# Use of MOFS in anesthesia machine

Anesthesia Machines are used to sedate the patient with controlled amount of anesthesia agent given to the patient with every breath. As the patient is sedated, his/her breathing has to be controlled and vitals have to be monitored. The breathing system in anesthesia machine enables the patient to respire artificially avoiding breathing difficulties during an operation. During exhalation, $CO_2$ is added to the patient gas that has to be removed to maintain the fresh gas percentage at every breath.

Soda lime is currently being used to remove the carbon dioxide from the system. MOFs can replace it as they have many benefits over soda lime.

### Q. How does the anesthesia machine work?

In order to carry out the natural functions, the breathing system provides the patient with the same amount of gases in the same proportion as the patient would get from regular environment along with anesthetic agent. As the patient breathes in a closed circuit system, it should continuously get rid of all the harmful gases and be supplied with the fresh gases as per the needs of the patient. The exhaled breath from the patient consists of gases like oxygen, nitrogen, air, nitrous dioxide and carbon dioxide. The air being inhaled should be free of carbon dioxide. Hence the carbon dioxide needs be removed continuously through the flow stream after the expiratory port and before going again to the lungs of the patient.

### Q. How is the carbon dioxide removed from the system?

Currently, soda lime is being used for this purpose. It provides a very high absorption capacity of absorbing carbon dioxide from the system. It works on the principle of absorbing carbon dioxide by chemisorption producing water and heat.

### Q. Why is soda lime preferred over other absorbents to absorb carbon dioxide in anesthesia machine ?

Soda lime is the most popular carbon dioxide absorbent for the anesthesia machines because of the following reasons:

1. Soda lime efficiently absorbs carbon dioxide without any harmful by product.
2. It is non toxic .
3. It also gives a very high absorption capacity even in the dynamic conditions.
4. It gives a self indication of saturation when it is completely utilized.
5. It is very cheap and readily available.

## Q. What are the challenges with soda lime?

- The moisture generated by the soda lime along with the moisture exhaled by the patient condenses at different points in the breathing system and disturbs the flow meters and alters their readings.
- Another major drawback with the soda lime is its non reusability. Once all the soda lime reacts with carbon dioxide it is considered to be saturated and is not suitable to absorb more carbon dioxide. Hence once the cycle is over, the saturated soda lime needs to be replaced with fresh one.

## Q. How are MOFs useful for the removal of carbon dioxide from the system?

This is where the metal organic frameworks come to picture. We propose that MOFs which have the capability to capture carbon dioxide in a regenerable way in humid conditions can replace soda lime.

## Q. What are the benefits of MOFs over soda lime granules?

Since MOFs work on the principle of physisorption, they don't add to the moisture already present in the system and also they can be regenerated and reused. Moreover their capacity to also absorb moisture along with carbon dioxide is also greatly helpful as the patient exhales moisture along with the other gases which poses a problem to the sensors.

## Q. What are the operating conditions of the system?

The internal environment of the system is highly dynamic. However there are some regulations under which the compositions are artificially maintained.

| S.NO. | Parameters | Properties |
|---|---|---|
| 1. | Pressure | Less than 1 bar |
| 2. | Temperature | 37-40 deg C |
| 3. | Flow rate | Maximum flow rate is 30 L/Min. The system operates at much lower flow rates. |
| 4. | Flow composition | The components in the flow are air, oxygen, nitrogen, nitrous oxide, carbon dioxide and anesthesia agent. There is no fixed proportion for the composition. Agent generally remains 2% of the flow. However two regulations to be followed are :<br>1. O2 cannot fall below 21% and<br>2. O2:N2O should be at least 1:2. |

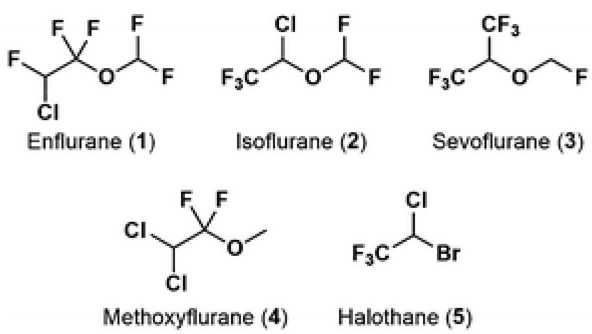
The experimentation can be started with static conditions in the beginning and can be advanced to the dynamic conditions of varying flow rates and compositions.

**Q. Which anesthesia agents are used in the machine?**

The anesthesia agents used in the machine can be any one the following compounds:

1. Enflurane
2. Isoflurane
3. Sevoflurane
4. Desflurane
5. Halothane

They are a class of highly fluorinated ethers. Their kinetic diameters are around 5.2 A. Their structures are as follows:



Enflurane (1) Isoflurane (2) Sevoflurane (3)

Methoxyflurane (4) Halothane (5)

