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Controlling Chemical Dosing into Sewers for Odour and Corrosion Abatement

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Sewers conveying domestic or even industrial wastewater are subject to release of odours and other compounds from the liquid into the gaseous phase. This can cause odour nuisance and also massive damage to the sewer network itself due to corrosion of concrete and metal. In order to prevent the formation of the responsible substances, mainly sulphide, chemicals, mostly oxygen carriers, can be dosed into the sewer network. If odorants or sulphide are present in discharges or have been formed in the sewer already, especially with pressure mains, chemicals that oxidise odorants and chemicals that precipitate sulphide can be dosed in order to mitigate or suppress the negative effects. Large communities like the Paris area spend up to 7 million € per year just for the chemicals that are dosed into the sewer system for these purposes.
Proper dosing of chemicals that always is in line with the actual demand is not realized today. There are several reasons for this that will be highlighted, and it will be explained how a proper solution looks like. First results from an ongoing research project at a large German city will be shown, where the new improved strategy & methodology is adopted.

1. Introduction and current status

Today, dosing usually is controlled with a simple open loop control strategy, which normally uses only one input signals as quality parameter, namely hydrogen sulphide H_2S_g, in the gaseous (sewer) atmosphere. However, H_2S_g is not a suitable quality parameter, as the concentration of H_2S_g not only depends on the sulphide concentration and the pH-value in the liquid, but is also largely influenced by the physical conditions of mass transfer from liquid into gaseous phase – laminar or turbulent current of the wastewater, dynamic of air current in the sewer etc.. In addition, H_2S_g is not the only odorant, and measuring only H_2S is not sufficient to tackle odour problems that arise due to non-sulphuric odorants, as can often be found in industrial discharges.
Due to the fact that

- an open loop control and
- an unsuitable quality parameter, measured at the wrong position

are used, the results in terms of dosing accuracy, regarding actual dosing needs in varying circumstances, are poor. In order to assure a dosing success, the open loop control constantly overdoses. Also, with some dosing solutions, the owner of the sewer network does not even apply its own control strategy, but instead uses an open loop strategy including instrumentation that is delivered by the supplier of the chemicals, without having knowledge of the control algorithms at all.

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The situation is schematically depicted in Figure 1 (left). The dotted red line “100% safe” shows the usual strategy of dosing, which results in overdosing at all times.

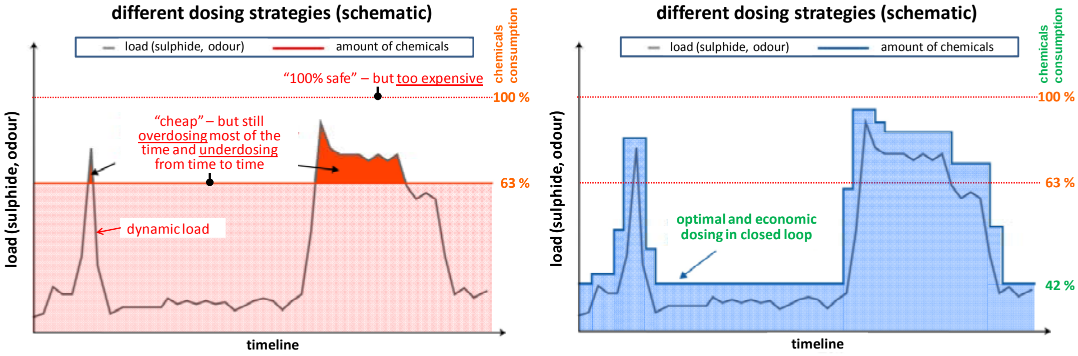

Figure 1: open loop dosing control (left), closed loop control (right)

If the dosing amount is reduced, a situation may occur as depicted by the solid red line. Less chemicals are used, but during some periods still overdosing occurs, whereas also periods are observed where dosing is not sufficient. Both situations result in their specific costs/disadvantages. This can only be avoided using a closed loop dosing control as schematically depicted in Figure 1 (right).
In order to be able to realize a closed loop dosing control, it is as a first priority necessary to be able to measure the appropriate quality parameters at the correct location.

2. Preconditions for an optimized dosing control

2.1 Relevant quality parameters and measurement possibilities

Although the H_2S_g concentration is most relevant for corrosion and much of possible odour nuisance, H_2S_g is not applicable in a closed loop control strategy. The reason for this is that the true source of H_2S_g is sulphide in the liquid, and due to time lag between sulphide formation and H_2S emission from the liquid into the sewer atmosphere, using H_2S_g would result in a much too long dead-time, making a closed loop control impossible. The second reason is that mass transfer of H_2S from liquid into gaseous phase depends upon several other physical boundary conditions, see above, and thus can vary remarkably, whereas the phenomenon needed as the decisive signal in the closed loop control is sulphide in the liquid.
The same drawbacks concerning suitability as a quality parameter apply to the odorants concentration. Here, it is necessary to know the odorants concentration in the liquid rather than the odorants concentration in the sewer atmosphere, too.
Thus, in case of dosing control for the purposes of minimizing corrosion as well as odour, the parameters

