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Original

Effective Safety and Health Measures in Preventing H_2S Poisoning among Wastewater Network Operators

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Abstract

Background: Waste water networks were constructed and established to collect and transfer the swage in cities. In this regard, the occupation related to the operation of wastewater networks was created and flourished to improve and study the application of networks. One of the hazards that threaten the life of wastewater operators is poisoning by inhalation of hydrogen sulfide gas produced by wastewater. The aim of this study was to investigate the effective safety and health measures in prevention of hydrogen sulfide gas poisoning among the wastewater network operators. **Methods:** This qualitative study was carried out on 23 operators who worked in the main lines of wastewater transfer in Tehran. In order to collect the data, we used the focused group discussion in five months; from August 1, 2017 to the end of December 2017. The results were collected using the databases' analysis and the focused group discussions. The collected information was implemented and practiced in various maneuvers under probable scenarios and the possibility of operating them was investigated.**Results:** The average age of participants was 34.8 years and they were in the range of 24- 51 years. Participants were male and their educational degrees included diploma and lower degrees (N =4), bachelor's degree (N =11), and master's degree (N =3). The effective control measures to prevent H_2S poisoning were classified into three categories of engineering controls, managing controls, and using the personal protective equipment. **Conclusion:** The results showed that the highest frequency of efficient control measures was related to engineering controls, which indicated the high effect of engineering maneuver on the prevention of H_2S poisoning among operators of wastewater networks. Management controls and use of personal protective equipment were in the next steps, respectively. In order to have complete efficiency, we should consider the control measures in all three areas.

Keywords: H_2S; Asphyxiation by gas; Wastewater network

Introduction

Population growth and urbanization have already highlighted the need to create, maintain, and operate the waste collection and transportation facilities.[1] Wastewater collection networks are the most important urban infrastructures constructed by spending huge capitals on preventing the environmental pollution and ensuring the health of citizens.[2] The wastewater

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network and pipelines require proper operation, repair, maintenance, and defect fixations after implementation.[3] One of the main hazards that wastewater network operators experience is asphyxiation by hydrogen sulfide gas (H_2S) produced by anaerobic bacteria in the wastewater.[4]

Hydrogen sulfide (H_2S) is a colorless, extremely toxic, and explosive gas with the odor of rotten eggs at low levels. The physical characteristics of this gas are molecular weight of 34.08, specific gravity of 1.19, the melting point of 82.9 ° C, and the boiling point of 61.8 ° C.[5] This gas is produced in the wastewater network in the anaerobic conditions. It has heavier molecular mass in comparison with air and accumulates at the bottom of the wastewater manholes and pipelines. High levels of hydrogen sulfide eliminate the ability to smell. Therefore, at the time of entering a manhole with a high concentration of H_2S gas, the person may not smell the gas.[6] Exposure to this gas in high concentrations leads to immediate death because it disturbs respiratory system, At lower levels, it leads to anesthesia, lethargy, loss of power, and disorientation.[7] In the past, the Association Advancing Occupational and Environmental Health (ACGIH) declared that the permitted threshold limit value and time-weighted average (TLV-TWA) of hydrogen sulfide gas was 10 part per million (ppm). Furthermore, they announced that the permitted threshold - short-term exposure limit (TLV-STEL) was 15 ppm. In 2010, this organization revised these amounts as 1 and 5 ppm, respectively.[8] The study by Mehrabi et al. (2010) on H_2S gas in underground tunnels showed that the main source of this gas in tunnels was the underground water that poisoned the workers of tunnels and mines.[9]

