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Accidents with gases from liquid manure in pig farms

The risk of accidents with gases from slurry is often underestimated by farmers, deadly accidents of humans and animals are the result. Nine pig farms were visited to picture the facts, which had passed to accidents. At the same time selective measurements of slurry gases were made in stalls. Unavailable gas stopper, badly regulated ventilation systems, unfortunate circumstances and too little knowlegde about the conditions of gas release have been the reasons for these accidents.

Keywords

Accident, harmful gas, hydrogen sulfide, ammonia, liquid manure, pig

Abstract

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The risk of accidents with gases while handling slurry, in the form of intoxication, asphyxiation and explosion, is very often underestimated. Such personal accidents are registered by the Agricultural Accident Insurance Funds. In addition, there is a dangerously high figure of unreported near accidents, and sadly, animals are repeatedly injured or killed.

Nine pig farms were visited for the following report. These farms were known to the Agricultural Accident Insurance Funds Baden-Württemberg through accidents with gases from liquid manure. The farm managers were each asked about their farm and the occurrence of the accident, and existing construction plans were seen. This report was to study and illustrate the situations which had become accidents. Special attention was paid to the slurry handling systems, including tanks and ventilation systems. At the same time, selective measurements of slurry gases were carried out in stalls and slurry tanks. The measuring instrument Multiwarn II, from Dräger, which can simultaneously and continuously measure four gases, was used. Carbon dioxide (CO_2; 0-15 Vol.-%) was measured by an infrared sensor, methane (CH_4; 0-100% lower explosion limit) by a catalytic bead sensor, and ammonia (NH_3; 0-200 ppm) and hydrogen sulphide (H_2S; 0-100 ppm) via electrochemical sensors. In addition, action already taken and additional safety measures were discussed with each farm manager.

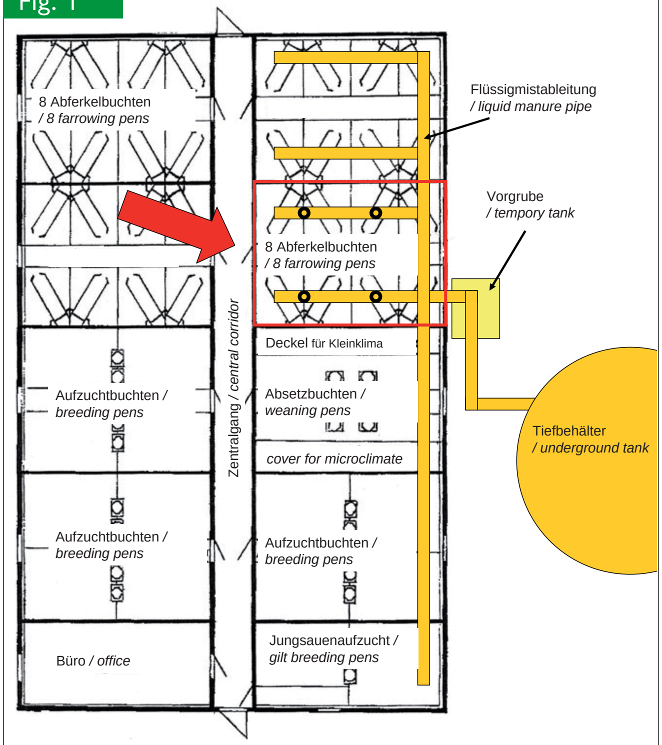
Description of a deadly accident

As an example of one of the nine accidents, the situation at one farm was described more precisely. The stall complex, built in 1995, was divided into ten compartments with a central corridor; it was used for farrowing pens and for piglet breeding (**figure 1**). The liquid manure was accumulated below the grids and piped into an enclosed underground tank. The pipes were closed with plugs. An original intermediary temporary tank with a direct connection pipe was taken out of operation because it functioned poorly. The influent of liquid manure was one metre below the tank ceiling. Using a ventilation system under partial vacuum, the incoming air was led from the central corridor through manually operated slides into the compartments (**figure 2**) and from there distributed with trickle canals. The air exhaustion occurred underfloor and, at the same time, the cross-sections of the outlet air holes were clearly too small (**figure 3**).

The course of events of the deadly accident could be reconstructed as follows. Because of a cold morning, the ventilation system was working with a minimal air change rate in a compartment fully occupied with farrowing pens. The farmer was dumping the liquid manure from this compartment by pulling the plug out of the pipe slurry handling system with a hook.

At the same time, the liquid manure inside the underground tank was homogenized by a slurry mixer and pumped out by a slurry tanker. About an hour later, the farmer entered the compartment again to closing the pipe with the plug. In the process, he leaned into the pen, probably even into the manure canal (the plug was missing or badly fitted) and breathed in too much hydrogen sulphide, which resulted in his death. Another person tried to help him, entered the compartment, lost consciousness immediately, fell down with the upper part of his body in the central corridor and therefore survived. The animals in the compartment also survived because they are standing in the part of the pen without grids. It is not known whether they became unconscious. At the time of the accident, the underground tank was mostly empty and the pump was working at the surface of the liquid manure, so more gases were expelled, especially H_2S, and flowed back through the pipe into the compartment.

