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OCCUPATIONAL SAFETY CHALLENGES IN CLEANING GRAVITY PIPELINES TRANSPORTING HAZARDOUS MIXTURES

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Abstract: Our work focuses on the occupational safety aspects of periodic cleaning and maintenance work on underground gravity pipeline systems used to transport chemical industrial materials. We develop specific technical and organisational recommendations that can be applied in practice to reduce the identified hazards. Some of our findings are based on objective measurement data, official test reports and standards, while certain conclusions necessarily reflect subjective experiences, as the specific characteristics of similar systems and local conditions significantly influence the severity of the risks. Our goal is to ensure that the conditions for safe working are met as fully as possible during cleaning work, thereby reducing the risk of serious accidents and occupational diseases.

Keywords: *occupational safety, EHS, hazardous mixtures, central drainage*

1. Introduction

Sewerage is the totality of facilities for the drainage of rainwater and sewage, including sewers, cleaning and other manholes, pumping stations and sewage treatment plants (Cséki and Völgyesi, 1995; ASCE, 2007).

The maintenance of sewerage systems can be planned preventive maintenance (TMK) or action taken after problems occur. Costs and resources must be provided to ensure continuous, trouble-free operation (Blazsó and Péterfi, 1982; WEF, 2017).

The most common problem is a reduction in the cross-sectional area of sewer pipes (blockage). A reduction in cross-sectional area is usually caused by foreign objects entering the system through the network's water inlets, but even the displacement of a single section of pipe can cause a blockage. The reduction in cross-section can be partial or complete.

In a well-maintained, regularly cleaned network, even the smallest reduction in cross-section is eliminated without any external signs.

Closed sewer pipes are cleaned (with a few exceptions) using complex machines or simple tools. Simple tools (manual or electric tools) are hand-held devices (Figure

1.). They are used to clean small-diameter pipes and are generally used inside buildings (WEF, 2017).

Figure 1
3S manual pipe cleaner with spiral (WEB_1)

For drains with a diameter of 100 mm or more, mechanical cleaning solutions are used. High-performance drain cleaning machines (VOMA) are mounted on self-propelled trucks, with the truck's engine providing the energy required to operate the pump (ASCE, 2007). The most important parts of the machine are the truck chassis with running gear and drive, driver's cab, water tank, pressure booster pump, hoses, washing head and operating controls. The VOMA tank is filled with clean drinking water. Depending on the model, the water pressure is increased to 100–1000 bar using the pump. The choice of pressure for washing is critical, as excessive pressure can damage the material of the sewer system and significantly increase the occupational safety risk of the activity. However, cleaning at low power will not achieve the desired result. The high-pressure water is fed through a hose specially designed for this purpose to the washing head, which performs various movements in the sewer pipe. The design of the washing head determines its operating mechanism (forward washing head, backward washing head, breaking head, etc.). For effective cleaning, the washing head and hose must also be moved in the opposite direction to the direction of travel, as this allows the loosened material to be directed towards the cleaning shaft. The hose and washing head can be moved either manually or mechanically.

During the cleaning of sewer pipes, the normal flow of liquid must be prevented, as this endangers the persons performing the work and impairs the effectiveness of the cleaning. In this case, the work area can be separated from the operating system by preventing the passage of pipes. The flow cross-section can be closed off using inflatable rubber plugs. Rubber plugs can be used in cross-sectional ranges (e.g. 90 mm – 110 mm). They fit precisely thanks to their flexible shape and utilise internal pressure increase with compressed air.

The liquids behind the closed cross-section are pumped or sucked into another section of the sewer. If there is no supply of backflow liquids, the transfer can be omitted, but the separation cannot be omitted.

A sewer inspection camera is an essential tool for cleaning sewer pipes and assessing their condition. The camera allows us to visually inspect the condition of the pipe. Camera systems are available in manually operated and machine-driven "self-propelled" versions. "Self-propelled" cameras are systems mounted on small trucks that display and record images in real time as the camera moves through the sewer pipe. The machine is connected to the vehicle via optical and electrical cables.

