Résultats d’une aération linéaire d’un égout sous pression grâce à de minuscules bulles pour éviter l’émission d’odeur et la corrosion.
(Mots clefs : Odeur, égout sous pression, hydrogène sulfide, corrosion)

Résumé :

Cet article présente les résultats d’une aération linéaire sur 7 km de long d’une canalisation sous pression transportant des eaux usées dont l’âge atteint jusqu’à 17, 5 heures.
Un enrichissement en oxygène a été observé avec des températures basses. Durant cet été, avec des eaux usées à 17 ° C, il n’a pas été possible de détecter des émissions d’odeurs à l’extrémité de la canalisation. Dans ce cas, grâce au dosage linéaire, la moitié de la quantité d’air donnée comme recommandation dans la brochure ATV-M 168 suffit. La valeur maximale mesurée de sulfides a été de 1,4 mg/l et a réduit le seuil de corrosion. Avec ceci, l’efficacité de l’aération linéaire a été démontrée. Dans l’article, les résultats jusqu’à juin 2003 sont évalués en détail et une comparaison des coûts des alternatives est présentée.

1. Initial situation

The reduction of odour emissions from sewer networks represents an increasing problem for operators of widely spread sewer networks. The causes of the formation of the odours in the sewer network are numerous, such as, for example, deposits, the composition of the wastewater and, in particular, long retention times in closed systems. Long retention times lead to odour emissions through the formation of various osmogens. The odours escape at the transfer shaft of the pressure pipeline into the gravity sewer. This concerns, in particular, newly created central wastewater systems in the new [German] Federal States. The wastewater yield used in the planning is not achieved in practice and thus the wastewater ages. Therefore, additional measures for the minimisation of odours, which at the same time serve for the reduction of biogenous sulphuric acid corrosion, are necessary.
ATV Advisory Leaflet ATV-M 168 was issued in 1998 in order to provide information for planning, construction and operation of drains. Here an empirical formula for the calculation of the oxygen demand for the anaerobic operation of pressure pipelines is given:

$$OV = 0.024 * \left\lfloor \pi \cdot D \cdot L(Z_{sf} + D / 4 \cdot Z_{ww}) \; _{-}Q_{24} \, c_{02} \right\rfloor$$

with OV oxygen consumption in kg/d
D pipe diameter in m
L length of pipeline in m
Z_{sf} oxygen depletion in the sewer film in g/m²h (at 20 °C ca. 0.5 – 1.0 g/m²h)
Z_{ww} oxygen depletion of the wastewater in g/m³h
Q_{24} delivery over 24 h given in m³/h
c_{O2} oxygen content at the start of the pressure pipeline in mg/l

To prevent corrosion and therefore to maintain the value of the structures an oxygen concentration of 1 mg/l in the discharge of the pressure pipeline is given as being sufficient. The required parameters, in particular the oxygen depletion of the sewer film are, however, usually not known in the planning phase. Therefore an estimated compressed air requirement of 1 m³ air per m³ wastewater (ATV-M168) is given.

Long pressure pipelines, according to this calculation, show a high oxygen depletion, which can no longer be covered by point aeration. For this reason with the investigation of the Schwerin wastewater disposal system ([1]) the design oxygen enrichment for the interconnected network was ruled out. Currently the following strategies for solution are being considered:

- dosing with chemicals,
- feeding in of infiltration water,
- compressed air flushing
- installation of biofilters and
- extension of the pressure pipeline

In the main these are associated with high investment or operating costs so that many operators are seeking more favourable strategies. This is only possible through careful basic working and intricate consideration of the pipeline system.

In the article the results of the demonstration project for the linear dosing of atmospheric oxygen in a pressure pipeline are presented, whereby a constructive oxygen enrichment is also possible for pipelines with high air demand. The linear treatment indicates an alternative in order to solve the problem effectively and efficiently.

2. Theoretical bases

To avoid odour emissions it is necessary to displace the milieu into the aerobic range. For this the addition of oxygen is required.
Fig. 1 shows the reactions of sulphur in the sewer with aerobic and anaerobic sewer atmospheres. In the aerobic milieu the offgasing of volatile sulphur compounds, which lead to odour emissions and corrosion, does not occur. In the depth of the sewer film and deposits a sulphate reaction still takes place. These reaction products, under aerobic conditions, are again oxidised before reaching the wastewater.

