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A novel tool for odor emission assessment in wastewater treatment plant

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ABSTRACT

Odor emissions are one of the major environmental impact generated by wastewater treatment plants (WWTPs) perceived by exposed population. Consequently, the control of odor emissions is a relevant aspect that must be considered in the management of the WWTPs. Any efficient strategy for odor control was based on direct and/or indirect monitoring and characterization of odor emissions. The presented work focuses on the identification of new indirect indicators for the measurement of the odors emitted by different treatment units in a full-scale wastewater treatment plant, as to reduce the cost of environmental monitoring and the environmental impacts of the plant. The work focuses on the existing correlation in each treatment unit between the odor emission capacity (OEC) of wastewater and the odor concentration measured by dynamic olfactometry according to EN13725:2003 in ambient air. In addition the research shows the correlation between the organic contents measured by BOD_5 and COD and the OEC of the wastewater by analyzing different treatment units.

Keywords: Dynamic olfactometry; Multisensor array system; Odor emission capacity (OEC); Organic content (BOD_5, COD); Wastewater

1. Introduction

Odor emissions from wastewater treatment plants (WWTPs) induce impacts in the surrounding areas including devaluation of lands and reduction of life quality [1–4]. In the last year, odor complaints from the residents located near the WWTPs against plant managers have grown [5]. In this context, the control of the odor emission has become a key issue in order to limit related impacts [6,7].

In order to control odor at WWTPs, the first step is their monitoring and characterization that was generally made by direct measurement of odor by Dynamic Olfactometry according to EN13725:2003 [7,8]. This way, it is possible to have the real measure of the odor concentration emitted according to EU standard, but this approach may imply high cost of analyses, practical issues with sampling a representative volume of emitted gas and negative influences with measures due to meteorological conditions; in addition, measurements are related to instantaneous values, and high frequency of sampling was required in order to achieve a representative data-set [1,9,10].

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Several studies propose the measurement of Odor Emission Capacity (OEC) for the characterization of odors emitted by wastewater [1,10]. OEC from liquids sources measure the total amount of odor substances emitted in ambient air, which can be stripped from a liquid under given standardized conditions according to procedure proposed by [11] and measured by dynamic olfactometry according to EU standards. The measured value of OEC represents the maximum value of the potential odor emitted by liquid sources and its measurement according to [11] presents many strengths and some weaknesses [12]. The main limitation is related to the expensive and time consuming analysis [13]. In order to optimize the original method, recent study [14] proposes the use of multisensor array systems (e.noses) instead of the dynamic olfactometry. In addition, several studies show the existence in wastewater influent of a good correlation between the OEC values and the biochemical oxygen demand ($BOD_{5)}$ and chemical oxygen demand (COD) values. No information is available in the literature on the possible correlation between odor emissions measurable in ambient air at treatment unit and OEC.

This study investigates the correlations among OEC, BOD_5, and COD and odor concentration measured in ambient air in different unit at a WWTP with the overall aim to define a novel tool for monitoring and control odor emissions using an indirect parameter already monitored in the plant for other purpose.

2. Materials and methods

2.1. Sampling program

Research studies were carried out at conventional WWTP designed for 700.000 PE (Population Equivalent), located in the industrial area of the municipality of Salerno (Campania Region, Italy). To investigate the correlations among OEC, BOD_5, and COD, and odor concentration measured in ambient air, were selected two treatment units of the plant with highest tendency to odor emissions [2]: grit channel (P1) and primary sedimentation (P2). From this treatment units, wastewater and air samples were collected once a month for ten consecutive months. A total of 20 samples were collected over the research period at each selected treatment unit: 10 wastewater samples and 10 air samples. Each month, all sampling were conducted during the same day in stable meteorological conditions with wind speed below 1 m/s. During the sampling program the WWTP was operating with an average daily flow of 8,000 m^3/h.

2.2. Wastewater characterization

Wastewater samples were collected according to the APAT CNR-IRSA1030 MAN 29/03 method taking a sample of 10 liter in an amber glass container. Each wastewater sample was characterized in terms of OEC and in terms of COD, BOD_5. All analyses were carried out at the Sanitary Environmental Engineering Division (SEED) laboratory of the University of Salerno. BOD_5 and COD measurements were determined following the Standard Methods [15] according to Section 5,210 and Section 5,220, respectively.

