Log Book: Mining Water on Mars for Sustainable Human Colonisation

By Emily Estcourt Hughes

Notes

- Some of the conditions on Mars are equivalent to the dryer parts of the Atacama Desert in Chile
- There is almost no liquid water on Mars but there is evidence that water has flowed on Mars' surface in the past
- The humidity on Mars is tied to temperature fluctuations
- During the night the relative humidity levels on Mars can rise to 80 - 100 percent with the air sometimes reaching saturation
- In the daytime the air has a much lower humidity level due to warmer temperatures
- Four things that are needed for human survival, food, water, air and shelter
- Because there is so little air pressure on Mars, liquid water can't last long. When exposed to the atmosphere water evaporates from a solid to a gas
- The atmosphere on Mars holds 10 000 times less water vapour than on Earth
- Water vapour is a dynamic trace gas
- Water vapour is very seasonally variable on Mars
- Very high levels of super saturation occurs fairly frequently in Mars' middle atmosphere which is around 20 - 50km above the surface during the aphelion season
- The aphelion season is the time where Mars is at its furthest point away from the sun
- This supersaturation is up to 10 times greater than Earth
- Relative humidity is the ratio of the partial pressure of water vapour to the equilibrium vapour pressure of water at a given temperature
- It depends on temperature and the pressure of the system of interest

- MOFs stands for metal organic frameworks
- MOFs are a class of porous materials formed by strong bonds between metal ions and organic linkers
- MOFs have a very high surface area
- MOFs have good chemical stability and large pore volume

- Australian Renewable Energy Agency (ARENA)
- The SOURCE system can produce 4 – 10 litres of water a day
- ARENA is providing $420,000 to have 150 solar powered drinking water
- Developed by zero water mass
- The material absorbs water and the solar panels harvest energy to evaporate and purify the water
- 1 device produces 5 litres of water in a day on average

Human Daily Water Intake

- About 15.5 cups (3.7 litres) of fluids for men
- About 11.5 cups (2.7 litres) of fluids a day for women

Hydrogel Alternative Option
- Temperature responsive
- Highly absorbent
- Incorporate polymer chains that respond to external stimuli
- Reversible transition from hydrated to a dehydrated state

20 /5/20 - 31/5/20

Completed some research using the websites https://www.space.com/29857-mars-humidity-alien-life.html and https://www.astrobio.net/mars/mars-atmosphere-is-supersaturated-with-water/ about water vapour and humidity on Mars. Did some research on MOFs and about the current ARENA source technology in place.

24/5/20 - 28/5/20

I came up with some experiment ideas.

Experiment ideas:
- Material, weigh it put it in a box and leave it, weigh it again, heat it up with a condenser weigh it again, measure liquid
- The way the water is condensed, cone vs flat surface vs…
- The absorbing material used not original
- Change the number of MOFs how much MOFs is the most efficient amount.
- Different types of MOFs
- Change the way the MOFs is laid out
- Use different water sources

I decided for my variable to be different amounts of MOFs to find the most efficient amount.

1/6/20

Found out that the school can't source any MOFs for the experiment so I will need to find an alternate way to get it or a different experiment.

4/6/20 - 6/6/20

I did some more research on the SCORCE panels and some more research on MOFs.

1/6/20 – 10/6/20

I started thinking about an alternate experiment based on the same principal as my original experiment using different resources and variables.

7/6/20 and 8/6/20

I sent emails to 3 people trying to source MOFs for my experiment.

Emily Estcourt Hughes Sent - Exchange 7:42 pm EH

MOFs inquiry

To: online@arena.gov.au

Hello,

I am a year 8 student at Walford Anglican School For Girls. I was wondering if you have any MOFs from the SOURCE panels that I would be able to access or purchase?

I am doing an experiment about mining water on Mars for sustainable human life. I am basing this experiment on the engineering behind the SOURCE panels and relate it to life and conditions on Mars. It would be great if I was able to use MOFs as my material to absorb the water. I only need a small amount and I am trying to find how to source some as my school was unable to get any. This is a follow up on my experiment last year titled, The Feasibility of Creating a D.I.Y Photobioreactor for Space Tourists. This project won both the Oliphant Science Awards and the BHP Science and Engineering Awards, as well as being sponsored by The Australian Institute of Energy.

Thank you for your time.

Kind regards,
Emily Estcourt Hughes

Emily Estcourt Hughes Sent - Exchange 7:38 pm EH

MOFs inquiry

To: manufacturingcomms@csiro.au

Hello,

I am a year 8 student at Walford Anglican School For Girls and I am wondering if you have any MOFs that I would be able to purchase or access? I am also wondering about the pricing of MOFs.

I am doing an experiment about mining water on Mars for sustainable human life based on the SORCE panels. These panels absorb moisture out of the water vapour in the air during the night, the solar panel heats up during the day and the water evaporates, the collected water is condensed using a condenser run using the energy collected by the solar panel. I am trying to replicate this to an extent and relate it to life on Mars.

