



# Chapter 1

## More MOFs, less mess: State-of-art and MOFs application perspectives

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### Abstract

Metal-organic frameworks (MOFs) is a class of compounds consisting of metal ions or clusters coordinated to organic ligands to form one-, two-, or three - dimensional structures. MOFs are formed by anchoring metal-containing units or secondary-building units (SBUs) with organic linkers. Open frameworks that show exceptional features of permanent porosity, stable framework, enormous surface area, and pore volume are obtained. Due to these properties, MOFs are of interest for many different applications, including storage of gases, gas purification, gas separation, water remediation, and catalysis. They can also be used as conducting solids and supercapacitors. The wide range of different applications makes MOFs very important materials in our lives, for example, in areas of health, environment, and energy.

In this work, the set of MOFs information is presented.

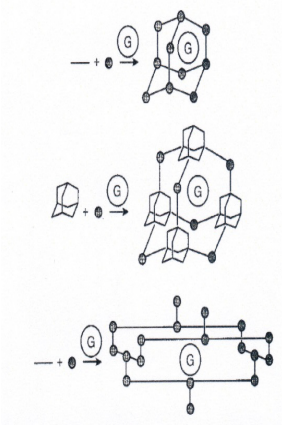
## 1. Definitions

When you search for information: “What is metal-organic framework (MOF)?”, you can receive the answer: “Full text search our database of 158 300 titles for metal-organic framework (MOF) to find related research papers.” It means that metal-organic framework (MOF) is under immense investigation in various places around the world. Different definitions for the MOF abbreviation can be found.

### 1.1. O.M. YAGHI in *J. Am. Chem Soc.* 1996, 118, 295–296 (Yaghi & Li 1996: 295–296)

The successful assembly of extended frameworks from molecular building units has delivered a remarkable class of materials with a diverse architecture and function. These include metal-organic solids with open frameworks, having zeolite-like attributes, and others having important electronic and magnetic properties.

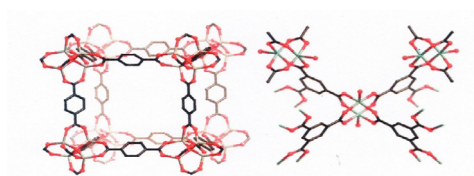
This definition was proved with the simplest strategies employed in the production of 3-D networks. In each case, the assembly is accompanied by the inclusion of a guest molecule G, which occupies the voids (Figure 1).



**Figure 1:** A schematic representation of the assembly of metal ions (dark spheres) and organic ligands (dark rods) or metal tetrahedral cluster to yield diamond-like frameworks (top and middle) or open frameworks with rectangular channels (bottom)

- 1.2. S.T. BATTEN in *Pure Applied Chemistry* 2013, 85, 8, 1715–1724 (Batten, Champness, Chen, Garcia-Martinez, Kitagawa, Ohrstrom, O’Keeffe, Suh & Reedijk 2013:1715–1724)

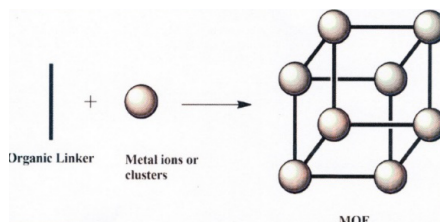
A metal-organic framework abbreviated as MOF, is a coordination network with organic ligands containing potential voids. This wording accounts for the fact that many systems are dynamic, and changes in structure and thus corresponding changes in potential porosity or solvent and/or guest-filled voids may occur depending on temperature, pressure, or other external factors. For these reasons, it is also not required for a MOF to be crystalline. Arguments based on both theory and experiment can suggest that some of these coordination polymers with direct anion-cation binding are more prone to form structures with open frameworks exhibiting permanent porosity than those forming positively charged networks. However, the grey zone between these extremes is large and increasing so that a definition based on such a charge distinction would be too restrictive. The archetypal MOFs structures are shown in Figure 2.



**Figure 2:** Archetypal MOFs: (left) the zinc and carboxylate-based MOF-5 where each  $[Zn_4O]$  unit is bridged by six benzene-1,4 dicarboxylates; (right) HKUST-1 with copper paddlewheel dimers bridged by benzene-1,3,5-tricarboxylates. Colours description: light grey - Zn; turquoise - Cu; grey - C; red - O. Hydrogen atoms are not shown.

