THE USE OF GRAVITY AERATORS FOR THE PREVENTION OF HYDROGEN SULPHIDE PROBLEMS IN SEWER SYSTEMS

ANVÄNDNING AV GRAVITATIONSLUFTARE FÖR ATT FÖRHINDRA PROBLEM MED SVAVELVÄTE I AVLOPPSSYSTEM



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Sammanfattning

Svavelväte (H_2S) kan orsaka lukt och korrosionsskador redan i låga koncentrationsnivåer. Korrosionsskador i betong av upp till 5 cm på 5 år har observerats med svavelvätehalter runt 20 ppm. Svavelväte bildas i tryckavlopp när avloppsvattnet befinner sig i anaeroba förhållanden. Anaeroba miljöer uppstår efter 0,5 – 2 timmar i tryckavlopp. Kemikalier, syretillsats, korrosionssäkra material, biologiska metoder, luftning etc. kan användas för att förhindra problem orsakade av vätesulfid. En nackdel med att använda dessa metoder är att de kan vara kostsamma. Det är inte heller att rekommendera att ha aeroba förhållanden i hela avloppssystemet för att undvika att det verkar som ett reningsverk som använder 0 – 20 mg O_2/l/h. Vid användning av gravitationsluftare som en del av avloppsystemet kan problem med vätesulfid lösas verkningsfullt och kostnadseffektivt, framförallt om det hanteras redan i planeringsstadiet. Gravitationsluftare har visat sig vara i stort sett underhållsfria där endast ventilationsfiltren emellanåt behöver tillsyn.

Abstract:

Hydrogen sulphide (H_2S) causes odours and concrete corrosion even in very small concentrations. Concrete corrosion of 5 cm in 5 years has been observed when the hydrogen sulphide content has been 20 ppm. Unavoidable hydrogen sulphide formation in pressure sewers begins when wastewater is put under anaerobic conditions. Anaerobic conditions begin after 0.5 – 2 hours in the pressure sewer. Chemicals, oxygen feed, corrosion resistant materials, biological methods, aeration etc. can be used to prevent problems caused by hydrogen sulphide. A drawback of the use of these methods is that it can be quite expensive. In addition, it is not recommended to have aerobic conditions in the entire sewer system to avoid the sewer acting as a wastewater treatment plant using 0 – 20 mgO_2/l/h of oxygen. Using gravity aeration as part of the sewer system, hydrogen sulphide problems can be solved efficiently and cost-effectively, especially when considered in the planning phase. Gravity aerators have proved to be nearly maintenance free only the filters in ventilation require some maintenance.

Keywords: Hydrogen sulphide; gravity aeration; step aerator; pressure sewer; concrete corrosion, odours; gravity sewer

Introduction

Wastewater treatment is centralized to large units. Small wastewater treatment plants in sparsely populated areas have been closed down and long transportation sewers have been built. In most cases long pressure sewers are in use. In long pressure sewers the formation of hydrogen sulphide (H_2S) is an unavoidable phenomenon. In anaerobic conditions in the pressure sewer, sulphate (SO_4^-) present in wastewater is reduced to sulphide. Total sulphide in wastewater can be classified as precipitated metallic sulphides and dissolved sulphide species: hydrogen sulphide (H_2S), bisulfide ion (HS^-), and sulphide ion (S^{2-}). At normal domestic sewage pH, some 20–50 % of the dissolved sulphide exists as gaseous H_2S.

Hydrogen sulphide (H_2S) causes bad smells and concrete corrosion even in very small concentrations (Shammay et al. 2019). Concrete corrosion is the result of aerobic microbial activity that converts hydrogen sulphide to sulphuric acid in oxygen-rich areas, such as gravity sewers or pumping stations (Wang et al. 2020, Wu et al. 2020). This bionic corrosion of sewers represents a cost of about 10 % of total sewage treatment costs, as shown in the study by Zhang et al. in Belgium (Zhang et al. 2008). In USA it was estimated that the total annual cost of hydrogen sulphide corrosion in sewer networks in 2000 was around USD 14 billion (Brongers et al. 2002).

