A XIV-a Conferinţă internaţională – multidisciplinară,
"Profesorul Dorin PAVEL – fondatorul hidroenergeticii româneşti",
SEBEŞ, 2014

MONITORIZAREA MIROSURILOR ÎNTR-O INSTALAȚIE DE DIGESTIE ANAEROBĂ

Marco RAGAZZI, Elena Cristina RADA, Roland PLANK,
Matteo ZANDONAI, Stefano ANTOGNONI, Paolo STEFANI

ODOUR MONITORING IN AN ANAEROBIC DIGESTION PLANT

In the latest years the problem of odour emissions has got an increasing emphasis, due to the expansion of urban areas with the consequent approach of the settlements to the industrial areas and the increase of public awareness towards environmental issues. Odours do not cause toxic effects to human health. However they can cause symptoms in both physiological (as respiratory problems, nausea and headaches) and psychological levels. In this article, the results of odour monitoring emissions in an anaerobic digestion plant fed with dedicated crops in which there is a feeding/mixing tank uncovered are presented. The role of this tank concerning the odour emissions is the object of the paper.

Keywords: odour emission, anaerobic digestion, mixing tank, SOER, OER

Cuvinte cheie: miros, digestie anerobă, rezervor de amestecare, SOER, OER

1. Introduction

In the latest years the problem of odour emissions has increased its emphasis, due to the expansion of urban areas in the proximity of industrial areas. Also the public awareness towards environmental issues evolved significantly [1, 2]. Although odours do not cause toxic effects to human health, they can cause symptoms in both physiological (as respiratory problems, nausea and headaches) and psychological levels [3].

The odour emissions are a mixture of gaseous compounds that produce olfactory annoyance, and generally are not subjected to specific limits. In Italy, in absence of national legislation, the Lombardy Region issued guidelines for the characterization of odorous emissions produced by human activity (n. IX/3018/2012). The Emilia Romagna Region also issued a regional decree n. 1495/2011 which defines the technical criteria for the mitigation of the environmental impact of a biogas plant.

The anaerobic digestion (AD) plants treat organic matter because it is possible to take advantage of its characteristics in terms of degradability of material in input [4]. The decomposition of organic matter can lead to the formation of unpleasant odours if it is not effectively managed. The quality of design and especially the ability of management of the phases related to biological processes, appear to be decisive factors in controlling odours [5]. The potential critical phases that can produce odour impact are:

- reception and storage of biomass waiting their loading in the system;
- biogas energy conversion;
- separation processing, storage of digestate and its spreading.

The measurement of odour emissions is composed of two components: one objective (constituted by the intensity, duration and frequency), and one subjective (characterized in nuisance) [6, 7].

There are two different approaches for the quantification of the odour impact. The first one is based on the evaluation of emissions, i.e. on the source responsible for the odours. In the past, the trend has been to set limits in odour concentration directly to emissions. In order to evaluate an emission into the atmosphere it is not sufficient to consider the concentration of the pollutant but it is necessary to associate the concentration with the gas flow emitted [OUE s^{-1}] [8].

The second approach concerns the evaluation of concentration, i.e. the odour impact to the receptor. The fact of considering only limits on emissions has the disadvantage of not taking into account the real impact on the ground. From this it comes the need to apply dispersion models able to simulate the emissions fall back to the ground.

The methods of measuring odours are divided in two groups: the first one is based on chemical analyses, which includes gas chromatography and mass spectrometry (GC-MS), while the second one is based on sensorial analyses such as dynamic olfactometry [9].

With the first method it is possible to obtain the chemical composition of the odour mixture and therefore to identify the odour compounds responsible for the effect. On the other hand, it is not possible to correlate these values with sensorial values [7]. Instead, the dynamic olfactometry is based on olfactory perceptions of a committee of people (called panel) who evaluate the odours submitted to them. In this case it is determined the concentration of odours of the mixture, but the identification of the individual substances that compose the mixture lacks. This method of measurement is regulated by EN 13725:2003 "*Air quality-Determination of odour concentration by dynamic olfactometry*", and it is used in central and northern Europe and in some regional guidelines in Italy being considered the reference method for the assessment of odour emissions.

2. Materials and Methods

For the development of the research a plant equipped with a pre-mixing tank that receives fresh biomass pre-treated mechanically and a part of the liquid digestate previously separated has been selected.

Fig. 1 Alimentation tank of anaerobic digestion plant

The mixing tank has width, depth and height equal to 5 m, 7 m and 3 m respectively. It is provided with two vertical mixers (one for each half of the tank) and inclined respect to the vertical to make the mixture the most homogeneous as possible (figure 1).