- 1.3. E. SHARMIN in *Introductory Chapter in Metal Organic Frameworks (MOFs)*, published by INTECH, 2016 (Sharmin & Zafar 2016:3–16)

MOFs as defined by Yaghi *et al.* are porous structures constructed from the coordinative bonding between metal ions and organic linkers or bridging ligands. The interesting feature is their porosity that allows the diffusion of guest molecules into the bulk structure. The shape and size of pores govern the shape and size selectivity of the guest to be incorporated. A simple MOF structure is shown in Figure 3.



**Figure 3:** Structure of a MOF

#### 1.4. Methods of MOFs naming

There are methods of naming the metal-organic frameworks (MOFs) structures. Nomenclature of metal-organic frameworks can be presented, for example, in the following ways:

##### 1.4.1. *Jemal Mohammed Yassin, Haramaya University*

1. naming by Sequential Number of Synthesis; for example, MOF-n (metal-organic framework), RPF-n (Rare-earth Polymeric Framework), MPF-n (Metal Peptide Framework), etc.
2. naming by Initials of Institution or Place of Discovery; for example, HKUST-n, MIL-n, NU-n, NENU-n, SNU-n, JUC-n, CPO-n, and POST-n, etc.
3. naming by Sequence of Isostructural Synthesis, for example, IRMOF-n and also their other unclear mechanisms.

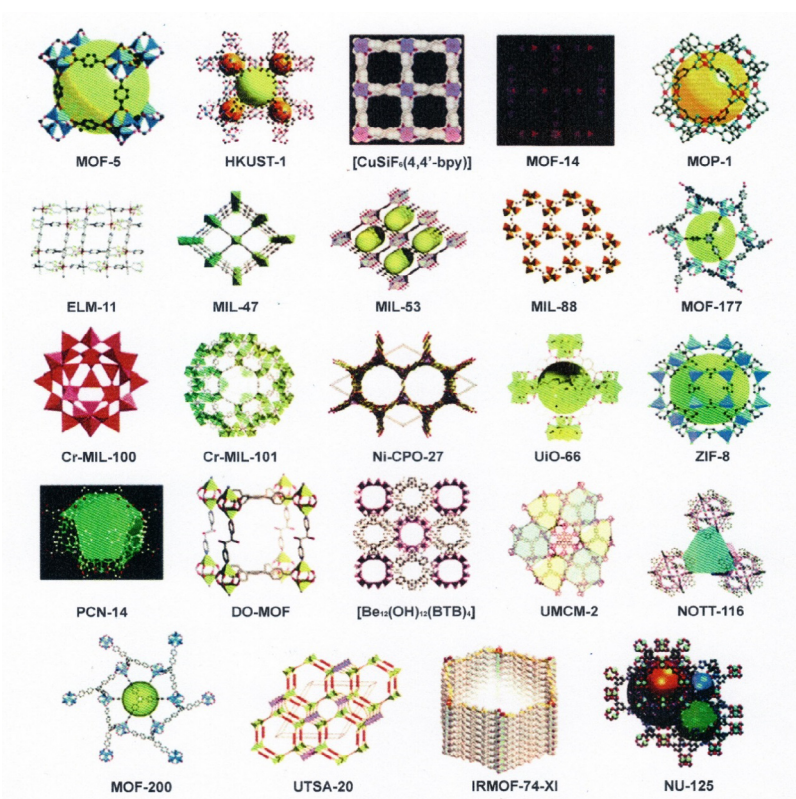
##### 1.4.2. *Andreas Schneemann, Technische Universität Dresden*

Naming MOFs is completely up to a scientist; there is no real consensus in the literature. Some people use an abbreviation highlighting their university or place of origin (UiO, MIL, STAM, UMCM, SNU, or DUT) while some use an abbreviation describing the material (MOF, ZIF, MAF, PIZOF, CID, or PCN), and some people just use the formula unit ( $\text{Fe}_2\text{dobdc}$ ,  $\text{Zn}_2\text{bdc}_2\text{dabco}$ ,  $\text{Fe}_2\text{dobdc}_n$ , or  $\text{Zn}_2\text{bdc}_2\text{dabco}_n$ ). The formula unit can be used if it is not complicated, so that everybody understands what it means. However, how a MOF is called upon publication is completely up to the scientist. As long as it makes sense, it is acceptable.

