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Trimethylamine (fishy odor) adsorption by biomaterials: Effect of fatty acids, alkanes, and aromatic compounds in waxes

Phattara Boraphech, Paitip Thiravetyan[∗]

School of Bioresources and Technology, King Mongkut's University of Technology Thonburi, Bangkok 10150, Thailand

h i g h l i g h t s

g r a p h i c a l a b s t r a c t

- TMA is mainly caused fishy odor leading to awful breath even at low concentrations.
- All leaf materials as adsorbents are efficient and rapid to absorb gaseous TMA.
- Sansevieria trifasciata leaf is the most effective to remove TMA up to 100%.
- Specific components in the wax are necessary to enhancement of TMA adsorption.

a r t i c l e i n f o

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A B S T R A C T

Thirteen plant leaf materials were selected to be applied as dried biomaterial adsorbents for polar gaseous trimethylamine (TMA) adsorption. Biomaterial adsorbents were efficient in adsorbing gaseous TMA up to 100% of total TMA (100 ppm) within 24 h. Sansevieria trifasciata is the most effective plant leaf material while Plerocarpus indicus was the least effective in TMA adsorption. Activated carbon (AC) was found to be lower potential adsorbent to adsorb TMA when compared to biomaterial adsorbents. As adsorption data, the Langmuir isotherm supported that the gaseous TMA adsorbed monolayer on the adsorbent surface and was followed pseudo-second order kinetic model. Wax extracted from plant leaf could also adsorb gaseous TMA up to 69% of total TMA within 24 h. Another 27–63% of TMA was adsorbed by cellulose and lignin that naturally occur in high amounts in plant leaf. Subsequently, the composition appearing in biomaterial wax showed a large quantity of short-chain fatty acids ($\leq C_{18}$) especially octadecanoic acid (C_{18}) , and short-chain alkanes $(C_{12}-C_{18})$ as well as total aromatic components dominated in the wax, which affected TMA adsorption. Hence, it has been demonstrated that plant biomaterial is a superior biosorbent for TMA removal.

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1. Introduction

Trimethylamine (TMA) is a basic aliphatic tertiary amine gas at room temperature. It is very soluble in water and in organic solvents. TMA is a nitrogenous base and can be readily protonated to give trimethylammonium cations. TMA is a product of decomposition of plants and animal, particularly animal husbandry is estimated to constitute a main source of atmospheric TMA

 $[1-5]$. TMA is used as a warning agent for natural gas, a synthetic flavor (fish) ingredient, and in the synthesis of photochemicals, choline salts, flotation agents, dyes, pesticides, ion-exchange resins, cationic starches, and intense sweeteners [\[6\].](#page--1-0) TMA has the highest global flux of all alkylamines and can either react with atmospheric oxidants or partition to the particle phase through dissolution or reaction with ambient acidic species [\[7\].](#page--1-0) In general, TMA is the substance mainly responsible for the odor often associated with rotting fish, some infections, and awful breath $[8-10]$, especially TMA is difficult to degrade [\[11\].](#page--1-0) TMA has pungent, strong fishy ammonia-like odor with a significantly low odor threshold has been reported as 0.00021 ppm [\[12\],](#page--1-0) 0.00033 ppm [\[13\],](#page--1-0)

[∗] Corresponding author. Tel.:+66 2 470 7535; fax: +66 2 452 3455. E-mail address: paitip.thi@kmutt.ac.th (P. Thiravetyan).

0.00044 ppm $[14]$, and 0.00058 ppm $[15]$. However, in the industrial scales were reported the high TMA discharge in the range of $5-100$ ppm $[1,16,17]$. Thus, it is very necessary to be aware of the danger and find a proper way to get rid of TMA. Nowadays, several conventional methods are estimated to minimize TMA odorant such as air scrubbing, high temperature combustion, chemical inactivation, adsorption–adsorbent materials (activated carbon, silica gel, and zeolite), photocatalysis, and biological oxidation (e.g., biofiltration, biotrickling filtration, and bioscrubbing) which provide high performance, however they are high operation costs and complicate to use [\[5,11,17–22\].](#page--1-0)

Another attractive alternative strategy is biosorption display technology, which has been used to improve the performance of biomass in pollutant removal from contaminated sites such as water, soil, and air. A large quantity of materials has been extensively investigated as natural biosorbents for the removal of metals or organics such as bacteria, fungi, yeast, algae, industrial wastes, agricultural wastes, other polysaccharide materials, etc. [\[23–28\].](#page--1-0) Some potential biomaterials with high metal binding capacity have been identified to bind a variety of heavy metals to different extents [\[29–31\].](#page--1-0) It already exists for cheap biosorbents and is more economical and environmentally friendly that should be considered with highest priority at the early stage in innovative green technologies. Kapoor and Viraraghavan [\[32\]](#page--1-0) proposed several factors affecting the application of a biosorbent in practice, including the biosorptive capacity, the availability of the biosorbent, the cost of the biosorbent, the ease of regeneration and subsequent use of the biosorbent, and the ease with which the biosorbent can be used in various reactor configurations. Due to high biomass offering from plants, leaves of plant are applicable as bioadsorbents are of interest. In a study by Treesubsuntorn et al. [\[33\],](#page--1-0) plant leaf materials were applied for non-polar benzene adsorption in a static system and were found to have high benzene adsorption efficiency, but were also influenced by quantity and composition of wax.

