Influence and Interaction of Temperature, H_2S and pH on Concrete Sewer Pipe Corrosion

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***Abstract*—**Concrete sewer pipes are known to suffer from a process of hydrogen sulfide gas induced sulfuric acid corrosion. This leads to premature pipe degradation, performance failure and collapses which in turn may lead to property and health damage. The above work reports on a field study undertaken in working sewer manholes where the parameters of effluent temperature and pH as well as ambient temperature and concentration of hydrogen sulfide were continuously measured over a period of two months. Early results suggest that effluent pH has no direct effect on hydrogen sulfide build up; on average the effluent temperature is 3.5°C greater than the ambient temperature inside the manhole and also it was observed that hydrogen sulfate concentration increases with increasing temperature.

***Keywords*—**Concrete corrosion, hydrogen sulphide gas, temperature, sewer pipe.

I. Introduction

SULPHIDE induced corrosion in concrete sewer pipes is considered to be one of the dominating factors affecting the structural vulnerability of pipes, leading to premature pipe wall failure and possible subsequent collapse [1]-[4].

The corrosion problem is recognised in countries with increased urbanisation factors (i.e. use of hot water and the discharge of household detergents containing sulfur and toxic metals by industries) [5]. For example, in the UK, the gross replacement cost for sewer mains has been estimated at £104 billion [6]. In Belgium, the cost of sewer corrosion has been estimated at £4 million per year, representing around 12% of the total cost for wastewater asset management [7]. In Germany, the costs of concrete sewer rehabilitation due to corrosion were estimated to be €100 million [8].Where it was estimated that the annual cost of water and wastewater asset concrete corrosion in the USA is costing $36 billion [9]. In the Sydney area, Australia there are nearly 900km of concrete sewer pipes, with an attendant rehabilitation programme costing AUS $40 million annually; much of the deterioration is caused by pipe corrosion [10].

A number of models have been created to address the problem of pipe corrosion and timely predict possible failure [11], however these models lack reliable filed data and interaction between key parameters which this paper reviews.

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II. Background

The process of sewer pipe corrosion has been studied since 1940[th] and a set of representative knowledge has been gained over years, which are referred to as microbially induced concrete corrosion (MICC) [12]. The bacteria class *Acidithiobacillus thiooxidans* [12]-[14] which are active in the effluent biofilm [15] convert sulphate to sulphide [16]. Some part of sulphide is released in atmosphere as gaseous hydrogen sulphide (H_2S) [16]. Further, the hydrogen sulphide is oxidised [17] to sulphuric acid (H_2SO_4), which subsequently attacks susceptible pipeline materials [18]. Fig. 1demonstrates the chemical reaction of microbially induced concrete corrosion process in sewer pipe.

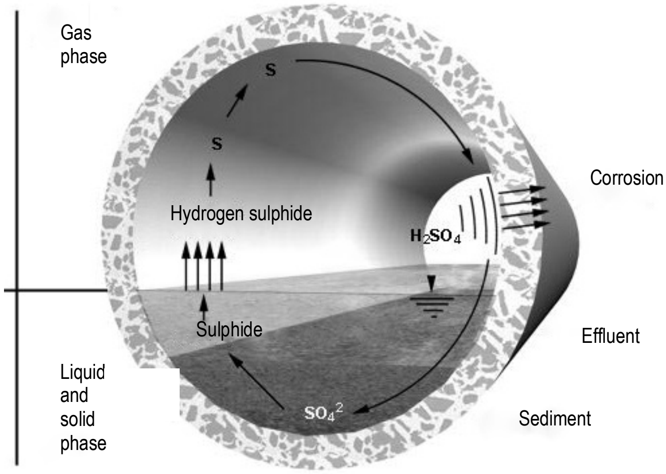

Fig. 1 Microbially induced concrete corrosion in sewer [19]

Limited works on corrosion process in pipes show that the corrosion may establish slowly, however when commenced it may rapidly accelerate and result in dry incrustation, gypsum [20] and loss of pipe wall and crown [13] and [15]. Further works confirm that severe concrete pipe corrosion occurs at points of high turbulence and constant releases of H_2S into the atmosphere even at steady state condition of all parameters [21] and [22]. Experimentally it was concluded that corrosion process accelerates when the pH of pipe wall surface drops below 4 [23] and [24], pipe surface if flushed from time to time to remove corrosion layer flocks [25], and when temperatures are in range of 10-30°C and H_2S are at 3-400ppm [14] and [16].