To characterize the role of the mixing tank, a measurement campaign of odour emissions was developed. The purpose of this monitoring was to determine the specific flow of odour (*Odour Emission Rate-**OER***) from the mixture of fresh biomass and the liquid digestate. A flux chamber as an extractor from passive areal sources without induced flow was used and is presented in figure 2.

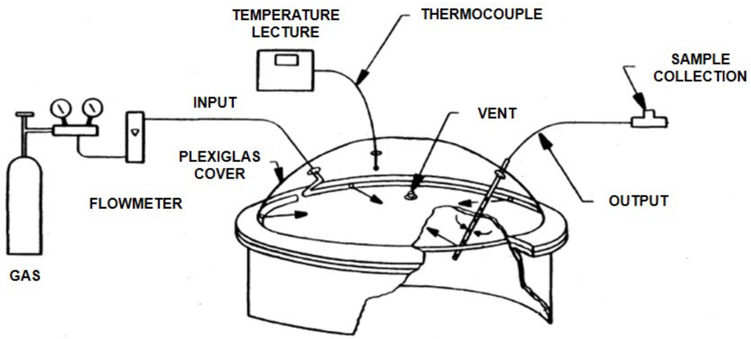

Fig. 2 Diagram of the flux chamber and equipment [10 modified]

The flux chamber is a Plexiglas floor fixed on an aluminium support of known area. It is equipped with an input and an output for neutral air and venting valves [11]. The air is blown at a known flow rate and is charged with odour emitted from the surface where the hood is placed. The samples were sent to a laboratory and subjected to dynamic olfactometry, within 30 hours from sampling. This technique allowed determining the concentration of odour [OUE m^{-3}] according to the UNI EN 13725:2004. Using this data the osmogene flow per unit area (*Specific Odour Emission Rate-**SOER***) was calculated using the following equation:

$$SOER = C * \frac{Q}{A} \tag{1}$$

where:

- SOER: Specific Odour Emission Rate [OUE m^{-2} s^{-1}];

▪ C: odour concentration of sample, according to the UNI EN 13725:2004 [OUE m^{-3}];
▪ Q: air flow rate introduced into the flux chamber [m^3 s^{-1}];
▪ A: area of the base of the flux chamber [m^2].

Once defined the extension of the emissive surface (S [m^2]), i.e. the feeding tank and known the specific flow, it is possible to calculate the flow rate of the overall odour of the plant [OUE s^{-1}] using the following relationship:

$$OER = SOER * S \tag{2}$$

Figure 3 reports the position of the flux chamber in the mixing tank. One of the mixer is visible in the back part of the tank. The flux chamber is located in the right part of the surface.

Fig. 3 Picture of the positioning of the flux chamber for sampling in the mixing tank

The choice of this methodology to define the odour emissions is due to the need to perform the monitoring in acceptable and specific time for the identified source and the presence of a mixture with a density close to the one of water. In fact, unlike other instruments such as the wind tunnel, the flux chamber has the ability to remain on the free surface thanks to a floating system.

Three samplings during the full load of the feeding tank were carried out. However a complete characterization of the odour emissions would need the monitoring of various receptor sites and/or a numerical modelling of dispersion in order to understand how and where the emissions fall to the ground.

The authors made also a comparison of measured data with data from the literature in order to understand the acceptability level of the obtained values.

3. Results

The physical parameters and the data obtained from the olfactometric test are presented in Table 1 (Physical parameters and odour emissions of sampling carried out at the supply tank). The samples were taken with an air flow of 5 [l min^{-1}] in three points of the tank, placed to 3.5 m, 2 m and near the border respectively. From the values of specific stream (SOER), it was possible to determine the odour flow (Eq. 2) using the tank surface (35 m^2).

Table 1

No. Sample	**1**	**2**	**3**
Distance from the board [m]	3.5	2	0.3
Air Temperature [˚C]	31.4	31.6	31.7
Water Temperature [˚C]	40.2	40.2	40.3
Humidity [%]	52.8	52	56
Wind [m/s]	0.5	0.5	2.7
Odour concentration [OU_E m^{-3}]	3,250	2,300	2,050
SOER [OU_E $m^{-2}s^{-1}$]	2.16	1.53	1.36
OER [OU_E s^{-1}]	75.60	53.55	47.60

In order to give an opinion on the level of odour flow emitted from the mixing tank, these values were compared with data from a wastewater treatment plant in the North of Italy. These data are reported in Table 2 (Odorous emission parameters of wastewater treatment plant (average size, capacity 104 ÷ 105 [m^3 d^{-1}])) and were obtained with a flux chamber and olfactometry analysis in accordance with Directive EN 13725:2003 [12].