In our previous work, we screened twenty-three C3 and CAM plant species for phytoremediation of TMA and they were found to have high polar gaseous TMA removal within 24 h, and especially their crude wax extracts had influence on TMA removal. Thereby, the chemical and physical properties of the leaf cuticular waxes are important for studying pollutant uptake rates and bioaccumulation in plants. As Walton $[34]$ reported that the composition, polarity, quantity, and structure of the leaf cuticular wax differs widely among plant species, the uptake of TMA in the leaf wax may be plant specific. A mixture of both polar and non-polar constituents is contained in the cuticular wax $[35,36]$; hence it might be affect TMA uptake. Although various attempts have been reported over the years, the information on the correlation of leaf wax compositions and adsorption efficiency of polar gaseous pollutant, specifically TMA was insufficiently implied and is still not known.

The objective of this work was to evaluate leaves of various plant species used as biomaterial adsorbents available for polar gaseous TMA adsorption application, and to summarize our current knowledge on the biomaterial waxes and differences in their compositions correlated withTMAadsorption. This is a kind of gas–solid sorption system. Chloroform was used as a solvent for wax extraction because it is able to dissolve almost all compounds known to occur in leaf waxes [\[37\].](#page--1-0)

2. Materials and methods

2.1. Biomaterial preparation for adsorption and desorption study

Thirteen plant species, including Plerocarpus indicus, Sansevieria trifasciata, Dracaena sanderiana, Homalomena rubescens, Ficus religiosa, Dieffenbachia picta, Musa paradisiaca, Alstonia scholaris, Mangifera indica, Cananga odorata, Polyalthia longifolia, Acrostichum aureum, and Lagerstroemia inermis, were used in the experiments. A leaf of each plant was cut and dried at 60° C for 2 days. The dry leaves of the plants were powdered by a Retsch ultra centrifugal mill at 14,000 cycles/min and dried again at 60 ◦C for 2 days without chemical treatment was done. As similar to several adsorption works on pollutant contaminated water or air, was carried out varying dosages of 0.2–1.4 g of material in the experiment [\[27,28,33,38,39\],](#page--1-0) thereby in this work, 1.0 g of each biomaterial was placed in a glass chambers with 30 cm of height, 12.86 cm of radius, and 15.6 L in volume, and acted as a virtual closed static system for TMA fumigation. Because high levels of TMA discharge reported 5–100 ppm, 100 ppm of TMA was estimated as an initial concentration for this experiment. Trimethylamine (40% aqueous solution) is of analytical grade from Merck was injected to generate the concentration of 100 ppm inside the system (three replications) under room temperature (30 ± 2 °C) and pressure (\sim 760 mm Hg). To measure the remaining TMA concentrations in post-treatment air, a 4 ml air sample was taken from the chambers every 4 h to be analyzed by gas chromatography.

After the adsorption process, some of the TMA-adsorbed biomaterials were taken to desorb using deionized water (DI) as eluent solution until there was no TMA occurrence. TMA-adsorbed biomaterials were placed in a sealed glass bottle with 40 ml DI water and shaken at 150 rpm at 30 \degree C for 2 days. The sample was centrifuged and filtered, and then TMA concentration was measured in the supernatant and analyzed by gas chromatography (GC).

2.2. Chemical structure identification by FT-IR analysis

Fourier transform infrared spectrometer (FTIR, PerkineElmer Spectrum One) was used for identifying the structures and types of functional groups of plant leaf materials. The adsorbent spectra were obtained using the potassium bromide (KBr) pellets technique. The plant leaf biomaterials were milled and mixed with KBr (1 mg sample: 100 mg KBr) to form a very fine powder, which was then compressed into a thin pellet that could be analyzed.

2.3. The effect of leaf material dosages, adsorption isotherms, and kinetics models

Determination of equilibrium adsorption isotherm, different dosages of leaf material powders were varied in the range of 0.2–3.5 g, which were fumigated for the adsorption of gaseous TMA for 24 h at the initial TMA concentration of 100 ppm. The amount of TMA adsorption at equilibrium, q_e (mg g^{-1}), was calculated by:

$$
q_{\rm e} = \frac{C_0 - C_{\rm e}}{M} V \tag{1}
$$

where C_0 (mg L⁻¹) is the initial TMA concentration, C_e (mg L⁻¹) is the remaining TMA in system at a constant temperature, $V(L)$ is the volume of the solution, $M(g)$ is the mass of leaf material powder.

The pseudo-first order and pseudo-second order kinetic models were used to describe the phenomena of gaseous TMA adsorption by using leaf material powders.

2.4. TMA adsorption by extracted waxes of biomaterials

In order to study the ability of biomaterial waxes to adsorb gaseous TMA, the wax yield of leaf material powder was determined. Approximately 1 g of each biomaterial was weighed and extracted by immersing them into 50 ml of chloroform for 2 days at room temperature while shaking gently with a horizontal shaker. The extracted solution was filtrated and transferred into a 130 cm^2 aluminum plate, after that extracts were evaporated to eliminate the solvent completely. Four decimal balances were used to Download English Version:

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