- Sulphide in the liquid phase and
- Odorants concentration in the liquid phase (to be measured according to the OEC measurement method)

are needed. The odorants concentration in a liquid can be measured using the Odour Emission Capacity (OEC) measurement method. Frechen and Köster (1998) presented this method for the first time international in the year 1998, although the methodology was established by them since 1993. Frechen (2009) reported on the method and gave a summary of ten years of using this measurement method, doing more than 800 OEC measurements. The OEC method, see Frechen (2012), will soon be issued as German VDI guideline 3885/1 “Olfactometry – Measurement of the Odour Emission Potential of Liquids”.
In other words, a device is necessary that is able to perform both measurements. This device was developed by DESEE: the sulphide and odour measurement unit SOU. It basically consists of two

parallel stripping reactors. One is dedicated for sulphide measurement in analogy with DIN 38409-29 (2003), thus lowering pH-value of the sample from the sewer, and H_2S_g in the off-gas of this stripping reactor is the responsible signal and is converted into “sulphide in liquid concentration in mg/L”. The second stripping reactor is filled with the sample from the sewer network without changing the conditions. Here, it is necessary to measure in analogy to the OEC measurement method, thus an electronic nose has to be used to determine the “odorants concentration in the liquid in ou_E/m^3_{liquid}”

2.2 Measurement device hardware – the sulphide and odour measurement unit SOU

As mentioned, liquid has to be withdrawn from the sewer and has to be analyzed by an automated device that is able to perform sulphide and OEC measurement in order to deliver relevant quality parameters for the intended closed loop control strategy.
Figure 2 shows as an example the measurement device for sulphide and odour measurement unit called SOU that was manufactured by DESEE for a research project carried out recently by the Competence Centre Berlin, Berlin Water Services and DESEE. DESEE was obliged to build the SOU, and also had the task to evaluate the raw data obtained from four different electronic noses, as olfactometric measurement was done in parallel. Results were presented by Rouault et al (2013).
As pointed out earlier, two parameters have to be obtained from the liquid, and in the SOU, the liquid sample (wastewater from the sewer) is filled into two reactors in parallel as denoted in Figure 2. Both reactors perform an OEC-like stripping test as described above.

Figure 2: “Research” version of the SOU at the Berlin Water services test ground

In order to analyse the sulphide concentration, the left reactor is acidified to reach a pH value as low as 4. The stripped air then is analysed by a H_2S_g analyser, and from the result, sulphide concentration in the liquid is calculated.
The sample in the right reactor is stripped without any change in pH value, temperature etc., so this represents the liquid in the sewer as it is. The off gas of this reactor also is analysed by a H_2S_g analyser, which gives valuable additional information, especially due to the fact that by lowering the pH value to as low as 4, some elements like ferrous sulphide – that might have been formed in the liquid due to iron salt dosage into the sewerage – tend to be resolved at least partially. If the reactor without püH value adjustment to pH 4 does show H_2S_g and the other reactor does not show H_2S_g at a pH value around 7, this indicates that ferrous sulphide was present in the sample which gives valuable information concerning the dosing activities and this signal will be included in the closed loop control.
In addition to H_2S_g measurement, the off gas from the right reactor is analysed concerning odour emissions by means of an electronic nose – or four electronic noses in parallel in the Berlin case in

order to test these devices, as described in Rouault et al. (2013). Anyway, in the right reactor, in addition to H_2S_g measurement, the most important measurement is the electronic nose measurement leading to a calculated “OEC analogous” parameter describing the amount of odorants in the liquid

3. Results

3.1 Odour – using an electronic nose

It is necessary to carefully evaluate and test the sensor array (=electronic nose) that is foreseen to be used in the SOU, and to do this in the location it will be used later on. If no measurement for calibration has been made at the point of use so far, then as a first approach mathematical models for sulphide and OEC measurement derived in similar circumstances can be used as a first approach.
DESEE has tested and evaluated many electronic noses in the past, which always includes parallel measurement (=from the same sample) between olfactometry and the respective electronic nose. Table 1 shows the data pool DESEE has collected and evaluated in the past 10 years, which, to the best knowledge of the authors, is the most comprehensive data pool worldwide. More details on the mathematical evaluation can be found in Frechen and Giebel (2011) and Frechen (2014).

