for each graph. The R^2 value ie goodness of fit of the regression line, and Pearson's correlation coefficient (r) which measures the strength of the relationship between two variables FEV1 and Pack Years.

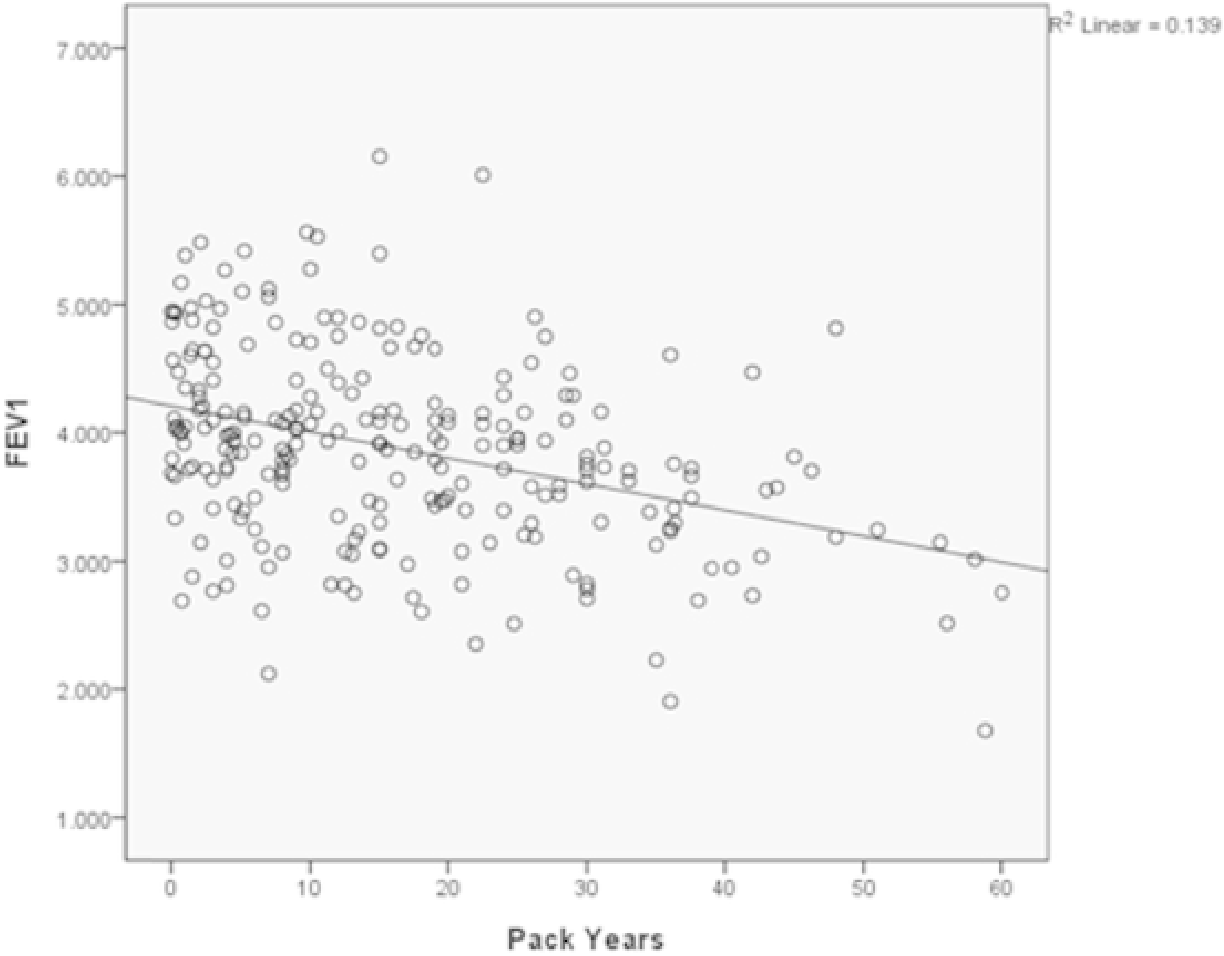

Figure 6: The effect of smoking (Pack Years) on FEV1 (litres) for the study group ever smokers (n=242) (R^2=0.14) (r=-0.46).