OEC was determinate using the multisensor array system Simple Environmental Electronic Device for Odor Application (seedOA) according to procedure proposed by [14]. SeedOA is a novel prototype of e.nose of Salerno (Italy). This system consists a set of 16 sensors: two series of six different metal oxides semiconductor (MOS), non-specific gas sensors (S), two MOS specific gas sensors (SS), and two internal conditions sensors (humidity and temperature), placed in an innovative fluid dynamics chamber (CODE®) [16] patented by the SEED. The measurement sensors were selected on the basis of the odor substances emitted from the investigated type of plant according to literature studies [17]. Commercial sensors used in this work are shown in Fig. 1.

During the analysis in the CODE® chamber the temperature is kept at 50˚C and relative humidity is also controlled; work flow rate was settled at 300 ml/min. All the acquired data are saved in an external computer and processed in real time by statistical and mathematical tools designed for this specific purpose by SEED. The quantitative model elaborated according to [13] was applied to OEC detections.

2.3. Air samples characterization

Air samples were collected according to the methods recognized by the technical-scientific literature and using the “lung” technique, whereby the sampling bag is placed inside a rigid container, and the container evacuated using a vacuum pump in accordance with [18]. Nalophan® sampling bags with 7 l volume are used for the sampling.

Air samples, collected during the sampling program at WWTP, were characterized by dynamic olfactometry at the SEED Laboratory of the University of Salerno. Olfactometric analyses were conducted to measure the odor concentration (OU/m^3) in ambient air at selected treatments according to [18]. The analyses were carried out using the olfactometer model TO8 (ECOMA, GmbH) with the “yes/no’ method.

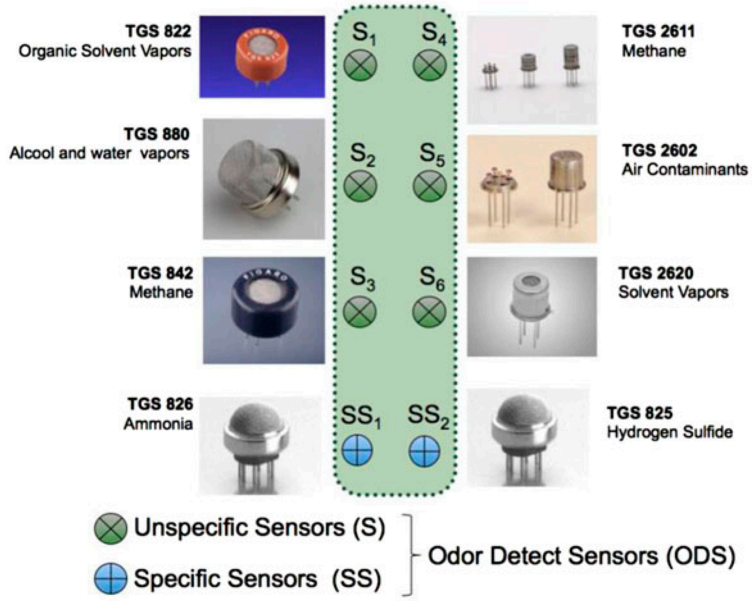

Fig. 1. Odor detect sensors used in the CODE® chamber of seedOA.

3. Results and discussion

3.1. Wastewater characterization

Fig. 2 shows the box-whisker plots of the measured concentration of the organic contents in terms of BOD_5 and COD of wastewater samples at each investigated treatment unit over the investigated period.

Results show that the detected values of the concentration of BOD_5 and COD were higher at grid channel (P1) than in primary sedimentation (P2). The reduction of the concentration of BOD_5 and COD from the screening phase (P1) to the primary sedimentation (P2) is about 55% for BOD_5 and 58% for COD.

Measured concentration of organic contents at P1 show a greater variability compared to the values detected at P2, specially in terms of COD. On other hand the variability of the BOD_5 and the COD is almost the same at P2.

