

Adsorption of odorous gases in and around activated sludge based Sewage Treatment Plant

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Sewage Treatment Plants (STP) are one of the major sources that cause atmospheric odour pollution as a result of the biological degradation of organic matter by microorganisms under anaerobic conditions. A case study has been done around the **Titagarh Sewage Treatment Plant**, uses the activated sludge process for the secondary treatment which is operated by the Kolkata Municipal Development Corporation, Kolkata, India. So to control odour various equilibrium adsorption isotherms have been studied using experimental data. Depending on the nature of the sample and their range of concentration levels, Freundlich and Langmuir Isotherm give better fits than the Tempkin Isotherm.

1. Introduction

Sewage treatment works are one of the major sources that cause atmospheric odour pollution. The increase in the number of complaints about odour nuisance is due to the increase in environmental concerns. (Ziya Öztürk et al., 2009) Wastewater treatment facilities have frequently been regarded as major sources of odour nuisance, and a variety of odorous volatiles are known to be emitted during the handling and processing of wastewater at these facilities. These odorous emissions from sewer systems and wastewater treatment plants can cause serious problems within the nearby area (Frechen, 1994). In recent years complaints related to sewage odour have been increasing (Gostelow et al., 2001). There is, therefore, a need to identify, quantify and control the odour generated at the process units such as inlet works, aeration tank, grit chamber, gravity thickeners, sludge cleaning tank etc.

A case study has been done around the **Titagarh Sewage Treatment Plant**, which falls under the purview of the KMDA (Kolkata Municipal Development Corporation, Kolkata, India). The plant basically employs activated sludge process for the treatment of the municipal sewage to be subsequently used for the irrigation purpose.

In the case of Titagarh sewage treatment plant, odour emissions are associated both with the waste water and the sludge processing units. In this specific case, the principal odour sources identified at the Titagarh sewage treatment plant are marked as STPT₁ till STPT₇.

Table 1: Sewage samples collected from STP Titagarh

Sample ID	sample collected	Sample ID	sample collected	Sample ID	sample collected
STPT ₁	Raw Sewage	STPT ₄	Secondary Clarifier	STPT ₇	Oxidation Pond
STPT ₂	Grit Chamber	STPT ₅	Final Effluent		
STPT ₃	Aeration Tank	STPT ₆	Sewage sludge		

Odour intensity was measured using panel method.

2. Design of experiments

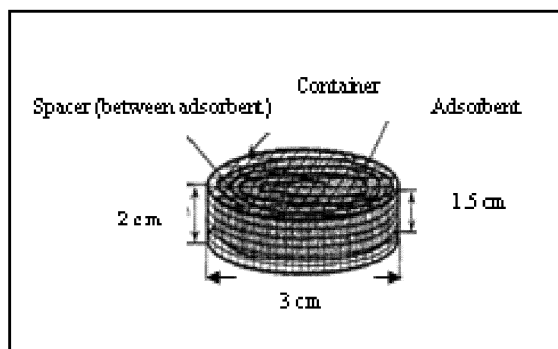


Figure 1: Schematic diagram of an adsorbent bed

2.1 Adsorbent bed preparation

For making an adsorption bed we have used absorbent cotton wool I.P of 100gms. Nett as a supporting material. First we take a small amount of adsorbent cotton wool and spread it to pour activated carbon for making a bed depth of 1.5 cm. We always try to take care that contact of odourous gas through adsorption zone should be correctly done. Activated carbon is used for adsorbent bed (shown in Fig 1).

2.2 Adsorption Technique

We have taken 30 gm of each sample in wide mouth TARSONS PP 125ml, bottle with cap. Then adsorbent bed is placed near the mouth of the bottle. After that, bottles are properly labeled by code. Then samples are presented in front of the panel member to judge, starting from 0 hour and is repeated till equilibrium condition does not come. When intensity of one sample does not change with time then equilibrium condition comes. That means adsorbent can't adsorb any more odorous gas from odorous sample. From Fig 2 we can see the results of equilibrium time to attend zero-odour state for various samples with their intensity.

Weight of the absorbent used (powdered activated carbon): 1.25 gm.

Weight of the each sample: 30 gm

3. Odour Control by Adsorption

Adsorption systems for odour treatment is a very well known phenomena for treating of odourous gas. The surface of a solid always accumulates a concentration of molecules from its gaseous or liquid environment; this phenomenon is called *adsorption*. The “surface” includes all accessible areas, and can therefore be extensive for solids that incorporate an inner network of pores, including those with diameters down to molecular dimensions. Such solids are known as *adsorbents*. The removal of adsorbed matter (*adsorbates*) from a solid is called desorption.

Adsorbents are useful in odour control because they serve as media for removing odourous gases and vapours from air streams by concentrating and retaining them, thus facilitating their subsequent disposal or their conversion to odourless products. Adsorbent systems also serve to recover valuable chemicals, but this function does not ordinarily apply to wastewater operations.