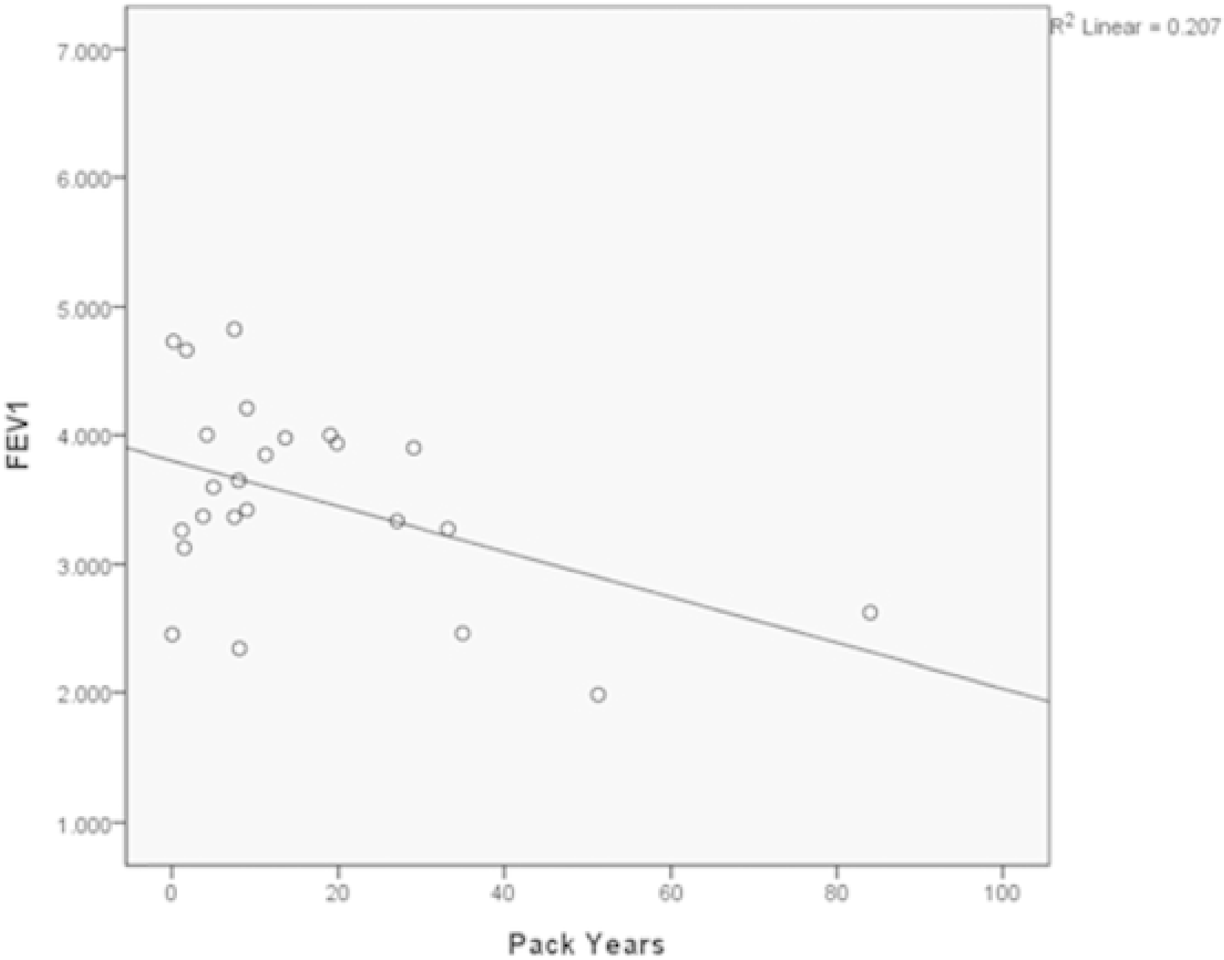

Figure 7: The effect of smoking (Pack Years) on FEV1 (litres) for the control group ever smokers (n=24) (R^2=0.21) (r=-0.37).