Table 1: DESEE’s data pool concerning mathematical evaluation of enoses

project	eNose	period	olfactomery	origin of odour	number
Vienna	A	2005	Lab 1	wastewater	382
Vienna	B	2005	Lab 1	wastewater	156
Hilter	A	4/2008 - 5/2008	Lab 2	wastewater	40
emscher sewer	A	1/2007 - 1/2008	Lab 2	wastewater	150
Biofilter	C	2009	Lab 2	wastewater	12
OEC with wastewater	A,A	2010	Lab 2	wastewater	88
safety research part 1	*A,A*	*2007*		*drugs/explosives*	*(8)*
safety research part 2	*A,A*	*2010*		*drugs/explosives*	*(40)*
lab test	*C*	*2009*		*hydrogen sulphide*	*(20)*
Verden	A,A	2010/2011	Lab 3	wastewater	110
Aachen	A,A	2011	Lab 3	wastewater	156
Berlin	A,B,D,E	2011/2012	Lab 3	wastewater	1429
eNoses_Datenübersicht_Bilder_2014-06-19				total with olfactometry:	**2.523**

During the most recent test of the SOU on the premises of the city of Hannover, a simplified version of the SOU was recently installed, see Figure 3.

Figure 3: SOU installed in Hannover

So far, no parallel measurement, analyzing the odorants concentration ou_E/m^3 as well as the electronic noses' raw data from the same sample was made here. Thus, no site specific mathematical model is available but under development.

3.2 Sulphide measurement

Figure 4 shows a sample evaluation of the sulphide concentration measured with the SOU.

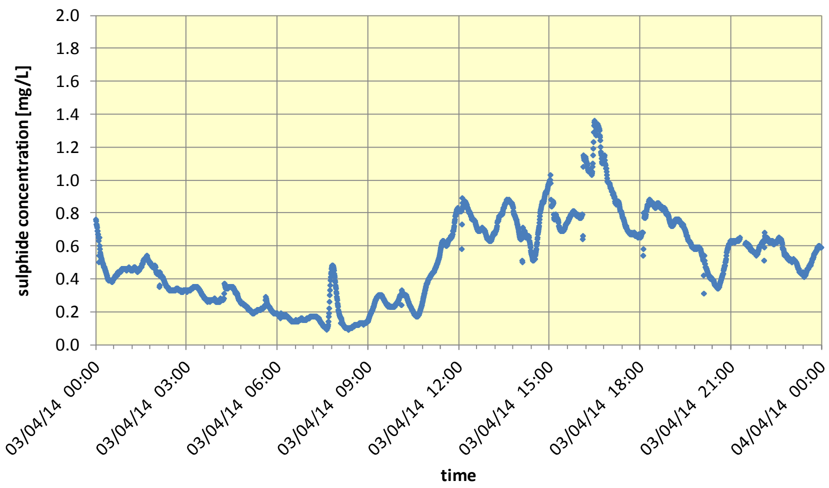

Figure 4: Dynamic behaviour of the sulphide concentration in the wastewater in Hannover

Here, calibration measurements were made onsite, thus an appropriate model for evaluation of the sulphide concentration in the liquid is available.

3.3 Dosing strategy

A very simplified scheme of a dosing control is given in Figure 5. In this case, two different chemicals are used, iron salt for precipitation of sulphide and hydrogen peroxide for odorants oxidation.

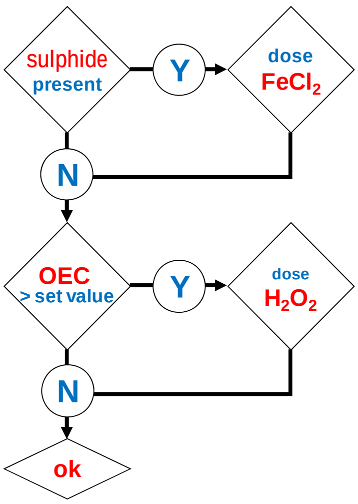

Figure 5: simplified control scheme

In Figure 5, one SOU is included, which can control dosing of two chemicals. However, in order to realize a closed loop control, where success of dosing has to be measured, it is necessary to employ at least a second SOU. Regarding a sewer network, it is essential to identify the relevant locations in the network where efficient dosing is possible, depending upon the relevant disturbing variables regarding sulphide (generation) and odour (development.

It is the work during the next year to develop appropriate control strategies in order to optimize corrosion and odour suppression along with a dosing that is tailored to the actual need of the dosing chemicals that are necessary for the task, see Figure 1 (right).

At the time of the conference, further examples will be demonstrated.

One important aim is to make the SOU self controlled incorporating blank samples, and that the process control software has a self-learning ability, improving results of the measures continuously.

4. Final remarks

Given the huge detriment of sulphide related corrosion, hydrogen sulphide caused nuisance and annoyance resulting from other odorants, resulting in high costs for the sewer network owner, dosing of chemicals in several cases in inevitable. It might be estimated that a closed loop controlled dosing, depending upon the actual situation, might save up to 25% of running costs. This gives an idea of the possible usefulness of a closed loop dosing control system. Now the next step after development of suitable and reasonable measurement devices is the composition of more and more intelligent systems that are able to fulfil the expectations that are set upon them.

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