

SHORT COMMUNICATION

HEALTH IMPAIRMENTS
AMONG REFUSE DERIVED
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We conducted this study to address concerns regarding a perceived increase in bronchitis, skin rashes, and diarrhea and long term health effects in workers at two Refuse Derived Fuel (RDF) processing plants. We abstracted medical records to assess symptom occurrence, and to identify spirometry and lab abnormalities. Overall FEV₁ and FVC showed no decrease over time for workers with more than five years of exposure. The primary self reported symptoms were low back pain and headaches followed by skin rashes, colds, 'flu', hay fever and ear problems. Conclusions from this analysis are limited by lack of standardized protocols or a control group. However, results from this analysis pointed out potential occupational health problems among RDF workers for future epidemiological and environmental studies.

Key words:

airborne dusts, bronchitis, pulmonary function changes, refuse derived fuel exposures, skin rash

Refuse derived fuel (RDF) plays an increasing role in the management of municipal solid waste. Large, non-combustible items are separated from the waste stream which is milled and shredded to a small enough size to be combusted in a boiler, often co-fired with fossil fuels. RDF aids in reducing the volume of material going to landfills, in recycling of valuable commodities, and in cost effective energy production. There are 38 facilities processing RDF in 25 of the United States, with Minnesota in the lead having 6 facilities (1).

This report presents the results of a systematic analysis of historical medical records intended to identify episodes of bronchitis, skin rash, and reported symptoms of diarrhea and to describe trends in disease prevalence for workers at two RDF processing plants operated by the same company. Concerns of company occupational health professionals and employees regarding worker health in the processing plants provided the impetus for this study. The primary concerns were a perceived increase in bronchitis, skin rashes and a diarrheal condition termed the »RDF Flu« as well as

concerns regarding possible long term health effects. The company provides annual physical examinations to the workforce in the plants and made the records available for review. The records included symptom information, pulmonary function data, and hematological profiles.

Throughout the world, little information is available concerning the health effects associated with handling and processing of refuse. Some of the few studies show a potential for various health effects including dry cough, exercise induced-dyspnea, asthma, bronchitis and organic dust toxic syndrome (2), folliculitis of the torso and lower limb xerotic dermatitis (3, 4), and work related injuries, especially of the back (5, 6).

Particulate sampling conducted at refuse processing plants has shown a wide variety of constituents, with measurements of some airborne contaminants exceeding levels associated with adverse health effects in other environments (7). Several studies of bioaerosols have been conducted at resource recovery plants and reports have shown a large variety of microorganisms associated with waste handling (8, 9). Studies on the respiratory health effects of refuse handling have been conducted by *Sigsgaard and co-workers* and *Nersting and co-workers* in Denmark (10-12). In their most recent study (13) they reported no evidence for chronic lung function changes among workers in resource recovery. However short history of exposure and high turnover (50% in one year) could have biased the results toward no observed effect according to the authors. A recent study by *Mustajbegović and co-workers*, found that FVC and FEV₁ were significantly lower than predicted values in sanitation workers with more than 10 years of employment (14).

The aims of this study were to : 1) assess the occurrence of episodes of bronchitis, skin rash, and reported symptoms of diarrhea through a review of worker medical records dating from the opening of the two RDF plants; 2) assess the occurrence of pulmonary function abnormalities and evaluate possible trends in pulmonary function results over time; 3) assess the occurrence of abnormalities in hematologic profiles and possible trends over time; 4) review medical records for other reported symptoms.

METHODS

The company operates two plants that process municipal solid waste from a large metropolitan area into refuse derived fuel. Plant A is the newer of the two plants, operating since 1988, and it produces 4-5 hundred tons of RDF per day. Plant B, operating since 1986 produces about 8-9 hundred tons of RDF per day. Plant A employs 65 workers and Plant B, 43 workers. The composition of the refuse is variable as it is a function of what people discard, but paper and paperboard products make up large portion of the waste stream. These and other organic materials in the waste stream such as yard waste, plastics and food products give RDF its energy value.