It would be great if I was able to use MOFs as my material to absorb the water. I only need a small amount and I am trying to find how to source some as my school was unable to get any. This is a follow up on my experiment last year titled, The Feasibility of Creating a D.I.Y Photobioreactor for Space Tourists. This project won both the Oliphant Science Awards and the BHP Science and Engineering Awards, as well as being sponsored by The Australian Institute of Energy.

Thank you for your time.

Kind regards,
Emily Estcourt Hughes

Emily Estcourt Hughes Sent - Exchange 7:45 pm EH

Mofworx Inquiry

To: Aaron.Thornton@csiro.au

Hello Mr Thornton,

I am a year 8 student at Walford Anglican School For Girls and I am wondering if you have any MOFs that I would be able to purchase or access? I was also wondering about the pricing of the MOFs.

I am doing an experiment about mining water on Mars for sustainable human life based on the SORCE panels. These panels absorb moisture out of the water vapour in the air during the night, the solar panel then heats up during the day and the water evaporates and then the water is condensed using a condenser run using the energy collected by the solar panel. I am trying to replicate this to an extent and relate it to life on Mars.

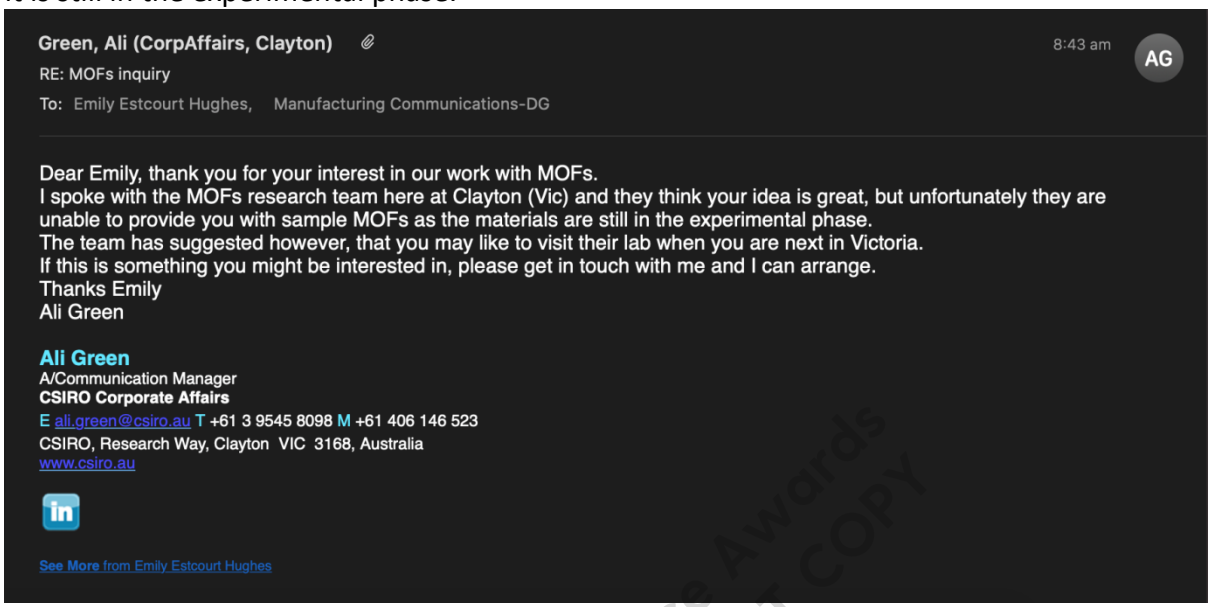
It would be great if I was able to use MOFs as my material to absorb the water. I only need a small amount and I am trying to find how to source some as my school was unable to get any. This is a follow up on my experiment last year titled, The Feasibility of Creating a D.I.Y Photobioreactor for Space Tourists. This project won both the Oliphant Science Awards and the BHP Science and Engineering Awards, as well as being sponsored by The Australian Institute of Energy.

Thank you for your time.

Kind regards,
Emily Estcourt Hughes

9/6/20

I got a reply from Ali Green at the CSIRO saying that they are unable to give me any MOFs as it is still in the experimental phase.



Green, Ali (CorpAffairs, Clayton) 8:43 am AG

RE: MOFs inquiry

To: Emily Estcourt Hughes, Manufacturing Communications-DG

Dear Emily, thank you for your interest in our work with MOFs.
I spoke with the MOFs research team here at Clayton (Vic) and they think your idea is great, but unfortunately they are unable to provide you with sample MOFs as the materials are still in the experimental phase.
The team has suggested however, that you may like to visit their lab when you are next in Victoria.
If this is something you might be interested in, please get in touch with me and I can arrange.
Thanks Emily
Ali Green

Ali Green
A/Communication Manager
CSIRO Corporate Affairs
E ali.green@csiro.au T +61 3 9545 8098 M +61 406 146 523
CSIRO, Research Way, Clayton VIC 3168, Australia
www.csiro.au

See More from Emily Estcourt Hughes

10/6/20

I wrote a rough method for a new experiment.