Discussion

Potential confounding, due to differences in the profiles of the study and control groups were:

- the male to female employee ratio in the study group was 92% to 8%; and for the control group it was 68% to 32%
- the height range and mean height was different, with the study group range 155-200 cm, mean=177 cm, and the control group range 155–195 cm, mean = 173 cm, and
- the smoking status was different in the study group compared with the control group (ie 38% non-smokers and 33% respectively).

To overcome the effects of confounding, the study design included predicted normal values (Zapletal, et al, 1977) for gender, age, and height, computed into the software of the spirometer, against which to compare each individual's data. Potential confounding due to smoking status, being an asthmatic and pre-existing respiratory disorders were identified through the respiratory questionnaire and addressed during statistical analysis.

As to be expected, on statistical analysis (Simple Linear Regression) there was a positive correlation between lung function and height and, conversely, a negative correlation with lung function and age (data not shown) for both the study and control groups.

The lung function of the study group was considered significantly different from both the control group and the predicted normal group (Zapletal, et al, 1977) as there was almost a consistent significant difference (p=0.05) on comparison of their respective FEV_1s and FVCs. However, the R^2 values (goodness of fit) for the regression analysis came closer as the effect of the confounders related to poor lung function were removed (logistic regression). The difference of 5% more smokers in the control group was likely to account to some degree for the difference in prevalence of the non-work related respiratory disorders, which was 12.5% for the controls compared with 6.2% for the study group. There was a significant difference in both FEV_1 and FVC between the study group and their predicted values as all the obvious confounders (smokers, asthmatics and those with non-work related respiratory disorders) were removed. This may indicate the difference between a West Australian cohort (circa 2006) and the European cohort used as a reference (circa 1977).

The prevalence of respiratory disorders was determined by administration of a respiratory questionnaire and confirmed by spirometry. In the control population there were five individuals (5/40 = 12.5%) with poor spirometry results (ndd Medizintechnik AG, 2002): three with mild obstruction, one with mild obstruction and low vital capacity, possibly due to restriction, and one with low vital capacity possibly due to restriction of lung volumes. In the study population there were 26 individuals (26/418 = 6.2%) with poor spirometry results: 18 with mild obstruction, 5 with mild obstruction and low vital capacity possibly due to restriction, and 3 with moderate obstruction and low vital capacity possibly due to restriction. All were non-work related, each with a history of respiratory illness and/or smoking.

The effect of length of employment at the Murrin Murrin site (length of service) on lung function was investigated using linear regression plots, and by Multivariate Analysis of Variance for the main study group *presumed healthy workers*. The regression plots for FEV_1 and FVC for the presumed healthy workers were flat indicating no change. In addition, Pearson's Correlations were not significant (p=0.05) also indicating no effect. Furthermore, a MANOVA analysis showed no significant difference in FEV_1 with length of service between the non-smoker and smoker cohorts (p=0.05).

Upon further analysis, an evident decrease in FEV_1 with length of service was noted for the smoker subgroup while there was no such effect among non-smokers. The Pearson's correlation for length of service for the smokers was significant at the 0.01 level indicating a decrement in FEV_1 over time. However, there was a significant difference in FEV_1 between non-smokers and smokers (p=0.05). Therefore there was no decrease in FEV_1 for the study group of presumed healthy workers with length of service, while in contrast, there was a decrement for smokers over time.

A dependent t-test was conducted to determine if there were any statistically significant changes in FEV_1 and FVC as compared with their predicted values for the never-smoker populations in the 16 work areas studied. There were insufficient observations to conduct an analysis for two work areas and in the remaining 14 work areas, no decrease in lung function was detected.