The effect of H_2S on body depends on the factors such as exposure time, exposure frequency, concentration of gas in the environment, and the physiological state of the person poisoned by hydrogen sulfide gas. The studies indicated that people who consumed alcohol 24 hours before the exposure, died unexpectedly facing with low concentrations of H_2S. Some of the physical limitations that can reduce the person's ability to work in wastewater manholes containing hydrogen sulfide include having chronic obstructive pulmonary disease or asthma, high blood pressure, diabetes, and anemia, consuming alcohol, smoking, having weak physical conditions, and aging.[10] Engineering techniques are among appropriate methods to control H_2S gas. Pasban (2013) evaluated the removal of H_2S from petroleum using synthetic scungers and reviewed one of the technical engineering methods to control poisoning with this gas.[11] Kappes showed that another material could be replace by H_2S in the fatigue-corrosion testing of steel and eliminated the hazards of exposure to this gas.[12] In chronic toxicity by H_2S, a high amount of chemical material enters the body and its symptoms emerge in minutes to four hours. In the case that the treatment does not start within a few hours to several days, it will result in death.[13] After inhalation of H_2S at low concentrations, the gas enters into the bloodstream through lungs. The body begins to decompose and oxidize the H_2S and converts it into a harmless compound for protect the person.[14] However, in the case that a person inhales high concentrations of H_2S and be exposed to this gas for a long time, hydrogen sulfide, such as cyanide, will associate with the cytochrome oxidase existing in the mitochondria and prevent its function. Therefore, it prevents the cellular oxygen metabolism and consequently, the center of respiration in the brain is paralyzed, respiration stops, and the person asphyxiates.[15] In addition to the asphyxiation effects, it increases the rate of respiratory and ultimately leads to respiratory depression. People who survive after the initial exposure, may experience delayed pulmonary edema due to the direct effects of H_2S on the lungs.[16] Chronic poisoning with H_2S gas may occur without any warning and the wastewater

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operator anaesthetizes while descending or rising the manhole stairs containing high levels of H_2S gas. In this case his probability of surviving is low because the sense of smell quickly deactivates in the presence of this gas and leads to death within few seconds. Although the mortality rate is high in chronic toxicity, a probability of surviving exists if the survival measures take place promptly and quickly.[17]

The Environmental Protection Agency (EPA), the international agency of research on cancer, and the Health and Human Services (HHS) conducted some studies on the carcinogenesis of H_2S. These studies showed no symptoms of carcinogenesis in H_2S.[18] Hydrogen sulfide converts into sulfate and thiosulfate in the human body and is excreted in the urine. Therefore, by application of some special laboratory equipment and measurement of the thiosulfate in the urine of exposed person up to 12 hours after exposure, we can diagnose the presence of gas and confirm that the poisoning was caused by H_2S gas.[19] The aim of this study was to evaluate the effective safety and health measures to prevent H_2S gas poisoning among wastewater network operators.

Methods

The current study was a qualitative content-analysis research to evaluate the effective safety and health measures to prevent H_2S poisoning among the wastewater network operators.In order to collect data, we used the focus group discussion (FGD) during five months from August 1, 2017 to the end of December 2017. The FDG is a semi-structured discussion among six to 10 individuals to collect data according to a specific program or subject. One person guides the discussion as the facilitator and encourages the participants to engage freely in discussions to reveal their emotions and thoughts according to subject.[20]

To hit this target, we classified the participants into three separate groups of safety and crisis management experts, technical experts, and the operating technicians of the Wastewater main lines of tehran. Considering that in this type of research, knowledge, experience, and motivation of individuals are important to participate and provide the required data, random sampling was not an appropriate method to select the participants. Therefore, we used the goal oriented sampling method to select the participants, and the sampling process continued until the data saturation was reached. Finally, six experts of the safety and crisis management, five technical experts of wastewater operation, and seven technicians from the main lines of Tehran wastewater were selected to participate in group discussions and Brain Storming sessions. The groups consisted of six people, who attended in 14 discussion sessions; six sessions with safety and crisis management experts, three sessions with technical experts, and five sessions with technicians of the main lines of Tehran wastewater. The discussions were based on the data of training maneuvers and the information was finalized after data saturation, when no new data was achieved.

In the first step, occupations related to the wastewater network operation, in which people are exposed to H_2S gas and poisoning due to inhalation of this gas is probable were studied and identified. The list of exposure occupations are presented in Table 1.

After identification of the related occupations, the possible safety and health measures to prevent asphyxiation by H_2S were extracted and classified regarding each of the occupations mentioned in Table 1. Later, we determined the exact duties of each job and provided the required protective equipment based on the current standards. Furthermore, the necessary corrective measures were taken to promote the performance of the employees and to prevent from asphyxiation.