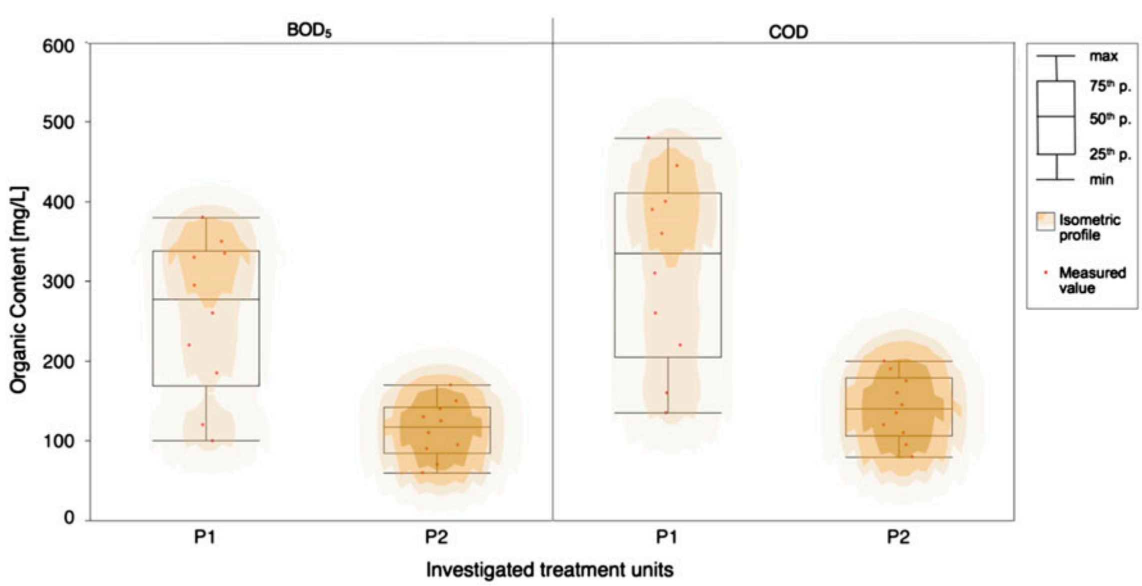

Fig. 2. Box-whisker plots on monitored chemical parameters at investigated treatment units.

Fig. 3 shows the variability of the OEC, measured with the seedOA multisensor array system, at the investigated treatment units over the monitored period.

Results show that the higher values of the OEC were detected for the unit P1, with concentration ranging between $5,429\text{OU}/^{\text{m3}}_{\text{liquid}}$ and $10,484\text{OU}/^{\text{m3}}_{\text{liquid}}$. In P2, OEC values ranged from $1,517\text{OU}/^{\text{m3}}_{\text{liquid}}$ to $5,398\text{OU}/^{\text{m3}}_{\text{liquid}}$.

3.2. Air samples characterization

Fig. 4 shows the variability of the odor concentrations (OC) detected by dynamic olfactometry at the

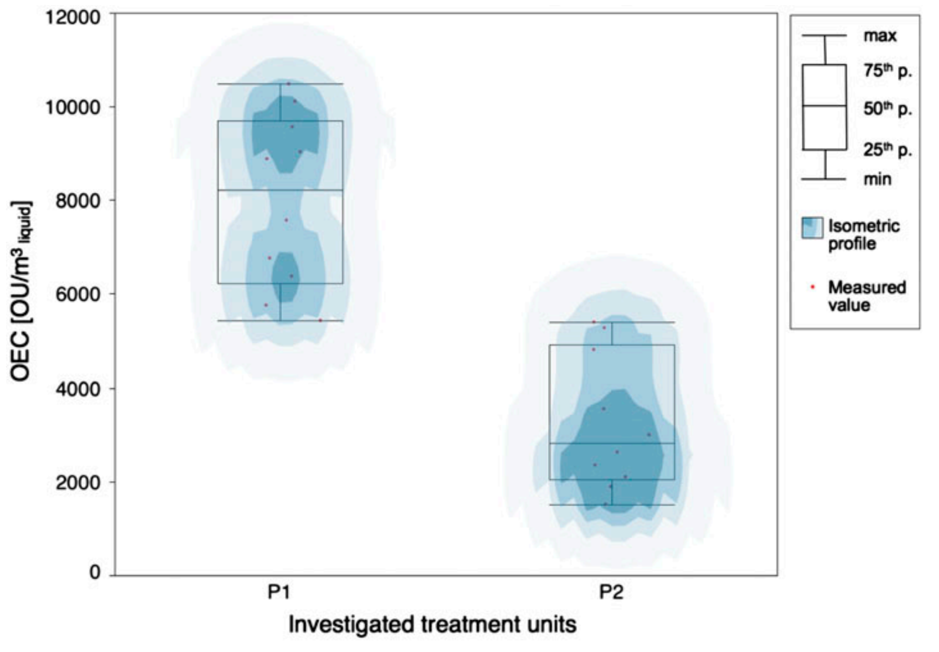

Fig. 3. Variability of OEC detected by seedOA at the investigated treatment units.