## 2. Structures

The presence of organic and inorganic primary building blocks (PBUs, i.e. organic linkers and metallic centres) in the structure of MOFs allows their potential application in several distinct fields due to the improved properties resulting from the symbiotic combination of these two different components. Porosity is undoubtedly the most desired property.

In this context, a great evolution has been observed concerning the pore/cage sizes leading to the isolation of several highly porous MOF structures. Examples are shown in Figure 4. Formed by the three-dimensional crystalline assembly of inorganic metal ions and organic ligand, MOFs enable a flexible structure design in which well-defined pore sizes, surfaces area and functionalities can be tailored by selecting different building blocks. This high degree of customisability of MOFs properties has attracted the interest of many researchers. To date, there are more than 20 000 different examples of structures of MOFs being reported and studied (Yap, Fow & Chen 2017:218–245), (Silva, Vilele, Tome & Paz 2015:6774–6803)



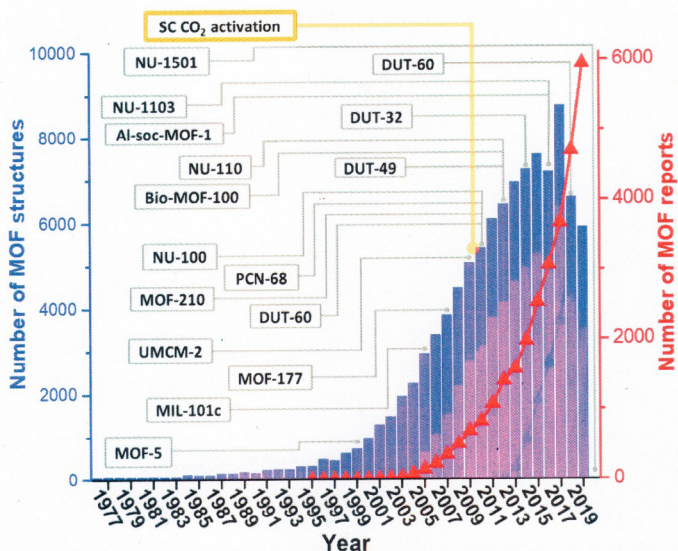
**Figure 4:** Porous MOFs prepared by several research groups aiming for accommodation or retention of chemical species in their pores/channels (Silva *et al* 2015:6774)

### 3. MOFs drop of history

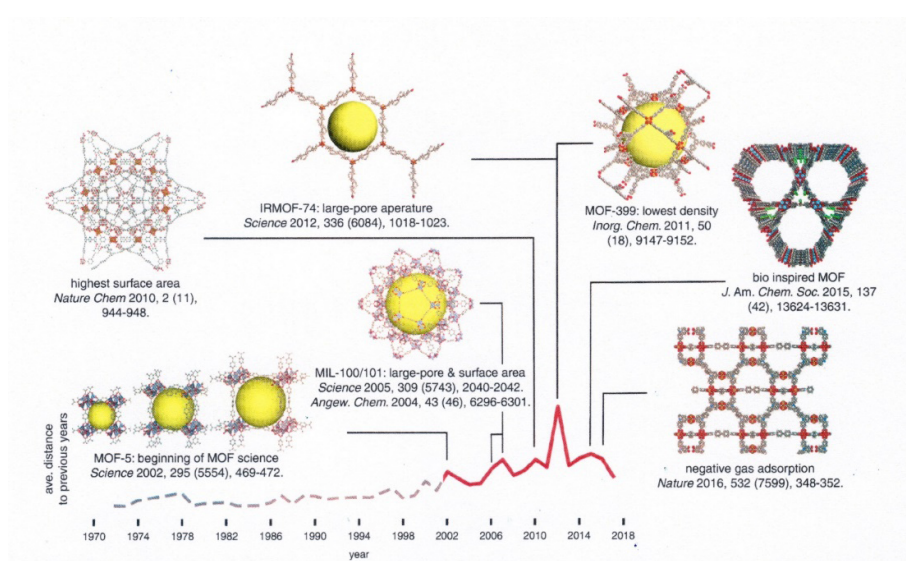
Synthetic zeolites – comprised solely of inorganic components, such as silicates and aluminates – have been extensively studied since the 1940s. It was not until the late 1980s and early 1990s that the first crystalline porous materials with pore size larger than 1 and 2 nm were reported. In 1995, a unique class of crystalline porous materials termed “metal-organic frameworks (MOFs)” by Yaghi, emerged and has since distinguished itself with permanent porosity and high surface areas, due to the strong bonds between metal ions and charged organic ligands. The highly tunable inorganic and organic building units of MOFs have opened up a new chapter in design and applications of porous materials. In addition to the various possible combinations of inorganic and organic building units with different geometries and functionalities, MOFs offer unparalleled adaptability in isorecticular manipulation. While keeping the structural design and topology invariant, a vast number of alterations in their structures and functionalities can be readily accessed during synthesis or via post-synthetic modifications. Over the past few decades, over 100 000 structures have been reported in the “MOF subset” of the Cambridge Structural Database (CSD) and the number of MOF-related research publications has been continuously increasing. Figure 5 shows the number of MOFs structures and reports in defined years. Numerous representative high-porosity MOFs are indicated in the plot according to the year they were reported. The first use of supercritical CO<sub>2</sub> drying for activation MOFs is indicated in yellow (Zhang, Chen, Liu, Hanna, Wang, Taher-Ledar, Malek, Li & Farha 2020:7406–7427).

