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Department of Chemical and Biological Engineering

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Project Title : Multi-functional Gel Materials for Malodor Treatment

Researcher(s) : FAN Yuwen

Supervisor(s) : Prof. Yeung King Lun

Work Plan No. : 17042

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Signature of Approval :

Prof. Marsh[illegible]
CBE Acting H[illegible]

Department of Chemical and Biological Engineering HKUST

HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF CHEMICAL AND BIOMOLECULAR ENGINEERING

Multi-functional Gel Materials for Malodor Treatment

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Supervisor: Prof. YEUNG King Lun
Work plan Number:
Date: 20th June 2017

1. General Information

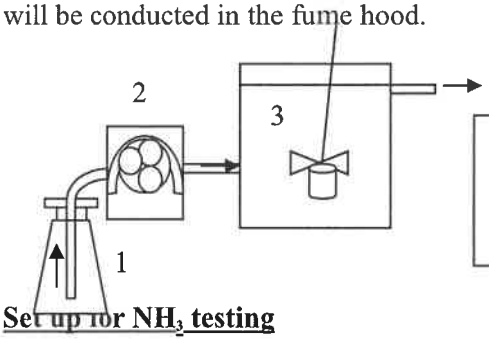
Name of Researcher:	FAN Yuwen
Name of Project Supervisor:	Prof. YEUNG King Lun
Project Title:	Multi-functional Gel Materials for Malodor Treatment
Research Area:	Advanced Materials and Environment
Location:	Rm. 7253 and 6115
Proposed Start Date:	20th June 2017

2. Experiment/Project Description

Project Description:

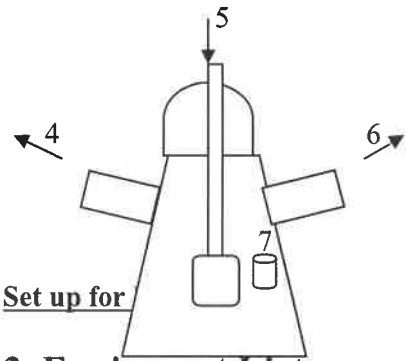
Malodor is an important class of air pollution that has a serious threat to personal health and quality of life. It also has an adverse impact on commerce and property values, and promotes a negative image of poor sanitation. Hydrogen sulfide and ammonia gases are two major causes of malodor complaints in Hong Kong and are produced by microbial decomposition of organic wastes. They are often found in waste treatment and handling facilities, landfills and indoor at lavatories and wet markets. Sewer is also a major source of malodor in urban environment and is particularly different to be treated. This project proposes a non-catalytic technology based on controlled-release of biocide, inhibitor and zeolite will also be developed to address the malodor problem at the source by killing odor-causing microbes, inhibiting odor generation and adsorb malodor compound.

A schematic diagram of the experimental setup is drawn as below. Low concentration of NH_3 in water phase is used in the experiment and the testing equipments are put outside of fume hood, while the H_2S experiment will be conducted in the fume hood.



1. Container with solution
2. Pump
3. Reactor in fume hood (with gel)

Set up for NH_3 testing



1. Water sampling
2. H_2S in Ar inlet
3. Gas sampling
4. Reactor in fume hood (with gel)

Set up for

3. Equipment List

Equipment	Location
1) Pump	7253
2) pH meter	7253
3) UV-Vis spectrometer	6115
4) Ion chromatography	7101
5) GC-MS	6115
6) TOC	7101
7) ICP	7101
8) H_2S analyzer	6115

4. Experimental Procedures

A polluted solution is simulated and introduced into a reactor with a hydrogel placed in it. Adsorption or reaction of NH_3 and H_2S are controlled by the flow rate of pollutant. This reaction is taken place at ambient pressure and temperatures to find out the optimum formulation of hydrogel to remove the pollutant effectively. The aim of the reaction is to adsorb, convert NH_3 and H_2S into nontoxic substance.

4.1 Hydrogel Preparation

The hydrogel, is prepared by mixing TEOS with metal chlorides, thymol, sodium chlorite and ion exchange zeolite. The mixture is stirred by magnetic bar for an hour to get a well-mixed solution with mild heating (60C) and the presence of dilute HCl. Dropwisely add AS-40 (colloidal silica) into the resulting solution and stirred for 30 minutes. The solution is then poured into a container for gelation overnight.

4.2 Flow Reactor

The reactor is made of transparent and the NH_3, H_2S gases or bacteria (S. Aureus, E. Coli, H_2S generating bacteria or NH_3 generating bacteria) in water phase are introduced into the system. NH_3 in water phase is using dilute ammonia solution while H_2S in water phase is using dilute sulfide ion solution (e.g. sodium sulfide). The flow rate of pollutants is controlled using the pump.

