International Journal of Occupational Medicine and Environmental Health 2009;22(1):35–41
DOI 10.2478/v10001-009-0007-6

EFFECT OF DURATION OF EXPOSURE TO POLLUTED AIR ENVIRONMENT ON LUNG FUNCTION IN SUBJECTS EXPOSED TO CRUDE OIL SPILL INTO SEA WATER

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Abstract
Background: Oil spill in sea water represents a huge environmental disaster for marine life and humans in the vicinity. The aim was to investigate the effect of duration of exposure to polluted air environment on lung function in subjects exposed to crude oil spill into sea water. **Material and Methods:** The present study was conducted under the supervision of Department of Physiology, College of Medicine, King Khalid University Hospital, King Saud University, Riyadh, Saudi Arabia, during the period July 2003 – December 2004. This was a comparative study of spirometry in 31 apparently healthy, non smoking, male workers, exposed to crude oil spill environment during the oil cleaning operation. The exposed group was matched with similar number of male, non smoking control subjects. Pulmonary function test was performed by using an electronic spirometer. **Results:** Subjects exposed to polluted air for periods longer than 15 days showed a significant reduction in Forced Vital Capacity (FVC), Forced Expiratory Volume in First Second (FEV_1), Forced Expiratory Flow in 25–25% ($FEF_{25–75\%}$) and Maximal Voluntary Ventilation (MVV). **Conclusion:** Air environment polluted due to crude oil spill into sea water caused impaired lung function and this impairment was associated with dose response effect of duration of exposure to air polluted by crude oil spill into sea water.

Key words:
Lung function, Oil spill, Crude oil, Tasman Spirit

INTRODUCTION

The sea ports are the most productive and populated spots on the planet but, unfortunately, their environments have been exposed to a series of natural disasters, such as Tsunami, and man-evoked hazards like oil spills.

Oil spills at sea is a major marine environmental pollution issue around the world. During the transportation of crude oil, some major oil spill accidents have been recorded [1–5]. A Greek oil tanker, the Tasman Spirit, carrying approximately 67 535 tons of crude oil ran aground in

Received: October 15, 2008. Accepted: January 21, 2009.
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the channel of Karachi port and hull damage which ruptured the tanker resulted in a major oil spill into the sea at the coastal area of Karachi, Pakistan. Over the next week, an estimated 28 000 tons of crude oil spilled into the sea and started coming ashore.

The air pollution was caused by approximately 11 000 tones of volatile organic compounds released into the air after the spillage. The polluted air contained volatile organic compounds at concentrations ranging from 44 ppm to 179 ppm sampled at various surrounding areas of the city.

The pungent odor was reported, while the vapor was perceptible at a distance of about 2–4 km from the beach area [6]. Crude oil is a combination of various chemical compounds, composed mainly of para-phenol aromatic hydrocarbons [7–8]. The aromatic hydrocarbons of toxicological interest are benzene, alkyl benzene and polycyclic aromatic hydrocarbons (PAH) [9].

The solubility and concentration of the aromatic hydrocarbons was higher in blood and low in brain, liver and kidney, with a tendency to accumulate in adipose tissues [10]. Crude oil spillage in the sea is considered to pose major health hazards, with symptoms including cough, shortness of breath, sore throat, runny nose, asthmatic attacks, redness of eyes, nausea, vomiting, abdominal pain, diarrhoea, headache, dizziness, back and leg pain [2,11,12]. Reports on the effects of duration of exposure to crude oil spill on lung function are not available. Therefore, the aim of this work was to investigate the effect of duration of exposure to polluted air environment on lung function in subjects exposed to crude oil spill into sea water in order to make occupational, environmental and marine pollution health officials aware of the gravity of the related health problems.

MATERIAL AND METHODS

The present study was conducted under the supervision of Department of Physiology, College of Medicine, King Khalid University Hospital, King Saud University, Riyadh, Saudi Arabia, during July 2003 – December 2004. The Institutional ethical committee approval was obtained in compliance with regulation of our institution and generally accepted guidelines governing such work.

Subjects

This study was commissioned immediate after the incident; the investigator visited the coastal areas of Karachi, Pakistan, and observed the situation and interviewed approximately 115 subjects who were engaged in oil cleaning operation at the coastal area. All participants were interviewed on their job, smoking status, and tobacco or betelnut chewing habit. After the initial interview, 31 apparently healthy male workers were selected. The main reason for the selection of 31 subjects out of 115 candidates was that the majority of the workers engaged by the administration of the Karachi city to clean the sea site from oil were employees of Karachi Municipal Corporation (KMC). The KMC workers were exposed to dust when performing their usual street and road cleaning jobs, while dust is known to impair lung function [13]. Therefore, KMC workers were excluded from the study. The reason for exclusion of a few different candidates was that they were already exposed to pollutants in cement [14], welding [15] and wood [16] industries that might impair lung function. Some other candidates refused to participate in the present study because they were afraid they could be forced to retire from their current jobs if their lung functions were found to be impaired. However, after the workers had been assured that such types of studies were to their benefit, they agreed to participate in the study. Therefore, we were able to recruit only 31 subjects in each group for lung function test.

