ODOUR EMISSION CAPACITY AS A SURROGATE PARAMETER FOR THE ASSESSMENT OF RIVER WATER QUALITY

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ABSTRACT

One of the major source of complaint in relation to water quality in rivers is linked to odour emissions. However, in the monitoring and regulations for water quality, odour normally is not directly considered. This paper explores the application of the Odour Emission Capacity (OEC) as a surrogate parameter in the assessment of river water quality and discuss the relationship between odour status and the traditional analytical parameters used in assessment of the ecological status. The study presents a novel and complete procedure for the assessment of the river water quality able to reduce the overall costs of analyses. At same time, the study presents the reliability of the novel procedure application with the discussion of its application in case studies. Correlation with conventional approach was studies and discussed. Results underline the strong relationship between the organic content in the river samples and their odour in terms of OEC. OEC can be easily integrated in the assessment protocol and it is a good subrogate indicator for the assessment of river water quality.

Keywords: ecological status, odour, olfactometry, river water quality, sensorial methods.

1 INTRODUCTION

A major source of complaint in relation to water quality in rivers is odour. The communities surrounding rivers greatly feel the effects of odour. At low concentrations, odour primarily lead to psychological stress while at higher concentrations, it may lead to poor appetite, impaired respiration, nausea and vomiting and mental perturbation [1], [2]. In the social context, the presence of odours can lead to the deterioration of personal and community pride, interference in human relations, dissuasion of capital investment and lowering of socio-economic status [1], [3].

However, in the monitoring and regulations for water quality, odour is not normally considered. Thus, recent researches have started focusing on the development of standardized methods of odour measurements. For example, in the US and Europe, the developed methods are specified by the American Society for Testing and Materials ASTM E679-04 [4], and European Committee for Standardization CEN EN 13725 [5], respectively [1]. Globally, the most recognized and most widely accepted standard is dynamic olfactometry according to the European standard [1], [6]. However, in order to resolve some of the limitations by these methods, Frenchen [7], has developed a method for odour quantification from a liquid as VDI 3885/1, also known as the Odour Emission Capacity (OEC) measurement method.

Current studies have started exploring the applicability of the OEC method for environmental studies. Zarra et al. [8], in their study of odour emissions from domestic wastewater have shown a high correlation between the Odour Emission Capacity of the wastewater and its organic content in terms of BOD_5 and COD. Results of a study by Zarra et al. [9], also showed a good correspondence between the odour impact of the wastewater treatment plant and the real odour annoyance level perceived by the citizens living near the investigated plant. A study by Sironi et al. [10], further presented a good

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correspondence between odour perceptions resulting from a social survey and simulated odour emissions based on olfactometric analyses.

In addition, odour is one of the most pronounced effects of river quality that the general public has a tendency to notice. The general public generally associates bad smell with conditions of "unhealthy air" even though this usually does not represent a real toxicological sanitary risk [8], [11]–[14]. Local people living near the river are directly affected by the impacts of water degradation and are more aware of the water situation. This fosters more initiative in the local population to improve conditions, thus, their involvement can ensure the sustainability of river management programs.

The application of the OEC method as a novel tool in river assessment is explored in this paper. This study also aims to identify the relationship between odour and the traditional analytical parameters used in determining the ecological condition of rivers. The results can be used as the basis for the development of new methodology for the assessment of our water sources with less data requirements, less cost and can be used by the public.

2 MATERIALS AND METHODS

2.1 Study area and sampling sites

The study area of this paper, Sarno River, is considered one of the most polluted rivers in Italy. This river which is 24 kilometers long crosses three provinces covering thirty-nine municipalities in Campania region and affects between 750,000 and one million inhabitants. The environmental degradation of the river is brought about by the combination of a high-density population and the presence of highly polluting economic activities in the areas [15], [16].

Investigation was focused on five monitoring stations which are part of the monitoring network set up by The Italian National Environmental Protection Agency for Campania region (Agenzia Regionale Protezione Ambiente Campania or ARPAC) in Sarno River. The names and locations of the stations are shown in the Fig. 1.