Samples are taken from the outlet and can be analyzed by pH meter, ion chromatography and UV-vis spectrometer.

4.3 Analysis

(a) Concentration Analysis

The concentration of the pollutant in the outlet stream is measured by ion chromatography and pH meter after collecting the water sample. The sample is taken after one volume change of the reactor and every hour.

UV-vis is used to analyze the total arbitrary amount of ion exchange zeolite and other colored compounds release. Water sample will be taken at the inlet and outlet as control and testing group with respectively for comparison.

(b) Bacterial Analysis

Water sample taken at the outlet is spread onto the agar plates and incubated for one day to count the total bacteria number on the plates and calculate the bacterial reduction efficiency.

5. PROCEDURE TEMPLATE

Experimental Procedure No.	Experimental Procedure Description	Scale (Mass/Volume)	Location (Fumehood,benctop,etc)	Method New or Existing
4.1(a)	Mixing and mild heating of TEOS with other ingredients (metal ions, thymol, sodium chlorite, ion exchange zeolite), dilute HCl as catalyst	100ml	Benchtop	existing
4.1 (b)	Add AS-40 drop wisely into the above solution	100ml	Benchtop	existing
4.1 (c)	Gelation of the resulting solution to form hydrogel	200ml	Dark environment	existing
4.2 (a)	Flow solution (ammonia, H_2S (Na_2S) or bacteria) through the hydrogel Bacteria: S.Aureus, E Coli., Desulfovibrio vulgaris or Bacteroides vulgatus	Reactor: 500ml Total: 2L	Sink (BSC for bacteria solution)	existing
4.2 (b)	Collect water sample from time to time	10 ml	Sink (BSC for bacteria solution)	existing
4.3 (a)	Extract 100ul of water sample and dilute to 10^{-2} (for bacteria count)	10ml	BSC	existing
4.3 (b)	Spread the water sample on the TSA plate	100ul	BSC	existing
4.3 (c)	Put the agar plates under 37C for 24 hours	/	Incubator	existing

6. Hazard and Operability Analysis

4.1 Preparation of hydrogel							
NO	HAZARD	HAZARD EFFECT	SEVERITY	PROBABILITY	RISK	MINIMISE RISK BY	RESIDUAL RISK
1	Contact with chemicals	Causes severe skin and eye burns.	H	M	H	Wear protective gloves, face shield and lab coats; Conduct experiments in the fume hood	L
2	Powder inhalation	Harmful by inhalation.	H	M	H	Take the measurement within the fume hood	L
3	Wrongly programed muffle furnace setting	Uncontrolled temperature increase	H	L	M	Set up the muffle furnace carefully and check the temperature within 2h	L
4	Hot surface of the muffle furnace	Skin burn if touched	H	M	H	Set a warning sign and operate with protective gloves. Take out the samples until the temperature decreases below 100 .	L
FINAL ASSESSMENT:						OVERALL RISK:	L

Remark: Severity–Low:1 (Minor injuries, first aid); Medium:2 (Hospitalization, medical leave); High:3 (Serious injuries, fatality)
Probability–Unlikely:1; Possible:2; Very Likely: 3.

HAZOP Template
Hazard and Operability Analysis

4.2 Flow system analysis of Hydrogen Sulphide, Ammonia and Bacteria

NO	HAZARD	HAZARD EFFECT	SEVERITY	PROBABILITY	RISK	MINIMISE RISK BY	RESIDUAL RISK
1	Contact with chemicals	Irritating to eyes and skin	H	M	H	Wear protective gloves, face shield and lab coats; Conduct experiments in the fume hood	L
2	No flow in the reactor	Reduce pumping efficiency in a long run	L	M	M	Monitor the water level of the inlet	L
3	H_2S gas leakage	Adverse health effect to people work in lab	M	M	M	Well sealed the reactor system in fume hood	L
FINAL ASSESSMENT:			OVERALL RISK:				L

Remark: Severity–Low:1 (Minor injuries, first aid); Medium:2 (Hospitalization, medical leave); High:3 (Serious injuries, fatality)
Probability–Unlikely:1; Possible:2; Very Likely: 3.

HAZOP Template
Hazard and Operability Analysis

4.3 Bacterial Analysis

NO	HAZARD	HAZARD EFFECT	SEVERITY	PROBABILITY	RISK	MINIMISE RISK BY	RESIDUAL RISK
1	Bacterial contamination	Adverse health effect to people work in lab	M	M	M	Well sealed the reactor system and place in BSC, use ethanol before and after experiment.	L
FINAL ASSESSMENT:			OVERALL RISK:				L

Remark: Severity–Low:1 (Minor injuries, first aid); Medium:2 (Hospitalization, medical leave); High:3 (Serious injuries, fatality)
Probability–Unlikely:1; Possible:2; Very Likely: 3.