MOF chemistry is not a static field; new classes of MOFs are and will be constantly developed.

Authors try to develop transparent and objective criteria to quantify how different a novel material is with respect to the state of the art. For example, the pore geometry was selected as novelty and is presented in Figure 6. For each year, the average of relative distance in the geometry descriptor space to the MOFs reported in the Cambridge Structural database (CSD) in the preceding years is shown in red line. The MOFs with the largest distance for some of the peaks are shown in coordination polymers reported in CSD before the beginning of the MOF chemistry as a separate field of research, shown in red (Moosavi, Nandy, Jablonka, Ongari, Janet, Boyd, Lee, Smit & Kulik 2020:4068–4078).



**Figure 5:** The number of MOFs in the Cambridge Structural Database (CSD) and MOF reports found in WoS, 1976–2019. The structural data was summarised from the MOF CSD subset of May 2020 (Zhang et al. 2020:7406)



**Figure 6:** Timeline of evolution of MOF geometry (Moosavi et al. 2020:4068)

#### 4. Methods of MOFs formation/production

Most of MOF synthesis are performed in the liquid state. The metal salt and ligand solvent are separately prepared and then mixed or metal salt and ligand are added to the solvent. In general, organic solvents, such as dimethylformamide, acetonitrile, acetone, diethylformamide, ethanol, and methanol are used. Since a solvent affects the properties of MOFs, it must be selected according to the desired characteristics of the targeted MOFs. The synthesis methods can be determined according to the solvent, the characteristics of the MOF, the required pore and particle size of the MOF, and laboratory conditions. The methods of synthesising MOFs are summarised in Figure 7 (Heo, Do, Ahn & Kim 2020:2061–2092).

##### 4.1. Solvothermal synthesis

Solvothermal methods are the most common techniques of synthesizing MOFs with various morphologies. Organic solvent or a mixture of metal salt solution reacts with organic ligands. Solvothermal synthesis is performed at a temperature higher than the boiling point of the solvent, and a relatively high yield of MOF materials can be obtained. The solvothermal synthesis route has advantages of precisely controlling the morphologies, crystallinity, and the size of produced materials. On the other hand, the solvothermal method has disadvantages, because it is a complex process that requires the removal of solvent molecules from the pores.

##### 4.2. Microwave-assisted synthesis

Microwave-assisted synthesis is widely used as a quick and simple method of generating MOFs. The driving force of this synthesis is microwave power. This synthesis method has a short reaction time and gives highly crystalline and porous textures and allows precise shape control and particle size reduction.

##### 4.3. Slow evaporation

The slow evaporation method produces MOFs by gradually concentrating a precursor dissolved in a solvent or mixture of solvents by evaporation in an inert atmosphere. The slow evaporation method requires seven days to seven months of synthesis time without external energy.