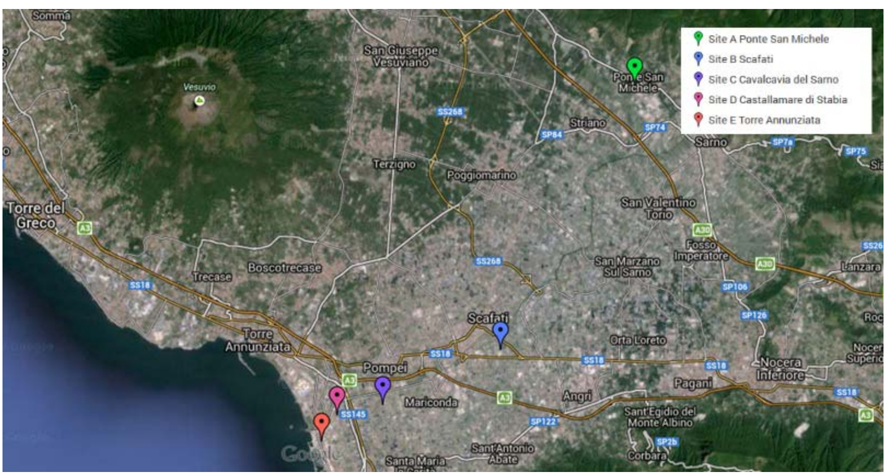


Figure 1: Geographic location of Sarno River and sampling sites. (*Map source: https://www.google.co.uk/maps;geographic coordinates from ARPAC.)*

2.2 Sampling protocol and analytical methods

Five monthly samples were examined from February to June 2014 in the five stations in Sarno River, namely, Site A, Site B, Site C, Site D and Site E. Surface layer samples of 5 L were collected midstream and laboratory analysis were done within 24 h of arrival at the laboratory.

Samples were then analysed for BOD_5 and COD. BOD_5 measurement was done using the Oxitop® Manometric BOD measuring device, while COD used the Open Reflux method specified by Standard Methods for the Examination of Water and Wastewater Section 5220B [17].

2.3 Odour Emission Capacity (OEC) determination

The samples were also subjected to OEC determination. Frenchen and Koster [18], defines OEC as the total mass of odorants, expressed in OU_E/m^3 liquid, which can be stripped from 1 cubic meter under given, standardized conditions. Using the standardized method VDI 3885/1 developed by Frenchen [7], as a model, customization of the protocol to Sarno River was done. The set-up (Fig. 2) involves placing the liquid sample into the test reactor equipped with an aerator. Odourless air is passed through the liquid and samples of off-gas of the test reactor are taken at the start and subsequent time intervals until the end of the test. The air samples were then analyzed using dynamic olfactometry according to the European standard EN 13725:2003 [5].

Dynamic olfactometry is a sensorial technique and allows the determination of odour concentration represented as the number of dilutions with neutral air that is needed in order to bring an odorous sample to its odour threshold. A dilution device, called an olfactometer is used in the analysis and data is expressed as European odour units per cubic meter (OU_E /m^3) [19], [20]. This method uses the human nose as a sensor and characterization of the odours is done by a panel of qualified examiners [3].

A sample volume of 3 L with an aeration flowrate of 3 L/min (equivalent to 60 hr^{-1} turbulence) was used in the study.

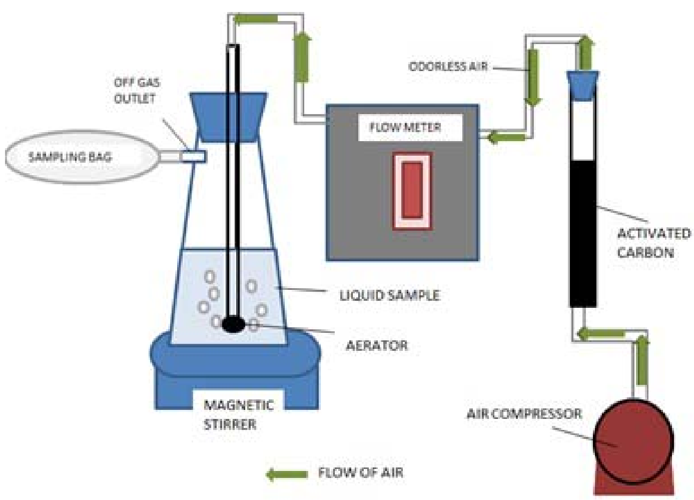


Figure 2: Odour Emission Capacity (OEC) set-up.