There are many ways to prevent hydrogen sulphide problems, such as chemicals, corrosion resistant materials, oxygen injection, biological methods, filters and gas treatment systems of ventilation air (US EPA 1985, Zhang et al. 2008, Kyhoohong et al. 2015). For example in Australia, five most popular mitigation strategies of hydrogen sulphide emissions in sewer networks are: oxygen injection and iron salts (big systems), nitrate and magnesium hydroxide (medium systems) and sodium hydroxide (small systems) (Kyhoohong et al. 2015).

In certain cases, the mentioned methods may be useful, but they can be quite costly. Alternatively, the use of gravity aeration as part of the sewer system can solve hydrogen sulphide problems, especially when considered in the planning phase. This paper describes the advantages of using gravity aerators for preventing hydrogen sulphide problems in sewer systems and the principles of these aerators.

Oxygen decrease in sewers and the formation of hydrogen sulphide

There are many factors affecting the oxygen depletion in pressure sewers: temperature, quality of wastewater, pipe dimension (smaller pipes have more active wall area), pH etc. (US EPA 1985, Zuo et al. 2019). Oxygen consumption rates vary greatly between 0–20 $mgO_2/l/h$, but are usually between 2–10 $mgO_2/l/h$. The main part of the oxygen consumption happens in the biomass attached to the pipe wall. When the oxygen consumption of

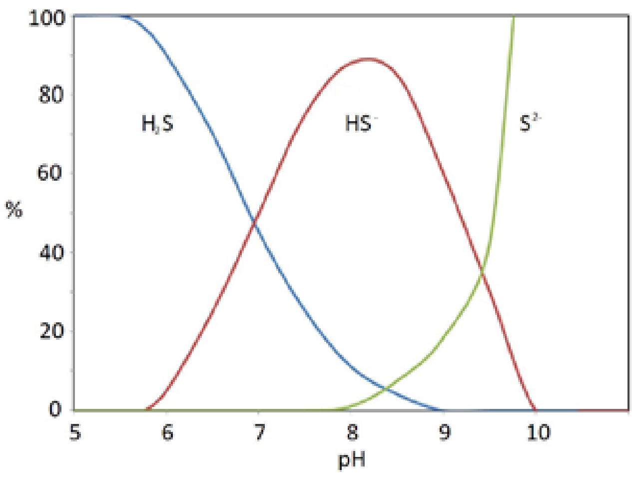

Figure 1. *Types of sulphide present based on pH. Sulphides are in hydrogen sulphide (H_2S) form at lower pH-levels. (US EPA, 1985, modified)*

wastewater in pressure sewers is compared to the maximum oxygen content of water at normal pressure, around 10 mgO_2/l, it is clear that anaerobic conditions start quite soon in pressure sewers.

Hydrogen sulphide production starts in sewers when the oxygen of wastewater is depleted, and anaerobic conditions start. The amount of hydrogen sulphide increases along the lag time in pressure sewer (Jiang et al. 2015). It is estimated that hydrogen sulphide problems are likely when pressure sewers are longer than 2 km or when the lag time in sewer is more than 2 h (Pekkala 2006).

Hydrogen sulphide is one form of sulphide. The ratio between H_2S, HS^- and S^{2-} depends on the pH value. The lower the pH the larger the percentage is in a hydrogen sulphide form (Figure 1).

It is possible to strip sulphuric compounds from wastewater when they are in H_2S form. In aerobic conditions, sulphuric compounds become oxidized mainly in 5–20 min (Clidence & Shissler, 2008).

Problems caused by hydrogen sulphide

Hydrogen sulphide has a bad smell, like rotten eggs, and the smell threshold is only 0.008 ppm or 0.011 mg/l. Ventilated gas, from pumping stations etc, can be treated with active coal filters, ozone or gas scrubbers etc. to avoid odour emissions to the surroundings.