III. Field Data Collection

A. Manhole Location

For the purpose of these experiments two manholes with concrete sewer pipes known to suffer from corrosion process were selected in Rochester and Maid stone, Kent area, UK. Manhole No.1 (Man1) was located in Chattenden residential area 4676m, 2415m and 2037m downstream from three pumping mains with direct T-type injection connection discharging into this manhole. Manhole No.2 (Man2) was located in Mote Park, Maidstone, further away from residential area however in the vicinity of industrial estate and336m away from the discharge manhole, where the pumped main is 2572m away. For both manholes the concrete sewer pipes were of 300mm external diameter and 35mm wall thickness. Man1 and Man2 were located 19.6km apart.

B. Data Collection

In each of the manholes an H_2S sensor (GAXT-H-DL from Environmental & Gas Monitoring) temperature sensors to measure effluent and ambient temperatures as well as effluent pH (Madgetech pHTemp101 and Madgetech pH-1 pH), was inserted and secured by the use of stainless steel cables above the manhole. The reading of H_2S sensor was sampled at 5secand the reading from temperature sensors and pH were all sampled at 5min. Additionally concrete cube samples were placed in the manhole above the effluent to record the relative rate of corrosion over time of experiment. The results reported in this paper are for a 2 months deployment in Feb-Apr.

IV. Results

A. Effluent pH

The effluent pH values were measured to be fairly constant in range of 6.7-7.1 with no severe variations. This is thought to be dictated by large amounts of fats carried within the wastewater which is specifically high in both areas of the manhole's location.

B. Effluent Temperature

The effluent temperatures for both manholes were found to follow very similar daily trend, however each of them has individual hourly pattern. Fig. 1 represents the data of effluent temperature recorded at a manhole 1 and manhole 2 in 5 days period in the beginning of April, where zero is set at 10am.

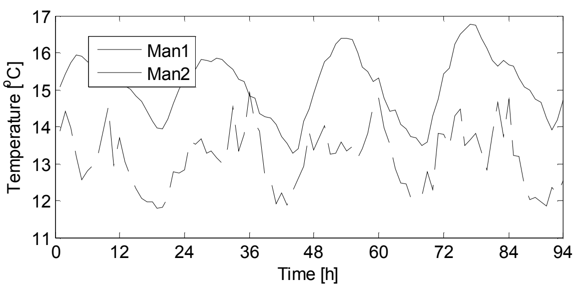

Fig. 1 Effluent temperature for Manhole 1 and Manhole 2 for a period of 4 days in the beginning of April shown in hours

The data on Fig. 1 and for all other graphs was resampled to represent an average value for each given hour. Overall, in Feb-Apr the temperatures measurements minimum, maximum and mean for Man1 and Man2 were, 10.8°C, 17.1°C, 13.2°C and 11.6°C, 17.6°C, 15.1°C, respectively. In general the temperatures in Man2 are found to be higher and this is thought to be influenced by a closer location to the rising main, pumping station and generally the industrial sector which have larger use of hot water.

C. Ambient Temperature

The ambient temperatures for both manholes were found to follow overall an identical pattern. The general pattern of this behavior for both manholes is illustrated in Fig. 2, with zero set at midnight. From Fig. 2 it can be noted that the temperature in Man 1 is generally slightly lower for that compared with Man 2, with mean temperature values of 9.3°C and 10.6°C, respectively. Overall, in Feb-Apr the temperatures measurements minimum, maximum and mean for Man1 and Man2 were, 7.6°C, 12.9°C, 10°C and 8.7°C, 13.8°C, 11.2°C , respectively. The temperatures increased over the day with peak times at 11pm-4am after which they declined. This coincided with the discharge of overflow in the pumping station which generally takes place at midnight or when the chamber is full. However each manhole had manhole-specific minor pattern which is thought to be governed by house hold and industry activity in the area.

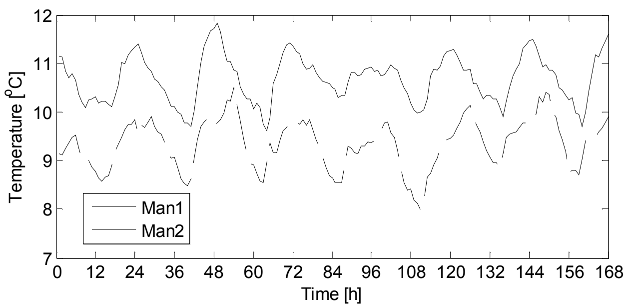

Fig. 2 Ambient temperature for Manhole 1 and Manhole 2 for a period of 1 week in the beginning of March shown in hours

D. Concentration of H_2S

The concentration of hydrogen sulphide for both of the manholes was measured with the sensor being placed in the middle of the manhole at 600mm above the effluent. The measurements of H_2S are presented on Fig. 3, where the data is shown for the same time period as in Fig. 2. From the figure it can be noted that the pattern of H_2S concentration is similar for both manholes even though they were located far apart and governed by different rising mains and pumping station conditions. Although, it should be noted that the operational time for all pumping stations in experimental area is the same. Graph identified large peak ofH_2S at Manhole 1 at 91ppm/ % vol, where manhole 2 identifies only 29ppm/%vol. A similar peak tends to appear app. every 48h closer to midnight.