Materials

- **Petri dishes**
- **30g of material/ chemical**
- **Silica Gel**
- **Calcium Chloride**
- **Hydrogels**
- **Spatula**
- **Zinc Chloride**
- **Calcium Sulphate**
- **Hygroscopic Salts**
- **Zeolites**

Method

Experiment 1

1. Get exactly 30 grams of each material
2. Carefully place the 30 grams of each material into separate petri dishes
3. Place all of the petri dishes outside to be left overnight where they are all exposed to the same conditions

4. Collect the petri dishes
5. Weigh the materials in the petri dishes
6. Record the results in a table
7. Find the difference in the weight before and after being left out
8. Record the results in a table
9. Put the petri dishes in a position where they are exposed to sunlight or some source of heat making sure they are all exposed to the same conditions
10. Measure the materials after 8 hours
11. Record the results in a table
12. Find the difference in the weight from before and after being exposed to sun of heat
13. Record your results in a table
14. Compare the results to find the most effective material

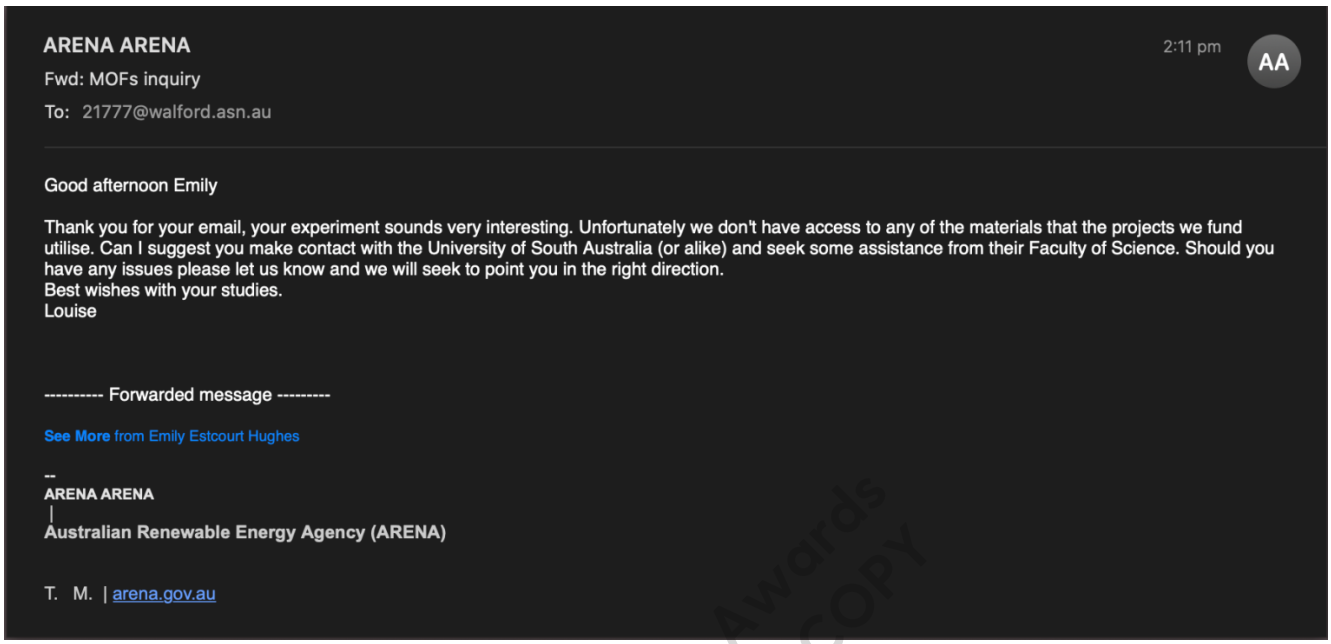
Materials

Beaker
Condenser
60 g of most efficient material
A reasonably sized black box with a lid and no holes
Petrie dish
Durofilm

Experiment 2

1. Take the most efficient material and measure out 60 grams
2. Place the 60 grams of material into a petri dish
3. Place the petri dish in the box
4. Place the condenser and beaker into the box so that any liquid formed by the condenser will roll into the beaker
5. Place the box outside in a place that is exposed to sun, overnight, with the lid off
6. Just before the sun comes up place the lid on the box and seal it with sealing tape so that no air can escape
7. Just after sunset take the beaker out of the box and measure the liquid collected
8. Record the results
9. Repeat steps 5-8 as many times as required
10. Make an average of the results.