Their physical properties can be briefly described as:

| S.no | Anesthetic Agents | Formula | Molecular Mass | Boiling point | density | Vapor pressure |
|---|---|---|---|---|---|---|
| 1. | Enflurane | $C_3H_2ClF_5O$ | 184.492 | 56.5 deg C | 1.5 g/cc at room temp. | 22.9 kPa (172 mm Hg) at 20 deg C |
| 2. | desflurane | $C_3H_2F_6O$ | 184.5 g/mol | 23.5 ° (at C or 1 atm 74.3 °F ) | 1.465 g/cm³ (at 20 °C) | 107 I804 kPa mmHg (at 24 Deg C |
| 3. | Sevoflurane | $C_4H_3F_7O$ | 200.055 g/mol | 58.5 °C (137.3 °F) | 1.517 – 1.522 g/cm³ (at 20 ° C | 317 mmHg (42.3 kPa) (at 36 °C) |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4. | isoflurane | $C_3H_2ClF_5O$ | 184.5 g/mol | 48.5 deg C | 1.496 g/mL | 450 mmHg 60.0 kPa (at 35 °C ) |
| 5. | Halothane | $C_2HBrClF_3$ | 197.381 g/mol | 50.2 deg C | 1.868 g/cm³ (at 20 °C) | 288 mmHg (38kPa) (at 24 °C) |

## Q. What are the parameters upon which MOFs need to be tested ?

The MOFs need to be tested on the following aspects.

1. The absorption capacity in the stimulated operating conditions.
2. The selectivity and its reaction towards other components of the feed gas.
3. The environmental friendliness for the purpose of disposal.
4. The kinetics in the dynamic conditions.
5. The variations in the absorption capacity with varying operating conditions.
6. The possibility of detection of saturation point with visual indications (self indicative properties)
7. External indicator which can indicate of saturation on the basis of CO2 concentration or Ph change.
8. The toxic effects if inhaled (in traces as well as in considerable amounts).
9. Regeneration procedure and conditions.
10. No. of times it can be reused before losing its adsorption capabilities to a definite extent.
11. Inert and non-toxic binder for the preparation of the granules.
12. The appropriate granule size which provides highest absorption capacity in the stimulated conditions.
13. The physical, thermal and chemical stability of the granules in the presence of other gases.
14. Post synthetic modifications to improve absorption capacity and stability to improve the MOF.
15. Medical testing for biocompatibility with various human body parts.( the canister needs to be handled manually for refilling )

## Q. What are the considerations for the designing of a new MOF ?

Following points should be kept in mind apart from the above mentioned aspects while designing the MOFs:

1. They should absorb water and carbon dioxide and should have least affinity for other gases of the system viz. nitrogen, nitrous oxide, oxygen and anesthetic agent.
2. The bonding forces between the MOFs and the adsorbate particles must not be very strong as that would render us complete desorption of carbon dioxide from the MOF to be difficult and decrease its absorption capacity over cycles.
3. They should not be extremely costly.

## Q. In what manner should be the experimentation be organized for testing above mentioned parameters?

Based on these requirements, the whole experimentation can be divided into following steps:

1. Synthesis
2. Characterization
3. Testing
    1. Absorption capacity
    2. Selectivity for other components ( $CO_2$, water or anesthetic agent)
    3. Toxicity and biocompatibility
    4. Stability
    5. Reusable
    6. Self -indicative

If the MOF qualifies for these basic criteria, then the next step would be to test its environmental and other properties which would include tests on:

7. biodegradability and
8. regeneration requirements

needs to be checked. This should be followed by verifying other general characteristics of MOFs.

This would mark the completion of testing. Next step would be to improve upon the qualities of MOFs using Post synthetic modifications.

## MOFs FOR ANESTHESIA RECOVERY

Another potential use of MOFs lies with regards to storing and retrieving anesthetic agent being wasted in the scavenging system of machine. Anesthesia agent are very costly substances and hence by saving even a small amount of the same can save a lot of money while working on a large scale.

### Q. How is anesthesia agent currently being wasted in the machine?

The inhalation of fresh gas to the lungs is facilitated by applying pressure through a bellows system with the help of a drive gas. While maintaining the supply of fresh gas as per the needs of the patient, the extra amount goes to a scavenging unit attached to the machine. This is where a major amount of the agent gets wasted.

### Q. How can MOFs help us save Anesthesia Agent (AA)?

Our idea is to use a MOF which selectively absorbs the agent before letting it enter into the scavenging system. The stored agent can be recovered by regeneration which includes slight heating of the MOF or introducing it to vacuum suction.

For anesthesia recovery the following points should be kept in mind:

1. The designed MOF is supposed to selectively absorb anesthesia agent from the system without interfering with the other components.(only AA adsorption)

- **Regeneration**: Collecting the anesthesia vapors from the saturated MOF and then purifying it and then the collected agent can be reused.

2. Other possibility may be capturing anesthesia agent would lead to the absorption of carbon dioxide molecules .(co2+AA adsorption)
   - **Regeneration**: In this case the regeneration process will include collecting the anesthesia vapors along with the carbon dioxide and then letting the gas mixture undisturbed for some time and allowing the anesthesia molecules to condense as it remains in liquid form at room temperature and pressure ( it is a gas in the system due to a vaporiser present ) and the critical pressure of $CO_2$ is much above atmospheric pressure. Liquid anesthesia can be collected, purified and reused while carbon dioxide can be disposed off.
3. The above mentioned procedure will be followed if the MOF absorbs any other component of the flow stream.
4. The anesthesia molecules should not be strongly absorbed over MOFs in order to ease their recovery and reusability.

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