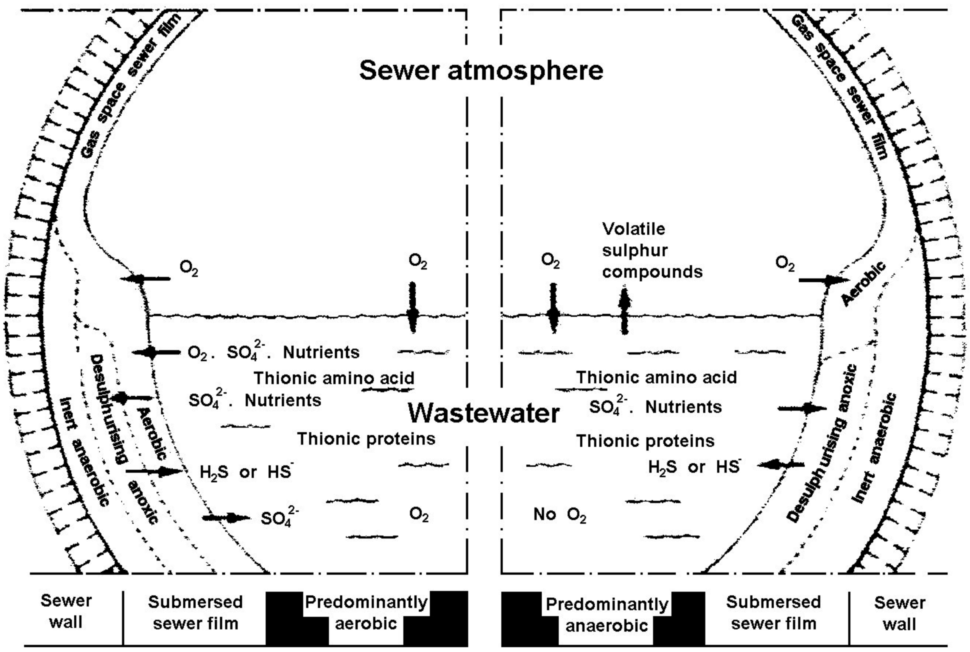


FIG 3.11: DEGRADATION PROCESS IN SUBMERSED SEWER FILM, MODIFIED ACCORDING TO (POMEROY, 1980) (U.S..1974)

Fig. 1: Sulphate conversion in sewers ([2])

The oxygen solubility under normal conditions is small. Therefore the physical possibilities of increasing the oxygen gas are used:

- enrichment of the volume content of the oxygen and
- dosing under higher pressure.

The first path is taken by dosing pure oxygen. The second variant is practicable through a direct dosing into the pressure pipeline. Table 1 shows the saturation concentrations of oxygen from the atmosphere under variation of the ambient pressure with 10° and 20° C wastewater temperature. High pressure enables a higher saturation concentration.
With modification of the ambient conditions the dissolved oxygen outgases and is no longer available for the metabolism of the bacteria further on in the pipeline. Thus, with the enrichment of the oxygen a repository dosing as with chemicals is possible to a qualified extent only.