The company offered all employees in the RDF plants voluntary annual examinations consisting of a health interview by a physician, pulmonary function tests, and blood chemistries. Advance notice was given to workers regarding the visit by the team

of health professionals performing the evaluations and several visits were made to optimize participation. Information on symptoms, pulmonary function, and blood chemistries was collected from the records of these physicals kept by company officials. A total of 108 workers were employed at the plants at the time of the health record review. The records dated from the opening of the plants, through September 1993.

The results of personal environmental sampling conducted at the processing plants were made available. The overall geometric mean (GM) total dust level was 1.0 mg/m^3 ($n=92$). The 2.1 mg/m^3 geometric mean level at Plant B ($n=32$) was significantly higher ($p=0.0002$) than the 0.7 mg/m^3 geometric mean at Plant A ($n=60$). Differences based on job title of worker sampled, month collected and year collected were tested via Analysis of Variance using Scheffe post hoc comparisons. The only significant difference ($p=0.00021$) was between the years of 1989 (GM= 4.4 mg/m^3 , geometric standard deviation (GSD)= 4.5 mg/m^3 , $n=12$) and 1990 (GM= 0.7 mg/m^3 , GSD= 3.1 mg/m^3 , $n=58$).

Reported Symptoms

Information regarding symptoms was abstracted from medical records. Symptoms were documented in three fashions: workers selected symptoms from a checklist of sixty-five symptoms; or they could indicate additional symptoms in freeform; and physicians also recorded comments about symptoms on the medical records. All three provided information for this report.

Pulmonary Function Data

Spirometry was performed by company nurses on the day of each subject's annual examination using a MultiSpiro-SX Pneumotachometer (MultiSpiro Inc., Scottsdale, AZ). No attempt was made to standardize time of examination in relation to start or end of the work shift. Spirometry was performed with the subject standing and no noseclips were used. We reviewed values for all trials for each individual. We abstracted the best observed values for FEV_1 and FVC, and compared them with published predicted values (15). The value for the subject's height used was the average of all values reported in the health record for that individual. A race adjustment factor of 0.85 was used for black workers (16). We chose FEV_1 and FVC because of their known intra-individual consistency. All measurements of FEV_1 and FVC are reported as percent of predicted. Abnormal pulmonary function tests were defined as below 80% of predicted for FEV_1 and FVC, and below 70% for the FEV_1/FVC ratio. Tests that did not meet American Thoracic Society (ATS) repeatability criteria (17) that the two largest tests had to agree within 5% were not included in the data analysis.

Statistics/Data Analysis

The data were entered into Paradox® databases (Borland International, Inc. Scotts Valley, CA) and analyzed with the SYSTAT® statistical analysis program (SYSTAT, Inc. Evanston, IL). Descriptive statistics were used to estimate the means and distribution of data. Normality was discerned through evaluation of skewness and kurtosis values along with graphical comparison with normal probability plots. Inter-plant comparisons of symptom occurrence was performed by Pearson's Chi-square test of

homogeneity. Pairwise comparisons with a null hypothesis of equal means (H_0 : $\text{mean}_1 = \text{mean}_2 = \dots = \text{mean}_k$) were performed for the laboratory and pulmonary function test variables of interest to evaluate differences between various subgroups such as between smokers and non-smokers, Plant A workers and Plant B workers, and years elapsed since initial spirometry. Comparisons between two groups were performed by 2 sample t-tests. Multiple group comparisons were performed via analysis of variance (ANOVA) with Scheffe's test used for post hoc comparisons because of the unequal cell sizes. Multiple correlation coefficients (R) were obtained by multivariate general linear hypothesis (MGLH) to test significance of relationships between pulmonary function test variables and time. A repeated measures ANOVA was used to verify if observed changes over time were significant. A significance level of 0.05 was used in all tests.

Laboratory Data

The hematologic variables we chose to analyze for this study were white blood cell count (WBC) and hematocrit measurements, and neutrophil, monocyte and eosinophil percents. These were chosen because of their availability and because they may reflect trends that could be indicative of diseases such as pulmonary or atopic disease. Normal ranges and abnormal data were defined based upon the laboratory's (Smith-Kline Beecham) criteria. The data appeared to be normally distributed with the exception of the monocyte and eosinophil percents which were log-normally distributed.