Adsorbed odorants, if they are stable and relatively unreactive in air (butyric acid, for example) may simply remain on the carbon indefinitely. Others, such as reduced sulphur compounds, including hydrogen sulphide, are more or less rapidly oxidised to products that are frequently less odourous and sometimes not odourous at all. In many instances, the oxidants products are higher in molecular weight and more strongly adsorbed and retained. Different adsorbed odorants, being concentrated and in close proximity to each other on the surface or in the pores of adsorbent, may interact and others, like styrene or acrylates, may polymerise. Most of these actions favour effective deodorization.

3.1 Models for Adsorption Isotherms

The Tempkin isotherm (Model 1)

Tempkin (Tempkin and Pyzhev, 1940) considered the effects of some indirect adsorbate/adsorbate interactions on adsorption isotherms suggested that the heat of adsorption of all the molecules in the layer would decrease linearly with coverage due to these interactions. The Tempkin isotherm has been used in the following form:

$$q = k_2 \log C + k_1 \quad \text{---(1)}$$

Here q is the equilibrium solid phase concentration in mg per 100 ml per gm of adsorbent C is the equilibrium liquid phase concentration in mg per 100 ml. The constant k_1 is related to the heat of adsorption.

The Freundlich isotherm (Model 2)

The Freundlich expression assumes that the adsorbate concentration increases along with the concentration of adsorbate on the adsorbent surface:

$$q = k_1 (C)^{k_2} \quad \text{---(2)}$$

In this equation k_1 k_2 are the Freundlich constants. This expression is characterized by the heterogeneity factor, k_2 so this isotherm may be used to describe various

heterogeneous systems (Moon and Lee, 1983; Al-Duri and McKay, 1988). The Freundlich equation agrees well with the Langmuir equation over moderate concentration ranges but, unlike the Langmuir expression, it does not reduce to the linear isotherm (Henry's law) at low surface coverage. Both these theories suffer from the disadvantage that equilibrium data over a wide concentration range cannot be fitted with a single set of constant.

The Langmuir isotherm (Model 3)

The theory for Langmuir isotherms assumes monolayer coverage of adsorbate over a homogenous adsorbent surface. Therefore, at equilibrium, a saturation point is reached where no further adsorption can occur adsorption takes place at specific homogeneous sites within the adsorbent. In the following equation, k_1 , k_2 are the Langmuir constants:

$$q = \frac{k_1 C}{k_2 + C} \quad -(3)$$

Table 2: Initial and equilibrium concentrations of different samples

Sample ID	Co	Ceq	(Co-Ceq)/ad
STPT ₁	667.937	18.55418	519.506266
STPT ₂	561.0495	14.68783	437.089313
STPT ₃	1193.775	24.00666	935.81478
STPT ₄	1044.793	34.59955	808.154979
STPT ₅	5126.102	312.2419	3851.08828
STPT ₆	437.3139	5.922926	345.11281
STPT ₇	159.437	2.666687	125.41623

4. Result and discussion

We have determined all the concentrations of sewage odour on the basis of the best model performed in odour analysis. Then we compared various equilibrium adsorption isotherms like Tempkin isotherm, Freundlich isotherm, Langmuir isotherm on the basis of experimental data. Depending on the nature of the sample, we can see from the graph that Langmuir Isotherm (Fig 4) and Freundlich isotherm (Fig 3) is giving much better result than the Tempkin isotherm isotherm (Fig 5).

Depending on the nature of sample and its range of concentration levels isotherm model by Langmuir did fit the data well on most of the occasions. Major assumptions of the Langmuir Model are: 1) The surface of the adsorbent is uniform, that is, all the adsorption sites are equivalent, 2) Adsorbed molecules do not interact, 3) All adsorption occurs through the same mechanism and 4) At the maximum adsorption, only a monolayer is formed: molecules of adsorbate do not deposit on other, already adsorbed, molecules of adsorbate, only on the free surface of the adsorbent. In case of our adsorbent, surface of the commercial activated carbon were found to be very smooth. The adsorbed molecules did not interact since they were just VOCs and nothing else. Conditions 3) and 4) were naturally satisfied.

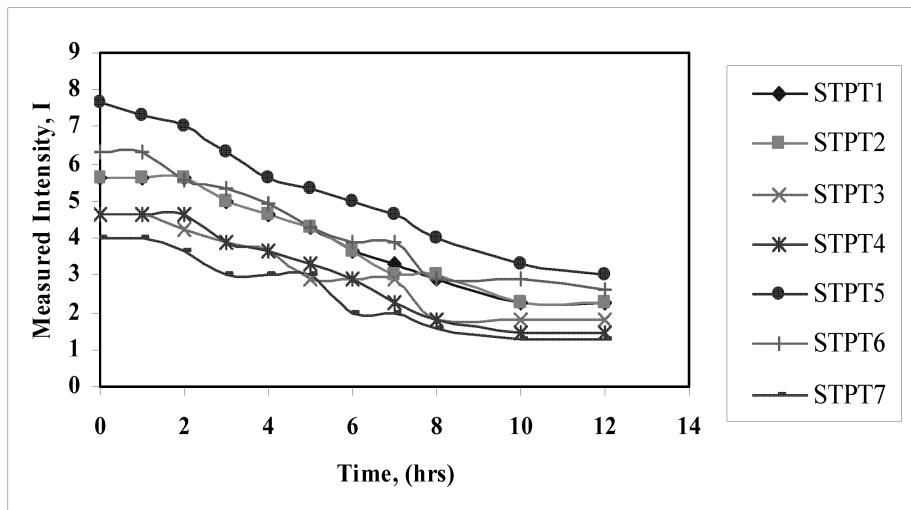


Figure 2: Equilibrium time to attend zero-odour state for various samples. Titagarh (STP)

