A. Conceição, R. Isidoro, H. Chaves*

WASTEWATER DRAINAGE NETWORK: WORKING ATMOSPHERE'S ANALYSIS

UDK 628.515:504.4
RECEIVED: 2022-12-13
ACCEPTED: 2023-06-04

SUMMARY: In the city of Beja, Portugal, there is an infrastructure for the conduction of wastewater for treatment, this infrastructure is subject to periodic and systematic rehabilitation and maintenance and can still be used by authorities and even by other companies. Each manhole is a potential confined space with all the constraints and problems that they usually present. A thorough and systematic analysis of the atmosphere inside the manholes of the wastewater drainage system was made to know the respective risks and hazards to all subjects exposed, throughout the East part of the city, from the gases produced and in these installations. The data collection was carried out in two different periods when the network presented minimum flows in normal operation. The flows were considered minimum after the reading of the flowmeters installed in the measurement areas indicated it.

Key words: *confined space's occupational safety, hazardous atmospheres, sewer networks, drainage network, gases of combustion and fermentation*

INTRODUCTION

A confined space is defined in the United States Occupational Safety and Health Administration (OSHA) regulation as ‘‘a space that: (1) Is large enough and so configured that an employee can bodily enter and perform assigned work; (2) Has limited or restricted means for entry or exit (for example, tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry and (3) Is not designed for continuous employee occupancy" *(OSHA, 1993)*. Many serious accidents related to work in confined spaces still occur, despite all the regulatory and standard-setting efforts that have been made, organizations seem to have difficulties with risk assessment for interventions in confined spaces *(Burlet-Vienney, 2015)*.

*António Conceição, (amconceicao@gmail.com), Rui Isidoro, (rui.isidoro@ipbeja.pt), Polytechnic Institute of Beja, Beja, Portugal, Humberto Chaves, (hc@ipbeja.pt), Polytechnic Institute of Beja and FibEnTech – Fiber Materials and Environmental Technologies, Covilhã, Portugal.

There are three broad categories of confined-space hazards *(Dow, 2017)*:

- Atmospheric
- Physical
- Psychological

It's important to identify all potential hazards, and then eliminate each one. If elimination is not possible, steps must be taken to control the hazard and ensure worker safety *(Dow, 2017)*.

Atmospheric hazards include too little oxygen (oxygen deficiency), too much oxygen (oxygen enriched), flammable gases or vapors (examples are methane and natural gas), or toxic substances (examples are hydrogen sulfide and carbon monoxide) *(Dow, 2017)*.

Physical hazards include engulfment, falling or tripping, poor visibility, noise, temperature extremes, biological hazards, energy sources, insects, rodents, and reptiles *(Dow, 2017)*.

Psychological hazards include claustrophobia, fear of heights, fear of darkness, or poor physical condition or restrictions of the worker, even a mild level of claustrophobia or fear of heights can be problematic. There is not a lot one can do for psychological hazards except not put affected workers into spaces that cause them such problems *(Dow, 2017)*.

Confined space work is a high-risk activity, posing a significant hazard for both workers and rescuers involved in the emergency response, risks due to working in confined spaces can be extremely dangerous *(Botti, 2018)*. The leading cause of accidents and fatalities in confined spaces is atmospheric condition, further common causes are fire, explosion, ignition of flammable contaminants, spontaneous combustion and contact with temperature extremes *(Botti, 2018)*. Every year, confined space work causes fatal accidents and injuries, despite the in force regulatory and standards on such activity *(Botti, 2018)*. This paper published in 2018 by Botti wrote that both **US and Italian data show that the highest number of accidents in confined spaces are in wastewater industry.**

Toxic gas accumulation, oxygen deficiency, poor ventilation, mechanical and flammable atmosphere can make confined atmospheres more dangerous than normal environments *(Rajakumar, 2023)*. Short-term and long-term exposure to hazardous gases creates various health issues, such as headaches, vomiting, unconsciousness, sudden collapses, and even death *(Rajakumar, 2023)*.

The European Union has not introduced any legislation specifically relating to work in confined spaces (apart from temporary or mobile construction sites).