Table 1. The occupations in exposure to H_2S gas in wastewater network process

Column	Occupations topic
1	Wastewater operator
2	Wastewater co-operator
3	Video-meter technician
4	Technicians of blank inflatable pipe stoppers
5	Welder and cutter

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Table 2 . Worksheet of safety measures for occupations in exposure to H2S in operation of wastewater network

Occupation		Revision date
Specific duties:		Safety measures to perform
General safety instruction required		
Required exclusive tutorials:		
Required permits:		
Personal protective equipment:		
Describe the function	Other hazards	Corrective measures, suggestions

The above-mentioned safety measures were collected from FGD using the analyses of databases and implemented by considering the present equipment in operating the wastewater networks in Iran. Then, these measures were implemented and practiced in different and regular maneuvers under the supervision of safety and health experts. In addition, we evaluated the operation of different safety programs according to the conditions of wastewater networks implemented in wastewater transfer lines in Tehran.

In conducting the maneuvers, we considered various conditions including:

•Different types of manhole entrances to the transfer lines based on their valves' diameters (including: 40-60-80 mm)

•Different diameters of transfer lines (including: 1000-1200-1400-1600-1800mm)

•Manhole construction year and wastewater transfer network

•Drainage sewage flow

•Different hours in day

•The situation of the manhole construction and the inlet and outlet pipes

•The variable depths of manhole

In this study, we considered the efficiency of the safety measures by emphasizing two points: involvement of all occupations Table 1 in different stages of maneuvers as well as accidents with high probability of occurrence in the transfer line and wastewater collection network in Tehran city, Iran.

We used Guba and Lincoln evaluation method to ensure the accuracy of the study, which is equivalent to the validity and reliability in quantitative research. The scientific accuracy in qualitative studies includes all measures that increase the probability of valid data. In qualitative studies terminologies such as scientific accuracy and reliability (trustworthiness) are used instead of validity. In this regard, we considered the criteria of reliability, transferability, credibility, and verifiability to evaluate this study.[21,22]

Results

Participants were in the age range of 24 - 51 years with an average of 34.8 years. They included both male and female individuals with diploma or lower degrees (N= 4 individuals), bachelor's degree (N=11 individuals), and master's degree (N=3 individuals). Data collection and analyses were carried out according to the frequency of maneuvers conducted with regard to the temporary obstruction of wastewater transfer lines by stopples, wastewater pumping, video-metery of transfer lines, and wastewater collection network (Fig. 1). In addition, applied control measures were used to prevent H_2S poisoning of the workers in the field of wastewater networks operation according to the situation of wastewater networks and transfer lines in Tehran.

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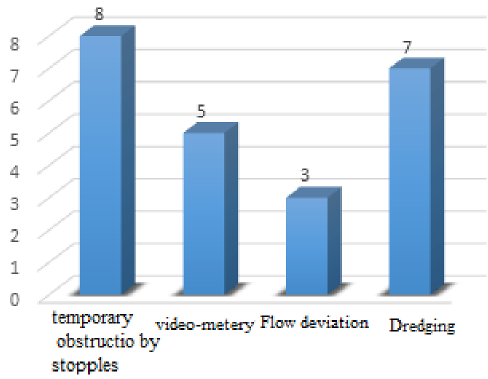

Figure 1. Frequency of applied measures in maneuvers

Effective control measures are divided into three categories of engineering controls, management controls, and use of personal protective equipment.

A. control engineering

1. Reduction of the exposures using equipment such as: vide-meter cameras and Quick view camera 2. Washing and removing the remaining sludge in the wastewater network using a combined washing system (wastewater combine)

3. Implementation of remote inspection method by video-meter Robot

4. Considering appropriate slope for the lines in the design and implementation to prevent stagnation of wastewater, sludge formation, and subsequent production of H_2S gas

5. Creation of drop in areas where decrease in the velocity of fluid flow and wastewater settlement happen

6. Using appropriate ventilation systems, opening the manhole doors before and after the operation

7. Converting H_2S into harmless substances using specific oxidizing chemicals such as hydrogen peroxide or sodium hypochlorite that can react with H_2S and produce less toxic or non-toxic substances. Other chemicals, such as sodium hydroxide increase the pH of the water and reduce the release of hydrogen sulfide as a result. However, these substances should be used in relatively high amounts to be effective. Therefore, the process is costly and time-consuming.[23]

B. Management controls

1. Preparation of a comprehensive and planned education curriculum at the beginning and during the recruitment of the personnel who are directly in exposure to H_2S using three areas: 1- Explanation of the chronic and acute hazards of H_2S gas. 2. The application strategy of the personal protective equipment. 3- First aids and rescue measures in emergency situations