When wastewater including hydrogen sulphide is released to aerobic conditions, into gravity sewers for example, microbes start sulphuric acid production from H_2S in the presence of moisture, which causes corrosion. Concrete corrosion as high as 5 cm in 5 years has been observed due to H_2S content of 20 ppm (Hughes 2009). The concrete corrosion can be quite severe even in small H_2S concentrations (Figure 2).

Concrete corrosion is not easy to see in the first phase. In the first phase the pH of the concrete falls down and there is no material loss. In this phase alkalinity protects concrete against microbial corrosion (MIC). When the pH of concrete decreases under 9, biological corrosion starts, and material loss rises exponentially (Figure 3). Damage comes forth clearly when the decreasing pH has reached rebar and iron starts to rust.

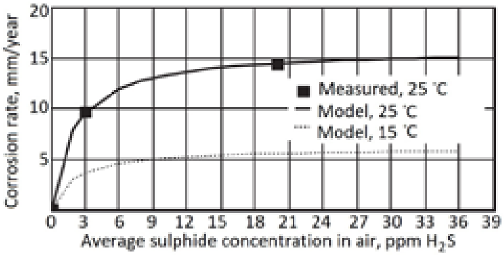

Figure 2. *Corrosion rates at 25°C versus the concentration of H_2S in air. The model 15°C is predicted with a temperature constant of kT= 1.1 (AEsöy et. al. 2014, modified).*

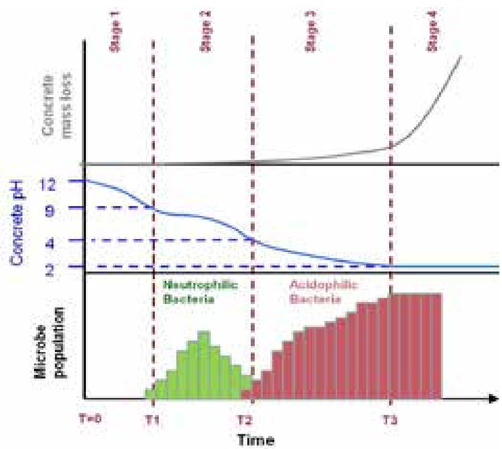

Figure 3. *Progression of microbial corrosion in sewer pipe: stage 1 – abiotic neutralization of concrete surface, stage 2 - colonization by neutrophilic bacteria, stage 3 – colonization by acidophilic bacteria, stage 4 – loss of concrete mass (Wells 2009).*

Use of gravity aerators

Gravity aerators can be used to strip out H_2S from wastewater and to dissolve oxygen to wastewater. Dissolved oxygen in wastewater then oxidises H_2S and other sulphide compounds. The aerators must be well ventilated. Ventilated gas must be treated using an active coal filter or a corresponding system. There must be enough contact time after the aerator to oxidise the remaining H_2S and other sulphide compounds. The contact part of the following gravity sewer must be plastic or some other corrosion resistant material and it must be well ventilated.

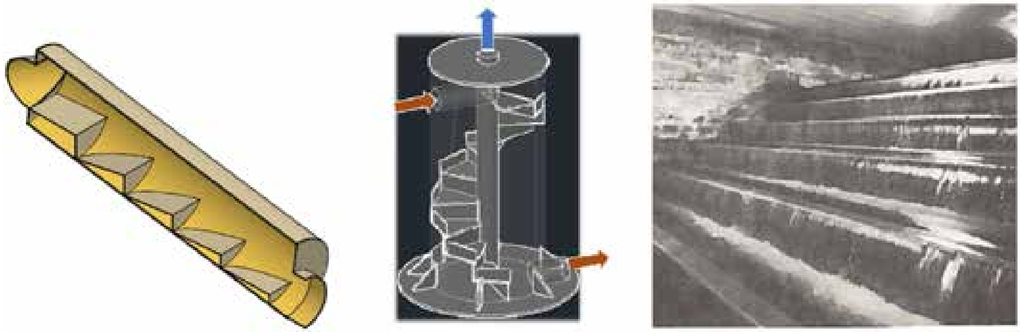

Figure 4. *Different types of gravity aerators applicable for H_2S removal and wastewater oxidation.*

When the H_2S problem is taken into account in the planning phase of sewer systems, the investment costs of gravity aeration systems are low. Gravity aerators are maintenance-free, as only the exhaust gas filters need any maintenance. Thus the operation costs consist mainly of the needed around 2 m extra pumping height and of the treatment of ventilation air.