11/6/20



ARENA ARENA 2:11 pm AA

Fwd: MOFs inquiry

To: 21777@walford.asn.au

Good afternoon Emily

Thank you for your email, your experiment sounds very interesting. Unfortunately we don't have access to any of the materials that the projects we fund utilise. Can I suggest you make contact with the University of South Australia (or alike) and seek some assistance from their Faculty of Science. Should you have any issues please let us know and we will seek to point you in the right direction.
Best wishes with your studies.
Louise

---------- Forwarded message ---------

See More from Emily Estcourt Hughes

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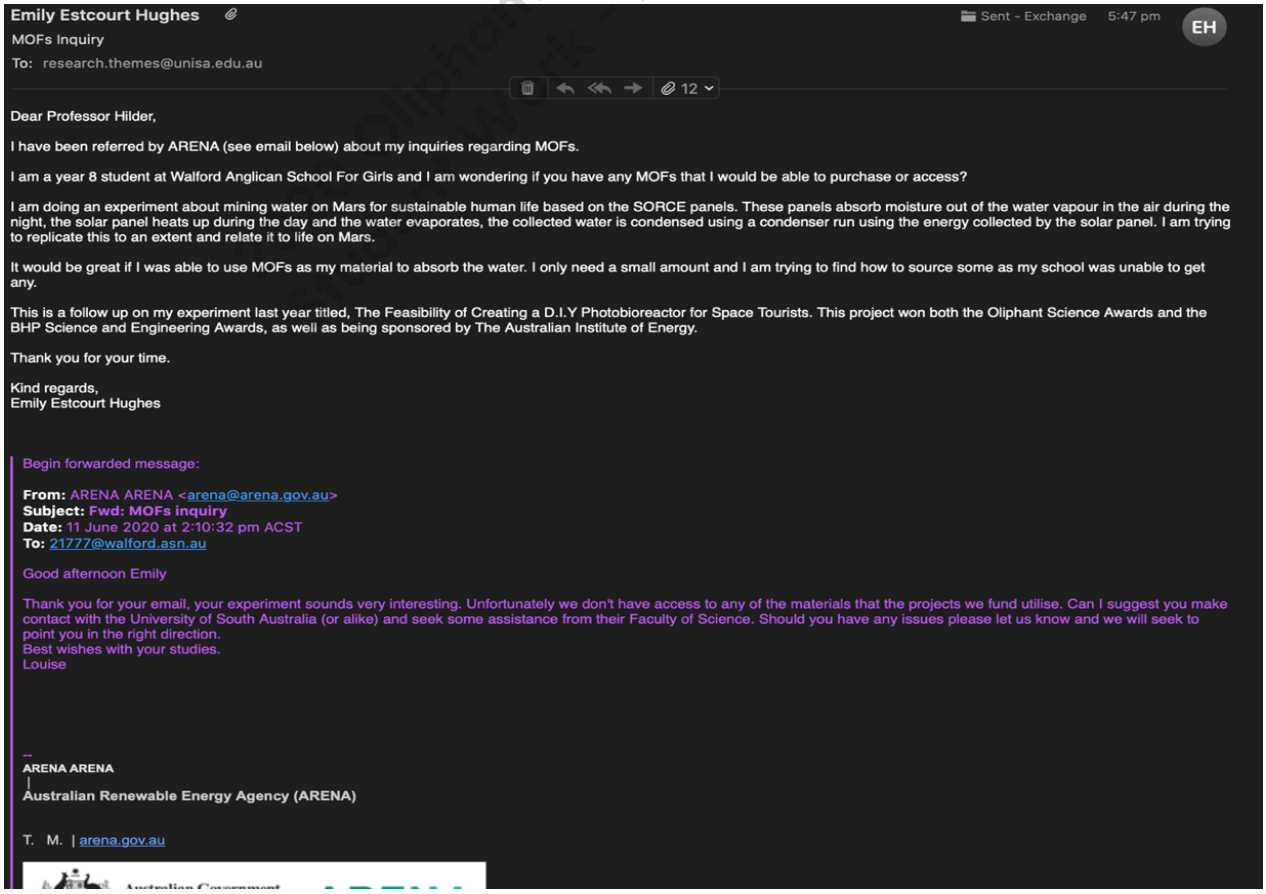
ARENA ARENA
|
Australian Renewable Energy Agency (ARENA)

T. M. | arena.gov.au

14/6/20

I followed the instructions given to me by Louise from ARENA and emailed University SA and University of Adelaide.



Emily Estcourt Hughes Sent - Exchange 5:47 pm EH

MOFs Inquiry

To: research.themes@unisa.edu.au

Dear Professor Hilder,

I have been referred by ARENA (see email below) about my inquiries regarding MOFs.

I am a year 8 student at Walford Anglican School For Girls and I am wondering if you have any MOFs that I would be able to purchase or access?

I am doing an experiment about mining water on Mars for sustainable human life based on the SORCE panels. These panels absorb moisture out of the water vapour in the air during the night, the solar panel heats up during the day and the water evaporates, the collected water is condensed using a condenser run using the energy collected by the solar panel. I am trying to replicate this to an extent and relate it to life on Mars.

