Detecting entrapped humans with combustion-generated gas sensors

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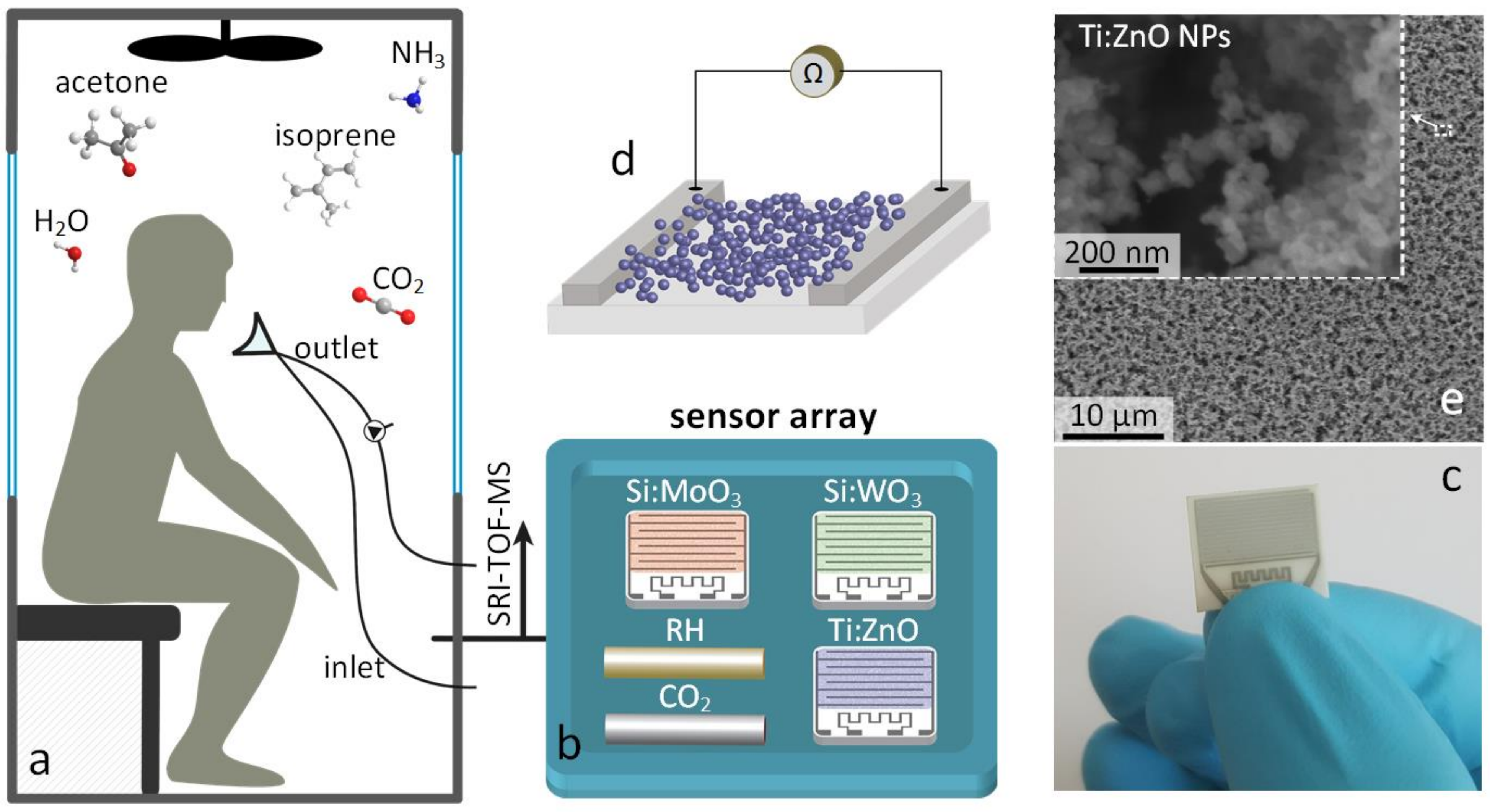
Earthquakes - deadly natural disaster

Earthquakes caused more than 780 000 deaths in the past decade. Following an earthquake, victims are entrapped under collapsed buildings and need rapid help, as survival rates drop dramatically within the first hours.[1]

Chemical recognition of the unique volatile signature of humans could improve urban search and rescue (USaR) massively, similar to the canines' sophisticated nose, the gold standard of USaR. Particularly promising as sign of life are breath- and skin- emitted metabolic tracers like acetone, ammonia, and isoprene.[2]