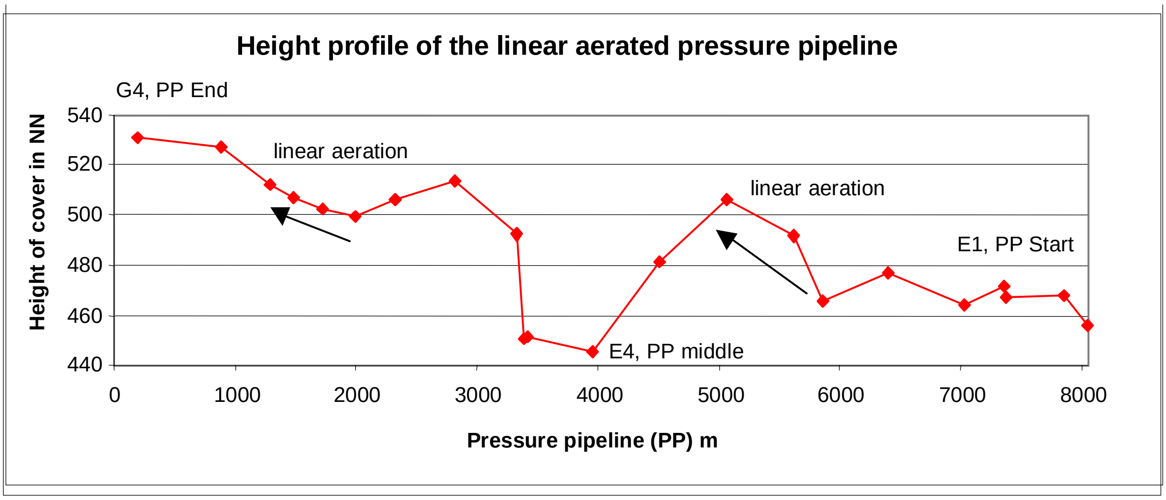
Pressure in the system (mbar)	1013	1500	3000	5000	6000	7000
Temperature in ° C	Oxygen saturation concentration in mg/l					
10	10.9	16.2	32.3	53.9	64.7	75.4
20	8.9	13.2	26.3	43.8	52.6	61.4

Table 1: Saturation concentration of atmospheric oxygen in water for various ambient pressures and temperatures (according to [3])

The fraction of oxygen in the gas fed in enters directly proportional in the saturation concentration. Thus the concentrations given in Table 1 with the dosing of pure oxygen can still be increased by a factor of 5.

3. Demonstration project Oberharz

Diag. 1 shows the pressure pipeline of the WAZV [Water-Wastewater Special Purpose Association] Oberharz, where the linear dosing of atmospheric oxygen is applied. The retention time in the pipeline is on average 2 hours. The wastewater is collected in the connected localities in gravity systems, so that a flow time of ca. 17.5 hours can be assumed ([4]).
According to ATV Advisory Leaflet ATV-M 168 an oxygen content of 1 mg/l at the outlet of the pressure pipeline is specified. For the pressure pipeline examined here a quantity of oxygen of 242 kg per day is required. In order to feed this quantity into the wastewater it would be necessary, with normal oxygen concentrations of 10 mg O_2/l, to treat a quantity of wastewater of 27,000 m³/d. However, over the distance considered here, only 1,600 – 5,500 m³ per day are transported. Thus, under normal conditions, an oxygen dosing is only possible with the maximum carrying capacity and through the dosing of pure oxygen.



Diag. 1: Height profile of the pipeline, HDPE 355x32.2 PN 16, volume 350 m³, length 7,380 m, 4 aeration valves, (linear aeration distances marked by arrows) (from [5])

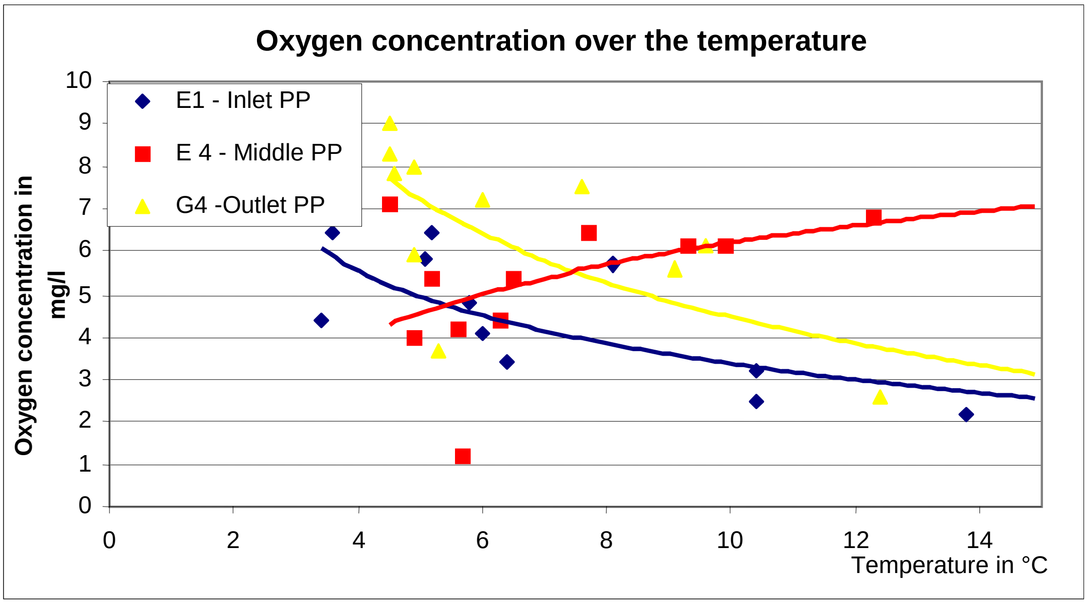
The linear dosing in the pressure pipeline can reduce the required quantity of air. The Oberharz Water and Wastewater Association has thus, for economical considerations, decided to test linear dosing of atmospheric oxygen into the pressure pipeline.
Through dosing directly into the pressure pipeline using an overpressure of 3 or 6 bar respectively the solubility of the atmospheric oxygen is 3-6 times higher than with normal pressure and thus corresponds with the solubility of pure oxygen. For this a hose is installed into the pressure pipeline which, through a patented specific cross-section and a type of microperforation, doses a constant quantity of air over the complete length.