It would be great if I was able to use MOFs as my material to absorb the water. I only need a small amount and I am trying to find how to source some as my school was unable to get any.

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Thank you for your time.

Kind regards,
Emily Estcourt Hughes

Begin forwarded message:

From: ARENA ARENA <arena@arena.gov.au>
Subject: Fwd: MOFs inquiry
Date: 11 June 2020 at 2:10:32 pm ACST
To: 21777@walford.asn.au

Good afternoon Emily

Thank you for your email, your experiment sounds very interesting. Unfortunately we don't have access to any of the materials that the projects we fund utilise. Can I suggest you make contact with the University of South Australia (or alike) and seek some assistance from their Faculty of Science. Should you have any issues please let us know and we will seek to point you in the right direction.
Best wishes with your studies.
Louise

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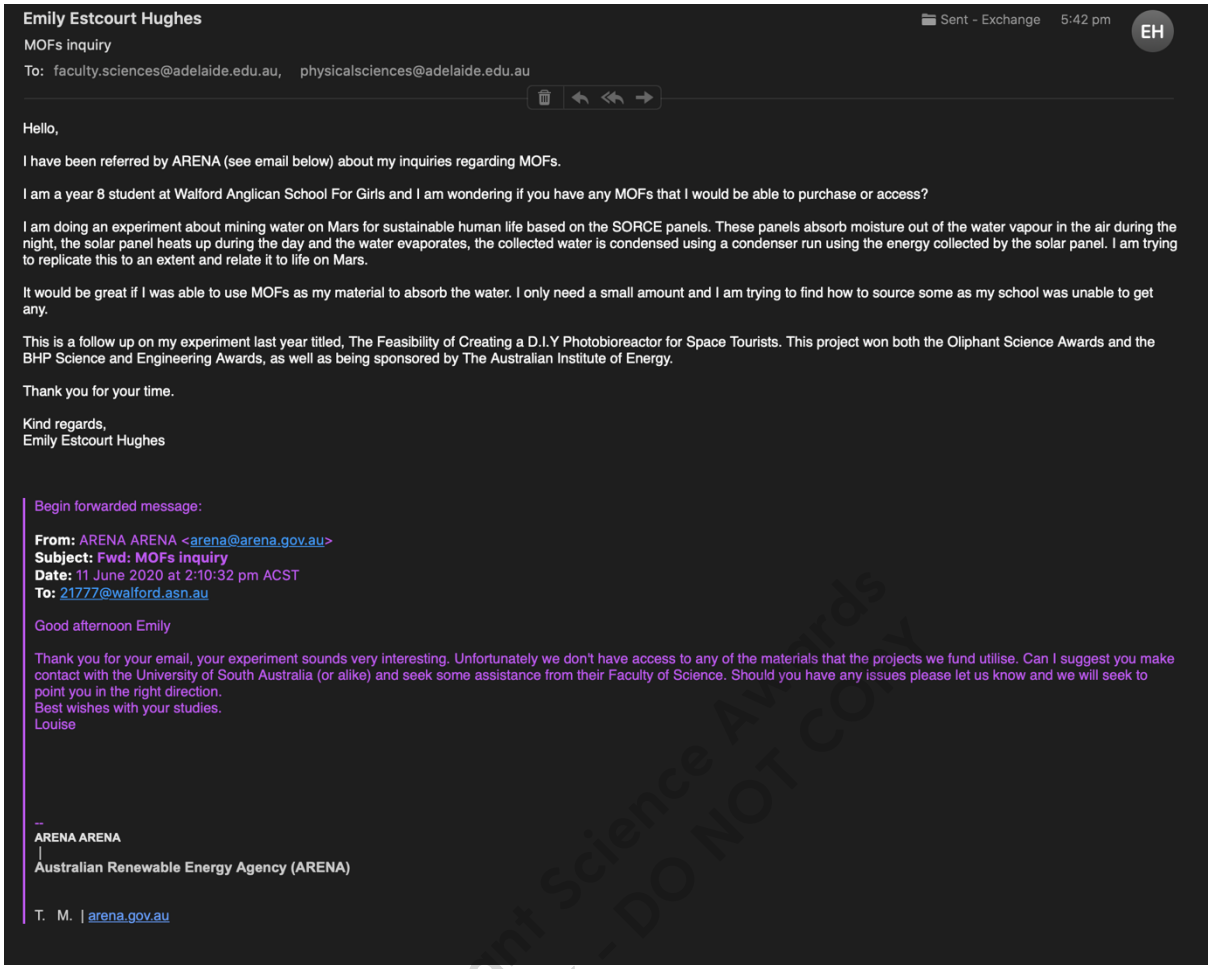
ARENA ARENA
|
Australian Renewable Energy Agency (ARENA)

T. M. | arena.gov.au



Emily Estcourt Hughes Sent - Exchange 5:42 pm EH

MOFs inquiry

To: faculty.sciences@adelaide.edu.au, physicalsciences@adelaide.edu.au

Hello,

I have been referred by ARENA (see email below) about my inquiries regarding MOFs.