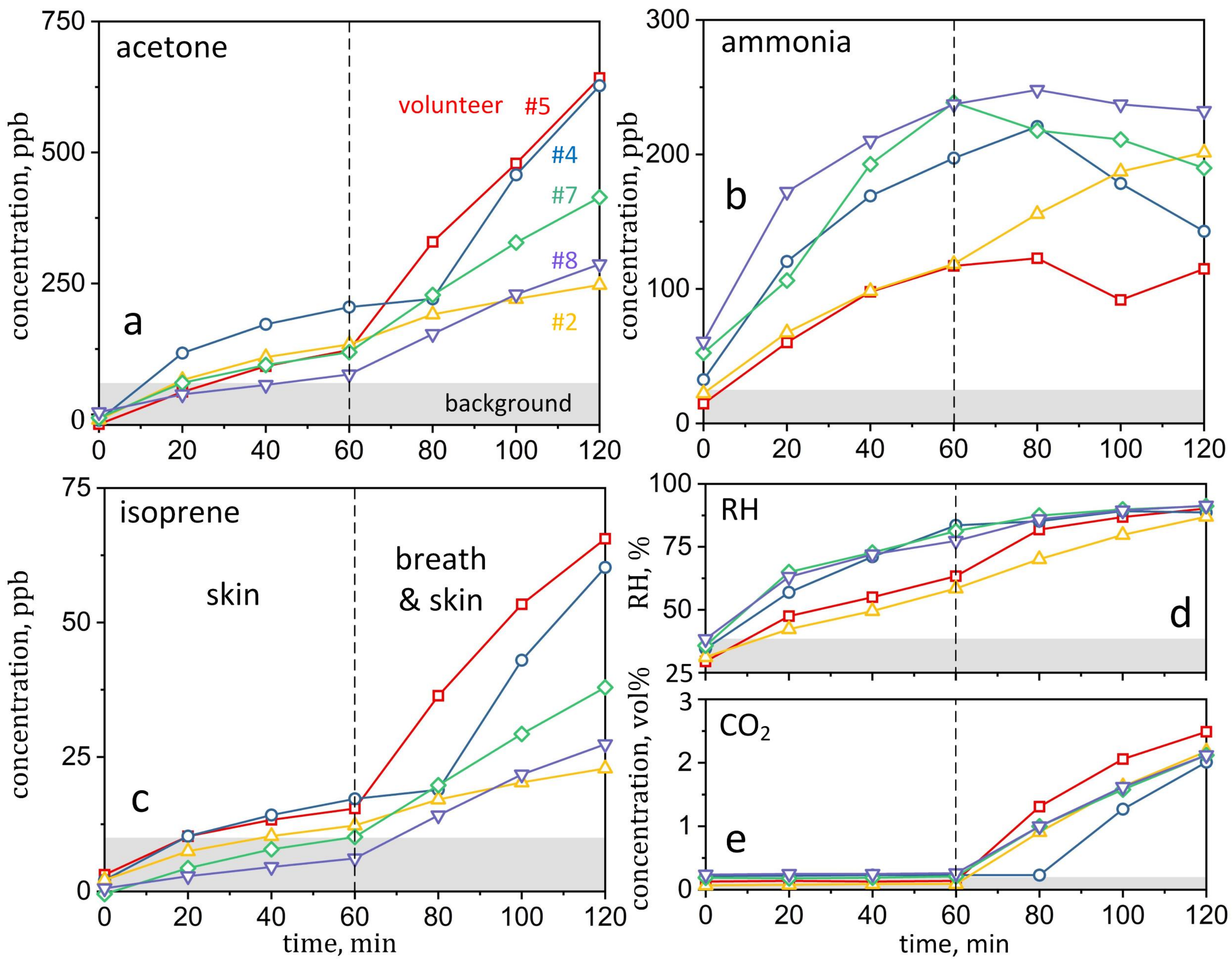
Mass spectrometry- based methods offer sufficient sensitivity and selectivity to detect the tracers. Such methods however, are too bulky, expensive or cannot analyze in real-time impeding their field use. Here we demonstrate how a compact and inexpensive sensor array can detect the human-emitted chemical signature.

