SOLAR-ASSISTED AIR CLEANING: PROSPECTS AND POTENTIAL APPLICATIONS

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Key points

- **Climate change presents numerous challenges to air quality in indoor and outdoor spaces.**
- **Solar-assisted air cleaning is a possible solution**
- **Possible air-cleaning schemes include natural ventilation, photocatalytic oxidation (PCO), and the solar updraft tower**
- **The analysis of the Xi'an solar air cleaning tower showed a potential for cleaning approximately 7 x 10^5 m3/day of air, on average. However, the system showed very low overall efficiency.**

Background

- Various solar-assisted air cleaning schemes are shown in Table 1.

Table 1. Solar-assisted air cleaning schemes.

Air cleaning scheme	Mode of cleaning	Example
Natural ventilation	Ventilation (impacted air replaced with cleaner air)	Concordia University Eng. Building [11]
PCO	Oxidation of ambient pollutants	Milan Pavilion [12]
Solar updraft tower	Ventilation and/or filtration of impacted air	Xi'an tower [13]

- **NATURAL VENTILATION**
- In this scheme, solar thermal energy is directly harnessed to create thermal gradients that cause natural ventilation
- The solar resource can be harnessed with fenestrations or solar collectors
- Many designs make use of a chimney, with windows allowing heating of an indoor space along the height of a multistory building, for example.
- **PHOTOCATALYTIC OXIDATION (PCO)**
- PCO involves the use of a photocatalyst (e.g., ZnO) that catalyzes an oxidation reaction after activation by photons of sufficient energy
- The sun can provide the energy needed to activate that catalyst
- A simple depiction of the process is shown in Figure 1.
- In one potential iteration, a conventional flat plate solar air-heating collector can have photocatalyst incorporated into the absorber (indoor air cleaning)
- In another, the photocatalyst can be incorporated into exterior building materials / coatings (outdoor air cleaning)

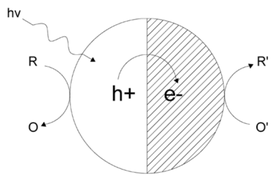
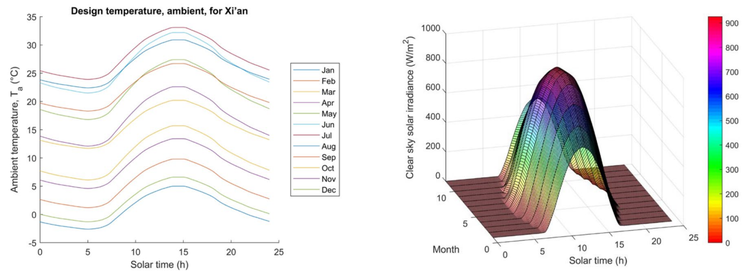


Fig. 1. Simple depiction of photocatalytic process on a semiconductor photocatalyst.

- **SOLAR UPDRAFT AIR-CLEANING TOWER**
- This concept is based on the solar chimney power plant
- A large circular canopy (to some degree transparent to solar irradiance) surrounding a central chimney
- Heated air rises in the chimney, and is released to the atmosphere
- The concept of an updraft tower for outdoor air cleaning was notably introduced by Pui and colleagues [21]
- This concept incorporates a filter bank within the solar tower, so that air pulled through the collector canopy is filtered for particulate matter pollution ($PM_{2.5}$)
- A prototype system was installed in Xi'an, China, in 2016
- Important design considerations for such a system include selection filter / filter media / filter bank design
- Changeout frequency of the filters needs to be considered

Case Study: Xi'an Air-Cleaning Tower

- As a case study, the performance of the Xi'an tower was estimated using a simple model
- For the ambient temperature in Xi'an, the ASHRAE fraction of daily temperature range method was utilized. Solar irradiance was estimated using the ASHRAE Clean Sky Model [30].
- The ambient temperature and clear sky solar irradiance are shown for all 12 months of the year in Figure 2.
- The beam-normal, diffuse horizontal, and collector irradiance for Xi'an in February are shown in Figure 3.



(a) (b)

Fig. 2. Design temperature (a) and clear sky solar irradiance (b) for Xi'an, China.

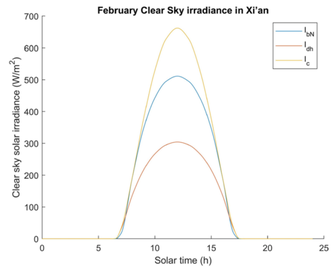
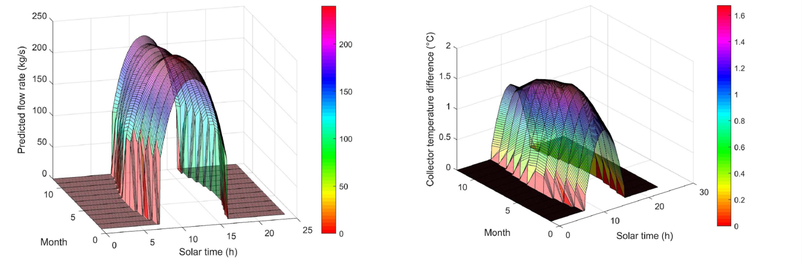


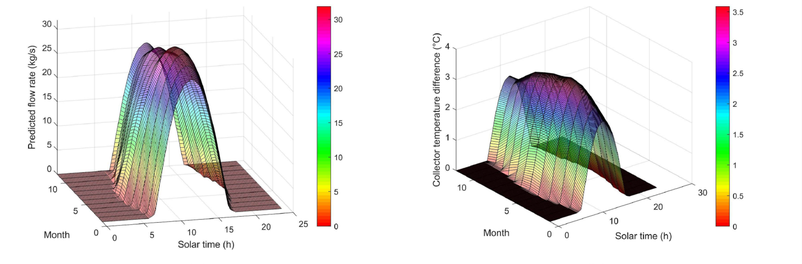
Fig. 3. Beam-normal irradiance, I_{bN}, diffuse horizontal irradiance, I_{dh}, and collector irradiance, I_c, for Xi'an in February, as predicted by the Clear Sky Model.

- **RESULTS**
- The air flow through the tower is shown for the no-filtration and filtration cases in Figures 4 and 5, respectively.



(a) (b)

Fig. 4. Predicted flow rate (a), in kg/s, and collector temperature difference (b), in °C, for the *no filtration* case



(a) (b)

Fig. 5. Predicted flow rate (a), in kg/s, and collector temperature difference (b), in °C, for the *filtration* case

Conclusions

- When no filters are present, the total air flow in the system is 79 kg/s, or roughly 6 x 10^6 m^3/day
- With filtration, the flow is 9.2 kg/s, or 7 x 10^5 m^3/day
- The analysis of the Xi'an solar air cleaning tower showed a potential for cleaning approximately 7 x 105 m3/day of air, on average.
- However, the system showed very low overall efficiency.
- The efficiency of the system can be improved by increasing the canopy width and/or the chimney height

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