Repeat lung function testing was conducted on a sample of 72 of the initial 418 mine site workers. Sampling was restricted to 72 participants due to attrition (loss of participants due to a high staff turnover rate (51%)) and drop out. The 72 repeat lung function tests included a cross-section of workers known to have been employed for approximately 6 months or longer, purposely including those known to have poor lung function (5 of the 72). This sample consisted of 29 non-smokers (4 of these were asthmatic) and 43 smokers from the original study group. Best attempts were made to gather a cross-section of workers from all work areas. A comparison of their initial and repeat lung function tests were statistically analysed to determine if there was a decrement in lung function over time from initial to repeat test. The mean time period for the repeat spirometry tests was 1.7 years (range 173–845 days). No decrease in lung function was detected for the presumed healthy subgroup. However, decreases were noted for the smokers and asthmatic subgroup (with

FEV_1 decreasing 41 ml/year and FVC 2 ml/year); this appears to be a typical profile of the early effects of smoking (Kerstjens et al, 1997; Heijdra, Pinto-Plata, Kenney, Rassulo, & Celli, 2002).

Across swing (work period of 14 days), decrements were not detectable among a cohort of 32 refinery workers.

A consistent negative effect on FEV_1 among smokers was demonstrated throughout this study in all levels of analysis.

Limitations

The high staff turnover rate complicated follow-up and may have produced a "healthy worker effect" (Checkoway et al, 2004) whereby individuals with work related respiratory disorders may have left the Murrin Murrin workforce. Furthermore the turnover rate of approximately 51% would have introduced new workers with less time on site (causing a dilution of the effect). Therefore attempts were made to focus on the longer-serving members of the workforce by limiting recruitment to those with at least six months service. Smokers and those with known non-work related respiratory symptoms were included with the intention of attempting to identify potential synergistic effects.

The intra-individual standard deviation of repeated measurements of FEV_1 and FVC in a healthy adult is considered to be approximately 200 ml and 340 ml respectively (Rozas & Goldman, 1982). To reduce within-session variability the ATS/ERS criteria (American Thoracic Society, 1995; Miller et al, 2005) and the manufacturer's guidelines (ndd Medizintechnik, 2002) were rigorously applied. Moreover a single competent person collected all data using the same instrument to conduct the spirometry tests.

Confounding factors that were identified included smoking, and non-work related respiratory diseases such as asthma. Furthermore, obesity and some cardiovascular diseases such as diabetes are known to have a pronounced effect on lung function (Poirier et al, 2006). Standard deviations in some instances were high due to the influence of these identified confounders.

Validity and Reliability

As well as regular calibration checks of the spirometer using a calibration syringe: a biological control with known normal lung function was incorporated into the study protocol to monitor intra-individual variation in lung function. The lung function of the trained researcher was repeatedly measured throughout the investigation to act as a biological control to demonstrate internal validity. There was no significant ($p=0.05$) decrease in lung function for this individual over the study period. Internal validity is the assurance that can be given to a cause and response relationship in a study (Checkoway, et al, 2004). In this study the lung function data of smokers acted effectively as a positive control, while the lung function of a healthy non-smoking person (biological control) effectively acted as a negative control for internal validity.

Conclusions and Recommendations

The overall conclusion of this study was that there was no measureable decrement in lung function for non-smoking employees irrespective of area worked or length of employment on site and that currently implemented primary preventive measures aimed at protecting workers are effective. It is however important to note that the effect of smoking was detected across all phases of the study; whether or not smokers are more vulnerable to the exposures is unknown.

Although the outcome of this study is specific to the Murrin Murrin Operation, it may also have some relevance to other lateritic mining operations using the high pressure acid leach (HPAL) method of extraction such as those in Indonesia, Brazil, Cuba, Colombia and New Caledonia (Intec, n.d.; Barnes, 1998; Mining-Technology.Com, n.d.).

The concern shown by the employees at the Murrin Murrin Operation that workplace emissions may be harming their respiratory health appears to be dispelled by this study.

It has been demonstrated that, when used in conjunction with a respiratory questionnaire, spirometry testing provides an effective diagnostic tool with adequate sensitivity to detect effects on lung function.

Asthma may be exacerbated by occupational exposures therefore asthmatic subjects should be monitored more closely than other employees for possible respiratory health effects. It is equally important not to ignore the effect of cigarette smoking, although this is a lifestyle issue rather than a workplace issue. Individual health ownership (Cameron, 2010) to protect those with asthma and to help smokers quit smoking should be encouraged within the workplace. This will be beneficial to both the company and the individual.

Further research to explore the respiratory health of smokers could be conducted as it is not know whether their smoking may be synergistically linked to exposures.

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