Design of gravity aerators

In wastewater gravity aerators, the design instructions for tap water aeration can be applied and the knowledge of aeration dams can be used. Examples of applicable gravity aerator types are step aerator and drop aerator (Figure 4).

Gravity aerators transfer oxygen quite cost-effectively and the energy consumption is approximately 0.3–0.8 kWh/kgO_2. The needed height of the aerators is 1.2–2.5 m while step height is normally 0.3–0.65 m. It is useful for the aeration capacity to design steps so that air can flow under the water fall (Figure 5).

Use of gravity aerator in Turku

In Turku city there were major hydrogen sulphide problems in the sewer system in the Raisio line (Figure 6). A lot of concrete corrosion in the gravity sewer line situated after 3 km long pressure sewer was observed. After 5 years' use there was significant damage in the first part of the gravity sewer

Figure 5. *Step aerator built in Turku, Finland. The aerator was placed after a pressure sewer line and before a concrete gravity sewer. The first 400 m of the gravity sewer was coated at the same time, as there was a lot of concrete corrosion caused by H_2S. The flaps beside the steps allow the air inflow under the fall.*

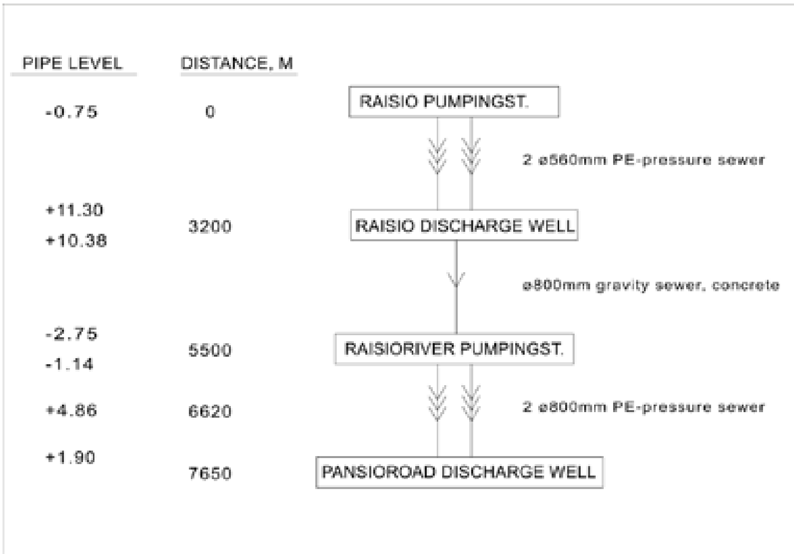

Figure 6. *Principal diagram of the Raisio sewer line.*

after the Raisio discharge well (Figure 7). Concrete corrosion in the gravity line was so massive that after 5 years' use the first 0.4 km of the sewer line had to be lined. There were also hydrogen sulphide problems at the end of the whole line. Average sewer flow of the line is 10 m^3/min.

In the Raisio line, ferric nitrate sulphite was used for hydrogen sulphide prevention after the hydrogen sulphide and concrete corrosion problems were observed. When the lining of the first 0.4 km of the gravity sewer from the Raisio discharge well was done, a step aerator was built at the beginning of the line and chemical feeding was stopped. At the same time, an active coal filter was built for the ventilation air from the step aerator and the ventilation of gravity sewer line was improved.

Figure 7. *Raisio sewer line after 5 years' use. Concrete corrosion was caused by hydrogen sulphide.*

After those line improvements the hydrogen sulphide concentration in the air just after the step aerator was 1/3 of the original and after 400 m of lined gravity sewer the hydrogen sulphide content was very low (Figure 8). In Raisio disharge well, original H_2S content of the air was usually in June 20–70 ppm and after these line improvements mainly under 0.5 ppm (Figure 9).