The removal of material loosened by the sewer cleaning machine and water introduced into the system during washing may be necessary when clearing a larger blockage (several metres long). The easiest way to remove the accumulated water and sediment from the cleaning shaft is with a suction vehicle. Similar to the VOMA, the suction vehicle is a machine mounted on a truck. It also has a tank (4–8 m^3 in volume) in which the sucked-up materials are collected. In order to fill the liquid storage tank, the drive chain of the vehicle is connected to a vacuum pump, which reduces the pressure inside the tank to such an extent that atmospheric pressure simply pushes the material to be sucked into the suction hose. The composition of the sucked-up medium determines where the accumulated material can be transferred from the tank.

Existing occupational risk assessments in sewer maintenance predominantly address municipal sewage networks, where the hazardous substance profile is relatively well characterised and collective protection measures (such as ventilation and atmospheric monitoring) are regularly feasible. The present study addresses a distinct and underrepresented operational context: the periodic cleaning of gravity pipelines in active chemical-industrial facilities, where the transported media may include corrosive, toxic, carcinogenic or asphyxiating substances at concentrations substantially exceeding those found in municipal sewage. This environment renders standard municipal-sector risk controls insufficient and necessitates a fundamentally different approach to hazard identification, exposure assessment and protective measures. The novelty of this work lies in (i) the systematic application of a structured occupational risk assessment methodology to this specific industrial context, (ii) the identification and quantification of 275 discrete hazards across 16 defined work processes, and (iii) the demonstration that in chemical-environment pipeline cleaning, individual protection is not merely one option among several, but the primary – and frequently the only – technically feasible means of risk reduction for the most critical hazard categories.

2. Effects on Sewer Cleaners

When cleaning sewer pipes, workers are exposed to significant levels of viruses, bacteria, fungi and parasites due to the biological composition of sewage (WHO, 2019). Communal sewage can contain significant amounts of pathogens that can cause serious health problems and, in extreme cases, epidemics. The most common pathogens in sewage are the Enterobacteriaceae family (salmonella), Ascaris lumbricoides (roundworm), Ancylostoma duodenale (hookworm) and Necator americanus (tapeworm) (Gerardi, 2006).

Among the diseases, bronchitis, i.e. inflammation of the inner surface of the bronchi in the lungs, is a common problem, but cancerous changes in the stomach, kidneys, brain and lymphatic system also occur.

Physical work (e.g. moving hoses) also increases the risk of joint and muscle disorders.

One means of protection against various diseases is vaccination, some of which is compulsory (e.g. typhoid, hepatitis A) in accordance with Decree 18/1998. (VI. 3.) NM on epidemiological measures necessary for the prevention of infectious diseases and epidemics. Providing vaccinations for employees is part of the employer's obligation to ensure safe working conditions that do not pose a health risk.

The use of personal protective equipment and compliance with hygiene rules can significantly reduce the likelihood of illness (Szilvási-Kassai Eszter, 2020).

3. Sewer cleaning activities carried out in a special chemical environment

The chemical environment poses additional difficulties in relation to cleaning activities. Industrial pipes must be cleared of industrial waste as much as possible before cleaning begins (OSHA, 2023). In the case of pipes transporting chemicals, this must be taken into account when planning the work, and the risks of not being able to completely clear the pipe of the chemical in question must be taken into account. The customer is responsible for preparing the pipeline to be cleaned for handover to the work area. If there is a technical problem in the section in question that prevents 100% neutralisation or if its completeness cannot be verified, the area must be considered to be full of chemicals (CCPS, 2010). The customer must notify the contractor in writing of the presence of specific compounds and provide the necessary Safety Data Sheets. The contractor may only use chemicals during cleaning with the written permission of the customer, as unwanted reactions or unsuitable substances can cause serious problems in the structure of the sewer system and in the technology of the plant that receives and disposes of wastewater. During cleaning activities, the classification of materials removed from the sewer system is always the responsibility of the owner (Muzaini et al., 2021).

In order to ensure that workers carrying out the work are aware of the hazards posed by the chemical environment, regular training must be organised and conducted. It is in the employer's best interest, beyond the legal requirements, to prepare their employees for possible emergencies. Relevant training and information must be provided before the start of any current task. The chemical plant providing the work area is also interested in ensuring that the work carried out on its premises is carried out smoothly and efficiently, so they also provide special training to everyone who enters their premises. The validity and repetition cycle of the training may vary, but it should not exceed one year (Nakpan and Noomnual, 2024).