##### 4.4. Mechanochemical synthesis

Mechanochemical synthesis causes a chemical reaction that occurs due to the mechanical agitation and impact interactions between materials.

The reaction can proceed without the use of carcinogenic, toxic, or environmentally harmful organic solvent.

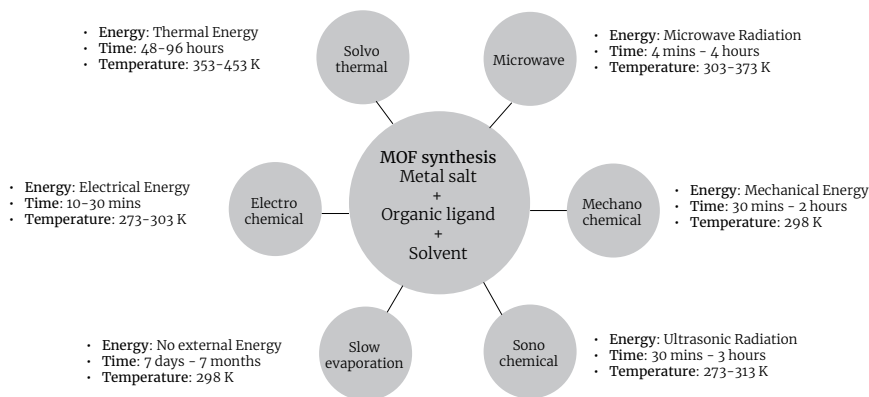
#### 4.5. Sonochemical synthesis

This is a method of synthesising MOFs by utilising sonic waves. When the reactive mixture is exposed to ultrasonic waves, the molecules are chemically altered to produce compounds with new morphologies and unique properties.

#### 4.6. Electrochemical synthesis

Since electrochemical synthesis does not require a metal salt, the anion associated with metal salt is not present; therefore, a high-purity substance can be obtained. In this method, metal ions are supplied through the oxidation of electrodes. When an appropriate voltage or current is applied, the metal dissolves and the metal ions necessary for MOF formation are released from the electrode surface. These metal ions immediately react with the linker present in the solution and a MOF is formed in proximity to the electrode surfaces.

Other ways of synthesizing MOFs include diffusion, spray drying, and ionothermal synthesis.



**Figure 7:** Summary of various MOF synthesis methods (Heo *et al.* 2020:2061)

## 5. Commercial MOFs

Besides scientific works on MOFs, there are some MOFs producers already. This means that MOFs required for specific applications are commercially available.

### 5.1. ProfMOF (Norway) (<https://profmof.com/>)

The company provides world-class metal-organic frameworks (MOFs) for industrial applications. Its MOFs can be applied to a wide array of industrial processes. The products have unique characteristics and provide high stability, high porosity, and functionalisation. The company offers some types of MOFs. For example:

1. UiO-66-ADC, Zr-acetylenedicarboxylate,  $[\text{Zr}_6\text{O}_4(\text{OH})_4(\text{C}_4\text{O}_4)_{6-x}]$   
SA (BET) =  $648 \text{ m}^2 \text{ g}^{-1}$ , pore volume =  $0,30 \text{ cm}^3 \text{ g}^{-1}$ , thermal stability =  $300^\circ\text{C}$ , particle size =  $0,1-0,5 \mu\text{m}$
2. UiO-66-BDC, Zr-benededicarboxylate,  $[\text{Zr}_6\text{O}_4(\text{OH})_4(\text{C}_8\text{H}_4\text{O}_4)_6]$   
SA (BET) =  $1266 \text{ m}^2 \text{ g}^{-1}$ , pore volume =  $0,52 \text{ cm}^3 \text{ g}^{-1}$ , thermal stability =  $400^\circ\text{C}$ , particle size =  $0,2-0,5 \mu\text{m}$

### 5.2. Merck (Germany) (<https://www.sigmaaldrich.com/PL/pl/technical-documents/technical-article/materials-science-and-engineering/photovoltaics-and-solar-cells/metal-organic-frameworks>)

The company offers MOFs under the tradename Basolite™. These materials provide a wide selection of different pore shapes and sizes, different metals (Al, Cu, Fe, and Zn), and different organic linkers (BDC, BTC, mIM). For example: Basolite® C 300, Cu-BTC MOF, HKUST-1, copper benzene-1,3,5-tricarboxylate with the empirical formula (Hill Notation):  $\text{C}_{18} \text{H}_6 \text{Cu}_3 \text{O}_{12}$ , can be found in their offer.