The step aerator has worked excellently, it has cured the hydrogen sulphide problems and there has been no need for maintenance of the step aerator. Operating costs consist mainly of change the coal to the active coal filter for the ventilation air. Earlier the chemical costs in this line were over EUR 100 000/year. Whereas, the total investment cost in the step aerator case was ca. EUR 100 000. The experiences of the step aerator in Turku were so good that new step aerators have been built in other sewer lines.

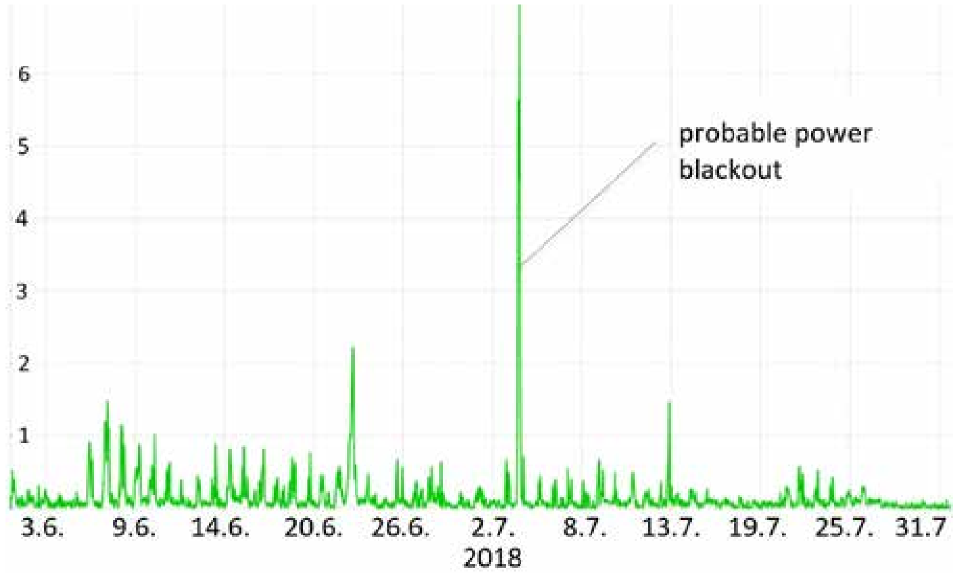

Figure 8. *After sewer line improvements hydrogen sulphide concentrations (ppm) 400m downstream of the step aerator were very low.*

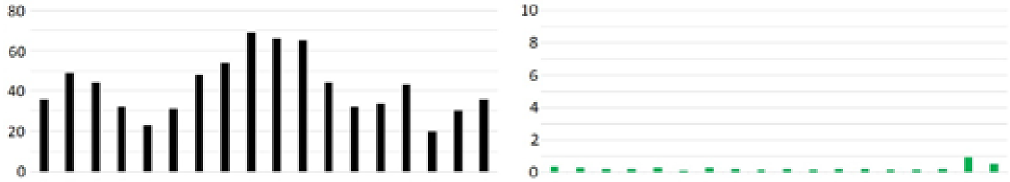

Figure 9. *Daily hydrogen sulphide concentrations (ppm) in Raisio discharge well before step aerator (left) and after the step aerator was built (right), 2½ week observation period in July, H2S concentration in air as ppm – y axis.*

Conclusions

The formation of hydrogen sulphide is unavoidable in long pressure sewers. Using gravity aerators is a functional and economical way to solve the odour and concrete corrosion problems. Gravity aerators can be used in old sewer lines, but the most economical way is to take the hydrogen sulphide problem into account at the design stage and install aerators to new lines. The use of aeration is best at the end part of the line, because if long pressure lines with long delay times are kept in oxygen-rich circumstances, the sewer system works like a waste water treatment plant using BOD. Also, the first part of the gravity line after the gravity aerators must be corrosion resistant. Gravity aerators themselves need no maintenance, but the filters for exhaust gas need some maintenance.

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