There are different pollutants and contaminants emissions, the diversity of chemical pollutants leads to classify emissions according to their etiological agent within different types of wastewaters *(Mohammed Khalid, 2021)*. The design of constructed sewage channels also affects the emission rate into the atmosphere, open wastewaters are more efficiently exhaust emissions than close box or underground constructed wastewaters, as a result of abiotic effects which leads to worm the water and stimulate more volatilize and release *(Mohammed Khalid, 2021)*. The reports indicated that wastewaters are considered as one of the detrimental sources of pollutants in environment specifically within atmosphere *(Mohammed Khalid, 2021)*.

Sewer gas is a generic name for a complex mixture of gases and airborne agents that result from the natural process of the decomposition (biodegradation) of organic materials in sewage *(Pennel, 2013)*. Typically, the agents of human health concern are hydrogen sulfide (H_2S), ammonia (NH_3), methane (CH_4), carbon dioxide (CO_2), nitrogen oxides (NO_x) and another volatile organic compounds (VOCs), such toxic gas mixture is fatal for those who come to the proximity/exposure of these gases *(Pennel, 2013, Ojha, 2017)*. An alarming number of human fatalities is reported each year by the newspapers and the other agencies.

Volatile organic compounds (VOCs) are discharged to municipal wastewater collection systems from various sources including industries, commercial facilities, public institutions, and residential households. These discharges cause several concerns related to transfer of VOCs from the aqueous to gaseous phase *(Quigley, 1995)*. These include:

- worker exposure to toxic chemicals during wastewater collection and treatment,
- accumulation of explosive gases in sewer atmospheres,
- emissions of toxic air contaminants,
- emissions of reactive organic gases (ROGs) that contribute to tropospheric ozone formation *(Quigley, 1995)*.

For sewer networks there are often potential complainants near a discharge source, odors within sewer systems normally occur from a mixture of either volatile sulfur compounds (VSCs) and/or VOCs *(Shammay, 2016)*. VSCs can be generated within sewer networks both in gravity and in pressure (force) systems, although the processes are often accelerated in pressure systems due to the absence of oxygen (Shammay, 2016).

There is specific Portuguese legislation that safeguards worker's health and safety by imposing prevention procedures and mandatory requirements in occupational health and safety, namely:

- Portaria 762/2002 of July 1st aims to establish several requirements to ensure the health and safety of workers for public water operation, distribution and domestic, industrial and rainwater drainage systems *(EMAS, 2013)*. It states that circular manholes should consist of an eccentric cone and prefabricated rings in accordance with standards NP 881 and NP 882. These manholes should have a body with a prefabricated concrete structure with a diameter of 1.00 m for heights up to 2.50 m and 1.25 m diameter for greater heights. It also states that the risk factors inherent in the operation of wastewater drainage systems and water supply systems are characterized by the existence of high concentrations of toxic and/or asphyxiating vapors or gases and by the low concentration of atmospheric oxygen in the manholes of the wastewater drainage network.
- Decreto Regulamentar 23/95, of August 23th, establish that the manholes are composed by a threshold, formed in mostly by a concrete slab who serves as body's support; walls, which compose the body, with an arrangement in plan commonly circular or rectangular; roof, truncated cone or asymmetric plane, with a vertical unit, continuing the walls to provide the easiest access; access device, consisting of a fixed or removable ladder or recessed steps, the ladder being applicable only for depths of 1.7 m or more; strong locking device.

TECHNICAL REQUIREMENTS

The collection method was done using direct reading equipment, from the interior atmospheres of the manholes of the wastewater drainage system on the East side of the urban area of Beja, Portugal.

The collection method used focused on comparing the readings of the flow meters where the daily consumption of water distributed in the system is registered. In the normal operation regime, it is verified that the periods in which the water network has the lowest values in the daily distribution, i.e. when the flow in the wastewater drainage network is minimum *(Dias, 2008)*. It was considered a 5% sample of each interval of the level of quotas that compose the same drainage system, and for the East zone, readings were collected in all the 61 cases during two distinct periods of the day, the first one between 10 am and 12 pm and another between 3 pm and 5 pm *(Sousa, 2009)*.

