

# Work-Related Health Effects among Wastewater Treatment Plants Workers

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## 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 H<sub>2</sub>S 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 H<sub>2</sub>S 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.<sup>1</sup> 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.<sup>2</sup>

An increased risk for developing air-

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**TAKE-HOME MESSAGE**

- Wastewater treatment plants (WWTPs) workers are exposed to various pathogenic organisms including bacteria, viruses, fungus, worms and protozoa.
- Inhalation of aerosols containing microorganisms is a less-common route of entry.
- WWTPs developed various disease conditions such as chronic bronchitis, toxic pneumonitis, headache, tiredness, gastrointestinal symptoms, and eye irritation. These may be attributed to exposure to harmful gases such as hydrogen sulfide (H<sub>2</sub>S), methane and some air-borne bacteria.
- Obstructive type pulmonary impairment and cardiovascular problems such as hemodynamic instability, hypertetion, ischemic changes also reported.
- In these worker antibody level against both HAV and HEV was significantly higher compared to the comparison group.

way symptoms (as chronic bronchitis and toxic pneumonitis),<sup>3-5</sup> central nervous system symptoms (headache and tiredness),<sup>5</sup> acute non-specific self-limited gastrointestinal symptoms (jaundice and abdominal pain),<sup>5-7</sup> and eye irritation symptoms (conjunctivitis)<sup>4</sup> were reported. These symptoms may be attributed to exposure to harmful gases such as hydrogen sulfide (H<sub>2</sub>S) and methane.<sup>5,8</sup>

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.<sup>5,9</sup>

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.<sup>10-12</sup>

Ischemic changes, arrhythmias as well as hemodynamic instability in the form of hypertension were reported as a common cardiovascular disorders among sewage workers.<sup>4,13</sup> Respiratory manifestations as well as changes in the pulmonary functions (obstructive and restrictive types) were also reported.<sup>5,14,15</sup>

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-

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

Parameter	Wastewater treatment plants (WWTPs) workers (n=43)	Comparison group (n=43)	p value
Age (yrs)	47.14±3.65	48.23±2.37	NS*
Weight (kg)	74.84±7.21	72.31±6.58	NS
Height (cm)	170.3±5.37	171.92±6.48	NS
BMI (kg/m <sup>2</sup> )	26.64±1.68	25.96±2.09	NS
Systolic blood pressure (mm Hg)	122.60±11.47	120.36±12.95	NS
Diastolic blood pressure (mm Hg)	77.81±7.82	76.54±8.04	NS
Heart rate (beats/min)	69.64±3.91	72.33±3.84	<0.05

\*NS: Not significant

tory (current and previous occupations, mean hours of the daily work, number of days worked per week, and the use of personal protective devices), smoking habit and smoking index (number of cigarettes/day × years of smoking), symptoms suggesting infection, respiratory tract impairment and cardiovascular affection. The collected data were inserted in a pre-designed datasheet.

All participants were also underwent spirometric examinations using a portable computerized spirometer (Spirolab II) at the end of the work shift. The measured parameters were forced vital capacity (FVC), forced expiratory volume in the first second (FEV<sub>1</sub>), FEV<sub>1</sub>/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<sup>16</sup> criteria (two values of FEV<sub>1</sub> and FVC should not differ by more than 5% or 100 mL) and all measured values were expressed as percentages of predicted values.

A resting standard 12-lead ECG was

taken from all participants to identify cases with left ventricular hypertrophy (LVH) or any other findings according to the standard criteria.<sup>17</sup> 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 pipetted 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 antibodies against HAV and hepatitis E virus (HEV) by quantitative sandwich enzyme-linked immunosorbent assay (ELISA).<sup>18</sup>

#### Exposure to H<sub>2</sub>S:

The remaining 1 mL blood was put into a heparinized tube for measurement of sulfhemoglobin, as an indicator of H<sub>2</sub>S exposure, within one hour of collection. This method is based on the fact that the molecules HbO<sub>2</sub> and SHb have a maximum absorption at 620 nm. HbO<sub>2</sub> will disappear

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

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

\*NS: Not significant

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

#### 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 inhibit 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'-TCAGGAGTTCGAGACCAGC-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).<sup>20</sup>

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

Parameter	WWTPs workers (n=43)	Comparison group (n=43)	p value
FVC (% of predicted)	85.85±9.43	87.65±9.07	NS
FEV <sub>1</sub> (% of predicted)	83.43±7.93	86.06±6.04	<0.05
FEV <sub>1</sub> /FVC%	113.72±6.91	115.37±7.74	NS
PEF (% of predicted)	97.62±6.08	99.84±7.66	<0.05
Sulf-hemoglobin%	0.41±0.13	0.08±0.02	<0.001

## 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 FEV<sub>1</sub>% 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).