A large amount of drinking water is used during the cleaning process, but this cannot neutralise the hazardous substances found in the sewer sections, although it can significantly reduce their concentration.

Due to the nature of work carried out in a chemical environment, the use of the necessary personal protective equipment places an additional burden on employees.

With very few exceptions, collective protection can hardly be ensured, so the safety of individuals must be guaranteed on a personal basis.

The range of substances classified as hazardous during work is defined in Section 87 of Act XCIII of 1993.

4. STRUCTURE OF THE CLEANING PROCESS

The work processes of the activity we examined can be interpreted from a broader and more general perspective. In our work, we limited ourselves to evaluating the essential work processes, therefore we do not analyse the general work processes in this risk assessment. Nevertheless, we consider it necessary to note that the work processes not analysed are an integral part of the work and the risks arising during them should not be ignored. The process structure we have applied is only technical in nature. Figure 2 presents a simplified flow diagram of the core cleaning sequence (steps 4–19), covering the operations directly subject to risk assessment. Steps outside this range are administrative or logistical in nature and are excluded from the quantitative risk analysis.

Work processes

1) Order acceptance, work planning (not part of the analysis);
2) Departure of vehicles from the site (not part of the analysis);
3) Issuing the customer's work permit, technical consultation (not part of the analysis);
4) Arrival at the site, designation of the work area, positioning of vehicles;
5) Opening of manhole covers affected by cleaning;
6) Plugging, stopping fluid replenishment;
7) Unrolling the VOMA hose, connecting it to the manhole;
feeding into a closed pipe below ground level;
8) Placing the cleaning head and hose under pressure,
switching on the pump;
9) Move the washing head forwards and backwards, wash;
10) Release pressure in cleaning head and hose;
11) Lifting and rolling up the VOMA hose;
12 Fill the VOMA water tank;
13) Inserting the suction hose into the shaft;
14) Suctioning out the washed material with a suction hose;
15) Removing the suction hose from the shaft;
16) Emptying the suction truck's tank;
17) Removing the plug from the shaft;

Repeating the process several times

18) Sealing manhole covers affected by cleaning;
19) Clearing the work area, withdrawal;
20) Return of the client's work permit, technical consultation (not part of the analysis);
21 Refuelling of vehicles (not part of the analysis);
22 Return of vehicles to the site (not part of the analysis);
23 Administration, cost accounting (not part of the analysis).