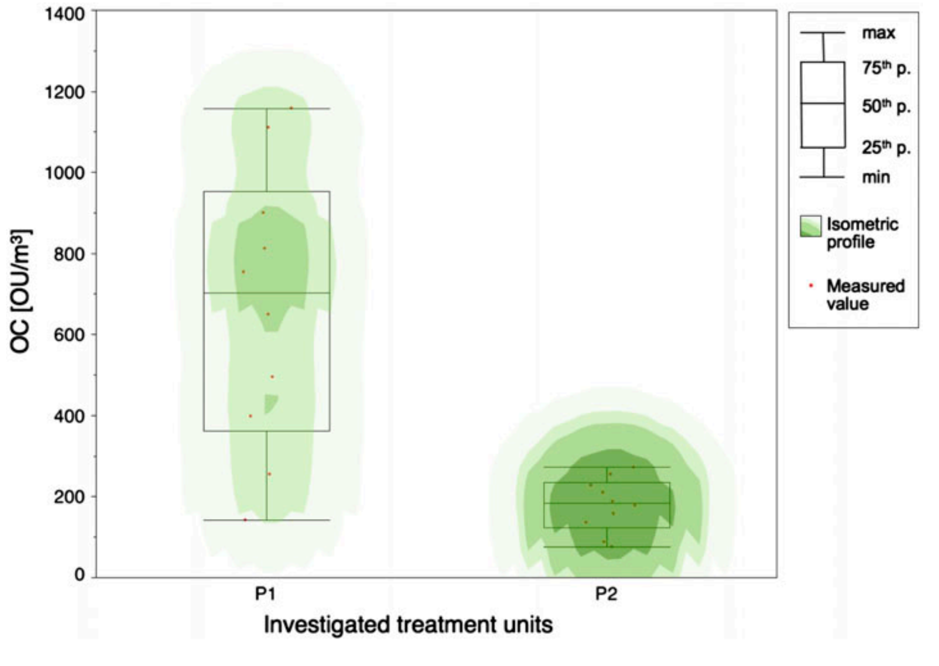

Fig. 4. Box-whisker plots on OC measured in ambient air by dynamic olfactometry at investigated treatment units.

investigated treatment units over the monitored period. Results show that the higher values of OC were detected for the unit P1, with concentration ranging between 140 and 1,158 OU/m^3. In P2 were detected OC values between 76 and 273 OU/m^3. These results are in line with previous studies that identify the grit channel, one of the more relevant units in WWTP in terms of odor emissions [19].

3.3. Correlation studies

Fig. 5 shows the correlation between the values of the OEC and the concentration of organic compounds (BOD_5, COD) measured from the wastewater samples collected at the investigated treatment units.

For the grit (P1), results show a strong linear correlation between OEC and COD ($R^2 = 0.96$), and between OEC and BOD_5 ($R^2 = 0.90$). Similar behavior but with lower correlation, measured in terms of R^2, was observed at sedimentation tank (P2). Overall, the bond OEC-COD is expressed by a strong linear correlation factor with $R^2 > 0.94$. Correlation equations, over the investigated period, for each parameter and treatment unit, are reported in Fig. 5. For both indicators of organic contents in wastewater (BOD_5 and COD) the slope of correlation line with the OEC is higher in sedimentation tanks (P2) that in grit (P1), where the measured concentrations were lowest.

Fig. 6 shows the trend studies between the OEC values, measured from wastewater samples, and the OC measured from air samples taken at both treatment units.

Results show a similar trend between OEC and OC at both investigated treatment units; when OEC values increase generally also OC values increase and vice versa. Therefore, macroindicators such as COD show a significant correlation with odor concentration in ambient air.