I am a year 8 student at Walford Anglican School For Girls and I am wondering if you have any MOFs that I would be able to purchase or access?

I am doing an experiment about mining water on Mars for sustainable human life based on the SORCE panels. These panels absorb moisture out of the water vapour in the air during the night, the solar panel heats up during the day and the water evaporates, the collected water is condensed using a condenser run using the energy collected by the solar panel. I am trying to replicate this to an extent and relate it to life on Mars.

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Thank you for your time.

Kind regards,
Emily Estcourt Hughes

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To: 21777@walford.asn.au

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Best wishes with your studies.
Louise

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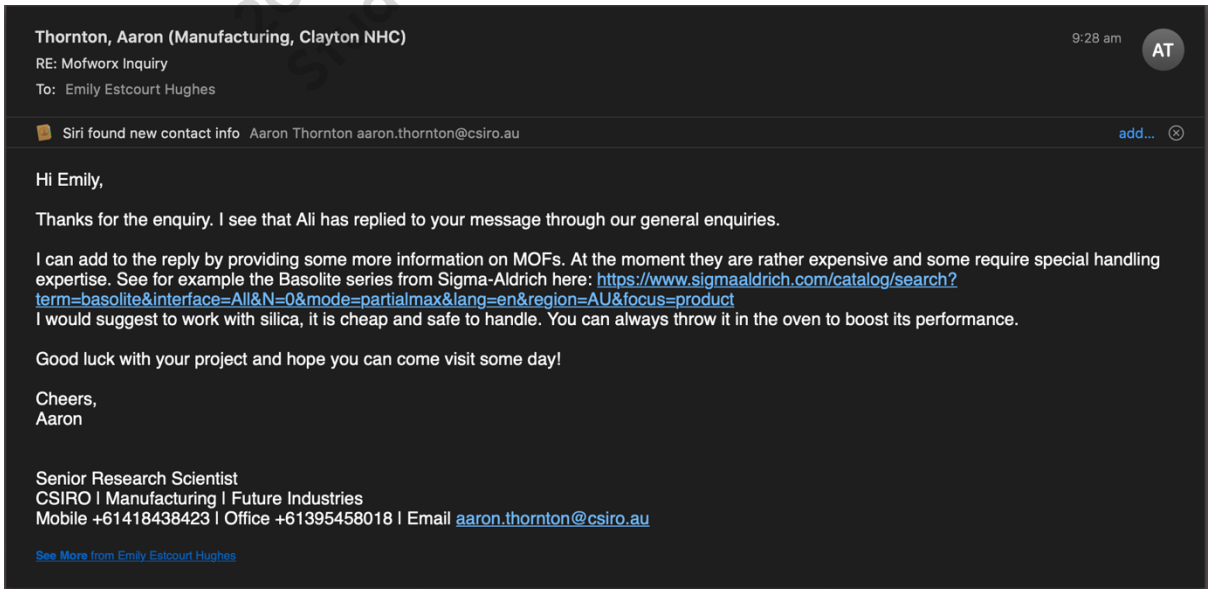
ARENA ARENA
|
Australian Renewable Energy Agency (ARENA)

T. M. | arena.gov.au

15/6/20

I received an email from Aaron from Mofworx at the CSIRO giving me some further information on the supply of MOFs. He also suggested I use silica gel for my experiment.



Thornton, Aaron (Manufacturing, Clayton NHC) 9:28 am AT

RE: Mofworx Inquiry

To: Emily Estcourt Hughes

Siri found new contact info Aaron Thornton aaron.thornton@csiro.au add...

Hi Emily,

Thanks for the enquiry. I see that Ali has replied to your message through our general enquiries.

I can add to the reply by providing some more information on MOFs. At the moment they are rather expensive and some require special handling expertise. See for example the Basolite series from Sigma-Aldrich here: https://www.sigmaaldrich.com/catalog/search?term=basolite&interface=All&N=0&mode=partialmax&lang=en&region=AU&focus=product
I would suggest to work with silica, it is cheap and safe to handle. You can always throw it in the oven to boost its performance.

Good luck with your project and hope you can come visit some day!

Cheers,
Aaron

Senior Research Scientist
CSIRO I Manufacturing I Future Industries
Mobile +61418438423 I Office +61395458018 I Email aaron.thornton@csiro.au

See More from Emily Estcourt Hughes

I had a further look to see what materials I can use for my experiment

- Silica Gel
- Calcium Chloride
- Hydrogels
- Zinc Chloride
- Calcium Sulphate
- Hygroscopic Salts
- Zeolites
- Silicon Dioxide

17/6/20

I received replies from my email to the University of Adelaide.

From: Physical Sciences
Sent: Monday, 15 June 2020 4:52 PM
To: Matthew Bull
Cc: Physical Sciences
Subject: Fw: MOFs inquiry

Hi Matthew

How is everything going? We have received this email from a Year 8 student below and we are not sure it is something we can help them with, part of the problem is we are not sure what it is they are asking for 😂

Could you read the email below and tell me exactly what MOF stands for and is this something we can provide?