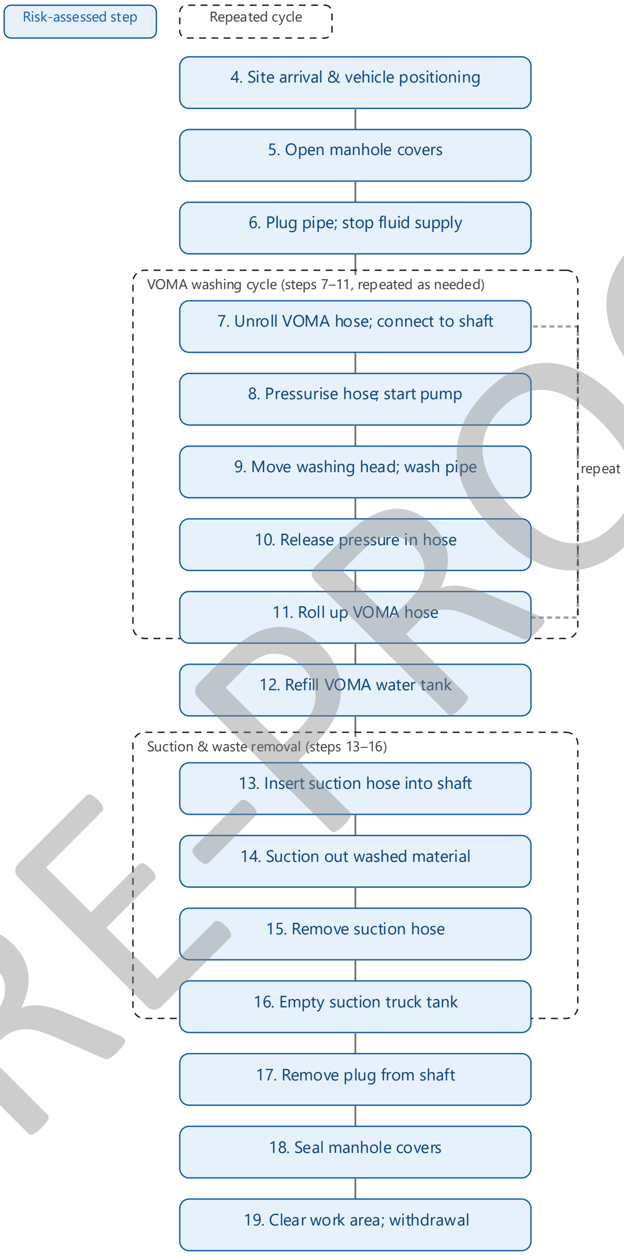

Figure 2
3S manual pipe cleaner with spiral (WEB_1)

5. Risk assessment and ranking

We chose a tabular format and a matrix-based evaluation system for risk assessment and its visual representation. The vertical axis of the matrix (Figure 2) shows the probability of occurrence (F), while the horizontal axis shows the severity of damage (C). The level of risk (R) can be read from the intersection of these two axes, calculated as $F \times C = R$, in accordance with established occupational risk assessment practice (Cox, 2008; HSE, 2014).

The likelihood (F) and severity (C) ratings assigned to each hazard are based on a combination of sources: the professional experience of the authors accumulated over 20–25 years of direct involvement in chemical-environment sewer cleaning operations; available accident statistics and occupational disease records from the relevant industrial sector; safety data sheets and technical specifications of the substances transported in the examined pipeline systems; and applicable Hungarian and international occupational safety regulations and standards. Where objective statistical data were not available for a specific hazard, expert judgement was applied conservatively, assigning the higher of two plausible ratings in order to avoid underestimation of risk. This combined approach reflects standard practice in occupational risk assessment for work processes where comprehensive accident statistics are not systematically collected.

$$F \times C = R \tag{1}$$

The risk level may be low, in which case a decision must be made as to whether the risk is considered acceptable and no further action is required, or whether measures should be taken to eliminate the risk entirely.

Even if an element is considered an acceptable risk, it is still necessary to mention it in the occupational safety training material and draw the attention of employees to its possibility.

In the case of high and medium risk identification, there is no room for consideration; measures must be introduced in all cases.

C Severity **F Likelihood of Occurrence**	**C1 No personal injury**	**C2 Minor personal injury: not resulting in incapacity for work**	**C3 Significant personal injury: resulting in incapacity for work**	**C4 Severe personal injury: serious work accident**
F1 Unlikely (inconceivable)	1	1	1	2
F2 Possible (not inconceivable)	1	2	3	4
F3 Likely (sooner or later)	1	3	4	5
F4 Inevitable (certain, only a matter of time)	1	4	5	6

R Risk Assessment	Risk level	Required action
RA 1–2	Low risk	Acceptable risk: No action necessary
RK 3–4	Medium risk	Risk reduction with a deadline necessary: Action: – deadline – responsible person
RM 5–6	High risk	Immediate risk reduction necessary: - Prohibition of use - Elimination of the hazard source
	RF Residual risk	To be indicated/specified: - in the operating instructions - on the work equipment

Figure 2
Evaluation matrix (Bujnóczki, 2024)

There are three possible courses of action:

1) Complete elimination of the source of danger, replacement of dangerous technology or materials with non-dangerous ones.
2) Reducing the impact of the hazard, replacing hazardous technology or materials with less hazardous ones, and introducing measures to protect workers (collective or individual protection).
3) When reducing the probability of occurrence, we aim to ensure that employees are exposed to the source of danger as little as possible and for as short a time as possible. This can be achieved primarily through technological change, work organisation solutions (e.g. reduced working hours, shift work) or protective measures that isolate the person concerned from the source of danger.