Also, the end of the test, which is considered as the inherent smell of the test setting was set at 20 OU_E/m^3 which was the odour concentration which resulted when stripping of water from Site A, the cleanest site, was performed. In order to discriminate between samples, dynamic olfactometric analysis was done for the air samples at different sampling times of 0, 2.5, 5 and 7.5 min. The OEC value was then calculated from the results using the following formula [7], [8]:

$$\text{OEC} = \int_{V_{air}\ at\ C=C_{initial}}^{V_{air}\ at\ C=20} \frac{(C_{od}-20)dV_{air}}{V_L}, \tag{1}$$

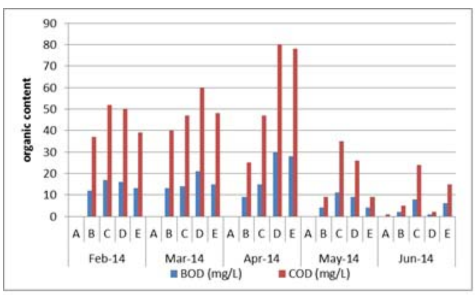
where OEC = odour emission capacity (in OU_E/m^3 liquid), C_{od} = concentration of odour emission (in OU_E/m^3 air), V_L = volume of the liquid sample (in L) and V_{air} = volume of air sample (in L).

2.4 Data analysis

Graphical analysis of the variables was initially done in Microsoft excel. The relationship among the parameters was analyzed using linear regression analysis in JMP®. Parametric correlations were also derived using the same software [21], [22].

3 RESULTS AND DISCUSSION

The values for BOD, COD and OEC for the months of February to June 2014 are presented in Fig. 3. BOD ranged from 0 to 30 mg/L while COD values ranged from 0 to 80 mg/L with all sites except Site A evaluated to be in poor to bad ecological condition. On the other hand, the values for OEC were from 0 to 2628 OU/m3. Both organic content and OEC exhibited high values during the months of February to April 2014 and low values during the months of May and June 2014. The highest values were seen in Site D during the month of April 2014.



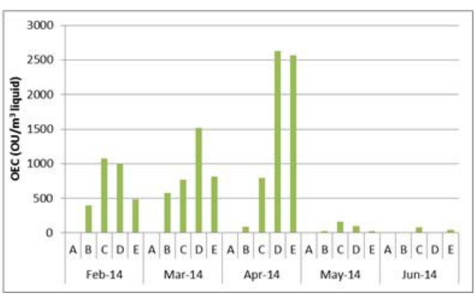


Figure 3: (a) BOD and COD and; (b) OEC values in Sarno River.

The relationship of OEC and organic content is shown in Fig. 4. It can be seen that linear trends exist representing two cases, namely for (a) clean and moderately polluted sites (COD < 35 mg/L; BOD < 11 mg/L) and (b) highly polluted sites (COD values > 35 mg/L; BOD > 11 mg/L). The latter represent a classification of 5 (bad ecological condition), as stipulated in the Italian surface water regulation [23].

Pearson correlation coefficients are presented in Table 1. Results show that OEC is more correlated to COD compared to BOD and that the relationship is stronger in highly polluted conditions. The presence of correlation proves that the initial hypothesis presented by Zarra et. al (2012) is indeed valid, especially for water with high organic content. Further, it also explains that activities during the summer season are the contributing factor in the poor correlation observed in the initial investigation.

Linear regression analyses were done for these two conditions and are shown in Fig. 5. Good linear fit was observed in both cases and proves the viability of utilizing OEC for rapid estimation of organic content in rivers. In terms of odour regulation, the regression equations can also be used to determine the allowable values for odour concentration in relation to organic levels in surface waters.