Cheers Jacqui

From: Matthew Bull <matthew.bull@adelaide.edu.au>
Sent: Tuesday, 16 June 2020 12:52 PM
To: Physical Sciences <physicalsciences@adelaide.edu.au>
Subject: RE: MOFs inquiry

Hi Jacqui,

MOF stands for 'metal organic framework'.

I don't have any in the teaching lab; however you can try either Chris Sumby or Christian Doonan. Most of their research is based on them and they might have something suitable the student could use (or even suggest they make).

Thanks,

Matthew Bull
Level II/III Advanced Teaching Laboratory
Department of Chemistry
School of Physical Sciences
University of Adelaide, AUSTRALIA 5005
+61 8 8313 4335
matthew.bull@adelaide.edu.au

CRICOS Provider Number 00123M

IMPORTANT: This message may contain confidential or legally privileged information. If you think it was sent to you by mistake, please delete all copies and advise the sender. For the purposes of the SPAM Act 2003, this email is authorised by The University of Adelaide.

Hi Chris and Christian

We have received an email from a Year 8 student enquiring about MOF, Matthew Bull suggested I speak to both of you to see if you can assist them. There email is at the bottom of this email trail

Cheers Jacqui

On 17 Jun 2020, at 8:10 pm, Christopher Sumby <christopher.sumby@adelaide.edu.au> wrote:

Hi Emily,

As you can see from the email trail, your request is made it through to me. I'm an academic who carries out research into MOF chemistry.

MOFs are by and large still research materials so your ideas about small-scale may be a little difficult for us to accommodate; we can try though. How much material do you want? Also, did you have a particular MOF in mind as there are several thousand known materials.

Best wishes,

Chris

Sent from my iPhone

I then replied to these emails.

Hello Chris,

Thank you very much for getting back to me.

I would be interested in your opinion of what kind of MOF would be the most suitable for my experiment, but I would be very grateful for any type of MOF.

I am doing an experiment about mining water on Mars for sustainable human life, based on the SORCE panels. My research has shown that MOF is likely the material with the most potential to absorb water vapour out of the air, in a low humidity environment and release it when heated. I think that MOF is a very exiting new field. For this experiment I would like to compare the absorbency rate of MOF compared to readily available substances including silica gel, calcium chloride, zinc chloride and calcium sulphate.

Secondly, I was going to recreate one of these SOURCE panels, using MOF to see how much water I could produce and theoretically how many panels I would need to sustain human life. In regards to the amount of MOF I require, it would be great if there was enough to weigh prior to and after absorbing moisture so that I could demonstrate a measurable difference in the weight. This may be five or ten grams? I know that MOFs is still being researched so I understand it is in limited supply.

If it is more suitable I could come and do the experiment at the university or can pick up the MOF and return it after doing my experiment in the labs at my school.

I look forward to hearing back from you.

Thanks,
Emily Estcourt Hughes

18/6/20 & 19/6/20

I conducted my first experiment

Materials

- Calcium Chloride
- Silicon Dioxide
- Zeolites
- Water Storage Crystals
- Silica Gel
- Zinc Chloride
- 6 Petri Dishes
- Spatula
- Scale
- Sticky labels
- 6 weighing boats

Experiment 1

1. 6 different petri dishes were labelled, one for each different chemical
2. Using an electronic scale 10 grams of each material were measures, using a weighing boat
3. Carefully place the 10 grams of each material into the labelled petri dishes
4. Place all of the petri dishes outside to be left overnight with no covers on where they are all exposed to the same conditions
5. Collect the petri dishes
6. Weigh the materials in the petri dishes
7. Record the results in a table
8. Find the difference in the weight before and after being left out
9. Record the results in a table
10. Put the petri dishes in a position where they are exposed to sunlight or some source of heat making sure they are all exposed to the same conditions
11. Measure the materials after 8 hours
12. Record the results in a table
13. Find the difference in the weight from before and after being exposed to sun of heat
14. Record the results in a table
15. Compare the results to find the most effective material

Results

Chemical	Before being left out	After being left out
Calcium chloride	10.002 g	15.373 g
Silicon dioxide	10.002 g	9.965 g
Zeolite	10.002 g	9.685 g
Water absorbing crystals	10.002 g	10.662 g
Zinc chloride	10.003 g	16.573g
Silica gel	10.001 g	10.756 g

The experiment had too many variables and the measuring system was not the most accurate. Originally the petri dishes were tared so that only the chemicals were being measured. This was not the best way to do this. When the petri dishes were collected it was realised that previously just the chemicals were measured, as each individual petri dish was tared before having the materials put into them. When measuring the second time it wasn't possible to just measure just the material without introducing many more variables that would have made the measurements very unreliable including spilling and losing some of the material. Instead a different petri dish was placed on the scale and tared to try and remove the weight of the petri dish and just isolate the material. While this may have worked to some extent it was definitely not as accurate as it could have been as the petri dishes are not all exactly the same weight. I am going to re-write my method to make this much more accurate and I will repeat my experiment.