If no further measures are possible because measures related to the impact of the hazard would make the work process impossible and the best available occupational safety solutions have been implemented, it must be identified as a residual risk and given prominence in regulations, inspections and training topics! A classic example of residual risk is cutting knives and their blades. Although the blade poses a mechanical hazard, eliminating it would result in a loss of function, so the only measures that can be taken to reduce its impact are those that do not make its use impossible (e.g. personal protective equipment – cut-resistant gloves).

6. RISK ASSESSMENT EVALUATION AND RECOMMENDED MEASURES (COLLECTIVE AND PERSONAL PROTECTION)

During the investigation, 275 hazards were identified in the sixteen operations. Due to the similarity of the operations, some hazards and their risks appear more than once , but since the persons involved in the work processes are not the same, we considered it appropriate to include all of them in the evaluation.

Of the identified hazards, 3 were rated as low risk, 211 as medium risk and 77 as high risk.

The 77 high-risk assessments originate from 9 hazards. This is due to the repetition of events occurring during the 16 operations examined.

Of the 77 high-risk work processes, 16 belong to the mechanical hazards group, grouped around 3 hazards. 59 work processes were identified in which the high risk is caused by hazards associated with materials/preparations. The risk of fatal electric shock due to electrical hazards was identified in 2 cases.

Similar to the previous cases, the 211 medium-risk assessments can be grouped into 40 hazard sources. Mechanical hazards were identified in 104 work processes. Ergonomic hazards were identified in 24 cases and hazards related to the machine's operating environment in 64 cases. Seven electrical hazards, two vibration hazards and six material/preparation hazards were identified. Noise hazards arising from the use of machines were identified in four cases.

The assessment clearly shows that mechanical hazards are present in significant numbers in both high and medium risk cases, but the presence of hazardous substances in the workplace is much more dominant in high risk cases. Without exception, hazards arising from chemical substances can always lead to serious personal injury, so their probability of occurrence must be reduced to the lowest possible level. Due to the nature of sewer cleaning technology, collective protection is difficult or impossible to implement in most cases. This is particularly true for contact with hazardous substances, where individual protection is much more effective and efficient, even at the cost of placing an additional burden on the employee.

The assessment clearly shows that in the case of high risks, the sources of danger cannot be eliminated, so even with appropriate measures, they can only be reduced to a medium risk. The remaining risks must always be treated as priority issues in the regulatory, control and training system by the employer in order to ensure safe working conditions that do not endanger the health of employees.

7. High risks and risk reduction recommendations, residual risks

7.1. Mechanical hazards – high risk

Motor vehicles are considered dangerous in themselves, according to Section 6:535 of Act V of 2013 on the Civil Code, but when applied to specialised trucks, it is easy to see that any movement of a vacuum truck or VOMA truck poses a significant hazard.

When reversing, drivers have two side-view mirrors at their disposal for manoeuvring (in basic cases). The tank of a truck creates a significant blind spot, so the risk of someone being there cannot be ruled out with complete certainty, and based on the law of large numbers, sooner or later someone is likely to be there (Table 1). If the driver has to position the vehicle alone, he can only reduce the risk by exercising extreme caution. Slow driving reduces the impact, as the weight of the vehicle is constant and speed and changes in speed are the only physical quantities that affect its momentum and thus the force it can exert on a person or object. In the event of an accident, when a truck runs over a person, the person involved may suffer very serious injuries, even injuries that are incompatible with life. Based on the risk assessment matrix, the probability of occurrence in this case is LIKELY (sooner or later) – F3 and the severity is SERIOUS PERSONAL INJURY – C4. Based on this, the level of risk is HIGH – RM5.

Recommendation: In addition to the driver performing their work properly and carefully, it is necessary to supplement their work with work organisation solutions and/or technical devices, so that the blind spot can be completely eliminated.