### 5.3. novoMOF (Switzerland) (<https://novomof.com/>)

The novoMOF is a company active in the field of advanced materials with a focus on synthesis and production of metal-organic frameworks (MOFs). The company produces any MOF at the required speed, scale, and quality. It scales the production of ordered metal-organic from grams to kilograms.

## 6. MOFs application areas

MOFs' important properties are: low density, high surface area, tunable pore functionality, and structural flexibility. These properties make MOFs useful in a wide area of prospective applications. Many of the studies performed on MOFs still focus on the possibility of adsorbing in the empty space and releasing molecules like hydrogen and carbon dioxide. Several studies are aimed at possible emerging applications, as listed below.

**6.1. According to Pettinari *et al***, MOFs application can be divided into groups (Pettinari, Marchetti, Mosca, Tosi & Drozdov 2017:731–744). These are:

1. Gas storage and delivery
2. Biomedical applications
3. Catalytic applications
4. Luminescence properties
5. Sensing applications
6. Water, air, and fuel purification and horticulture
7. For magnetic materials
8. Electrochemical applications
9. MOFs membranes
10. Conductive MOFs
11. Polymer-MOF composites

**6.2. According to Safaei**, application of metal organic frameworks can be divided into groups (Safaei, Foroughi, Ebrahimipoor, Jahani, Omid & Khatami 2019:401–425)

1. Adsorption in aqua solutions, including biological compounds, antibiotics, and toxic pollution
2. Gas adsorption
3. Catalysts, including photocatalysts, electrocatalysts, and biocatalyst
4. Sensors, including electrochemical sensors, photoelectrochemical sensors, and biosensors
5. Electrochemical charge storage, including batteries, supercapacitors, and fuel cells
6. Drug delivery systems.

It is evident that there are similar points in Pettinari's and Safaei's works. These are:

1. Gas storage and delivery and gas adsorption
2. Water, air, and fuel purification and horticulture and toxic pollution remediation
3. Sensing applications and sensors

## 7. Gases applications area

As mentioned in point 6, MOFs applications in gases area are very important and needed.

### 7.1. Hydrogen storage

Hydrogen is a promising vehicle fuel due to its high specific energy, renewability, and its ability to be produced and oxidised without CO<sub>2</sub> emissions. But due to the low volumetric density of H<sub>2</sub> gas, the efficient and cost-effective storage of hydrogen remains a challenge. Storage in solid adsorbents has received significant attention as an alternative to compression in high-pressure tanks. Adsorbents have the potential to match or surpass the capacities typical for physical storage systems while doing so at lower pressures and with the potential to reduce costs. MOFs are perhaps the most intensively researched hydrogen adsorbents. Work was carried out to develop crystal structures of MOFs whose hydrogen was assessed experimentally following their identification by computational screening (Ahmed, Seth, Purewa, Wong-Foy, Veenstra, Matzger & Siege 2019:1568 –1577), (Ren, Musyoka, Langmi, Wartbooi, North & Mathe 2015:4617–4622).

### 7.2 Carbon capture

The energy demands of a global society are being met largely by combustion of fossil fuels, including coal, petroleum, and natural gas. A major greenhouse gas, carbon dioxide, is a key by-product of such combustion. The immense quantity of CO<sub>2</sub> emission has resulted in serious environmental issues, such as global warming, oceans acidification, extreme weather, and species extinction. The employment of MOFs in CO<sub>2</sub> capture and conversion applications has undergone three development stages:

1. the CO<sub>2</sub> adsorption capacity and selectivity of MOFs were tuned;
2. development of MOF-based materials and their use for the conversion of CO<sub>2</sub> to organic products; and
3. exploration and expansion of the scope of possible CO<sub>2</sub> transformation reactions involving MOF-based materials. MOF-based materials are already showing great potential as the next generation of CO<sub>2</sub> capture and conversion systems (Choe, Kim & Hong 2021:5172–5185), (Ding Flaig, Jiang & Yaghi 2019:2783–2830).

