Work-Related Health Effects among Wastewater Treatment Plants Workers

MA Al-Batanony¹, MK El-Shafie²

Abstract

Background: Raw sewage contains various pathogenic organisms including bacteria, viruses, fungus, worms and protozoa. Workers at wastewater treatment plants (WWTPs) are exposed to these organisms as well as to H₂S gas causing many health hazards.

Objectives: To assess some work-related health effects among WWTPs workers with special emphasis on the most common infections as well as cardiopulmonary disorders.

Methods: 43 workers at Berket Al-Sabih WWTPs were studied. An equal number of non-exposed comparison group were also studied. All participants were asked about their personal demographic data, symptoms suggesting infection, respiratory tract impairment and cardiovascular manifestations. Spirometric measurements were made at the end of the work shift. A resting standard 12-lead ECG was also taken for each participant. For those with a positive ECG finding, echocardiography was also performed. Serum examination for antibodies against hepatitis A virus (HAV) and hepatitis E virus (HEV) was also done. A heparinized blood sample to measure sulf-hemoglobin, as an indicator of H₂S exposure, was taken. Stool was analyzed by polymerase chain reaction (PCR) for Leptospira spirochete.

Results: WWTPs workers suffered from body ache, abdominal pain, wheeze, asthma and dyspnea more frequently than the comparison group (p<0.05). An obstructive pattern of pulmonary function impairment and a higher mean sulf-hemoglobin% were significantly more common among WWTPs workers than the comparison group. Antibody levels against HAV and HEV as well as frequency of positive/stool PCR test results for L. spirochete were significantly higher among WWTPs workers than the comparison group. The prevalence of left ventricular hypertrophy (LVH) according to ECG and mean ejection fraction (EF) as measured by echocardiography were significantly more frequent in WWTPs workers than in the comparison group.

Conclusion: WWTPs workers are high risk of developing various infections and cardiopulmonary diseases.

Keywords: Wastewater; Hepatitis A virus; Hepatitis E virus; Hydrogen sulfide; Cardiopulmonary

Introduction

Raw sewage contains numerous pathogenic organisms including bacteria, viruses, fungus, worms and protozoa.¹ Workers at wastewater treatment plants (WWTPs) are exposed to these organisms primarily by hand-to-mouth contact, or the fecal-oral route during eating, drinking or smoking, or by touching the face with contaminated hands. Mucous membranes contamination (as in eyes and nose) may also exist. Inhalation of aerosols containing microorganisms is a less-common route of entry.² An increased risk for developing air-

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way symptoms (as chronic bronchitis and toxic pneumonitis),
central nervous system symptoms (headache and tiredness),
acute non-specific self-limited gastrointestinal symptoms (jaundice and abdominal pain), and eye irritation symptoms (conjunctivitis) were reported. These symptoms may be attributed to exposure to harmful gases such as hydrogen sulfide (H₂S), methane and some air-borne bacteria.

Obstructive type pulmonary impairment and cardiovascular problems such as hemodynamic instability, hypertension, ischemic changes also reported.

In these worker antibody level against both HAV and HEV was significantly higher compared to the comparison group.

Hepatitis A virus (HAV) is considered by some authors as an occupational hazard in WWTPs although the incidence rate is low, as it can be stable at room temperature for up to three months.

Rodents usually live in underground sewers and are carriers of leptospira. Since their urine contaminates these sewers, workers at WWTPs are potentially at risk of leptospirosis.

Ischemic changes, arrhythmias as well as hemodynamic instability in the form of hypertension were reported as a common cardiovascular disorders among sewage workers. Respiratory manifestations as well as changes in the pulmonary functions (obstructive and restrictive types) were also reported.

Considering these hazards, we therefore conducted this study to determine the prevalence of certain infections as well as cardiopulmonary disorders among WWTPs workers.

Materials and Methods

This study was carried out on 43 workers at Berket Al-Sabih WWTPs (group A) with mean±SD age of 47.1±3.7 years and an equal number of non-exposed comparable workers working at different departments of faculty of Commerce who served as the comparison group (group B) with mean±SD age of 48.2±2.4 years. Both groups were matched for age, socio-economic status, educational level and smoking habit. Exclusion criteria included past history of neurological and mental diseases and those on medication with antipsychotic or anti-asthmatic drugs.

The Menoufiya Faculty of Medicine Committee for Medical Research Ethics reviewed and formally approved the study before it began. An informed consent was taken from each subject after the purpose of the study was explained to them. Standard ethical considerations were followed during the study, with total confidentiality of any obtained data.