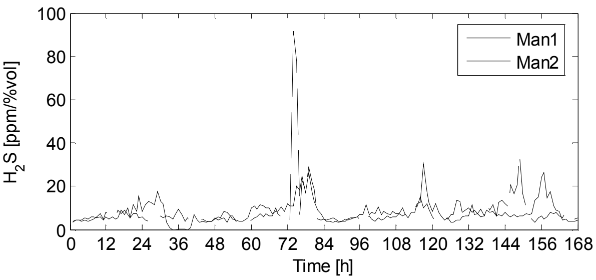

Fig. 3 Hydrogen sulphide concentration for Manhole 1 and Manhole 2 for a period of 1 week in the beginning of March shown in hours

Overall, in Feb-Apr the measurements of the H_2S concentration minimum, maximum and mean for Man1 and Man2 were, 3, 134, 12 and 0, 168, 12, respectively. Even though the minimum and maximum values of both of the manholes varied, the mean of 12ppm/%vol was observed in both, whereas in most of the times a value of 3-5ppm/%vol was recorded.

E. Interaction Between Parameters

The interaction between parameters of ambient temperature, effluent temperature and concentrations of hydrogen sulphide was investigated. Fig. 4 demonstrates the recorded data for the above for first four days in April for Manhole 1, with zero starting at 10am.

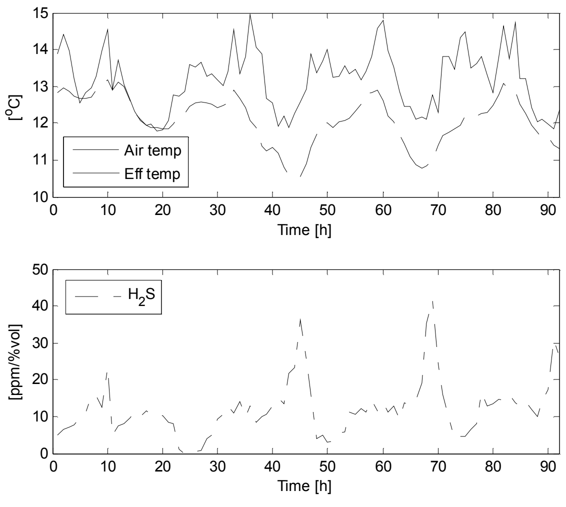

Fig. 4 Temperatures and hydrogen sulphide concentration for Manhole 1 for a period of 4days in April shown in hours

The data suggests that there is a relation between the ambient and effluent temperatures as they follow the same hourly pattern (which is governed by the effluent temperature, which in turn is related to domestic and industrial activities) and daily trend (governed by effluent temperature and general temperature of air outside the manhole). Furthermore, it can be noted that the H_2S level peaks together with the general decrease in temperature inside the manhole in late evening and early morning hours (during this time the general household and industrial actively is minimal, the flow levels are low to moderate which allows for gas build-up). Furthermore, there is an apparent 10h shift in H_2S level increase and decrease behavior compared to temperatures. The above findings were confirmed for both of the manholes during Feb-Apr period.

V.CONCLUSION

In the above study effluent pH, effluent and ambient temperatures, as well as hydrogen sulphide gas were collected in two manholes in Kent, UK for a period of two months in order to establish a relation between parameters. Below is the summary of key observations and findings:

1) Effluent pH values do not have a direct influence on hydrogen sulphate concentration.
2) Ambient temperature is influenced by effluent temperature which both are thought to follow general trend of the temperature outside the manhole.
3) Hourly temperature patterns are individual for each manhole, whereas the general daily trend is similar that is governed by the domestic and industrial use as well as discharges from rising mains and pumping stations.
4) On average effluent temperature is higher by 3.5°C than the ambient temperature.
5) Concentration of hydrogen sulphide was found to peak with the decrease in temperature inside the manhole as well as during times of low wastewater activity and have a 10h shift in general pattern.

To supplement these findings further work will focus on correlating H_2S and temperature parameters, where an easy-to use model will be proposed, as well as relation to parameters of humidity, CO_2 and flow rate will be investigated.

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