### 7.3. Gas separation

The separation and purification processes are critical for the modern chemical industry. The processes isolate pure components from chemical mixtures, which accounts for about half of industrial energy consumptions. Gas separation is widely involved in the production of bulk chemicals for manufacturing fuels, plastics, and polymers. A significant

number of important separations have been achieved by making use of MOFs as adsorber materials. Microporous MOFs for gas separation, pore engineering through the functionalisation strategies is confirmed as a powerful tool for efficient separation of different gases (Lin, Xiang, Xing, Zhou & Chen 2019:87–103). Examples of such uses/applications are listed below.

1. Separation of linear alkanes from their branched isomers can boost octane ratings in gasoline, which is a very important process in the petroleum industry.
2. Kinetic separation of  $D_2/H_2$ ; deuterium is a stable isotope of hydrogen that has a number of commercial and scientific applications. The isotopic separation in deuterium is necessary for deuterium production due to its low abundance (0.0156% of all the naturally hydrogen).
3. Separation of  $C_2H_2/C_2H_4$ ; ethylene ( $C_2H_4$ ) is an essential raw chemical widely used in the manufacture of many polymers and useful chemicals. Acetylene is one important by-product/impurity of about 1% concentration. It can seriously affect the polymerisation of ethylene during production of polyethylene. Acetylene can be explosive in defined conditions. During the ethylene production, acetylene must be reduced to an acceptable low level.
4. Sulphur dioxide capture, the efficient capture of  $SO_2$  is very important for gas purification processes, including flue and exhaust gases desulfurisation and natural gas purification
5. Separation of  $C_2H_2/CO_2$ ; acetylene ( $C_2H_2$ ) is an important source of many chemical products.  $CO_2$  impurity during the production of  $C_2H_2$  occurs and exists. Both compounds have almost identical sizes, shapes, and physical properties. The exploitation of efficient physical  $C_2H_2$  adsorbent is demanded.

## 8. Water applications area

### 8.1. Desalination

Globally, the demand for fresh water is increasing due to population growth and water contamination. The portion of drinkable water on Earth is less than 1%, and seawater accounts for more than 97%. Desalination is the technology of separating salts from water to produce drinkable water and it is considered as one of the major solutions for water shortage. The desalination process also involves removing salt ions from the saline source to produce potable water or high purity water for industrial uses. MOFs can be applied for liquid separation and water treatment. The examples

of techniques and MOF contributions to this process are: capacitive deionisation, forward osmosis, adsorption desalination, reverse osmosis, MOF membranes, and membrane distillation (Kahdom & Deng 2018:219–230), (Lee, Hann & Park 2020:16319–16326).

### 8.2. Water vapour capture and dehumidification

Continuous globalisation of a better standard of living leads to the consumption of excessive amounts of energy, such as for indoor air-conditioning in regions with extreme temperatures. Air-conditioning devices based on thermally-driven adsorption heat pumps or desiccant cooling systems are considered to operate with moderate consumption of electric power. The working principle is governed by reversible exothermic adsorption and endothermic desorption of water in micro- or mesoporous solid materials. Porous materials with distinct water sorption and remarkable water uptake are ideal for humidity control in confined and poorly ventilated spaces. Advances in MOF chemistry have permitted several strategies for the synthesis of water-stable MOFs. Hydrolytically stable and recyclable MOFs with superior total water uptake remain a point of intensive research in MOF chemistry. MOF type materials stable in water can be mentioned here: Zr-MOFs, chromium-based MOFs, and Al (Cr)-soc-MOF-1 (Abtab, Alezi, Bhatt, Shkurenko, Balmabkhout, Aggarwal, Weselinski, Alsadun, Samin, Hedhili & Eddaoudi 2018:94–105).

### 8.3. Water purification

Clean and sustainable freshwater is a basic requirement for daily life and industrial activities. The rapid growth in the global population and the never-ending industrialisation have increased the consumption of clean water, directly produced a huge volume of wastewater, and caused severe pollution of water resources. The degree of overall water pollution largely exceeds the self-purification ability of the natural water ecosystem. Several water-stable MOFs have been demonstrated in recent years. These have been increasingly explored for water treatment, typically including the MIL family, UiO-66 series, zirconium, and pyrazole-based MOFs. These water-stable MOFs usually have strong coordination bonds which can prevent the potential destruction of metal-ligand bonds in water/moisture containing environment (Gu, Ng, Zhao & Wang 2020: 04092–040115).