Each subject was personally interviewed for 15 minutes. All participants were asked about their personal demographic data, detailed occupational his-
tory (current and previous occupations, mean hours of the daily work, number of
days worked per week, and the use of per-
sonal protective devices), smoking habit
and smoking index (number of cigarettes/
day × years of smoking), symptoms sug-

gest infection, respiratory tract impair-
ment and cardiovascular affection. The

collected data were inserted in a pre-de-

signed datasheet.

All participants were also underwent
spirometric examinations using a por-

table computerized spirometer (Spirolab
II) at the end of the work shift. The mea-
sured parameters were forced vital capac-
ity (FVC), forced expiratory volume in the
first second (FEV1), FEV1/FVC%, and peak
expiratory flow (PEF%). Each spirometric

test was repeated three times to allow the
choice of the best values, according to the
American Thoracic Society criteria. Each spirometric

test was repeated three times to allow the
choice of the best values, according to the
American Thoracic Society criteria.16

Echocardiography

was done for those with a positive finding
in their ECG.

Viral hepatitis:

Five mL blood was withdrawn from each
participant; 4 mL of the blood was pipet-
ted into a plain tube, let to stand for 15 min
and centrifuged for 5 min at 4000 rpm. Serum was then divided into aliquots and
kept frozen at -80 °C until analysis of anti-

body against HAV and hepatitis E virus
(HEV) by quantitative sandwich enzyme-

linked immunosorbent assay (ELISA).18

Exposure to H2S:

The remaining 1 mL blood was put into a
heparinized tube for measurement of sulf-

hemoglobin, as an indicator of H2S expo-

sure, within one hour of collection. This

method is based on the fact that the mole-
cules HbO2 and SHb have a maximum ab-
sorption at 620 nm. HbO2 will disappear

Table 1: Age, anthropometric measurements and vital signs among the studied groups.
Values are mean±SD.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Wastewater treatment plants (WWTPs) workers (n=43)</th>
<th>Comparison group (n=43)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>47.14±3.65</td>
<td>48.23±2.37</td>
<td>NS*</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>74.84±7.21</td>
<td>72.31±6.58</td>
<td>NS</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170.3±5.37</td>
<td>171.92±6.48</td>
<td>NS</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>26.64±1.68</td>
<td>25.96±2.09</td>
<td>NS</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>122.60±11.47</td>
<td>120.36±12.95</td>
<td>NS</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm Hg)</td>
<td>77.81±7.82</td>
<td>76.54±8.04</td>
<td>NS</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>69.64±3.91</td>
<td>72.33±3.84</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

*NS: Not significant

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when a solution of KCN is added but SHb will still remain in the solution.¹⁹

**Leptospirosis:**

Stool analysis for detection of *Leptospira spirochete* by polymerase chain reaction (PCR) was done for all participants. Stool (180 mg) was collected and kept frozen until analysis.

Total DNA was extracted from stool using the QIA amp DNA Stool Mini Kit in which a special protocol is provided for isolating DNA by three steps—lysis of stool samples in buffer ASL, adsorption of impurities to inhibin EX matrix, and purification of DNA on QIA amp Mini Spin columns. DNA yields are measured by absorbance at 620 nm.

**PCR:**

PCR reaction was done by using 10 ng DNA and PCR master mix which contained 10 mmol tris HCl (pH 8.3), 2.3 unit of Taq polymerase, 100 nmol deoxynucleotides, and 100 nmol of each primer with the following sequences:

Forward: 5´-CAGCCTCTTGAGTAGCTGG-3´, reverse: 5´-TCAGGAGTTCGAGCCAGC-3´.

The reaction was performed for 40 cycles at 95 °C for 1 min, followed by 55 °C for 1 min and 72 °C for 2 min and one final cycle of extension at 72 °C for 10 min. The amplification products were separated by electrophoresis on 2% agarose gel stained with ethidium bromide and visualized by UV transillumination. Fragment sizes were 113 bp (Fig 1).²⁰

