Comment on “Water harvesting from air with metal-organic frameworks powered by natural sunlight”

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Kim et al. (Reports, 28 April 2017, p. 430) describe a method for harvesting water from air, using a metal-organic framework (MOF) as the adsorbent. The process as described in the paper is, however, inadequate, and the system cannot deliver the claimed amount of liquid water in an arid climate. A modification of the process design and the use of more suitable MOFs may be more likely to achieve the goals targeted by Kim et al.

In their report (1), Kim et al. claim that, starting from dry, warm air at 35°C and 20% relative humidity (RH), they can use low-grade solar energy (at a solar flux below 1 sun) to harvest 2.8 liters of liquid water per kilogram of MOF-801 per day. Their device, composed of an adsorber and a condenser, is similar to an intermittent heat pump consisting of an adsorber and an evapo-condenser. Nonetheless, it is original because it is open rather than airtight, and because the evaporator is replaced by ambient humid air. However, this system is inadequate for harvesting the aforementioned amount of liquid water in arid climates for the following reasons.

1) The results obtained from the experiment in the chamber cannot be generalized to the generation of liquid water under operating conditions typical of arid regions. The process can provide water vapor, but it cannot physically provide liquid water at 35°C condensing temperature at 1.2 kPa pressure. In fact, the authors do not carry out the cycle required for such a process (2), because water vapor is adsorbed and desorbed at the same water vapor pressure (1.2 kPa, corresponding to 20% RH at 35°C) but at two different MOF temperatures. Should a cycle be performed with condensation at 5.6 kPa, the 35°C saturating pressure, our calculation (based on data presented in the supplementary materials of (2)) indicates that much less liquid water would be harvested than what is claimed—0.05 kg (or 0.05 liters) of water per kg MOF per cycle, rather than 0.24 liters of water per kg MOF per cycle as stated in (1). It would be possible to obtain about 0.2 liters of water per kg MOF per cycle if the regeneration temperature were above 85°C, rather than around the cited temperature of 65°C.

2) In the proof-of-concept MOF-801 water-harvesting prototype built in this study, adsorption took place overnight and desorption took place on the second day. The authors performed a cycle and condensed water, but the operating conditions did not at all correspond to those of arid climates: RH was about 65% at 25°C during adsorption, and the condensation temperature was 23°C with a regenerating temperature of 66°C. Had the condensing temperature been 35°C rather than 23°C, the amount of water harvested would have been one-fourth as much.

3) On the basis of a harvested water quantity on the order of 0.24 liters of water per kg MOF per cycle, the authors claim that they would obtain 2.8 liters after 12 cycles per day. The intermittent direct solar heating system used in this study has been implemented for solar cooling in day/night intermittent solar-powered refrigerating systems such as cold store (3) or solar-powered icemakers (4). For continuous harvesting of water in a cyclic manner for a 24-hour period, however, the device requires a two-adsorber system connected to solar collectors and to a recooler through a secondary fluid (5).

The process as described, although interesting, is inadequate for operation at a condensing temperature of 35°C and a regenerating temperature of 65°C using MOF-801. Moreover, with the present design, only a single cycle per day can be carried out, and no more than 0.05 liters per kg MOF per day could be achieved under arid conditions. Thus, another MOF solar-powered water-harvesting system has to be designed to operate in a cyclical manner for a 24-hour period.

4) MOF-801 is a good candidate to operate at low RH ranging from 15 to 20% but with a regenerating temperature above 85°C. These conditions should be possible in an arid climate by using evacuated solar collectors coupled through a secondary fluid to an open MOF-801 two-adsorber solar-powered water-harvesting system and by performing 12 cycles per day. To operate at a 65°C regenerating temperature with a 35°C condenser, CAU-10, according to the relevant water vapor adsorption isotherms (6), would be a better solution than MOF-801, but under a slightly higher RH (20 to 25%) for adsorption at 35°C, assuming equivalent diffusion properties.

5) The water content in the dry air is about 6 g/m³. If 100% of the water vapor from the air is adsorbed, then an air stream of >150 m³ would be required to produce 1 liter of water, which corresponds to a huge volume that may be an issue to solve for the process.

Other MOFs (7) could be selected for other RH conditions. For example, aluminum fumarate should be a good candidate for 25 to 30% RH and a regenerating temperature around 60°C. Thanks to type V (S-shaped) vapor isotherm profiles, some MOFs show outstanding properties that could pave the way toward solar-powered water harvesting. For this goal to be achieved, however, the best MOF must be carefully selected for the given operating conditions, and the process must be designed according to the state of the art.

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REFERENCES AND NOTES
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