Fig. 1

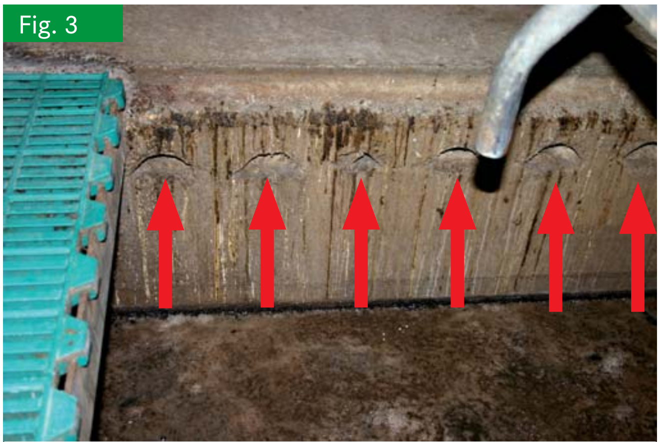


Ground plan with liquid manure pipes to the tank, temporary tank out of order

Fig. 2

Manual additional air slide – view from central corridor, face upwards

Fig. 3



Outgoing air holes of underfloor exhaustion

Measurements during the dumping of liquid manure from a pipe slurry system

To get an idea of which gas concentrations could have risen with this accident, the situation was reproduced, but there were no animals in the farrowing pens, the underfloor air exhaustion worked at its highest level and the liquid manure in the tank was not homogenized. The gas concentrations were measured 50 cm above the grid in this empty compartment (**table 1**). The gas concentrations before discharging were appropriately at a normal level for the liquid manure in the empty compartment. After pulling out the plug, the NH_3 data increased to 198 ppm till just under the measurement limit, and the H_2S data also increased to just under 40 ppm. The gas concentrations were different after the liquid manure had run off: above the grid, they decreased slowly, but below the grid, the gas concentrations of NH_3 and H_2S were extremely high, with the result that toxic effects could be calculated if one breathed in for a longer time. At the same time, extremely high gas concentrations inside the underground tank could be verified.

Since then, the farmer on this farm has taken additional safety measures. He installed slides for incoming air canals which could not be closed to always assure a minimal air change rate. The air change rate has to be increased in the compartment during liquid manure run-off. Further measures will be the expansion of the underfloor ventilation holes because they were clearly too small. The direct liquid manure pipe between the stalls and the underfloor tank should be reset and a gas stopper installed.

Summary of the course of events of the accidents at the farms studied

At the accidents at all nine farms studied, four people were harmed and one of them killed; pigs died on five farms. These accidents can be summarized in the following way: twice, liquid manure was allowed to run off from the canal during the period when liquid manure was being homogenized in the tank, and the pipe between the tank and stable did not have a gas stopper; once, a plug was open in a pipe during the liquid manure run-off, and another time, a plug was open during flushing – animals in a neighbouring compartment died in each case. Four times, accidents happened during flushing work, once during homogenizing liquid manure in a deep channel. Only one farm has installed a gas stopper in the form of a siphon in the pipe between stall and tank.

In addition, it was pointed out that air change rates of eight farms were too low, or there were generally problems with the ventilation systems. Furthermore, the operating system – plug/gate valves of run-off from liquid manure or stop chocks from flushing pipes – were installed inside a pen or a compartment, this means in the danger area. Five times the compartments were used with pigs. There was no one responsible for the safety of the workers at any of the farms; twice, other people tried to help the injured person at the risk of their own lives. One farmer's family exhibited a grave error by disposing of cigarette butts in a closed underground liquid manure tank.

More measurements of slurry gases at the farms studied

At the other eight farms – excepting the farm with the deadly accident – 39 selective gas measurements in compartments with pigs were taken. The recommended limits of the German Animal Welfare Livestock Regulation [1] were exceeded: there were 4 examples of excess CO_2 (0.30–0.50 Vol. %), 14 examples of excess NH_3 (22–77 ppm) and 1 example of excess H_2S (6 ppm). Most of these excesses were caused by insufficient ventilation systems, for example, due to construction faults, closed sliders in the incoming air way, ventilation engine power at the lowest settings, or very blocked holes in the incoming and outgoing air ways. Gas measurements were taken in nine underground tanks on six farms, and four of the farms had gas concentrations comparable to the stalls. All in all, CO_2-concentrations increased to 2.29 Vol. % (≈ 22 900 ppm). Methane was measured either not at all, or at 12.9–23.3 % under the explosion limit (≈ 10 000 ppm) in four tanks. Ammonia was verified in four tanks with concentrations between 31.3 and 66 ppm and the concentration was about 200 ppm only in one tank. These concentrations alone were not life-threatening, however, these gases eliminate oxygen in closed tanks.