2. Conducting safety practicing maneuvers to enter the manholes, perform operations in wastewater networks, and analyze the data

3. Implementing the HSE management system in the organization and adopting strict rules in this area

4. Implementation of Safe Work Permit System (Permit)

5. Periodic change of shifts and reduction of working hours of staffs in exposure to H_2S

6. Performing pre-employment tests and periodic examinations according to the respiratory and cardiovascular system

C: use of personal protective equipment(PPE)

1 . Gas detection by the detector and ensuring the absence of H_2S gas before entering the manhole and wastewater transfer lines

2. Use of a full body harness belt, a rescue tripod, and a Life line for entering the manhole

3. Using different types of masks (in the case of adequate oxygen)

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4. Using a self-contained breathing apparatus (SCBA) and an air supply system for short-term work in the range of specific concentrations of H_2S gas.

5. Using escape systems such as escape mask and emergent respiratory system (escape)

It should be noted that training on the use of personal protective equipment should at least include:

-Explanation about the reason of selecting the available personal protective equipment

-Discussion and evaluation of the capabilities and limitations of the selected instruments

-Showing the correct ways to use the personal protective equipment, including how to wear and remove them

-Providing the workers with opportunities to use the equipment practically

Discussion

This qualitative study provided effective and practical results to prevent poisoning and death by inhalation of H_2S gas in the wastewater network, facilities, and transfer lines. The findings showed that the highest rate of efficient control measures was related to engineering controls, which indicated the effect of safety engineering measures in preventing H_2S poisoning among wastewater network operators. Then, management controls had the highest frequency followed by application of personal protective equipment at the next level. The importance rank of measures was in the same line with the ones recommended by Occupational Health and Safety Administration (OSHA).[24] However, the results of study by Helwani et al. showed that education, as a management control measure was the last priority.[25]

Rodríguez et al. in Spain showed a significant relationship between education and risk perception in the training group. On the other hand, they pointed out that non-engineering measures such as education were preventive measures.[26] Moreover, the results of the study by vrbeek et al. indicated that although non-engineering measures were effective in reducing the risk level, no significant difference was observed in reducing the risk level after application of this type of control.[27] These results vary from the findings of the present study.

The results of the study by zhi yuan et al. showed that the risk probability of technical and engineering controls could be reduced efficiently. They suggested the non-engineering controls as additional safety measures and introduced them as beneficial tools to prevent the exposure to potential hazards.[28] These findings were consistent with the results of the current study. In another study, Halwani et al. showed that engineering controls had a positive effect on reducing the probability of risk occurrence. In addition, the highest effect of non-engineering controls was on improving the risk discovery and the highest effect of simultaneous controls was on reducing the severity of the risk.[29] In fact, engineering controls are efficient in separating the risk source from the individual and vice versa. The engineering controls have much higher efficiency in terms of cost and safety than the management controls and personal protective equipment.[30] Considering the focus of qualitative studies on the research environment as well as their social and organizational conditions, the findings of this study were limited to the studied population; so, they are generalizable to different organizations with the same economic and social structure.

Conclusion

According to the results of this study, engineering controls were the most efficient method to prevent H_2S gas poisoning in wastewater network operators, because these controls often lead to elimination of the risk factor, that is the sludge and sewage remained in the wastewater network. The next important measures included the management controls and application of personal protective equipment.

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The current study had some limitations, such as lack of cooperation by the participants, provision of personal protective equipment due to their high price, and making the necessary coordination to conduct the maneuvers and economic issues around them. We overcame the last limitation by continuous pursuit of an active company in the field of wastewater process and justified the importance of research. Contrary to these limitations, the participants of this study were selected by taking into consideration their diversity of professions, occupational capability, experience, and education to improve and increase the generalizability of the findings in the same society. Another advantage of the current study was implementation of multiple maneuvers to measure the practicality of the collected data according to the situation of the network and wastewater transfer lines in Tehran. The results of this study can be provided to the public and private companies that are active in the field of water and wastewater in Iran. These companies should consider these recommendations as a basis for promoting the safety and setting the technical regulations on the wastewater network operation to reduce the unwanted incidents, loss of monetary capital, human resources, as well as credibility and reputation of the organizations.

Conflict of interest

The authors did not report any contradiction of interests

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