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**Table 2:** Prevalence of smoking, infection, respiratory and cardiovascular symptoms among the studied groups.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>WWTPs workers n(%)</th>
<th>Comparison group n(%)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smokers</td>
<td>19 (44)</td>
<td>16 (37)</td>
<td>NS*</td>
</tr>
<tr>
<td>Mean±SD smoking index</td>
<td>157.3±45.7</td>
<td>144.31±31.84</td>
<td>NS</td>
</tr>
<tr>
<td>Infection manifestations:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fever</td>
<td>14 (33)</td>
<td>8 (19)</td>
<td>NS</td>
</tr>
<tr>
<td>Body ache</td>
<td>13 (30)</td>
<td>3 (7)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Abdominal pain</td>
<td>21 (49)</td>
<td>9 (21)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Headache and dizziness</td>
<td>8 (19)</td>
<td>4 (9)</td>
<td>NS</td>
</tr>
<tr>
<td>Respiratory manifestations:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persistent cough</td>
<td>8 (19)</td>
<td>8 (19)</td>
<td>NS</td>
</tr>
<tr>
<td>Persistent phlegm</td>
<td>7 (16)</td>
<td>4 (9)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Wheeze</td>
<td>13 (30)</td>
<td>3 (7)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Asthma</td>
<td>8 (19)</td>
<td>2 (5)</td>
<td>NS</td>
</tr>
<tr>
<td>Breathlessness</td>
<td>4 (9)</td>
<td>2 (5)</td>
<td>NS</td>
</tr>
<tr>
<td>Cardiovascular manifestations:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anginal pain</td>
<td>2 (5)</td>
<td>1 (2)</td>
<td>NS</td>
</tr>
<tr>
<td>Atypical chest pain</td>
<td>5 (12)</td>
<td>1 (2)</td>
<td>NS</td>
</tr>
<tr>
<td>Dyspnea</td>
<td>13 (30)</td>
<td>4 (9)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Palpitation</td>
<td>3 (7)</td>
<td>2 (5)</td>
<td>NS</td>
</tr>
</tbody>
</table>

*NS: Not significant
Results

There was a significant decrease in the mean value of heart rate among WWTPs workers than the comparison group (Table 1). Body ache and abdominal pain was significantly more prevalent among WWTPs workers when compared to the comparison group for cardiopulmonary manifestations, presence of wheeze, asthma and dyspnea (Table 2).

The mean value of both FEV₁% and PEF% of predicted values was significantly lower in WWTPs workers when compared to the comparison group (Table 3). The mean sulf-hemoglobin% was significantly higher among WWTPs workers than in the comparison group (p<0.001).

Antibody levels against HAV and HEV as well as the frequency of positive stool PCR results for L. spirochete were significantly higher in WWTPs workers than in the comparison group (Table 4).

The prevalence of LVH according to ECG, and the mean ejection fraction (EF) as measured by echocardiography were significantly higher in WWTPs workers than in the comparison group.

Discussion

Raw sewage and wastewater contain many pathogenic organisms including bacteria, fungi, parasites, worms, protozoa, viruses and gases which can cause several diseases. We found that the prevalence of abdominal pain followed by body ache (as a probable manifestation of infection) was significantly higher among WWTPs

Table 3: Spirometric measurements and sulf-hemoglobin%. Values are mean±SD.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>WWTPs workers (n=43)</th>
<th>Comparison group (n=43)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC (% of predicted)</td>
<td>85.85±9.43</td>
<td>87.65±9.07</td>
<td>NS</td>
</tr>
<tr>
<td>FEV₁ (% of predicted)</td>
<td>83.43±7.93</td>
<td>86.06±6.04</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>FEV₁/FVC%</td>
<td>113.72±6.91</td>
<td>115.37±7.74</td>
<td>NS</td>
</tr>
<tr>
<td>PEF (% of predicted)</td>
<td>97.62±6.08</td>
<td>99.84±7.66</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Sulf-hemoglobin%</td>
<td>0.41±0.13</td>
<td>0.08±0.02</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Figure 1: PCR results: Lanes 1, 3, 4 represent positive samples for leptospirosis. Lanes 2, 5 represent negative samples.
workers than the comparison group. Although smoking was reported as a cause of abdominal pain, we found no significant difference between WWTPs workers and the comparison group. The frequency of positive stool PCR test for *L. spirochete* was significantly higher among WWTPs workers than the comparison group. This finding is in agreement with other reports which reported that leptospirosis considered an occupational disease among sewage, agriculture and animal slaughtering workers who all are presented with fever, abdominal pain and body ache.7,21,22

We also found that the antibody level against both HAV and HEV was significantly higher among WWTPs workers than the comparison group. This finding is in agreement with other reports which reported that leptospirosis considered an occupational disease among sewage, agriculture and animal slaughtering workers who all are presented with fever, abdominal pain and body ache.7,21,22