Observations

Some of the materials gained weight but there were too many variables to tell whether these results are accurate or not.

The Zinc Chloride had actually turned into water with a small amount of milky substance at the bottom. The calcium chloride had also physically changed. When collected, the fine powder seen previously was now a much coarser powder and it could be seen that water had been absorbed. The silica gel changed colour. Originally the little balls were a variety of different blue colours, when collected they had changed and were a variety of blues and purple colours.

18/6/20

Christopher Sumby Yesterday at 5:32 pm

RE: MOFs inquiry

To: Emily Estcourt Hughes

Hi Emily,

1. I'm sending you a couple of references to commercial suppliers, not because I think you should buy them but so you get an idea of what can be brought.

Sigma Aldrich:
https://www.sigmaaldrich.com/materials-science/material-science-products.html?TablePage=103996366

Strem:
https://www.strem.com/catalog/family/MOF/

There are a large number of start-ups making MOFs.

2. The other thing to consider is MOF stability, especially to water vapour, as this dictates reusability. Not all MOFs are equally stable. The other point relates to how much water they absorb.

This review (attached) is from a few years back but this probably lists the MOFs that could be used. MOFs made with Al, Zr and metals like these are more stable.

3. The major issue from your perspective is which MOF can you secure access to. We could easily make a material called HKUST-1 for you on this scale but I'm not sure that you'll be able to cycle it to release water without destroying it. We might be able to source some Al-fumarate which will be more stable. The rest are not so easy to make without specialised equipment. I'm looking into the synthesis of Al fumarate but I might know someone who could send us some.

Best wishes,

Chris

See More from Emily Estcourt Hughes

c4cs00078a.pdf

21/6/20

I re-wrote my method

Materials

- Calcium Chloride
- Silicon Dioxide
- Zeolites
- Water Storage Crystals
- Silica Gel
- Zinc Chloride
- 6 Petri Dishes
- Spatula
- Scale
- Sticky Labels
- 6 weighing boats

Method

Experiment 1

1. 6 different petri dishes were labelled, one for each different material
2. A petri dish was placed on the scale and the scale was tared
3. The material corelating with the sticky label was collected
4. Using a spatula 10 grams of the material was measured in the petri dish that was sitting on the scale
5. Un-tare the scale and record the total measurement of the petri dish and the material
6. Record the weight in a table
7. Repeat steps 2 – 6 were repeated for each material
8. Place all of the petri dishes outside to be left overnight with no covers on inside a plastic tub
9. The petri dishes were collected the next morning around sunrise
10. The petri dishes were weighed
11. The results were recorded in a table
12. The petri dishes were placed in an oven
13. The oven was turned on and set to 60 degrees Celcius
14. An hour later the petri dishes were removed from the oven
15. The petri dishes were weighed
16. The results were recorded in a table
17. The petri dishes were placed outside in the same tub and the same place as the previous night to be left there
18. The petri dishes were collected and weighed
19. The results were recorded in a table
20. Any observations from the experiment were written

22/6/20

I completed steps 1- 8 of my experiment

23/6/20

I completed steps 8 – 17 of my experiment

24/6/20

I completed steps 18-20 of my experiment

22/6/20 - 24/6/20

Materials	Calcium chloride (g)	Silicon dioxide (g)	Zeolites (g)	Water absorbing crystals (g)	Silica gel (g)	Zinc chloride (g)
Total weight of 10 grams of each material and a petri dish	17.045	16.986	17.308	17.842	18.380	17.776
After being left outside for the first night	25.788	17.429	18.554	20.334	20.587	25.667
After being heated in the incubator	24.215	16.173	15.981	17.536	18.374	22.653
After being left outside for the second night	28.646	17.377	17.748	19.823	20.552	26.666

Observations

Calcium chloride second time= 24.231
3rd= 24.245

- There were bugs in some of the chemicals
- The Zeolites spilt inside the tub when being collected after being left out the second time, the Zeolites from inside the tub were poured back into the petri dish before being measured but not all of them could be put back into the petri dish.
- The silica gel was originally blue but after being left outside overnight and absorbing water the silica gel turned light pinks and purples and after cooling returned to being blue.
- The Calcium Chloride started out as a white powder, after being left out overnight part of the powder had turned into a watery gel with some clumps of powder still being left as solids. After heating there was no powder left and it was all the gel, as it cooled down after being heated parts of it started to crystalize and this continued the longer that it had been out of the incubator.
- The Zinc Chloride after being left out overnight turned to a Zinc Chloride solution which looked like water. This did not change after being heated.
- The Zeolites, silicon dioxide and the water absorbing crystals had no visible change in physical state but did change in weight

Bibliography

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