The quantities of air calculated for the linear dosing are ca. 50 % lower, compared with the calculations in accordance with ATV-M 168, as the oxygen depletion, in particular of the sewer film, is held at a lower level. The dosing into the pressure pipeline suppresses the anaerobic processes as sufficient oxygen is continuously available. Thus linear aeration of atmospheric oxygen, even with high oxygen depletion, represents an alternative to chemical dosing.

3.1 Results from available analyses

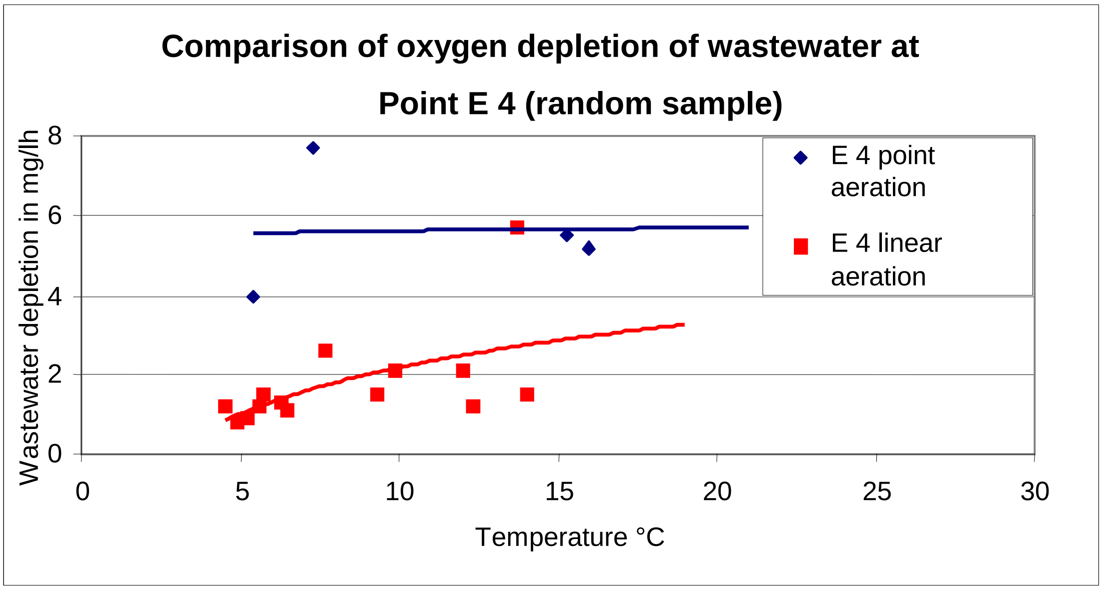
Both the above characterised aeration distances of 1,100 and 830 m have been in operation since December 2002. 375 l/min of air are dosed evenly over the length of the hose installed in the pressure pipeline.
The analyses in April and June with wastewater temperatures of 8 – 13 ° C indicate an increase by 0.4 – 3.6 mg/l of dissolved oxygen in the wastewater in the pressure pipeline. With this there is currently an underdosing and the depletion of the oxygen through the sewer film and the wastewater is more than covered by the system. The oxygen content at the end of the pressure pipeline is currently between 2.6 and 7.5 mg/l and is thus significantly higher than the value of 1 mg/l given in accordance with ATV-M 168. Thus the dosed oxygen can be depleted further on in the pipeline and suppresses the anaerobic processes in the following reaches.