Advice for accident prevention

Ventilation: homogenization or the flushing of liquid manure release more gases, especially H_2S. This gas often emits in gushes into the stall complex air [2]. To prevent problematic gas concentrations, enough (forced) ventilation must be ensured, this means the ventilation has to work at its highest speed [3; 4; 5]. There are diametric opinions in the technical literature [6]: „The ventilation has to be turned off for a short time in order to avoid mixing the heavily loaded air above the liquid manure with the rest of the stable air.“ This statement is irritating and dangerous, because a short break of ventilation does not reduce life-threatening gas concentrations. An underfloor exhaust ventilation with maximal air rate can be the quickest remedy.

Gas stopper: the best available technology is a gas stopper that is installed between the stall and liquid manure tank, even for liquid pig manure [3; 5; 7]. There are several possibilities: a pipe siphon, a „diving tongue“ which always dips into the liquid manure, a pipe which always ends under the surface of the liquid manure, or a gate valve (its end is always in the liquid manure when it is open) [4]. In practice, most pig stalls or pens do not install a gas stopper, for example, a pipe siphon, because farmers think that a gas stopper will silt up with deposits (mineral, sand). Because of this, plugs and gate valves are installed but only in a few cases are they used simultaneously as a gas stopper. This configuration is problematic in case a second gate

Table 1

Gas measurement by re-enacting the accident

Standort der Messung ***Place of measurement***	**CO_2 [Vol.-%]**	**CH_4 [% UEG]**	**NH_3 [ppm]**	**H_2S [ppm]**
Abferkelabteil unbelegt, 50 cm über perforiertem Boden *Farrowing pen without animals, 50 cm above grid*	0.03	0	8.6	0.8
Stöpsel gezogen, 50 cm über perforiertem Boden *Pulled plug, 50 cm above grid*	0.06	0	198	38.8
Flüssigmist ist abgelaufen, 50 cm über perforiertem Boden *Liquid manure run off, 50 cm above grid*	0.03	0	88.9	14.8
Flüssigmist ist abgelaufen, 40 cm unter perforiertem Boden *Liquid manure run off, 40 cm below grid*	0.14	0	>200	>100
Behälter, Flüssigmist ist aus Abteil abgelaufen, 50 cm unter Behälterdecke *Tank, liquid manure run off farrowing pen, 50 cm below tank ceiling*	0.27	3.0	>200	90.6
Vergleichswerte *Relation value*				
Grenzwert nach TierSchNutztV [1] *Limit value according to TierSchNutztV [1]*	0,3 Vol.-% = 3 000 ppm	—	20	5
Tödlich *Deadly*	9-10 %	—	5 000	500
UEG (Untere Explosionsgrenze) *UEG (Lower exploxion limit)*		4,4 Vol.-% = 44 000 ppm		

valve is accidentally opened at the same time and the gases are allowed to flow back into the compartments with animals.

Flushing systems and liquid manure run-off systems: flushing systems are normally placed in a compartment at the outside wall. When opening and closing the stop chocks, the farmer always stands directly above the place where the flushing liquid meets the compacted manure in the canal. This induces gas emissions. Plugs and gate valves of liquid manure run-off systems are also mostly located inside a compartment, and the operator would have to stoop down to correctly open and close them. In both cases – flushing and run-off systems – it would be better to locate them in the central corridor [4; 8], because of an easier overview and less risky handling. In addition, no animals should be in the compartment during run-off or flushing. The numbers of people entering or working in the stable should be minimized. In the worst cases of gas accidents, the rescuer is mostly injured because of breathing in deadly gases too. Firstly, one has to call the fire brigade and the emergency doctor, then all liquid manure mixers and pumps have to be stopped and a fresh flow of air at the accident scene must be provided. Only then can someone start a rescue effort, and it is only safe if there is a minimum of two rescuers [4].

Conclusions

The situations of the farms studied differed greatly: there were diverse systems, which are used differently, and the operational procedures are conducted independently. Most of the accidents happened because the safety arrangements were disregarded and/or because of constructional defects and/or ventilation faults. Another relevant cause of accidents is carelessness, for example, forgetting about closing gate valves and plugs after liquid manure run-off. Most of the accidents can be ascribed to a high concentration of hydrogen sulphide, but the replacement of oxygen with a mixture of gases can also be a possible cause of accidents in small compartments.

Further research is urgently required with accurate gas measurements during run-off, mixing up and flushing of liquid manure. At the same time, accident prevention recommendations should be refreshed. Only a permanent sensitizing and training of farmers will safeguard them from more and perhaps deadly accidents.

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