Sensor array & entrapped human simulator



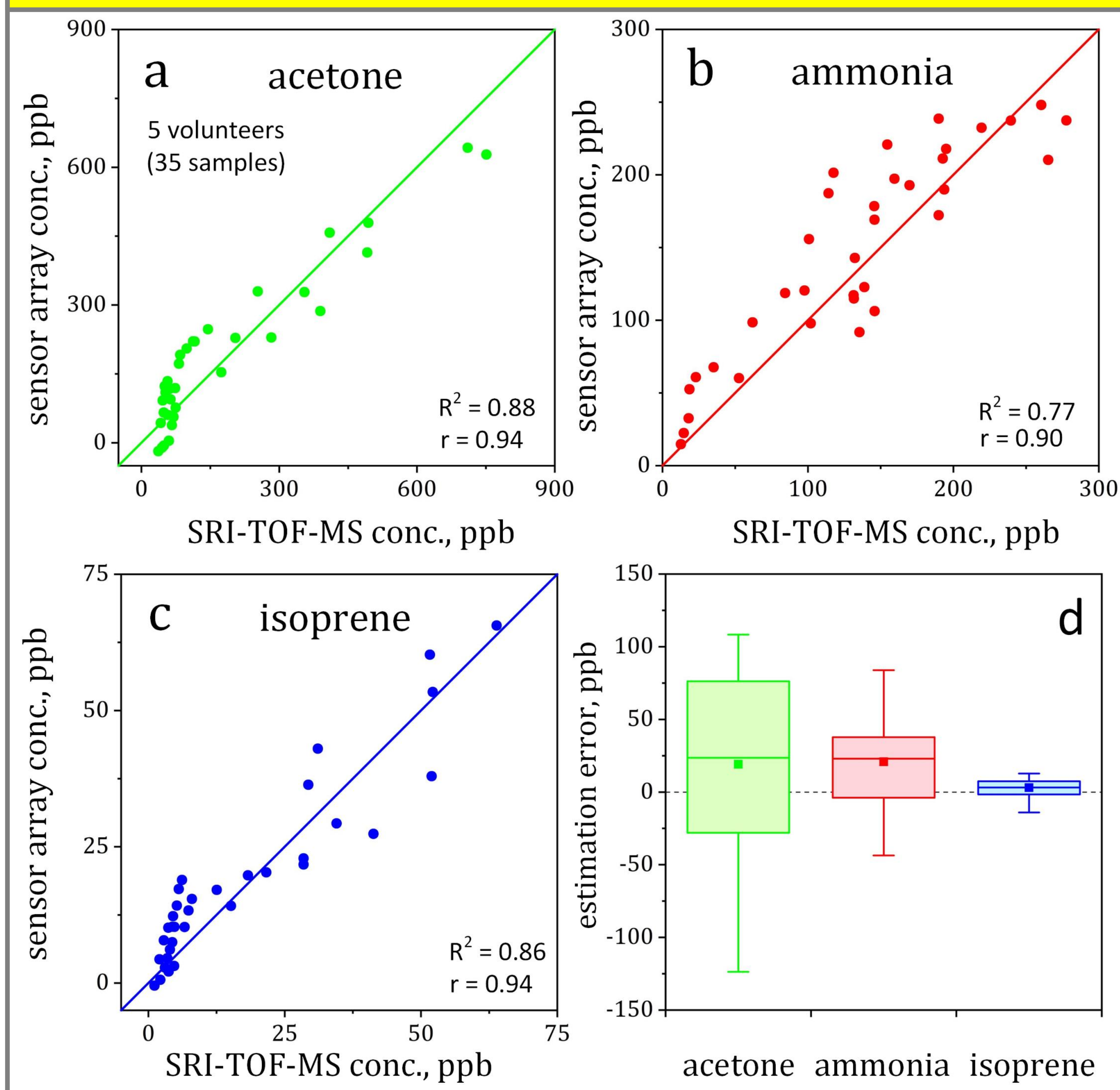
To simulate entrapment conditions, 9 volunteers were individually entrapped in a plethysmography chamber (a). The testing course lasted for 120 min, first with only skin (0-60 min) followed by breath and skin (60-120 min) emissions into the chamber. The sensor array consisted of 3 distinctly selective sensors, i.e. $Si:MoO_3$ (ammonia),[3] $Si:WO_3$ (acetone)[4], Ti:ZnO (isoprene)[5] together with commercially CO_2 and humidity sensors (b). The sensors consist of nanostructured, highly porous and chemoresistive metal-oxide films (c, d, e).

