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Alternative Sludge Treatment Method for Hazardous Odor Minimization

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유해성 악취 최소화를 위한 슬러지 대체 처리기법

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요 약

슬러지로부터 발생하게 되는 인체에 유해하고 독성이 강한 악취물질들은, 대다수 슬러지내의 단백질, 탄수화물등의 물질들이 미생물의 호기성 및 혐기성 분해과정을 통해서 생성되는 유·무기 물질들을 포함하게 된다. 슬러지로부터 발생하는 주된 악취물질로서 hydrogen sulfide, methanethiol, dimethyl sulfide, dimethyl disulfide, dimethyl trisulfide 등이 발견되어졌는데, 이 다섯 종의 악취물질들은 모두가 황을 포함하는 물질들이다. 본 논문에서는 인체에 유해한 슬러지 악취의 강도 및 세기를 결정하고 비교하는 데 이용되어 질 수 있는 odor index (ODI)라는 방식이 제시되어졌다. 세가지 종류의 슬러지, 즉 hypochlorite 용액으로 처리한 슬러지와 향수 물질로 처리한 슬러지 및 아무런 처리를 하지 않은 슬러지 세 종류를 대상으로 30일이 넘는 기간동안 인체에 유해한 악취물질들에 대한 누적 odor index (ODI) 값을 생성하여 비교하였다. 아무런 처리를 하지 않은 슬러지에서 가장 높은 odor index (ODI) 값들이 나타났으며, 이것은 슬러지 처리에 있어서 심각한 단기 및 장기적인 유해 악취발생 문제가 야기될 수 있음을 나타낸다. 이에 대하여 hypochlorite 용액으로 처리한 슬러지로부터는 인체에 유해한 악취 발생을 처리 즉시부터 30일이 넘는 기간동안 측정한계치 이하 단계로 낮출 수 있었다.

Key words : odor, sludge, chlorination, hydrogen sulfide, methanethiol

INTRODUCTION

Hazardous and obnoxious Odors and their quantification and control have been of concern for many years due to strict air quality regulations and increasing public concern with health and environmental deterioration. Quantification of odor has traditionally been a subjective phenomenon, unless specific compounds could be identified. Classically, hydrogen sulfide emissions have served as the prime indicator of wastewater treatment plant (WWTP) odor nuisances (Bowker, 1989; Taylor, 1989; WPF, 1995). WWTP sludges may be especially problematic as sources of odor when delivered to an ultimate disposal site, i.e. a co-disposal sanitary landfill.

One such permitted municipal solid waste facility, which is located at Lancaster, PA, USA, receives

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4,500 tons/day of materials, with an estimated 15% of the weight represented by wastewater sludges received from more than 20 different sources (Regan, 1998). The operators of this facility have been concerned about odors associated with sludge disposal for several years. Personnel at the facilities suspected that the most offending sludges were represented by relatively few of the sludges received. However, monitoring and characterization of the gaseous emissions from specific sludges along with potential means for their control where unsatisfactory. This paper focuses on the characterization of hazardous odor emissions from sludge and practical methods of control.

MATERIALS AND METHODS

The overall objective of the project was to study the formation and control of hazardous odor emissions from selected sludges under conditions similar to those at the municipal waste facility. Components of the odor were identified with an HP5890 gas chromatograph equipped with a 5972 mass selective detector. Organic species were quantified with the GC/MS, while hydrogen sulfide concentrations were determined with the Draeger Chip Measuring System (CMS). Drager CMS consists of two key components: the gas selective chips and the analyzer. Approximately 0.2 to 0.5 liters of air from the sample was passed through the Drager CMS. The GC/MS was calibrated for hydrogen sulfide from the results of the Drager CMS tests.

Sludge samples were collected in one gallon sealed containers. These samples were transported from the solid waste facility and stored at 4°C within a secondary sealed 5-gallon plastic container. The initial headspace analysis was performed within 24 hours.

Experiments were carried out to determine the effectiveness of various oxidants on the hazardous odor compounds in the headspace. To make sure the process was not oxidant limited, air from the headspace in the one gallon sample container was bubbled through a gas diffusing stone in the oxidant containing liquid as shown in Fig. 1. The gas was collected and the odor compounds remaining were identified and quantified with the GC/MS and CMS.

