# Hydrogen economy

We read with great interest the guest editorial by Yadav[1]. It is nice to see the details of production and utilization of hydrogen, and how it could help mitigate the problem of climate change, global warming and greenhouse gas emission (mainly carbon dioxide emission).

While we appreciate this, we would have been very happy, had the author also discussed the issue of leakage of hydrogen once large-scale production and utilization starts. As hydrogen is the lightest gas, it is expected to reach the stratosphere. This could lead to depletion of the ozone layer, which is so important for the survival of life on Earth[2]. It has also been suggested that additional water would be created at high altitudes. This in turn would result in a cooler lower stratosphere and disturbance of ozone chemistry. Concerns have also been expressed that hydrogen near the ground may interact with microbes and alter them in unforeseen ways[3].

A discussion of these aspects, along with more recent detailed studies, if any, would have been very valuable.


1. Yadav, G. D., *Curr. Sci.*, 2021, **120**, 971–972.
2. Tracey, K. T., Shia, R.-L., Mark, A., John, M. E. and Yung, Y. L., *Science*, 2003, **300**, 1740–1742.
3. Mondher Khdhiri *et al.*, *Appl. Environ. Microbiol.*, 2017, **83**(11), e00275-17.



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*Response:*

The contention that hydrogen will leak and deplete the ozone layer is very old[1], which has been debated and subjected to scrutiny by others over the years. Vogel *et al.*[2] considered two scenarios: minimum 1% and worst case scenario of 20% hydrogen leakage. Further insight is also provided by Derwent[3]. The possible amount of additional hydrogen emission into the atmosphere in a hydrogen-based economy is strongly dependent on future hydrogen production (assuming 25% future energy comes from hydrogen based on BP Energy report) and leakage rates throughout the entire process chain. However, the anticipated emissions are highly uncertain. Sensor technology is highly advanced to detect leaks and take remedial actions in real time in the so-called Industry 4.0. The anticipated stratospheric water vapour rise caused by a possible future hydrogen economy is considered as a systematic change in the stratospheric water vapour due to extra emissions of hydrogen should there be no control or it is fugitive. This increase and its influence on both stratospheric cooling and stratospheric polar ozone loss is projected to be small compared to the variability of stratospheric water vapour values[2,3]. As is known today, the possible risks for the stratosphere, for polar regions, are most likely negligible using reliable estimates of future hydrogen emissions and contemplating the expected decreasing stratospheric chlorine loading in the next few decades because of the Montreal Protocol[3]. However, it is the green hydrogen, which was advocated in my Editorial, to be produced from renewable energy sources. The environmental benefits and the minor risks for the stratosphere underline the conclusion that hydrogen as an energy carrier is a reasonable alternative to fossil fuels and the so-called Net (carbon) Zero goal by 2050 which will most likely be achieved ahead of that deadline.

As regards, the second paper which they have quoted is out of context. Hydrogen is the lightest of all gases and does not ‘linger’ next to the soil, even if there is a leak, to be adsorbed. Many articles in the open literature show that biological sources and sinks of $H_2$ are found in oxic and anoxic environments and due to hydrogen above ground[4]; it will hardly be there. In anoxic ecosystems, such as wetlands, freshwaters under the chemocline, marine sediments and animal gastrointestinal tracts, $H_2$ is mainly produced as a reaction intermediate of organic matter degradation by organisms from the three realms of life. The main biological sinks of $H_2$ in anoxic ecosystems are acetogens, methanogens, sulphate-reducing microbes, iron oxide-reducing microbes and nitrate-reducing microbes[5]. In oxic environments, such as upland soils, freshwaters above the chemocline, and open oceans, $H_2$ is mainly generated by $N_2$ fixation and is consumed by Knallgas bacteria and high-affinity $H_2$-oxidizing bacteria[5]. Due to its energetic potential, $H_2$ is quickly consumed by microbes within the same microenvironment, indicating that $H_2$ production is likely the limiting step of the $H_2$ biogeochemical cycle[6]. This would show that there is no relation to the hydrogen economy.

When atomic energy was advocated, so much negative was talked about it and still it is the safest energy sector. I always say that the chemical industry should be as safe as the nuclear industry. To summarize, as I said in the opening as well as closing paragraphs of my editorial, it is high time India adopts the hydrogen economy. It is gratifying to note that just last week the US and India launched Hydrogen Task Force to develop clean energy, which is a testimony to its safety and relevance. Hydrogen will be the ‘SAVIOUR’ of the world!


1. Tracey, K. T., Shia, R.-L., Mark, A., John, M. E. and Yung, Y. L., *Science*, 2003, **300**, 1740–1742.
2. Vogel, B., Feck, T., Grooß, J.-U. and Riese, M., *Energy Environ. Sci.*, 2012, **5**, 6445–6452; https://doi.org/10.1039/C2EE-03181G.
3. Derwent, R. G., Hydrogen for heating: atmospheric impacts, Department for Business, Energy and Industrial Strategy Research Paper No. 21, UK, 7 October 2018.
4. Piché-Choquette, S. and Constant, P., *Appl. Environ. Microbiol.*, 2019, **85**(6), 1–19; https://doi.org/10.1128/AEM.02418-18
5. Thauer, R. K., *Eur. J. Inorg. Chem.*, Special Issue: Hydrogenases (Cluster Issue), 2011, **2011**(7), 919–921; 10.1002/ejic.201001255.
6. Thauer, R. K., Klein, A. R. and Hartmann, G. C., *Chem. Rev.*, 1996, **96**, 3031–3042.



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