Human emission profiles



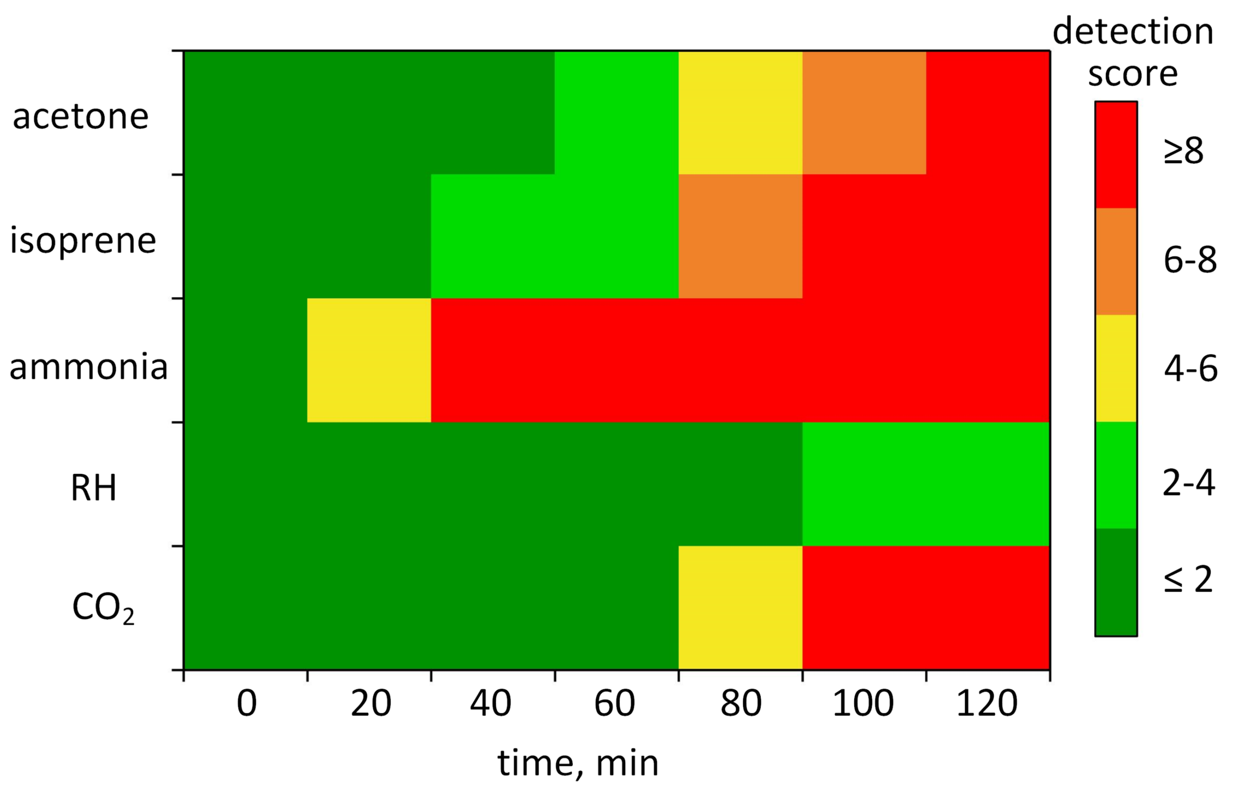
Sensor array measurements of acetone (a), ammonia (b), isoprene (c), RH (d), and CO_2 (e) of five volunteers during skin (0-60 min) and skin & breath (60-120 min) emissions. Their concentrations change rapidly in the vicinity of humans compared to background (gray) resulting in distinct chemical signatures.

Sensor validation by SRI-TOF-MS



Scatter plots indicating correlations between sensor array and Bench-top SRI-TOF-MS for acetone (a), ammonia (b), and isoprene (c). High Pearson's correlation coefficients (r) and coefficients of determination (R^2) indicate good agreement between both methods. Box-and whisker plot of sensor array estimation errors (d).

Human detection score



Color map indicating human detection by their skin (0-60 min) followed by breath and skin (60-120 min) emissions. For each analyte the detection score (c_c/c_b) is calculated representing the ratio of concentration in the chamber (c_c) and background air (c_b). Yellow, orange and red indicate a high likelihood of an entrapped person.

Conclusions

- A novel portable sensor array was developed for rapid detection of entrapped humans from their volatile chemical signature.
- By choosing tailor-made and nanostructured gas sensors with distinct selectivities, accurate detection of breath- and skin-emitted acetone, ammonia, and isoprene down to lowest ppb levels was achieved.
- When applied on entrapped humans, the array recognized human presence by multitracer assessment, as validated by SRI-TOF-MS.
- The sensor array shows high potential as portable human detector for USaR teams after a calamity.

References

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