These workers were engaged in oil cleaning operation for at least 8–10 hours a day, six days per week, using self-made protective masks (a piece of cloth to cover nose and mouth). The control group was selected in a similar way. Approximately 80 subjects were interviewed and finally 31 matched healthy men were selected. The control group comprised clerical staff, shopkeepers and salesmen who lived about 15–20 kilometers away from the affected coastal site. All subjects were individually matched for age, height, weight and socioeconomic status. A written questionnaire including anthropometric data was answered.

Exclusion criteria

Subjects with clinical abnormalities of the vertebral column and thorax, neuromuscular diseases, known cases of gross anemia, diabetes mellitus, pulmonary tuberculosis, bronchial asthma, chronic bronchitis, bronchiectasis, emphysema and malignancy were excluded from the study. Drug addicts, cigarette smokers, tobacco chewers and those who had undergone abdominal or chest surgery as well as subjects exposed to any industry which generated smoke and dust and subjects currently or formerly employed at petrol pumps or gas stations were also excluded from the study [17].

Lung Function test (Spirometry) Protocol

Spirometry was performed on an electronic spirometer (Compact Vitalograph, UK). All pulmonary function tests were carried out at a fixed time of the day (9.00–13.00 hours) to minimize the diurnal variation. The apparatus was calibrated daily and operated within the ambient temperature range of 20–25°C. The precise technique used in the measurement of the various lung function tests for the present study were based on the operation manual of the instrument with special reference to the official statement of the American Thoracic Society of Standardization of Spirometry [18]. After a detailed history and anthropometric data had been taken, the subjects were informed about the whole procedure. They were encouraged to practice this procedure before doing the pulmonary function test. The test was performed with the subject in the standing position without using a nose clip. The test was repeated three times after adequate rest and the results were recorded.

Statistical analysis

Statistical analysis was conducted using a paired t-test (two-tailed). The level of statistical significance was established at $p < 0.05$.

RESULTS

The results are presented in overall group and according to the duration of exposure to crude oil spill in sea water (less than 8, 8–15 and more than 15 days). In Tables 1–4, the formal statistical comparisons of the 'matching' variables (age, height, and weight) were similar for the two groups and hence, statistical confirmation of this fact is not discussed.

Overall group results

Overall anthropometric and lung function data for subjects exposed to crude oil spill and their matched controls are shown in Table 1. The exposed group had statistically

Table 1. Comparison of anthropometric and lung function parameters between subjects exposed to crude oil spill and their matched controls

Parameters	Subjects exposed to crude oil (mean ±SEM) (n = 31)	Control Subjects (mean ±SEM) (n = 31)	Percentage change	Significance level
Age (year)	30.03±1.24	28.96±1.30	–3.69	NS
Height (cm)	172.03±0.93	172.25±1.02	+0.12	NS
Weight (kg)	65.67±1.50	67.48±1.62	+2.68	NS
FVC (l)	3.82±0.10	4.67±0.11	+18.20	p = 0.001
FEV_1 (l)	2.94±0.13	3.58±0.07	+17.87	p = 0.001
FEV_1/FVC (%)	76.51±2.32	77.8±1.70	+1.65	NS
PEF (l/min)	417.70±25.01	425.48±22.29	+1.82	NS
$FEF_{25–75\%}$ (l/s)	2.92±0.21	3.87±0.22	+24.54	p = 0.002
MVV (l/min)	110.38±4.74	134.61±2.88	+18.00	p = 0.001

NS — Non-significant.

Table 2. Anthropometric and lung function data for subjects exposed to crude oil spill for less than 8 days compared to their matched controls

Parameters	Subjects exposed to crude oil (mean ±SEM) (n = 8)	Control Subjects (mean ±SEM) (n=8)	Percentage change	Significance level
Age (year)	33.25±3.45	33.00±3.76	–0.75	NS
Height (cm)	174.12±1.77	172.75±1.93	–0.79	NS
Weight (kg)	70.05±2.97	70.50±3.08	+0.63	NS
FVC (l)	3.95±0.14	4.71±0.19	+16.13	p = 0.001
FEV_1 (l)	3.07±0.17	3.51±0.16	+12.53	NS
FEV_1/FVC (%)	77.37±2.96	74.62±2.03	–3.68	NS
PEF (l/min)	426±28.97	395±31.31	–7.84	NS
$FEF_{25–75\%}$ (l/s)	2.91±0.38	3.58±0.39	+18.71	NS
MVV (l/min)	115.25±6.47	132±6.02	+12.68	NS

NS — Non-significant.