RESULTS

Demographics

During the study period the company was in the process of reorganizing its health record filing system so not all records were available for review. A total of 92 employees comprised the study population, and overall the populations of the two plants were similar. Both were predominately male (87%) and white (96%). There were no significant differences between the plant populations regarding age, gender, race or smoking status. Demographic information is presented in Table 1.

Reported Symptoms

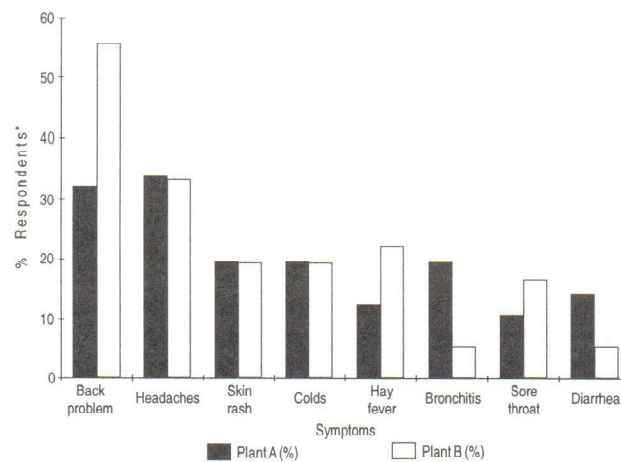
Frequency of symptoms by plant is presented in Figure 1. The data represent the percent of workers who reported the symptom at least once as documented in the medical record (i.e. individual workers were not counted more than once for reporting the same symptom in successive years). The most common symptoms occurring among the workers, both plants taken together, were back problems and headaches. These were followed by skin rashes and colds, then flu, hay fever and ear problems. Next in order of frequency were knee problems, bronchitis and throat problems and diarrhea. The only symptom to differ significantly in occurrence between the plants was that of back problems ($p=0.026$).

Table 1 Demographic data of refuse derived fuel workers

	Plant A (%)	Plant B (%)	Total (%)
Employees, number	56	36	92
Male, number (%)	47 (83.9)	33 (91.7)	80 (87.0)
Female, number (%)	9 (16.1)	3 (8.3)	12 (13.0)
Black, number (%)	2 (3.6)	2 (5.6)	4 (4.4)
White, number (%)	54 (96.4)	34 (94.4)	88 (95.6)
Smokers, number (%)	26 (46.4)	12 (33.3)	38 (41.3)
Non-Smokers*, number (%)	30 (53.6)	24 (66.7)	54 (58.7)
Mean Age (std. dev.)	32.8 (7.0)	34.1 (7.1)	33.5 (7.1)
Range Years Employed in 1993**	0-6 (mean=4.2)	0-7 (mean=5.2)	0-7 (mean=4.6)

*Never smoked and former smokers

**Years employed as reflected by time since first pulmonary function test at plant



* reporting the symptom at least once

Figure 1 Worker symptoms

Pulmonary Function Data

Because of the voluntary nature of worker participation, not all workers consistently participated in the pulmonary spirometry and information was available on a total of 87 workers, 53 from Plant A and 34 from Plant B. Five workers were removed from the data set because they did not have tests that met the ATS repeatability criteria that the two largest tests had to agree within 5% or 100 ml.

Table 2 shows the annual pulmonary function testing information.

Ten workers (all males) had abnormal (less than 80% of predicted) FVC values and nine had abnormal FEV₁ values, five of which had both. There were no differences from workers with normal tests regarding plant of employment, race, or smoking status. Four male and one female workers had abnormal (less than 70% of predicted) FEV₁/FVC tests.

Table 2 Pulmonary function test findings among refuse derived fuel workers

Year	n	FEV ₁ *		FVC*		FEV ₁ /FVC%	
		mean	(SD)	mean	(SD)	mean	(SD)
1986	5	99.4	(9.6)	93.3	(6.1)	88.4	(2.2)
1987	46	100.0	(11.0)	99.2	(11.6)	83.6	(6.6)
1988	46	100.7	(11.9)	96.5	(13.8)	86.4	(6.1)
1989	64	99.8	(11.8)	101.5	(11.3)	81.3	(6.3)
1990	71	99.5	(13.9)	100.3	(13.4)	81.7	(6.4)
1991	72	104.2	(13.5)	105.3	(13.5)	81.7	(5.8)
1992	60	103.3	(11.3)	105.7	(11.3)	80.3	(4.8)
1993	51	103.0	(12.8)	99.1	(11.7)	85.4	(3.9)