The maximum value found in the supply tank, 75.60 [OUE s^{-1}], results to be lower two orders of magnitude compared to the values form the oxidation compartment and the primary sedimentation of wastewater treatment plant. This last one is one of the most critical units in terms of odour emissions.

Table 2

Lines	Treatment	Surface [m^2]	SOER [OU m^{-2} s^{-1}]	OER [OU s^{-1}]
2	Primary sedimentation	1,472	0.834	1,227.65
4	Oxidation	1,568	0.67	1,046.17
2	Secondary Sedimentation	2,740	-	-
2	Anaerobic Digestion	354	-	-
1	Sand separator	200	0.104	20.80
1	Loot treatment	118	0.104	12.27

Additional values from three composting plants that treat organic waste form selective collection and sludge generated from wastewater treatment were used for a comparison [13,14]. The surface emissivity, material volume, concentration and flow rate of odour coming from the open areas of each composting plant are reported in Table 3 (Values of surface emissivity, material volume, concentration and flow rate of odour related to some composting plants [11]). These measures were carried out through flux chamber with an airflow rate of 6.3 neutral [l min^{-1}] and a surface of the hood of measurement equal to 0.25 [m^2]. Also in this case, the maximum value found in the supply tank is below the almost totality of the odour flows.

Table 3

Plant		Input	Maturation	Storage or final product
Case 1	Surface [m^2]	1,200	250	24
	Volume [m^3]	4,800	1,000	96
	Odour conc. [OU m^{-3}]	11,820	2,520	1,224
	OER [OU s^{-1}]	7,588	674	31
Case 2	Surface [m^2]	100	2,400	100
	Volume [m^3]	300	7,200	300
	Odour conc. [OU m^{-3}]	3,364	1,254	739
	OER [OU s^{-1}]	360	3,220	79

Case 3	Surface [m^2]	50	990	25
	Volume [m^3]	250	4,950	125
	Odour conc. [OU m^{-3}]	19,011	12,699	10,992
	OER [OU s^{-1}]	508	13,453	294

The analyses carried out and their interpretation highlight how not critical is the mixing tank from the odours point of view in the present case study.

In addition the data obtained on the day of the test were compared also with previous data inherent to the odour emissions monitoring and modelling carried out in the same plant [15]. This modelling study reports the data of odour concentration of the supply tank of the plant equal to 2378 [OU m^{-3}]. As can be seen, the value has the same order of magnitude of the obtained value.

A possible solution for reducing odour emissions from the tank could be the use of a cloth active carbon, which can be placed over the mixing tank and removed during the stages of loading of the biomass. Considering the obtained values this cloth is not compulsory. It could be useful if the staff activities around the tank are affected buy the odour impact close to it. Also in this case the manual activities related to the operation of the tank are limited, pointing out that this unit of the plant is not critical.

4. Conclusions

■ The analysis and processing carried out and described in this paper have enabled a framework and an assessment of the possible problems due to odour emissions caused by the feeding tank (that is open air).

■ Based on a comparison of the data obtained from the performed sampling with those available in literature, it is possible to argue that the supply tank in the plant presents values clearly below those emitted from wastewater treatment activities known to present problems regarding the odour emissions. In particular a significant difference has been verified comparing the mixing tank with the settling stage of the wastewater treatment plant.

■ For a more complete and comprehensive characterization it would be necessary to provide an overall monitoring of all sources of odour in the system (storage areas of organic material, anaerobic digester, storage of digestate).

■ Such a campaign would enable, thanks to the use of dispersion models, to obtain exhaustive and characteristic values of the individual phases of the plant and the site (morphology and meteorology) as it would be to expand the area of investigation both in space and in time.