Table 1

Mechanical hazards – high risk

Type of hazard	**Risk of operation**	**Residual risk**	**Changed risk**	**Comment**
Hazard source → Consequence → Cause	F × C = R	**Risk reduction proposal**		
Mechanical hazards				
Acceleration, deceleration → running over → person in the vehicle's dead	**F3 × C4 = RM5**	RF: Running over caused by driver inattention. Provide monitoring personnel to assist the driver when recording the position of the vehicle. Use of reversing cameras and blind spot monitoring systems.	**F2 × C4 = RK4**	To be given priority in training material!
Acceleration, deceleration → collision → vehicles rolling away	**F3 × C4 = RM5**	RF: Running over caused by driver inattention. Use of wheel chocks!	**F2 × C4 = RK4**	To be emphasised in training materials!
Approaching a moving part → collision, crushing → person pinned between vehicle and fixed object (e.g. wall)	**F3 × C4 = RM5**	RF: Running over caused by driver inattention. Provision of monitoring personnel to assist the driver during vehicle positioning. Use of a reversing camera and blind spot monitoring system.	**F2 × C4 = RK4**	To be emphasised in training materials!

Work organisation solution: An employee is assigned to the driver who, during problematic manoeuvres (e.g. reversing), can use hand signals and audible signals to inform the driver about obstacles or people in the blind spot.

Use of technical devices: Today's technological advances offer solutions that provide the driver with immediate visual and/or acoustic information about areas that are not visible or difficult to see (e.g. reversing camera and display, blind spot monitoring system, radar).

The parallel use of these two options significantly increases the effectiveness of risk reduction, but also increases the employer's costs.

With the above solutions, we can reduce the probability of occurrence to level F2 (POSSIBLE – not inconceivable). The severity (C4) does not change because it is not affected by the measures. Based on the above, the new risk level cannot be reduced to an acceptable range, and the measured level is RK4 – medium risk. RK4 requires continuous attention as a residual risk and must be given priority status in documentation, regulations and training materials during inspections.

When manoeuvring a motor vehicle, another possible source of danger outside the blind spot is the approach of a moving element to a fixed part, i.e. a vehicle approaching a fixed object. The reasoning discussed above can also be applied here.

Despite the fact that work areas are cordoned off during all work, the appearance of unauthorised persons or the careless movement of authorised persons must be taken into account.

The positions occupied by vehicles may vary significantly depending on local conditions. Due to varying terrain conditions, the use of parking brakes is mandatory for vehicle drivers in all cases, but due to human or technical error, the possibility cannot be ruled out that sooner or later (F3) the vehicle will move from its position (roll away). Uncontrolled movement of structures can cause serious personal injury (C4). Using an assessment matrix, it can be determined that the level of risk is high (RM5).

Recommendation: In addition to using the vehicle's parking brake, protection against rolling away is necessary in all cases, which can be easily achieved by the driver using wheel chocks.

Since the placement of wheel chocks depends on human decision and action, it is not possible to reduce the probability of occurrence to improbable, but it can be reduced to F2 – possible. Thus, the high (RM5) risk can be mitigated to a medium (RK4) level, and RF – as a residual risk – must be given special attention during inspections in documentation, regulations and training materials.

7.2. Electrical hazards – high risk

When recording the position of motor vehicles, overhead cables that are below the highest point of the vehicle (overhanging) pose an active hazard (Table 2). There are numerous reasons for overhanging, such as the breaking of a tension wire. Due to the high density of structures in the work areas, the probability of overhead cables sagging is F3 – Probable (sooner or later). The severity of personal injury resulting from electric shock is C4 – Serious. The risk level is RM5 – High risk.

Recommendation: In the absence of technological solutions, the probability of occurrence can only be reduced by means of work organisation solutions. Therefore, in addition to the limited view from the driver's cab, at least one employee (local conditions may justify the need for more than one person) is required to monitor the overhead cables from an external perspective and assist the driver in changing position by means of hand and voice signals.

Table 2

Electrical hazards – high risk

Type of hazard	**Risk of operation**	**Residual risk**	**Changed risk**	**Comment**
Hazard source → Consequence → Cause	F × C = R	**Risk reduction proposal**		
Electrical hazards				
Insufficient distance from high-voltage live parts → Fatal electric shock → Overhanging wire	**F3 × C4 = RM5**	RF: When moving vehicles, attention must be paid to overhanging wires. Provide supervisory personnel.	**F2 × C4 = RK4**	To be highlighted in training materials!