Parameters analyzed:

- Hydrogen Sulfide (H_2S)
- Methane (CH_4)
- Carbon Monoxide (CO)
- Oxygen (O_2)
- Depth
- Temperature

Methodology:

- Collection of outdoor temperature reading near the manhole cover (Figure 1a)
- Calibration of the multi-gas detector with reference to the outside atmosphere (Figure 1b)
- Opening the manhole cover (Figure 1c)
- Simultaneous introduction of the probes into the manhole, collection of readings and depth measurement (Figure 1d)
- Closing of the manhole cover (Figure 1e)

Figure 1. Stages of the methodology: a) Stage 1; b) Stage 2; c) Stage 3; d) Stage 4; e) Stage 5
Slika 1. Faze metodologije: a) Faza 1; b) Faza 2; c) Faza 3; d) Faza 4; e) Faza 5

RESULTS

The data were collected in 2015 between June and August, at all elevations in the Eastern part of Beja, Portugal, between elevations 156 and 290 m above the sea line.

In the morning period, higher hydrogen sulfide values were detected in eight manholes along the analysis area. In the afternoon the number of manholes with higher Hydrogen Sulfide values increased to 12. The results obtained in the morning period are lower at lower elevations than at higher elevations (Figure 2).

In the afternoon, an inverse behavior is verified, as can be seen in Figure 3.

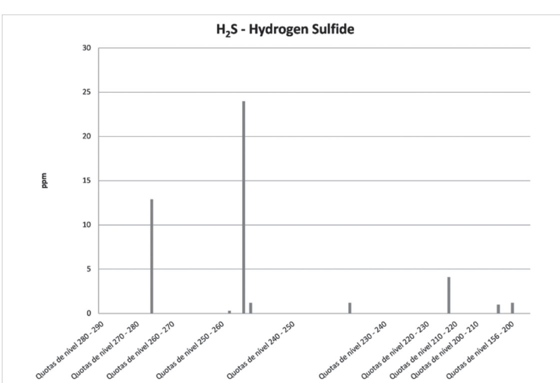

Figure 2. Hydrogen Sulfide concentrations in the morning reading periods in different elevation

Slika 2. Koncentracije sumporovodika u jutarnjim razdobljima očitanja na različitim visinama

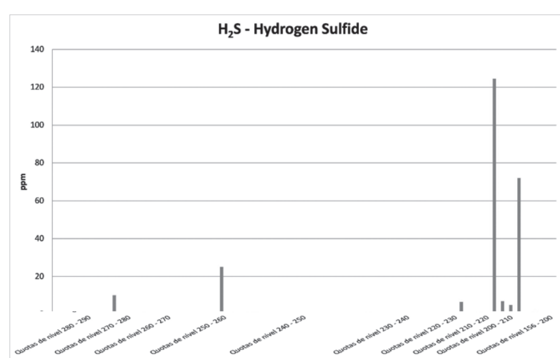

Figure 3. Hydrogen Sulfide concentrations in the afternoon reading periods in different elevations

Slika 3. Kocentracije sumporovodika u poslijepodnevnim razdobljima očitanja na različitim nadmorskim visinama

For methane, one high value was detected in the afternoon and another in the morning (Figure 4 and 5).

Carbon Monoxide values were higher in the afternoon than in the morning (Figure 6 and 7).

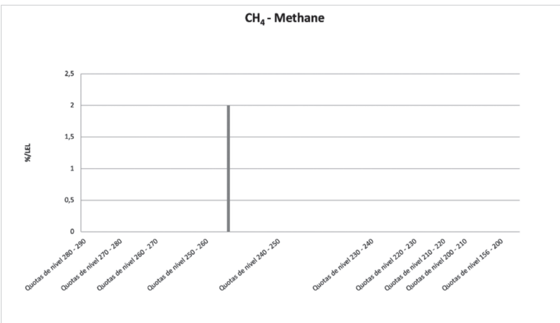

Figure 4. Methane concentrations in the morning reading periods in different elevations

Slika 4. Koncentracije metana u jutarnjim razdobljima očitanja na različitim visinama

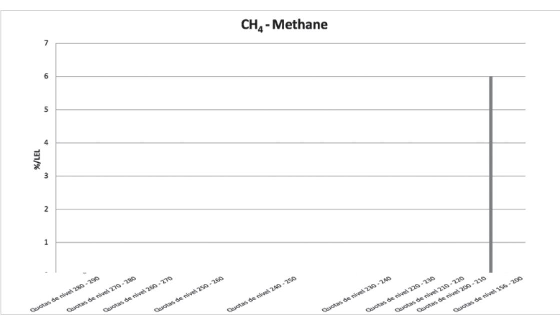

Figure 5. Methane concentrations in the afternoon reading periods in different elevations