## 9. Works performed in PET-MOF-CLEANWATER project

Project PET-MOF-CLEANWATER is realised in the frame of joint research programme between the National Research Foundation (NRF), South Africa

and the Polish National Centre for Research and Development (NCBR). The project is a cooperation in the area of water and green technology. The title of the project is: “The Studies on Waste PET-derived Metal-Organic Frameworks (MOFs) As Cost-effective Adsorbents for Removal of Hazardous Elements from Polluted Water.” The project acronym is: PET-MOF-CLEANWATER. It shows three parts of the project: (i) PET - Polyethylene terephthalate, (ii) MOF - Metal Organic Framework, (iii) CLEANWATER - clean water. This project is important for three reasons: (i) PET waste reduction, (ii) water purification from radioactive ions and heavy metals, and (iii) joint works with bilateral cooperation. More information on this project was shared during the first workshop organised on 16 October, 2019 at the Institute of Nuclear Chemistry and Technology in Warsaw. The presented information and results were shown in the PET-MOF-CLEANWATER project monography. The monography was edited by Wojciech Starosta and Bożena Sartowska, and published by the Institute of Nuclear Chemistry and Technology in 2020 (Starosta & Sartowska 2020)

## 10. Perspectives /possibility

### 10.1. New proposal

The BATMOF project is prepared and ready for use. Project title: “Evaluation of Metal-Organic Frameworks (MOFs)-mediated Process for Recycling Spent Li-ion Batteries”, with an acronym BATMOF. The subject is connected with the general topic: “Recycling and Re-use of End-of-Life Products”. Joint works were made with participants organised in the consortium: University of Johannesburg, South Africa; Institute of Nuclear Chemistry and Technology, Poland; National Institute for Cryogenics and Isotopic Technologies ICSI-Rm. Valcea ICSI Energy, Romania; ULENA Sp. z o.o., Poland; and the University of Limpopo, South Africa. The project objectives are:

1. Development and optimisation of the process using waste PET-derived organic linker as collector to selectively capture the particular metal ions (i.e. Mn) from the dissolved Li-ion batteries solution and form MOFs materials (i.e. Mn-MOF).
2. Process design and validation of using the waste PET-derived MOF membranes to selectively filter out raw materials in the dissolved Li-ion batteries solutions.
3. Numerical simulation and evaluation.

## 10.2. Possible PET-MOF-CLEANWATER continuation

A joint research programme between the National Research Foundation (NRF) of South Africa and the Polish National Centre for Research and Development (NCBR) is in progress. The aims of the programme are:

1. to support (through a co-funding model) joint research projects between South African and Polish researchers,
2. to facilitate the development of sustainable institutional links between partners of the two countries, and
3. to foster new linkages and engagements with small teams of young researchers for new links between South Africa and Poland. Areas of cooperation are: health sciences, agriculture, biosciences and biotechnology, environment and climate change, water and green technology, maritime economy, clean coal technology, and information and communication technology. According to this project history, in 2015 the first programme saw the acceptance of six projects accepted. In 2018, during the second programme, 10 projects were accepted. In 2022, the new joint research programme between the National Research Foundation (NRF) of South Africa and the Polish National Centre for Research and Development (NCBR) is expected.

We predict that MOF subjects mentioned above will be very interesting for our work's continuation and use of scientific teams' experience.

## 11. Conclusions

1. Metal-Organic Frameworks – MOFs – are considered as a new member of porous materials that have recently attracted attention to materials chemistry.
2. To date, there are more than 100 000 different structures of MOFs being reported and studied, as well as 50 000 modelled structures.
3. Five main areas are defined for the MOFs applications: adsorption, catalysts, sensors, electrochemical charge storage, and drug delivery systems. These examples are applicable and relevant to many other applications of MOFs.
4. Current and future MOFs structures are and can be applied in clearing away, cleaning up, tidying up, and putting in order our lives in different areas: environment, health and medicine, and science.
5. The phrase MORE MOFs – LESS MESS is true.

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