By providing monitoring personnel, the probability of the risk occurring changes to F2 – Possible (not inconceivable), and as a result, the risk level changes to RK4 – Medium. As a residual risk, it must be given priority in regulations and other documents during training and inspections.

7.3. Hazards of materials and preparations – high risk

During the maintenance of organic and inorganic gravity networks, hazardous materials are present as part of their intended use (Table 3). In normal operating conditions, hazardous materials circulating in the closed system are completely isolated from the sewer network environment and therefore pose no danger. If we interfere with the closed system, for example by opening a cleaning manhole, we immediately create the possibility for hazardous substances to escape. During planned maintenance (no blockages), the section of sewer to be inspected/maintained can be flushed with water. The purpose of flushing with water is to dilute and drain the chemicals in the sewer section. It is the customer's responsibility to eliminate or reduce the hazards caused by chemicals travelling in the sewer pipe. When handing over the work area, the customer and the contractor must jointly ensure that the hazardous substances have been neutralised. It is common experience that it is impossible to be 100% certain that all chemicals have been completely removed, so all work processes must be treated as if no flushing had taken place. In the case of drains where cleaning must be carried out in a non-operational state (blocked), the chemicals present must be considered a clear source of danger.

The first exposure to chemicals occurs when manhole covers are opened. When removing the cover, the worker performing the activity may come into direct contact with hazardous substances on the inner surface of the manhole cover, which can be absorbed through the skin and cause various illnesses depending on the properties of the substances. When the manhole is opened, the chemicals present there can enter the airspace of the work area in the form of mist and gas. In sections of the sewer where there is an obstacle to laminar flow, turbulence, eddies and waves may occur.

Turbulent flow may be associated with elevated liquid levels, in which case liquid may splash out through the open cleaning manhole.

Table 3

Hazards of materials and preparations – high risk

Type of hazard	**Risk of operation**	**Residual risk**	**Changed risk**	**Comment**
Hazard source → Consequence → Cause	F × C = R	**Risk reduction proposal**		
Hazards of the substance or preparation				
Fog → breathing difficulties, suffocation, → evaporation of chemicals	**F4 × C4 = RM6**	RF: Vapour and mist escaping from the manhole! When opening the manhole cover, avoid leaning over it! Provide personal protective equipment (safety goggles, respiratory protection)!	**F2 × C4 = RK4**	To be given special attention in training materials! Personal protective equipment regulations!
Gas → cancer → release of chemical substances	**F4 × C4 = RM6**	RF: Steam and mist escaping from the manhole! When opening the manhole cover, avoid leaning over it! Provide personal protective equipment (safety goggles, respiratory protection)!	**F2 × C4 = RK4**	To be treated as a priority in training materials! Personal protective equipment regulations!
Liquid → poisoning → absorption of chemical substances	**F4 × C4 = RM6**	RF: Contact with surfaces contaminated with chemicals! Provide chemical-resistant extended gloves as personal protective equipment!	**F2 × C4 = RK4**	To be highlighted in training materials! Personal protective equipment regulations!

Before opening the cleaning manholes, relatively little information is available about the flow and level of liquids, so it is reasonable to assume that both gaseous and liquid hazardous substances are present.

It is inevitable (F4) that hazardous substances will escape from the opened manholes in some form. The effects of chemicals on human health can range from irritation to poisoning (cancerous tumours, organ failure) and can cause serious personal injury (C4), and therefore their risk level is the highest possible RM6.

Given the local conditions and the technology used, it is not possible to isolate hazardous substances or provide collective protection (e.g. extraction of gases, vapours, mist); only an extremely costly technological changeover (robotic technology) would be feasible, apart from the use of personal protective equipment. The use of robot technology is currently not a viable alternative for contracting organisations due to financial considerations.

8. Medium risks and risk reduction recommendations

The medium risks that occur are as follows:

- Mechanical hazards – medium risk;
- Noise hazards – medium risk;
- Vibration hazards – medium risk;
- Hazards posed by materials and preparations – medium risk;
- Ergonomic hazards – medium risk.

All medium risks identified during the risk assessment can be mitigated to a low (acceptable) level based on the recommendations shown in the overall risk matrix. There are no hazards whose probability of occurrence or severity of damage cannot be reduced to an acceptable level, so no residual risk needs to be taken into account in these areas.