250 mL septic bottles were used as odor control

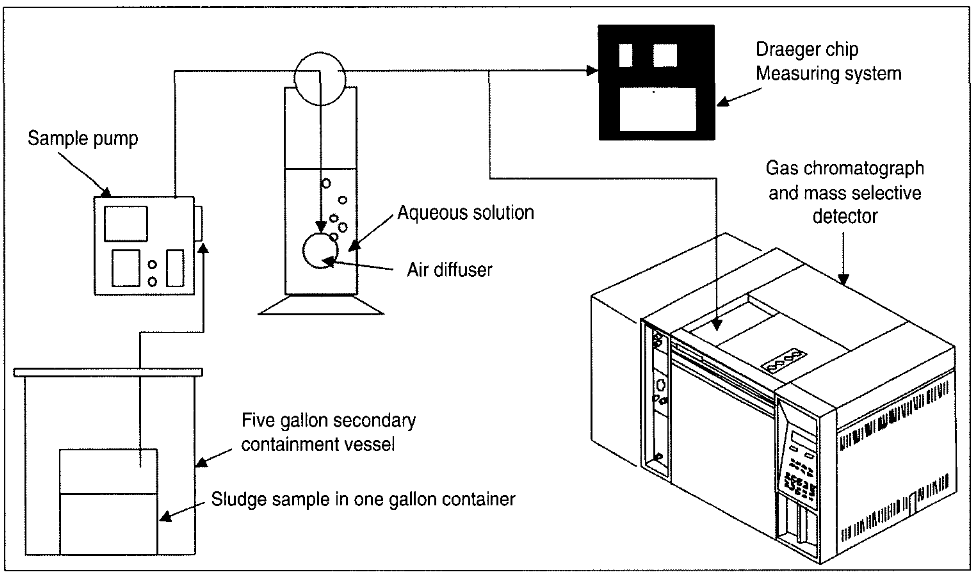

Fig. 1. Schematic of the odor scrubbing process.

reactors. Untreated sample bottles contained 100 g of sludge. Deodorant treated reactor bottle contained 10 and 50 g of deodorant along with the 100 g of sludge. In the case of deodorant, one of the most common and popular products for domestic usage was chosen for the experiment. The other reactor bottles contained 30 and 50 g of 3% hypochlorite solution added to 100 g of sludge. These samples were used to determine the chemical effectiveness at controlling odors directly from the sludge. Sample odor analysis was performed by injecting 500 μL from the bottle headspace into the GC/MS.

A unitless odor index (ODI) was defined by the author and used to compare the strengths of the sludge odors by dividing the concentration of the compound in the headspace, $C_{headspace}$ in ppb, by the odor threshold, $C_{threshold}$ in ppb:

$$ODI = C_{headspace}/C_{threshold} \quad (1)$$

The relative strength of an odor is dependent upon both the conversion of that compound in the air and the sensitivity of the human olfactory system. The sensitivity of the human olfactory system was assumed to be proportional to the odor threshold of each compound. Odor threshold values are commonly cited in the literature (Bowker, 1989; Cecil, 1992; WPF, 1995). Therefore, the total odor intensity from the sludge was assumed to be directly proportional to the threshold values and concentration (Cheremisinoff, 1994; WPF, 1995).

RESULTS AND DISCUSSION

Hydrogen sulfide, methanethiol, dimethyl sulfide, dimethyl disulfide, and dimethyl trisulfide were found to be the major hazardous odor generating compounds in the sludge. The five major odor compounds are sulfur-containing compounds. The concentration of these compounds varied over time as in Fig. 2. The average concentration of the odorous compounds in the headspace is shown in Table 1.

Preliminary methods to reduce the gaseous concentration of the odorous compounds with hydrogen peroxide and hypochlorite solutions are shown in Fig. 3. Water scrubbing reduced the concentration of hydrogen sulfide and dimethyl sulfide but did not significantly affect the concentration of methanethiol or dimethyl disulfide. Removal efficiencies of hydrogen sulfide and dimethyl sulfide were increased when the odorous gas was passed through a 50% solution of hydrogen peroxide. However, methanethiol and dimethyl disulfide was not removed to any measurable extent. The three-percent solution of hypochlorite achieved 99% removal or greater for all of the odorous compounds. Based upon the success of

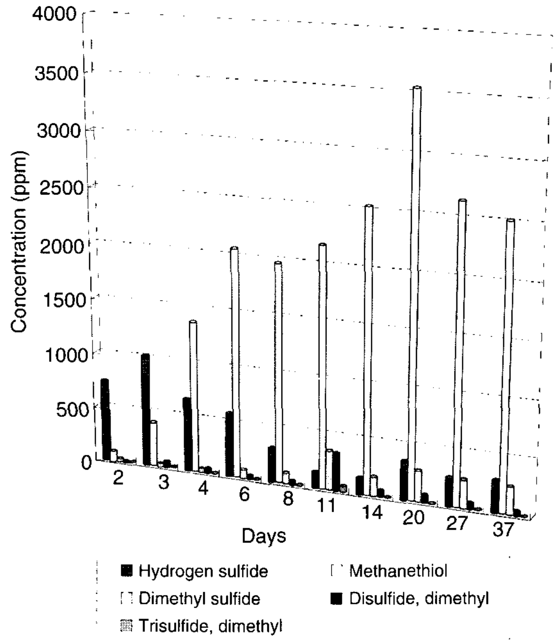

Fig. 2. Concentration of hazardous odor compounds from sludge sample.