*percent of predicted

Comparisons in lung function were made between the following subgroups: blacks and whites, males and females, smokers and non-smokers, Plant A workers and Plant B workers, groups by year of work, groups by years elapsed since initial pft, and job titles. Because of small numbers, black workers were excluded from the data set in all but the black versus white comparison. The comparisons found to be significantly different were a black versus white comparison for both FEV₁ and FVC in 1990, and a smoker versus non-smoker comparison for FEV₁/FVC during four different years. There was also a significant difference between the two plants mean FEV₁/FVC values in 1988 and FEV₁ and FVC mean values in 1990. Information regarding the significant comparisons is presented in Table 3.

Table 3 Pulmonary function data significant comparisons of refuse derived fuel workers

Comparison	Year	Test	P value	Group	Mean
black vs. white (race-adjusted)	1990	FEV ₁ *	0.013	black	75.5
				white	99.5
		FVC*	0.033	black	81.0
				white	99.8
smoker vs. non-smoker	1987	FEV ₁ /FVC**	0.018	non-smoker	85.1
				smoker	80.1
smoker vs. non-smoker	1989	FEV ₁ /FVC	0.010	non-smoker	82.8
				smoker	78.4
smoker vs. non-smoker	1991	FEV ₁ /FVC	0.034	non-smoker	83.1
				smoker	79.6
smoker vs. non-smoker	1993	FEV ₁ /FVC	0.036	non-smoker	86.3
				smoker	83.3
plant A vs. plant B	1988	FEV ₁ /FVC	0.007	plant A	88.9
				plant B	83.8
plant A vs. plant B	1990	FEV ₁	0.025	plant A	103.5
				plant B	95.9
plant A vs. plant B	1990	FVC	0.047	plant A	83.0
				plant B	81.4

*percent of predicted **percent

To look for trends that may occur in the workers over time a subset of workers with pft data that spanned over five years or more was made. There were 36 workers total in this subset, 19 from Plant A and 17 from Plant B. All 36 workers in both groups were male and they had about the same representation of ages, job titles and plant of employment as workers who did not have five years of test data. The values for FEV₁, FVC, and FEV₁/FVC were plotted against year since initial pft for this subset of workers. No significant correlation with time was shown for FEV₁ (R=0.109, p=0.140) or FEV₁/FVC, (R=-0.096, p=0.193). A slight positive correlation with time was shown for FVC (R=0.154, p=0.037). In this subset of workers there were two workers that showed an individual decrease in a pulmonary function test over time, one for FEV₁ (R=-0.948, p=0.014) and one for FEV₁/FVC (R=-0.937, p=0.019). The repeated measures ANOVA confirmed that there was no significant trend for decrease over time for the group as a whole.

Laboratory Data

Laboratory data are shown in Table 4. Comparisons of WBC and hematocrit measurements, and neutrophil, monocyte and eosinophil percents were made between blacks and whites, males and females, smokers and non-smokers, Plant A workers and Plant B workers, job titles and groups by year of exam. The only significant differences in the above stratifications were noted between smokers and non-smokers in the WBC (smoker mean=7.5x10³, non-smoker mean=7.0x10³, p=0.048) measurements, and the neutrophil % (smoker mean=57.19, non-smoker mean=60.3, p=0.004), and eosinophil % (smoker mean=2.3, non-smoker mean=1.9, p=0.01) percents.

Table 4 Laboratory data descriptive statistics

Measurement (units)	# Measurements	Range	Mean	SD
WBC count (thou/cu mm)	293	3.4-14.1	7.2	1.84
Hematocrit (vol. %)	293	36.1-54.8	44.8	3.16
Neutrophil (%)	215	39.5-79.0	58.9	7.85
Monocyte (%)	215	1.2-34.3	6.7	2.52
Eosinophil (%)	215	0.2-15.7	2.2	1.52

DISCUSSION AND CONCLUSIONS

This study was initiated because of reports of excess bronchitis, skin rash, and diarrhea among workers at these two RDF processing plants. The health records, however, showed the primary health problems to be back problems and headaches, followed by skin rashes. Bronchitis was the eighth most often reported symptom and diarrhea was the eleventh. Limited conclusions can be drawn from the reports we

reviewed since no control group was available. The high prevalence of back problems is similar to reports in other industries (6). The difference between the level of concern over bronchitis and diarrhea and their actual frequency may be due the ease with which symptoms such as back problems and headaches can be accepted as a »normal«, non-specific, part of daily life and overlooked.