We also found that the antibody level against both HAV and HEV was significantly higher among WWTPs workers than the comparison group. This finding is in agreement with other reports which revealed that HAV and HEV were significantly more prevalent among workers occupationally exposed to sewage and reported a high prevalence of abdominal pain and body ache among them.9,23

The most frequent and significant respiratory manifestations observed among WWTPs workers was wheeze followed by asthma. Dyspnea was the most prevalent and significant cardiovascular manifestation resembling acute respiratory distress syndrome which is in agreement with other reports.13,24,25 Dyspnea may be attributed to the exposure to H₂S which is the most characteristic gas exposure for WWTPs workers. H₂S is an irritant even at low concentrations and can cause asphyxia after massive exposure.13,26,27 WWTPs workers had a significantly lower heart rate than the comparison group. This observation was in accord to findings of another study who revealed that this finding may be due to heavy physical load and/or exposure to H₂S.28

WWTPs workers had reduction in both FEV₁ and PEF compared to the comparison group. This observation is in parallel with another report.29 The observed pattern is matched well with an obstructive type pulmonary impairment which may be caused by endotoxins, H₂S and some air-borne bacteria which can induce an immunological reaction. This finding is in concordance with other studies.13,30,31

The mean sulf-hemoglobin% observed was significantly higher among WWTPs workers compared to the comparison group. The mean sulf-hemoglobin% observed was significantly higher among WWTPs workers compared to the comparison group. The mean sulf-hemoglobin% observed was significantly higher among WWTPs workers compared to the comparison group.

### Table 4: Distribution of HAV antibodies, HEV antibodies, stool PCR test results, ECG and echocardiographic findings among the studied groups.

<table>
<thead>
<tr>
<th>Investigations</th>
<th>WWTPs workers n(%)</th>
<th>Comparison group n(%)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAV⁺</td>
<td>28 (65)</td>
<td>11 (26)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HEV⁺</td>
<td>22 (51)</td>
<td>13 (30)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>PCR for <em>L. spirochete</em></td>
<td>19 (44)</td>
<td>5 (12)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ECG:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ischemic changes</td>
<td>7 (16)</td>
<td>2 (5)</td>
<td>NS</td>
</tr>
<tr>
<td>LVH</td>
<td>9 (21)</td>
<td>1 (2)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Echocardiography (n=12)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean±SD EF</td>
<td>64.5±2.99</td>
<td>57.62±9.16</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Mean±SD FS</td>
<td>32.0±1.49</td>
<td>28.63±7.76</td>
<td>NS</td>
</tr>
</tbody>
</table>
group. H₂S interacts with hemoglobin to produce sulf-hemoglobin the level of which is normally near zero and its presence reflects the level of exposure.²⁶⁻¹³

By ECG, LVH was diagnosed in 20% of studied WWTPs workers; the prevalence was significantly higher than that observed in the comparison group. Although hypertension is an important cause of LVH,³² the prevalence of hypertension among WWTPs workers was not significantly different from that among the comparison group. LVH may be attributed to the possible hemodynamic instability with episodes of elevated blood pressure resulting from exposure to H₂S and/or heavy physical work load.¹³,²⁶,³³

We performed echocardiography in only those with abnormal ECG findings (n=12) and found a higher mean EF among WWTPs workers compared to the comparison group. This finding is in keeping with other studies.²⁶,³⁴,³⁵ Higher EF observed among WWTPs workers may be due to their chronic exposure to H₂S (which is irritant) and other noxious chemicals existing in WWTPs, with possible consequent inflammatory vascular reactions.²⁶,³⁴,³⁵

WWTPs workers are at risk of developing an array of diseases. To prevent work-related infectious diseases, more emphasis should be put on use of sanitary measures as well as employing protective means appropriate for the environment. Proper use of disinfectants along with use of personal protective devices as liquid-proof gloves, boots and eye/face protection are critical. Complete recording system for pre-employment, pre-placement and periodic medical examinations should be established. Measurement of sulf-hemoglobin, pulmonary function test, ECG and, if needed, echocardiography should be done periodically. Vaccination of all WWTPs workers against HAV is also needed.

This study has some limitations. Echocardiographic examination was only performed for those with abnormal ECG and we are not completely sure that those with normal ECG had normal echography if they would have examined. It was a cross-sectional study and further examination of variables needs larger cohort studies.

Conflicts of Interest: None declared.

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