Table 3. Anthropometric and lung function data for subjects exposed to crude oil spill for 8–15 days compared to their matched controls

Parameters	Subjects exposed to crude oil (mean ±SEM) (n = 9)	Control Subjects (mean ±SEM) (n = 9)	Percentage change	Significance level
Age (year)	29.77±1.89	29.55±1.84	–0.74	NS
Height (cm)	172.22±1.77	171.22±2.11	–0.58	NS
Weight (kg)	66.11±1.96	66.89±3.18	+1.16	NS
FVC (l)	3.94±0.25	4.53±0.16	+13.02	p = 0.05
FEV_1 (l)	2.92±0.26	3.43±0.13	+14.86	NS
FEV_1/FVC (%)	74.33±0.30	76.22±3.52	+2.47	NS
PEF (l/min)	420.11±55.61	383±39.16	–9.68	NS
$FEF_{25–75\%}$ (l/s)	2.94±0.54	3.79±0.33	+22.42	NS
MVV (l/min)	109.88±10.10	128.77±5.27	+14.66	NS

NS — Non-significant.

significant reductions in Forced Vital Capacity (FVC), Forced Expiratory Volume in First Second (FEV_1), Forced Expiratory Flow in 25–25% ($FEF_{25–75\%}$) and Maximal Voluntary Ventilation (MVV). However, the mean values for Forced Expiratory Ratio (FEV_1/FVC%) and Peak Expiratory Flow (PEF) were not significantly different. The mean duration of exposure in subjects exposed to crude oil spill was 13.06±0.90 days (mean ±SEM), range 1–17 days. The percentage change (average difference between subjects exposed to crude oil spill and control subjects) is also shown in Tables 1–4.

Duration of exposure less than 8 days

Table 2 summarizes the comparison of the anthropometric and lung function parameters between subjects exposed to crude oil spill for less than 8 days compared with their matched controls. There was a significant difference for FVC, in exposed group. However, there were no

Table 4. Anthropometric and lung function data for subjects exposed to crude oil spill for more than 15 days compared to their matched controls

Parameters	Subjects exposed to crude oil (mean ±SEM) (n = 14)	Control Subjects (mean ±SEM) (n = 14)	Percentage change	Significance level
Age (year)	28.35±1.45	28.50±1.56	+0.52	NS
Height (cm)	170.71±1.40	172.64±1.52	+1.11	NS
Weight (kg)	62.64±2.35	66.14±2.44	+5.29	NS
FVC (l)	3.66±0.13	4.74±0.22	+22.78	$p = 0.001$
FEV_1 (l)	2.87±0.20	3.72±0.10	+22.84	$p = 0.001$
FEV_1/FVC (%)	77.42±3.66	79.92±2.77	+3.12	NS
PEF (l/min)	411.50±41.32	469.71±36.78	+12.39	NS
$FEF_{25-75\%}$ (l/s)	2.91±0.28	4.09±0.39	+28.85	$p = 0.02$
MVV (l/min)	107.92±7.74	139.85±4.01	+22.83	$p = 0.002$

NS — Non-significant.

significant differences in FEV_1, FEV_1/FVC%, $FEF_{25-75\%}$, PEF and MVV data relative to controls. The mean duration of exposure in this group was 5.25±0.70 days, range 3–7 days.

Duration of exposure 8–15 days

Table 3 shows the comparison of the anthropometric and lung function parameters between subjects exposed to crude oil spill for 8–15 days compared to their matched controls. There was a significant decline for FVC, in exposed group. While the FEV_1 was 16% less, this difference was not statistically significant. There were no significant differences in FEV_1/FVC%, $FEF_{25-75\%}$, PEF and MVV data relative to controls. The mean duration of exposure in exposed group was 14±1.01 days, range 8–15 days.

Duration of exposure more than 15 days

Table 4 demonstrates the comparison of the anthropometric and lung function parameters between subjects exposed to crude oil spill for more than 15 days compared to their matched controls. There was a significant decline for FVC, FEV_1, $FEF_{25-75\%}$, and MVV in exposed group. However, there were no significant differences in FEV_1/FVC%, and PEF data relative to controls. The mean duration of exposure in exposed group was 16.71±0.12 days, range 16–17 days.