Slika 5. Koncentracije metana u poslijepodnevnim razdobljima očitanja na različitim nadmorskim visinama

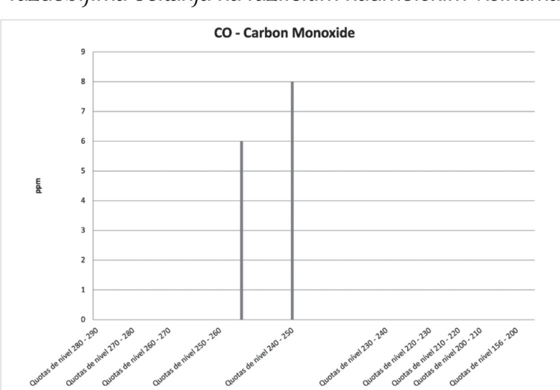

Figure 6. Carbon Monoxide concentrations in the morning reading periods in different elevations

Slika 6. Koncentracije ugljičnog monoksida u jutarnjim razdobljima očitanja na različitim visinama

The values of Oxygen present themselves reduced with some expression in two distinct cases. In the other the values within the permissible parameters for the presence of workers (Figure 8 and 9).

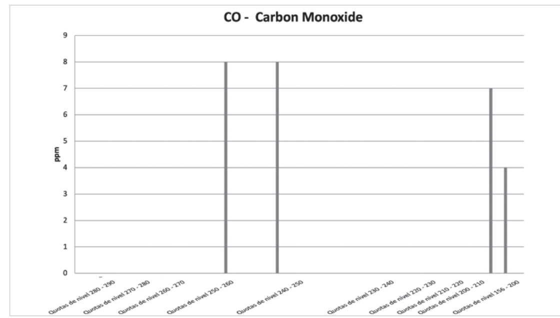

Figure 7. Carbon Monoxide concentrations in the afternoon reading periods in different elevations

Slika 7. Koncentracije ugljičnog monoksida u poslijepodnevnim razdobljima očitanja na različitim nadmorskim visinama

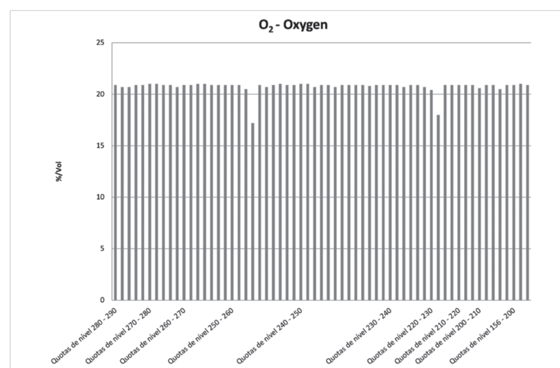

Figure 8. Oxygen concentrations in the morning reading periods in different elevations

Slika 8. Koncentracije kisika u jutarnjim razdobljima očitanja na različitim visinama

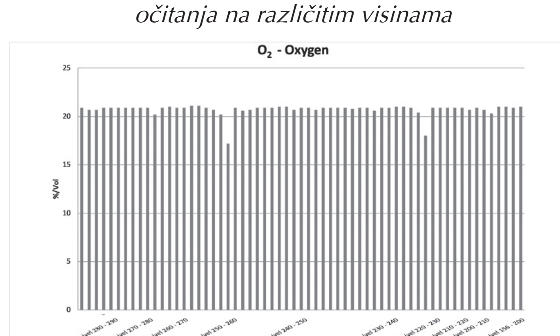

Figure 9. Oxygen concentrations in the afternoon reading periods in different elevations

Slika 9. Koncentracije kisina u poslijepodnevnim razdobljima očitanja na različitim visinama

The manholes studied vary in depth between 0.73 m and 5.48 m.

In the morning period the inside temperatures were always lower than the outside temperature, with the range of 24.4ºC - 39.5ºC for the outside temperatures and the valuer 24ºC - 34ºC for the inside temperatures.

As for the analysis made in the afternoon, the inside temperatures were always lower than the outside temperatures, the outside values were between 31.3ºC and 43ºC, and the inside temperatures between 30ºC and 40.9ºC.

CONCLUSION

Based in those results, a risk map was elaborated for the infrastructure under analysis (Figure 10). This map identifies the areas at greatest risk for the integration of workers in future works on the wastewater system.