7. Operating Conditions

Preparation of hydrogel

- Pressure : atmospheric during preparation
- Temperature : ambient temperature
- Flow rates : batch operations therefore not applicable

Preparation of Zeolite

- Pressure : atmospheric during preparation
- Temperature : 450-550 °C
- Flow rates : batch operations therefore not applicable

H_2S System

- Pressure : atmospheric
- Temperature : ambient temperature
- Flow rates : 1-10 ml/min

NH_3 System

- Pressure : atmospheric
- Temperature : ambient temperature
- Flow rates : 1-10 ml/min

Bacterial System

- Pressure : atmospheric
- Temperature : ambient temperature
- Flow rates : batch operations therefore not applicable

8. Services List

Electricity (AC 220V, 50Hz)

Double de-ionized water

Tap water

9. Chemicals List

Chemical	Purity
hydrochloric acid	99%
absolute ethanol	99.99%
Oxygen	99.999%
AS-40 (colloidal silica)	99.999%
$NaClO_2$	80%
Zeolite (NaA)	/
Thymol	

	99.5%
NH_3 solution	28%
H_2S	200ppm
$FeCl_3$	97%
Tetraethyl orthosilicate(TEOS)	95%
$ZnCl_2$	98%
$CuCl_2$	97%

10. Biological Agent List

BIOLOGICAL AGENT	BIOLOGICAL SAFETY LEVEL	REFERENCE FOR BSL LEVEL (Attachment: Compulsory)
S. aureus (used in flow test, procedure 2a)	2	See attachement
E. coli (used in flow test, procedure 2a)	2	
Desulfovibrio vulgaris (H_2S generating bacteria) (used in flow test, procedure 2a)	1	
Bacteroides vulgatus (NH_3 generating bacteria) (used in flow test, procedure 2a)	1	

11. Summary of Relevant Hazards and Incompatibilities

Material	Summary of Hazards	Incompatibilities
H_2S	Cause irritation to eye and respiratory tract. Avoid direct contact with eyes, skin and clothing.	oxidizing agents, organic peroxides, alkaline materials, metals (i.e. copper, lead), and metal oxides
$Na_2S.9H_2O$	Cause irritation to eye and respiratory tract. Avoid direct contact with eyes, skin and clothing.	Incompatible with strong acids. Air and light sensitive.
NH_3 solution	Corrosive to skin, irritant to skin, eyes and inhalation	React vigorously with metals, reactive with acids, slightly reactive with oxidizing agents
$CuCl_2$, $ZnCl_2$	Toxic when swallowed. Cause irritation when contacted by eyes, skin or lung.	Strong oxidizing agent, alkali metals.
$FeCl_3$	Toxic when swallowed. Cause irritation when contacted by eyes, skin or lung.	May undergo hazardous decomposition, condensation or polymerization, it may react violently with water

		or self-reactive if under shock, increase in temperature or pressure.
Thymol	Eye, skin, ingestion or inhalation irritation	Reactive with oxidizing agents, akalis
$NaClO_2$	Eye, skin, ingestion or inhalation irritation	Reactive with reducing agents, combustible materials
TEOS	Eye, skin, ingestion or inhalation irritation	Oxidizers and strong acid
AS-40	None	none

12. Waste List

The inlet NH_3 and Na_2S concentrations to the reactor are low and the waste water could be neutralized before disposal.

13. Assessment of Significant Risks

Some of the chemicals used in the experiments are irritating (NH_3) and toxic by ingestion, skin contact and inhalation. All of the used solvents and NH_3 are flammable and at least harmful if not toxic and must be disposed.

14. Safety Precautions

(i) Personal protective equipment

A lab coat and UV protective goggles must be worn through the experiment and nitrile gloves must be worn while handling, transporting and transferring chemicals.

(ii) Fume Extraction System Required and in Place:

The reaction system is running at low concentration and in water phase, the volatility of the pollutant should not be high. For H_2S setup, the reactor will be placed in fume hood.

(iii) Specific Containment Procedures:

Reactor covered by aluminum foil.

(iv) Specific Training Required:

None.

(v) Specific Supervision Required:

None.

(vi) Specific Monitoring Required:

None.

15. Action in Case of Abnormal or Emergency Situations

(i) Service Failure

Close the main valve on the air cylinder and reactant inlet.

(ii) Action in case of fire or explosion

1. When hear the fire alarm:
   - *Remain calm and check* if there is any sign of fire in the vicinity.
   - If you see fire or smoke, or hear the announcement asking you to evacuate, follow the evacuation procedures below.
   - If there is no sign of a fire, stay alert and pay attention to announcement until the fire alarm is silenced.
   - Evacuate if the alarm has sounded for more than two minutes.
   - If you hear the buzzer sound which indicates fire alarm is activated in an adjacent fire zone, stay alert and pay attention to announcement.
   - If you hear both the buzzer and the fire alarm, you are near the boundary of fire zones, treat as if you hear the fire alarm.