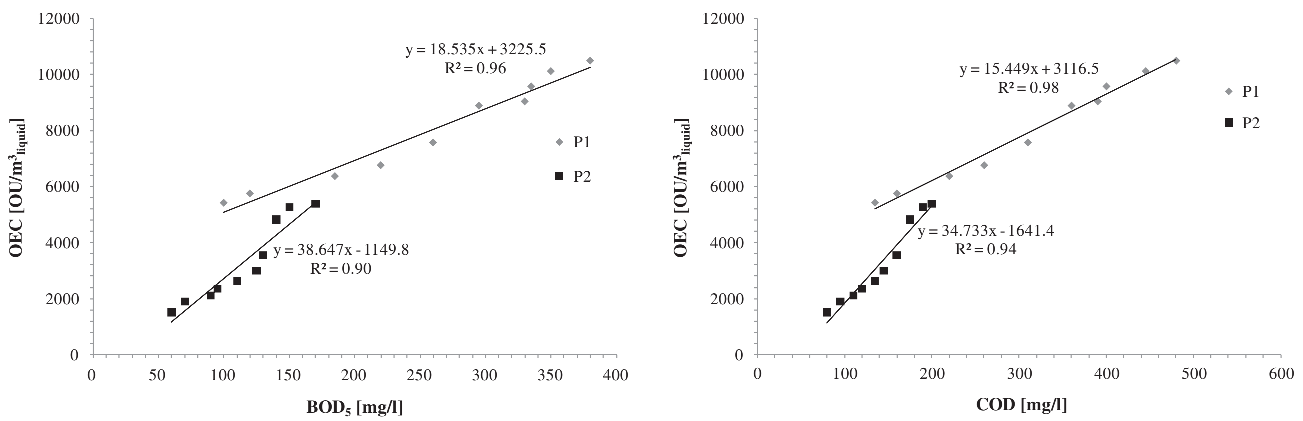

Fig. 5. Correlation between OEC vs. BOD_5 (left) and COD (right) at both investigated treatment units.

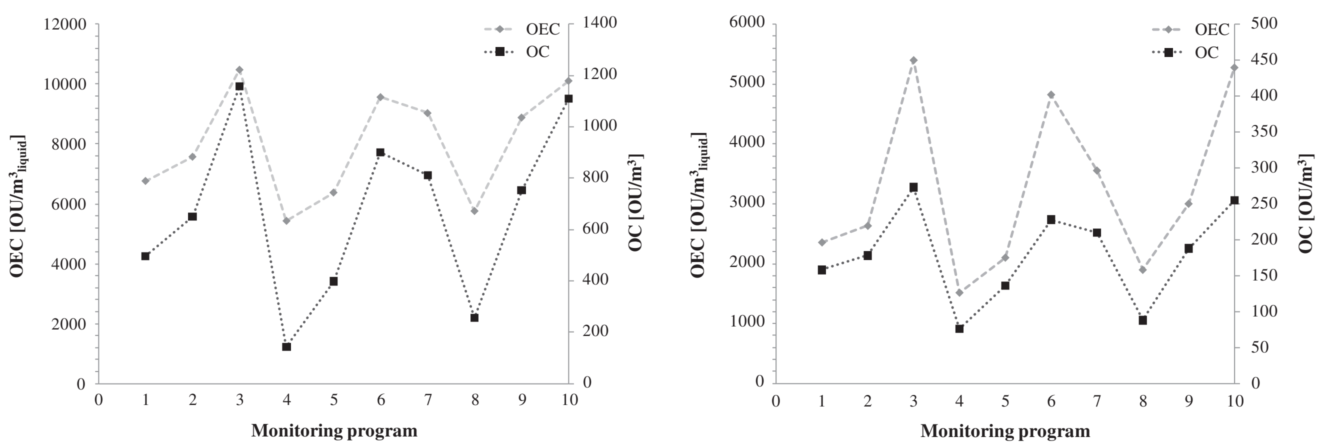

Fig. 6. Trend between OEC and OC in P1 (left) and P2 (right).

4. Conclusions

Research carried out in the present study shows the existence of a strong relationship between organic contents (i.e. BOD_5 and COD) measured in the wastewater and the OC detected in ambient air by treatment units in WWTPs.

Obtained results represent a significant contribution to the analysis of the problems related to odor assessment in WWTPs. The identification of a linear relationship between the odor emissions, at each treatment unit vs. the organic load allows using an immediately available parameter, already monitored in WWTPs, as an indicator of the maximum odor emitted (OEC), or better the emitted OC.

Further studies are needed to validate the obtained results in other treatment units and different WWTPs.

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