No decline in pulmonary function results over time was observed for the group as a whole, or for individuals with five or more years of pulmonary function test data. Only two of 36 individuals with more than five years of exposure had a decrease in FEV1. This is comparable to a study of Danish refuse workers which also found no evidence of chronic respiratory effects among resource recovery workers (2). However the study population had a high turnover (50% in one year) because of respiratory symptoms which could create a healthy worker effect. Since the plants in this study had only been in operation for 7 years, most workers may not have had a long enough exposure to exhibit chronic effects. The only apparent trends in the data were for factors unrelated to work – smoking, gender and race.

The out of normal laboratory data did not show any indications of anything that could be readily construed as indicative of trends in the population as a whole and no trends regarding differences between subgroups were noted, except between smokers and non-smokers.

To our knowledge, this is the largest population of refuse processing workers studied to date. Even so, the sample size may have limited our ability to detect adverse health effects in these workers. Our assessment for the three acute problems of interest (bronchitis, skin rash, and diarrhea) was also limited by the nature of the medical information collected although some trends such as respiratory decrements from smoking and incidences of other health complaints among workers were discernible from the health record data. The medical data we analyzed were collected as part of an occupational health surveillance program, not to test specific hypotheses concerning disease. Factors that may have contributed to the great year to year variability seen in the individual pft's include nonstandardization of time of day, day of the week, and season that the test was performed, as well as testing by different personnel. A more systematic collection of the information such as on the morning of the first day of the work week for each worker could allow for trends to emerge that may be masked by unsystematic testing. A cross sectional exposure-response study with a component of cross-shift lung function testing would address these concerns in a systematic fashion.

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Sažetak

UČESTALOST SUBJEKTIVNIH SIMPTOMA I NEKIH OBJEKTIVNIH NALAZA U RADNIKA ZAPOSLENIH NA PRERADI KRUTOG OTPADA U SEKUNDARNI OTPAD

Istraživanje je provedeno u dva pogona za preradu krutog otpada, prikupljanog iz velikog urbanog područja, u sekundarni otpad. U pogonu koji je u funkciji od 1988. proizvodi se 400-500 tona, a u nešto starijem (u funkciji od 1986.) 800-900 tona takvog otpada na dan. U otpadu za preradu, sastav kojeg varira ovisno o tome što se odlaže, dominiraju papir i kartonski proizvodi. Ti materijali uz druge organske materijale poput dvorišnog otpada, predmeta

od plastike i ostataka hrane čine energetska vrijednost proizvedenog sekundarnog otpada. Pregledom koji je bio usmjeren na respiratorne smetnje, kožne iritacije, probavne poremećaje te neke moguće kronične učinke obuhvaćena su 92 radnika koji su se odazvali ispitivanju (od ukupno 108 zaposlenih). Forsirani ekspiratorni volumeni (FEV₁ i FVK) u radnika s pet i više godina izloženosti nisu pokazali tendenciju smanjenja u odnosu na očekivane vrijednosti. Među registriranim smetnjama izdvajaju se bol u križima, glavobolje, slijede zatim kožni osipi, prehlade, influenza, hunjavica. Autori ističu da je mogućnost sigurnijeg zaključivanja o zdravstvenim rizicima bila ograničena činjenicom da ispitivanje nije provedeno uporabom standardiziranog protokola te da je nedostajala kontrolna skupina. Rezultati ipak upućuju na to da ovoj vrsti profesionalne aktivnosti treba obratiti potrebnu pozornost kako u ocjeni izloženosti tako i u epidemiološkim istraživanjima.

Ključne riječi:

aerogene prašine, bronhitis, izloženost sekundarnom otpadu, kožni osip, promjene plućne funkcije

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