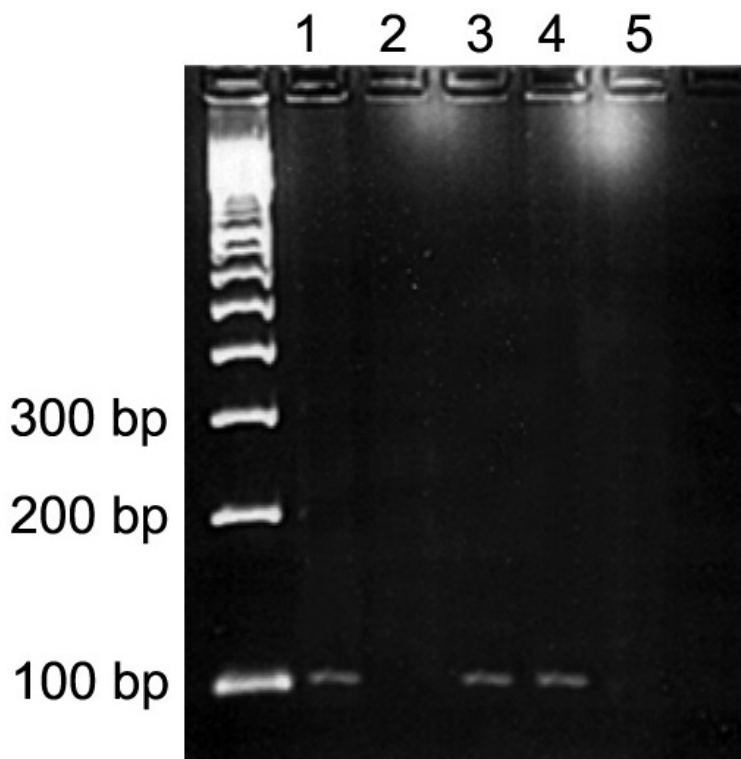
Antibody levels against HAV and HEV as well as the frequency of positive stool PCR results for *L. spirochete* were significantly higher in WWTPs workers than in the comparison group (Table 4).

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.<sup>1</sup> We found that the prevalence of abdominal pain followed by body ache (as a probable manifestation of infection) was significantly higher among WWTPs



**Figure 1:** PCR results: Lanes 1, 3, 4 represent positive samples for leptospirosis. Lanes 2, 5 represent negative samples.

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

Investigations	WWTPs workers n(%)	Comparison group n(%)	p value
HAV <sup>+</sup>	28 (65)	11 (26)	<0.001
HEV <sup>+</sup>	22 (51)	13 (30)	<0.05
PCR for <i>L. spirochete</i>	19 (44)	5 (12)	<0.001
ECG:			
Ischemic changes	7 (16)	2 (5)	NS
LVH	9 (21)	1 (2)	<0.05
Echocardiography (n=12)			
Mean±SD EF	64.5±2.99	57.62±9.16	<0.05
Mean±SD FS	32.0±1.49	28.63±7.76	NS

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.<sup>7,21,22</sup>

We also found that the antibody level against both HAV and HEV was significantly higher among WWTPs workers than the comparison group that is in keeping with other studies 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.<sup>9,23</sup>

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.<sup>15,24,25</sup> Dyspnea may be attributed to the exposure to H<sub>2</sub>S which is the most characteristic gas exposure for WWTPs workers. H<sub>2</sub>S is an irritant even at low concentrations and can cause asphyxia after massive exposure.<sup>13,26,27</sup> 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 H<sub>2</sub>S.<sup>28</sup>

WWTPs workers had reduction in both FEV<sub>1</sub> and PEF compared to the comparison group. This observation is in parallel with another report.<sup>29</sup> The observed pattern is matched well with an obstructive type pulmonary impairment which may be caused by endotoxins, H<sub>2</sub>S and some air-borne bacteria which can induce an immunological reaction. This finding is in concordance with other studies.<sup>13,30,31</sup>

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

group. H<sub>2</sub>S interacts with hemoglobin to produce sulf-hemoglobin the level of which is normally near zero and its presence reflects the level of exposure.<sup>26,13</sup>

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,<sup>32</sup> 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 H<sub>2</sub>S and/or heavy physical work load.<sup>13,26,33</sup>

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.<sup>26,34,35</sup> Higher EF observed among WWTPs workers may be due to their chronic exposure to H<sub>2</sub>S (which is irritant) and other noxious chemicals existing in WWTPs, with possible consequent inflammatory vascular reactions.<sup>26,34,35</sup>

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 per-

formed 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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