REFERENCES

[1] Ranzato, L., Barausse, A., Mantovani, A. *A comparison of methods for the assessment of odor impacts on air quality: Field inspection (VDI 3940) and the air dispersion model CALPUFF*, Atmospheric Environment, 61, pp. 570-579, 2012.
[2] Rada, E.C. *Local environmental impact from MSW aerobic biological treatment*, WIT Transactions on Ecology and the Environment, 163, pp. 13-24, 2012.
[3] De Gennaro, G., Brattoli, M., Dambruoso, P., De Pinto, V., Demarinis Loiotile, A., Trizio, L., *Sviluppo di un approccio metodologico per la regolamentazione ed il controllo delle emissioni odorigene*. Atti del convegno Ecomondo 2011- Industrial Ecology, Rimini, 9-12 Novembre 2011.
[4] Rada, E.C., Ragazzi, M., Torretta, V., *Laboratory-scale anaerobic sequencing batch reactor for treatment of stillage from fruit distillation,* Water Science and Technology, 67(5), pp. 1068-1074, 2013.
[5] Biagi, G., Corvaglia, M.A., *Per prevenire i cattivi odori occhio a progetto e gestione*, Ecoscienza, 1, pp 40-41, 2012.
[6] Rada, E.C., Ragazzi, M., *Municipal Solid Waste bio-drying: odor problem of three configurations*, Proceedings of Waste-to-Resources 2011: IV International Symposium MBT and MRF, 24th -26th May 2011, Hannover, pp. 375-386, 2011.
[7] Laura, Valli – C.R.P.A. (Centro Ricerche Produzioni Animali). *Metodi di misura degli odori: olfattometria dinamica*. In Prevenzione dell'impatto olfattivo producibile dagli impianti di trattamento dei rifiuti" Roma, 21 maggio 2004. http://www.crpa.it/nqcontent.cfm?a_id=1277.
[8] Capelli, L., Sironi, S. *Discussione dei limiti di accettabilità di impatto olfattivo in immissione basata su casi reali*, Proceedings of Ecomondo 2011, 9-12 Novembre 2011, Rimini.
[9] Klarenbeek, J.V., Ogink, N.W.M., Van del Voet, H., *Odor measurements according to EN 13725: A statistical analysis of variance compone*nts, Atmospheric Environment, 86, pp. 9-15, 2014.
[10] Eklund, B., *Practical Guidance for Flux Chamber Measurements of Fugitive Volatile Organic Emission Rates*, Journal of the Air & Waste Management Association, 42(12), pp. 1583-1591, 1992.
[11] * * * http://www.osmotech.it/ita/Default.aspx
[12] * * * ADEP– Technical report, 2013.
[13] * * * http://www.isprambiente.gov.it/it/pubblicazioni/manuali-e-linee-guida /metodi-di-misura-delle-emissioni-olfattive
[14] Rada, E.C., Ragazzi, M., *Selective collection as a pretreatment for indirect solid recovered fuel generation*, Waste Management, 34(2), pp. 219-297, 2014.

[15] * * * Servizi Integrati Gestionali Ambientali – Modelling of odorigenous emissions – Technical report, 2013.

***Note**:* This paper was made tanks to the collaboration among expertises present in the Euregio area (referring to specific Italian and Austrian regions), in the frame of a project called “BIOGAS IN AREE ALPINE: pre-trattamento delle matrici organiche" (Biogas In Alpine Areas: pre-treatment of organic matrices). The project was promoted by the Autonomous Province of Bozen with the provincial law 14/2008, with the coordination of the Consortium Alpibiogas.

Prof. Dr. Ing. Marco RAGAZZI
associate professor at Civil Environmental and Mechanical Engineering Department, University of Trento,
e-mail: marco.ragazzi@unitn.it
Dr. Ing. Elena Cristina RADA
senior research fellow at Civil Environmental and Mechanical Engineering Department, University of Trento,
e-mail: elena.rada@unitn.it
Dr. Roland PLANK
SYNECO SRL, GmbH
e-mail: roland.plank@syneco-consulting.it
Sott. Ing. Matteo Zandonai
Consorzio Alpi Biogas
e-mail: info@alpibiogas.it
M. of Sc. Stefano ANTOGNONI
research fellow at Civil Environmental and Mechanical Engineering Department, University of Trento,
e-mail: stefano.antognoni@unitn.it
M. of Sc. Paolo STEFANI
research fellow at Civil Environmental and Mechanical Engineering Department, University of Trento,
e-mail: paolo.stefani@unitn.it

PROCESUL BIOLOGIC - rezumat. Digestia anaerobă este un proces biologic complex prin intermediul căruia în lipsa oxigenului, substanţa organică este transformată în biogaz sau în gaz biologic, compus în principal din metan şi anhidridă carbonică. Procentul de metan în biogaz variază în funcţie de tipul substanţei organice şi de condiţiile de procesare, de la un minim de 50 % până la aproximativ 70 %. Pentru ca procesul să aibă loc este necesară acţiunea diferitelor grupuri de micro organisme care sunt în măsură să transforme substanţa organică în compuşi intermediari, în principal acid acetic, anhidridă carbonică şi hidrogen, ce pot fi folosite de micro organismele pe bază de metan care încheie procesul prin producerea metanului.