This map will also be made available to other entities that may have to use this infrastructure, such as paramedics, firefighters, subcontractors, among others, in order to prevent future risk situations.

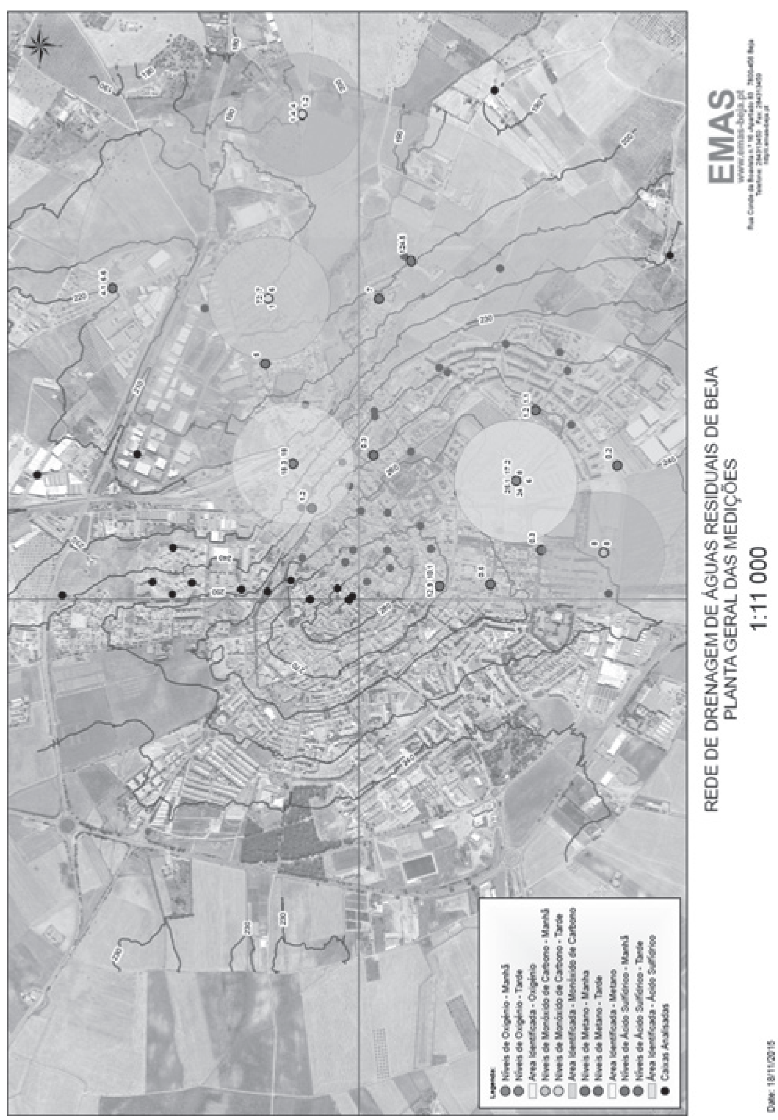

Figure 10. Risk map related to manholes in Beja, Portugal
Slika 10. Karta rizika povezana sa šahtovima u Beji, Portugal

LITERATURE

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DRENAŽNA MREŽA OTPADNIH VODA: ANALIZA RADNOG OKRUŽENJA

SUMMARY: Grad Beja u Portugalu ima infrastrukturu za odvođenje otpadnih voda na daljnju obradu. Ta se infrastruktura povremeno obnavlja i održava a radove obavlja gradska uprava ili druge tvrtke. Svaki šaht je potencijalno ograničen prostor koji predstavlja razne teškoće. U istočnom dijelu grada učinjena je sustavna analiza zraka u šahtovima odvodnog sustava kako bi se utvrdili rizici i opasnosti za osobe izložene plinovima u takvim instalacijama. Podaci su prikupljani u dva navrata kad je mreža normalno radila i bila najmanje opterećena protokom. Protoci su se smatrali minimalnima kad su mjerni instrumenti za bilježenje protoka tako pokazali.

Key words: *sigurnost ograničenog prostora, opasan zrak, kanalizacijska mreža, drenažna mreža, zapaljivi i fermentacisjki plinovi*

Izlaganje sa skupa
Primljeno: 13.12.2022.
Prihvaćeno: 4.6.2023.