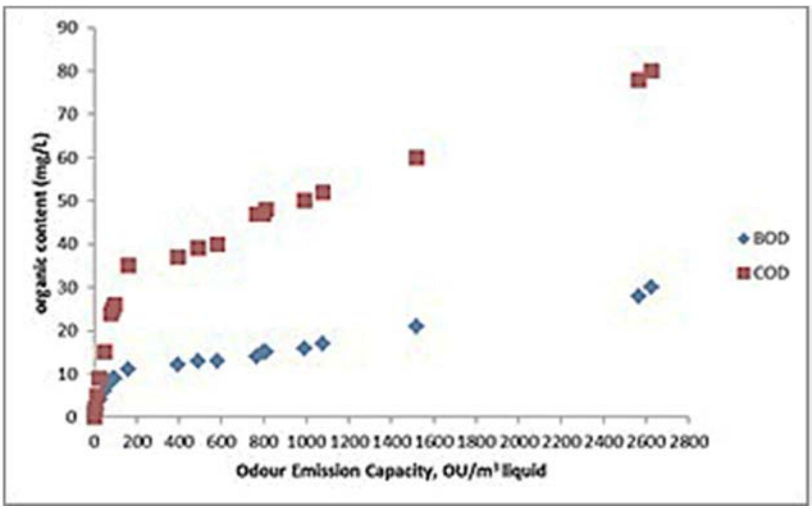


Figure 4: Correlation between OEC and organic matter for the period Feb–June 2014.

Table 1: Correlation coefficients for OEC and organic content for different conditions.

Condition	Pearson Correlation Coefficient (probability)			
	BOD		COD	
Clean and moderately polluted	0.95969	(p<0.0001)	0.98376	(p<0.0001)
Highly polluted sites	0.99688	(p<0.0001)	0.99615	(p<0.0001)

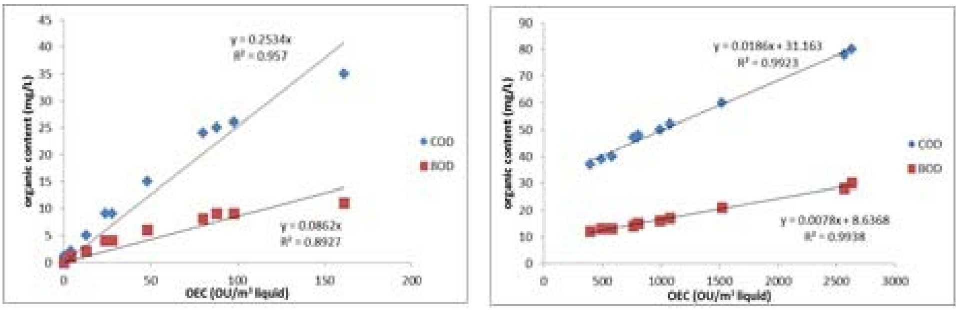


Figure 5: Correlation between OEC and organic matter for (a) clean and moderately polluted and; (b) highly polluted stations of Sarno River.

4 CONCLUSIONS

This work studied the Odour Emission Capacity (OEC) of river waters as a surrogate parameter in the assessment of environmental status and discussed the relationship between odour emissions of river waters versus conventional analytical parameters used in assessment of the environmental status. The study presents a novel procedure for the assessment of the river water quality able to reduce the overall costs of analyses.

OEC method was applied to water samples from Sarno River and values ranged from 0 to 2628 OUE/m3. Due to the nature of low odour concentrations of river water, a sample volume of 3 L and sampling times of 0, 2.5, 5 and 7.5 min with air flow of 3 L/min are recommended. The organic content and the odour of river water samples were strongly correlated and it can be deduced that odour can be used as a substitute indicator of organic content assessment in rivers. The relationship is more evident for COD and BOD values greater than 35 mg/L and 11 mg/L, respectively, which signifies the suitability of the OEC method for highly polluted rivers.

Results underline the strong relationship between the organic content in the river samples and their odour in terms of OEC. OEC can be easily integrated in the assessment protocol and it is a good subrogate indicator for the assessment of river water quality.

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