In many cases, education/training provides a solution. Incorporate the findings of the proposed assessment into the current monthly, quarterly, half-yearly and annual educational curriculum and teach them regularly.

9. Summary

The work processes we examined covered occupational safety issues related to the cleaning of gravity sewer pipes that transport underground chemicals. We consider a general understanding of the work area, the basic parameters of the sewer network's operation and the typical types of faults that can occur to be essential for assessing the activity.

During general sewer cleaning work, employees encounter a number of hazards (e.g. biological), but the risks posed by the presence of chemicals stand out among the risks associated with traditional activities. In order to protect effectively against hazardous substances, it is essential to know the properties of the chemicals involved and to be aware of their effects on living organisms.

We have made recommendations to reduce the risks of the identified hazards in order to further ensure that the workplace meets all the conditions for safe working practices that do not pose a threat to health. Our observations are based partly on events experienced over the past 20–25 years and partly on acquired knowledge. Our findings are partly subjective and partly objective, and the approach we have taken is only one of many possible paths.

The risk profile documented in this study is consistent with findings reported in comparable international settings. A systematic review by Muzaini et al. (2021) confirmed that sewage workers face elevated exposure to respiratory hazards including hydrogen sulphide, ammonia, bioaerosols and particulate matter, and that these exposures are directly associated with reduced lung function and increased rates of chronic respiratory disease. This finding is especially relevant to the chemical industrial environment examined in the present study, where the hazardous substance concentrations within the pipe system significantly exceed those typical of municipal sewage networks. The dominance of chemical substance hazards among the high-risk findings in our assessment – where 59 out of 77 high-risk work processes were attributable to material and preparation hazards – aligns with data reported by the French National Agency for Food, Environmental and Occupational Health Safety (ANSES, 2022), which identified high-pressure cleaning and grit tank cleaning as the tasks generating the greatest chemical and carcinogenic exposure for sewer workers, due to the aerosolisation of contaminants during pressurised operations. This parallel directly supports the emphasis placed in the present study on respiratory personal protective equipment during high-pressure washing steps. Furthermore, confined space statistics from the United States Bureau of Labor Statistics document an average of 129 worker fatalities per year in confined space incidents between 2011 and 2018, with 56% involving toxic atmospheres or oxygen deficiency (BLS, 2019). The finding that 60% of confined space fatalities involve attempted rescuers who entered without adequate preparation (BLS, 2019) directly reinforces the residual risk designation applied in this study to chemical substance hazards, and underlines the importance of treating these risks as permanent priority items in training, regulation and inspection regimes. Taken together, the international evidence validates the methodology and conclusions of this risk assessment and indicates that the identified hazard profile is not an isolated feature of this particular site, but a structural characteristic of chemical-environment sewer cleaning operations generally.

The present study makes several contributions that extend beyond a standard risk assessment. First, it addresses a largely underrepresented operational context: the occupational safety of sewer cleaning in a chemical-industrial rather than a municipal environment, where the nature and concentration of hazardous substances significantly elevate the risk profile relative to conventional sewer maintenance. Second, by systematically documenting 275 identified hazards across 16 work processes and tracing 77 high-risk assessments to a small number of recurring hazard sources, the study demonstrates that risk in this sector is structurally concentrated around vehicle movement and chemical substance exposure – a finding with direct implications for the prioritisation of preventive measures. Third, the analysis confirms that in the chemical pipeline cleaning context, collective protection is technically infeasible for the most critical hazard categories, making individual protection the primary – and in many cases only – available risk reduction tool. This has significant consequences for employer obligations regarding PPE provision, worker training and health surveillance. From a practical standpoint, the findings suggest that organisations operating in this sector should treat the residual risks identified here not as a secondary administrative matter but as a core element of their occupational safety management system. Future research should address the long-term health outcomes of workers engaged in chemical-environment sewer cleaning in Hungary and the wider Central European region, where systematic epidemiological data are currently lacking. The development of standardised risk assessment frameworks specifically adapted to chemical-industrial pipeline maintenance would also represent a valuable contribution to the field.

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