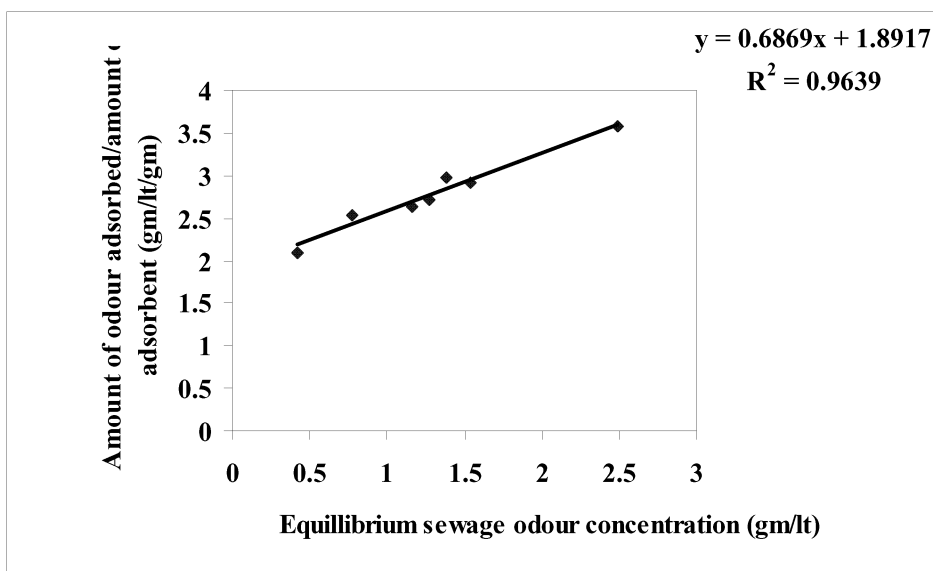


Figure 3: Data fitted to Freundlich Isotherm

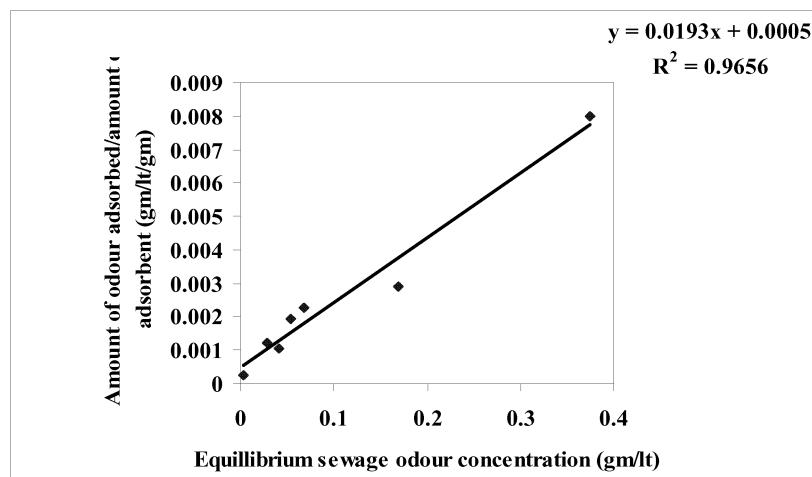


Figure 4: Data fitted to Langmuir Isotherm

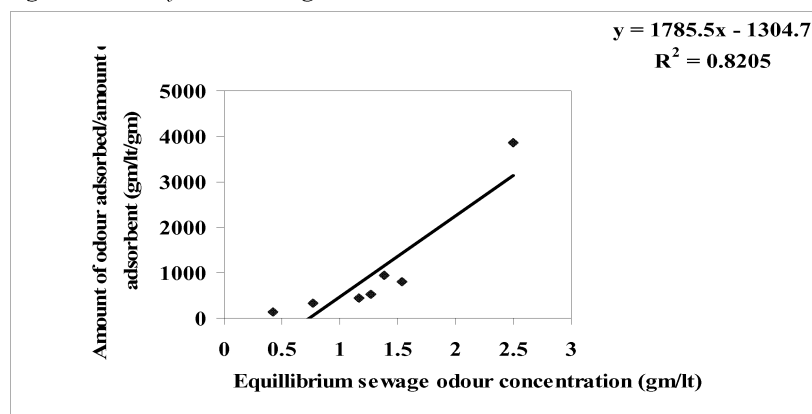


Figure 5: Data fitted to Tempkin Isotherm

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