DISCUSSION

A major oil spill in sea water represents a huge environmental disaster for marine life and humans in the vicinity. The present study was designed to quantify resulting abnormalities in lung function in subjects exposed to crude oil spill into sea water as compared to their matched control. The present study is the continuation of our studies on oil spill; in the previous study Meo et al. [17] reported that the subjects exposed to polluted air environment due to oil spill had impaired lung function and the impairment was reversible. The lung functions parameters were improved when the subjects were withdrawn from the polluted air environment.

However, the present study demonstrates a dose-response effect and shows that prolonged exposure to crude oil markedly decreased the pulmonary function and subjects who were exposed to crude oil for more than 15 days showed a significant reduction in FVC, FEV_1, $FEF_{25-75\%}$ and MVV relative to their matched controls. Kesavachandran et al. [19] showed that the lung function parameters (FVC and FEV_1) were decreased among petrol pump workers when compared to predicted value and also related to duration of exposure. They also showed that the reduced mechanical characteristics of breathing due to exposure to benzene in the vapours of petrol might result in respiratory impairment.

Similarly, Lees [20] demonstrated that workers exposed to vanadium compounds (a component of crude oil) during cleaning of boilers developed acute changes in lung function. In spite of the fact that the workers wore respirators, the changes in lung function appeared within 24 hours and pre-exposure levels were not regained as long as by the eighth day post exposure.

In addition, Elliott et al. [21] demonstrated that exposure to a volatile organic compound, 1,4-Dicholorobenzene (1,4-DCB), was associated with reductions in lung function parameters, and forced expiratory volume in first second (FEV_1) and Maximum mid expiratory flow rate (MMEFR) (often known as the $FEF_{25–75\%}$) in particular. Interestingly, higher levels of 1,4-DCB were associated with reduced lung function. The present study also found no significant difference in PEF but did find both significant differences and a dose response effect in FVC, FEV_1, $FEF_{25–75\%}$ and MVV in subjects exposed to crude oil spill cleaning operation compared to their matched controls.

This study attempts to minimize confounding factors by using matched controls, excluding smokers, workers with a history of occupational exposure, while the workplace exposure environment was approximately similar for all exposed subjects. The subjects were also matched for age, height, weight and socioeconomic status. To our best knowledge, this is the first matched comparative study to investigate the effect of duration of exposure to oil spill on lung function in subjects involved in clean-up operations following a massive oil spill compared to their matched control. This study has some limitations that need to be considered: First, we were able to recruit only a limited number of subjects (31 for lung function parameters) because of bad smell of crude oil, general harassment in the community, workers refusing to collaborate, rapid shift change among the workers and a large number of people who were temporarily shifted to other areas of the city. Second, the majority of the workers engaged by the administration of the Karachi city at the sea site and at oil cleaning process were employees of Karachi Municipal Corporation (KMC). The KMC workers were already exposed to dust while cleaning the streets and roads; dust is one of the known factors which impair the lung function [13]. Therefore, KMC workers were excluded from the study. Third, the workers were not willing to participate in the present study because they thought that they might they could be forced to retire from their current jobs if their lung functions were found to be impaired. However, after the workers had been assured that such types of studies were slowly to their benefit, they agreed to participate in the study. Therefore, we were able to recruit only 31 subjects in each group for lung function test (Table 1–4).

CONCLUSION

Exposure to crude oil spill adversely affects the lung function parameters (FVC, FEV_1, $FEF_{25–75\%}$, and MVV) and this impairment is associated with dose-effect response to duration of exposure to crude oil. It is suggested that protective measures, such as wearing apron, hand gloves, long shoes, and appropriate respiratory protective equipment should be provided to workers engaged in oil clean up operations; the workers should undergo pre-employment and periodic spirometry tests. These measures will help to identify susceptible workers so that they can take additional preventive measures. Besides, national/international concerned communities and officials should take suitable steps to prevent such types of environmental disasters and avoid adverse short- and long-term effects on human health.

ACKNOWLEDGEMENT

This work was supported by grant 03-459, College of Medicine Research Centre, KSU, Riyadh, KSA. We express our gratitude to Director CMRC for availability of funding and thank Dr Romina Qureshi, Mr. Nadir, AKU, Captain Ulfat Rasool and Captain Ahmed for their help during collection of data. We also thank to Prof. Allan L. Coates, Division of Respiratory Medicine, University of Toronto, Canada, for critical review of the manuscript. No conflict of interest with any institution/organization. Institutional approval was obtained.

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