Table 1. Average concentration of the odorous compounds in the headspace of the sludge container

	Hydrogen sulfide	Methanethiol	Dimethyl sulfide	Dimethyl disulfide	Dimethyl trisulfide
Average concentration (ppm)	445	1928	151	68	6

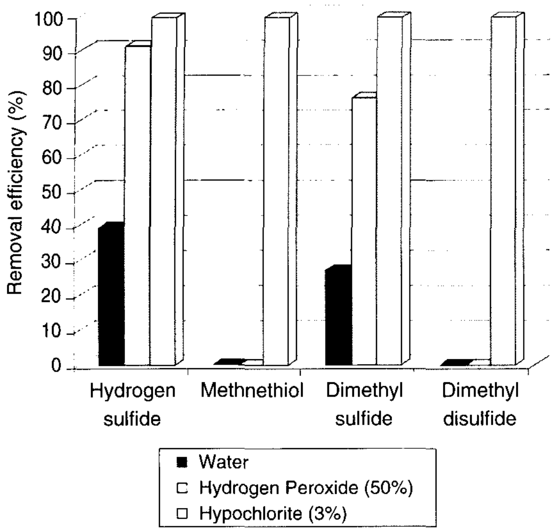

Fig. 3. Removal efficiency of water, hydrogen peroxide, and hypochlorite on the odorous compounds from the headspace of a sludge sample.

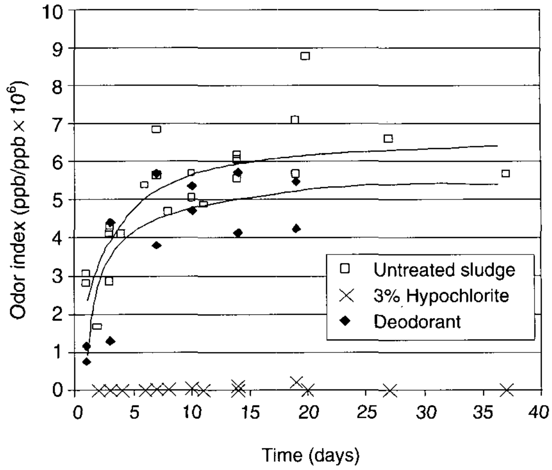

Fig. 4. Hazardous and obnoxious odor emissions from untreated sludge, deodorant treated sludge and hypochlorite treated sludge.

the initial hypochlorite treatment, attempts were made to treat the raw sludge with hypochlorite.

The odor index associated with each compound was calculated for each test. The cumulative odor index value for each sludge was then calcualated by adding the chemical specific ODI values as shown in equation 2.

$$ODI_{sludge} = ODI_{hydrogen\ sulfide} + ODI_{methanethiol} + ODI_{dimethyl\ sulfide} + ODI_{dimethyl\ disulfide} + ODI_{dimethyl\ trisulfide} \quad (2)$$

A comparison of the cumulative odor index generated over thirty days from untreated sludge, deodorant treated sludge, and hypochlorite treated sludge is shown in Fig. 4. The untreated sample had the highest initial odor index value. This represents a significant short term and long term odor problem for the solid waste disposal facility.

The sludge treated with 10% to 30% deodorant was nearly as odorous as the untreated sample. Even in this very concentrated application the deodorant did not destroy the odorous compounds from the sludge but only provided a chemical masking. The deodorant also adds to the volatile organic compound (VOC) emissions from the landfill.

The third sample treated with a 3% hypochlorite solution showed no measurable odor. More importantly, the characteristic increase in odor was prevented. The short term and long term odor problems associated with this sludge were eliminated with the hypochlorite treatment method.

CONCLUSIONS

Sludge treatment techniques do not adequately destroy hazardous odor emanating from sludge. Currently no technologies exist to deal with the intense odors at the sludge disposal facilities.

Primarily hydrogen sulfide, methanethiol, dimethyl sulfide, dimethyl disulfide, and dimethyl trisulfide cause the odors from the sludge. A 3% solution of hypochlorite eliminated these compounds in the gas phase. The hypochlorite also reduced the odor from the sludge to below detectable limits immediately after treatment and for a period of up to 30 days thereafter.

Hypochlorite is relatively inexpensive and readily available, especially at wastewater treatment facilities. Chlorination of sludge should be considered for particularly noxious odors in the wastewater treatment facility or for selective odor control of incoming noxious sludge at solids waste disposal facilities.

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