2. If discover a fire:
   - Activate the fire alarm by pressing the break glass fire alarm button.
   - Report to Security Control Centre by dialing 8999.
   - Alert other people. If SAFE to do so, try to put out the fire by firefighting equipment.
   - DO NOT take any personal risk. If the fire gets beyond your control, evacuate immediately by following the procedures below.
   - Close the door of the room on fire.

3. When there is a fire and need to evacuate:
   - Remain calm. Walk; do not run, especially when travelling on staircases.
   - Immediately leave the building and go to the assembly point using the nearest exit.
   - Try to help those who may have difficulties travelling such as disabled and pregnant persons.
   - DO NOT USE THE LIFTS.
   - Report to your Fire & Safety Officer at the assembly point as far as practicable.
   - Do not return to the building until permission is given by the Fire Services Department Officer in charge of the scene.

(iii) Action in case of spillage

1. Hazardous Chemical Spill in a Research Laboratory:
   - Alert co-workers.
   - If safe to do so,
     1. Confine the spill with appropriate materials.
     2. Turn off remotely all heat/ignition sources if flammable vapor is involved.

   Ask for assistance if necessary.
   Press the Emergency Ventilation button (do not activate this button in case of fire).
   Inform the Security Control Centre by dialing 8999 from a safe location.
   Evacuate everyone in the affected area. Leave contaminated clothing and close the door.
   Activate local warning system to prevent others from entering the room.
   If possible, maintain a safe distance from the scene, keep the entrance or access routes in sight and help to prevent entry to the affected room.
   If conditions allow, remain to assist the emergency response team.

2. Radioactive Material Spill:
   - Alert co-workers.
   - If safe to do so, confine the spill with appropriate materials.
   - DO NOT activate Emergency Ventilation UNLESS radioactive gas or vapor (e.g. Iodine-125) is involved.

- Inform the Security Control Centre by dialing 8999.
- Evacuate everyone in the room.
- Leave contaminated clothing or articles and close the door.
- Activate local warning system to prevent others from entering the room.
- If possible, maintain at a safe distance from the laboratory, keep the entrance or access routes in sight and help to prevent entry to the laboratory.
- If conditions allow, remain to assist the emergency response team.

Decontamination Procedures

- Persons contaminated by radioactive material should go through decontamination as soon as they arrive at a safe location.
- Treat any injury first. First-aiders should protect themselves against contamination.
- Remove any other suspected contaminated clothing or articles, seal in a plastic bag.
- Wash contaminated skin area with water and detergent. Avoid aerosol generation (e.g. scrubbing with brush).
- Immediately seek medical attention for any internal contamination.

3. Biohazardous Material Spill:

- Alert co-workers.
- If safe to do so, contain the spill with appropriate material.
- If the spill occurred in a biosafety cabinet, leave the unit on.
- Evacuate everyone in the affected area.
- Leave contaminated clothing or articles and close the door.
- Inform the Security Control Centre by dialing 8999 from a safe location.
- Activate local warning system to prevent others from entering the room.
- If possible, maintain a safe distance from the laboratory, keep the entrance or access routes in sight and help to prevent entry to the laboratory.
- If conditions allow, remain to assist the emergency response team.

Decontamination Procedures:

Any person contaminated by the biohazardous material spill should go through decontamination as soon as they arrive at a safe location.

- Treat any injury first. First-aiders should protect themselves against contamination.
- Remove any other suspected contaminated clothing or articles, seal in a plastic bag.
- Wash contaminated skin area with water, appropriate disinfectant and soap.
- If eyes have been contaminated, flush with water.
- Immediately seek medical attention for any internal contamination.

4. Hazardous Chemical Spill in a Teaching Laboratory:

Students or technicians upon discovering a chemical spill:

- Alert all persons in the vicinity.
- Inform the person in-charge in the laboratory.

Person-in-charge upon notification of a chemical spill:

- If safe to do so,

Confine the spill with appropriate materials.

Instruct the students to turn off remotely all heat/ignition sources if flammable vapor is involved.

- Press the Emergency Ventilation button (do not activate this button in case of fire).
- Evacuate everyone in the laboratory, leave contaminated clothing and close the door(s).
- Inform the Security Control Centre by dialing 8999 from a safe location.
- Activate local warning system to prevent others from entering the area.
- If possible, maintain a safe distance from the scene, keep the entrance or access routes in sight and help to prevent entry to the affected laboratory.
- If conditions allow, remain to assist the emergency response team.