Diag. 2 shows the oxygen concentration over the pipeline dependent on the wastewater temperature. From this it is clear that the oxygen concentration at the end of the pressure pipeline (G 4) is higher than at the beginning (E 1). The course of the oxygen concentration over the temperature at the start and end of the pressure pipeline falls in parallel. Through the linear aeration the oxygen concentration is elevated to an overall higher level.



Diag. 2: Oxygen concentration over the wastewater temperature at various cross-sections of the pressure pipeline,
E1: Beginning of the pressure pipeline, pump sump
E4: Rappbode siphon: pressure pipeline after 4 km,
G4:Gasing shaft at the end of the pressure pipeline

Since the commissioning of the linear aeration H_2S emissions have no longer been detected. The maximum sulphide content was measured as 0.13 mg/l and 39 mg/l sulphate. These values lie far below the average contents of municipal wastewater which is given as 250 mg/l sulphate by ([6]).



Diag. 3: Oxygen depletion at the Rappbode siphon with the operation of the point aeration in comparison with linear aeration over the wastewater temperature

Diag. 3 shows the comparison of the oxygen depletion of linear and point aeration. It is clear that the linear aeration effects a lowering of the oxygen depletion in the wastewater and thus leads to a reduced air demand.

The oxygen depletion of the wastewater was reduced to ca. 2.5 mg/l h and corresponds with fresh wastewater ([7]). Commensurate with a logarithmic development of the oxygen depletion the value of fresh wastewater with 4mg/l h even with 20 °C wastewater is not exceeded. With this the assumption of a lower oxygen demand and the theoretical considerations presented for the design are confirmed.
Previously results of analyses of wastewater temperatures up to 13.8 °C have been available. Therefore the trend development applied has still to be confirmed by further analyses.

4. Outlook

The results of analyses of the demonstration project show the efficiency and effectiveness of linear aeration.
According to Lohse ([8]) ca. 1-2 kWh of energy are required for the dosing of 1 kg of oxygen. Through the linear dosing a reduction of the quantity of air to ca. 50 % is possible. For this ca. 8,800 Euro per year energy costs (0.10 Euro/kWh) result. With normal aeration systems the annual costs are more or less double. The project in the Harz is the first of its type. Therefore one can assume a high potential for optimisation, for example increase of the oxygen concentration ([9]) or through liquid oxygen carriers.

A dosing of chemicals in accordance with extrapolations from the details of ([10]) for the example presented here would cost ca. 25,000 – 50,000 Euro. Due to the potential for saving an investigation of where dosing is suitable is sensible for operators.

In order to make the results from the demonstration project transferable further investigations are sensible. In the first place the forecast of the actual oxygen demand is to be improved. The objective is to create foundations for planning in order to take into account in this phase an avoidance of odour and corrosion and, with this, to prevent biogenous sulphuric acid corrosion in new pipelines. Simulation software for the degradation is to be applied as method, comp. dynamic simulation of wastewater treatment plants.

For the retrofitting of linear aeration the hydraulic conditions in the pressure pipeline and the working point of the pump are to be recorded accurately in the conception phase in order to reduce the effect on the carrying capacity. The selection of the suitable installation point is to be specified through the determination of parameters.
In addition, a COD degradation due to the aeration was observed. The effect on the treatment performance of the wastewater treatment plant, in particular with regard to the usage of carbon compounds, is to be investigated further. With this particular attention is to be placed on the corrosive metabolism products. For this additional partners and material sponsors, who can support this investigation, are being sought.

[Translator's note: as far as known there are no official translations into English of the references below. Therefore a courtesy translation of the title is included as an aid.]

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