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NTU scientists devise method to turn plastic waste into valuable chemicals using sunlight

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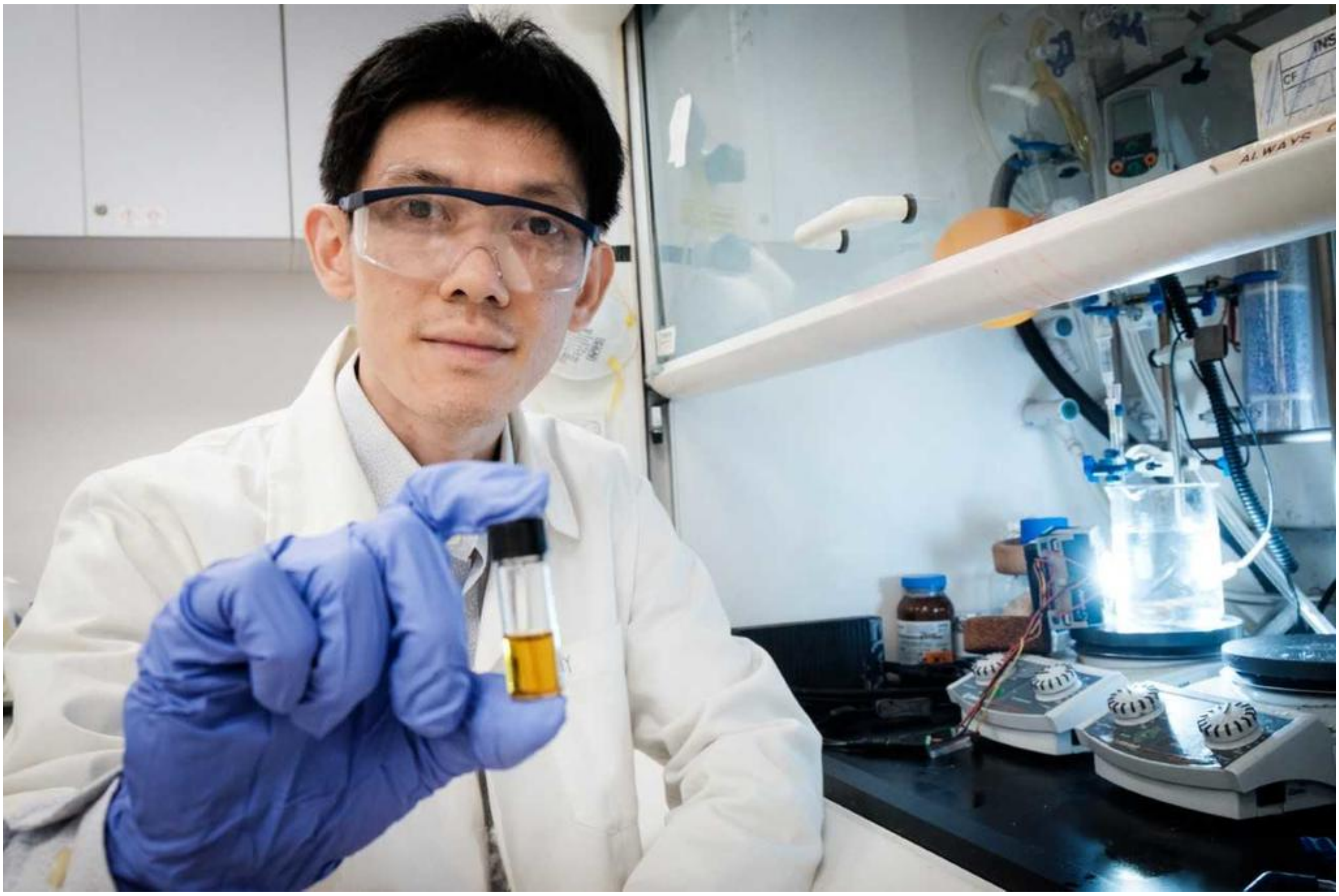

NTU

Asst Prof Soo Han Sen, from NTU's School of Physical and Mathematical Sciences, holds a vial with a mixture that dissolves plastic when combined with sunlight.

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SINGAPORE — Scientists at Nanyang Technological University (NTU) have devised a way to turn non-biodegradable plastic waste into valuable chemicals using sunlight.

The technique uses a low-toxicity "catalyst" to dissolve the plastic molecules through exposure to sunlight, said Assistant Professor Soo Han Sen, who led a team of five scientists on the project.

At a press conference on Wednesday (Dec 11), Asst Prof Soo said the process resulted in formic acid – a highly versatile natural chemical that can be used as a food preservative, antibacterial cleaning agent or in fuel cells for hydrogen energy.

"The market for formic acid is millions of tonnes every year," said the chemist from NTU's School of Physical and Mathematical Sciences.

The catalyst used in the process is a metal called vanadium which is biocompatible and has low toxicity, and is commonly used in alloys for vehicles or aircraft, he added.

Asst Prof Soo said: "This new chemical treatment is the first reported process that can completely break down a non-biodegradable plastic such as polyethylene using visible light and a catalyst that does not contain heavy metals."

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He said the technique is not yet commercially viable, and needs perhaps five years more work – but it could eventually lead to an important method to deal with plastic waste in an environmentally sustainable way, and produce valuable chemicals in the process.

The team's work was first reported in the scientific journal Advanced Science in October.

WHY THE RESEARCH IS IMPORTANT

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He said that 58 per cent of plastics end up in landfill, rivers or oceans. Only about 18 per cent is recycled by melting or reprocessing, he added.

As most plastics are non-biodegradable, oceanic plastic waste is especially worrying. In reports last year, researchers estimated the problem is so bad that a vast dump of plastic waste swirling around the Pacific Ocean is bigger than France, Germany and Spain combined.

Instead of decomposing, large pieces of plastic get broken down over time into tiny microplastics, and consumed by fish that end up on dining tables. This in turn affects human health when the plastic finds its way into our bodies.

A study by the World Wide Fund for Nature estimates that an average person ingests about one credit card worth of plastic a week.

Asst Prof Soo said that much of Singapore's plastic waste ends up being incinerated, which produces greenhouse gases, such as carbon dioxide, that contribute to the global climate crisis.

The resulting incineration ash is buried at Singapore's only landfill at Pulau Semakau, which is estimated to run out of space by 2035.

The research by Asst Prof Soo and his team may help provide one of the solutions Singapore needs to extend the landfill's lifespan.

"Instead of creating this solid waste, we want to turn plastics into fuel or other chemical feedstocks," said Asst Prof Soo.

HOW IT WORKS

Most plastics are not readily broken down without the application of high temperatures because they contain extraordinary inert chemical bonds called carbon-carbon bonds, he said.

However, the traditional way of obtaining energy requires the burning of fossil fuels or liquid natural gas, which produces undesirable greenhouse gases.

“On the other hand, light is very abundant,” said Asst Prof Soo. “The sun is a virtually infinite source of (clean) energy.”

The process first involves dissolving the vanadium into a solution containing consumer plastic — such as polyethylene cups and bags — and then exposing it to light. It currently does not work with a type of plastic called polyethylene terephthalate (PET).

Using an analogy, he said the carbon-carbon bonds can be likened to a zipper. The vanadium acts as a handle on the zipper, and when pressure — in this case, light — is added, it unravels the zipper to break the bonds.

This process, which currently takes about six days to be completed and has so far involved artificial light in laboratory conditions, eventually produces formic acid.

Asst Prof Soo said the team is currently conducting experiments using 10mg of plastic pellets, which can yield the same amount of formic acid.

“The good thing about plastics is that they're all carbon-carbon bonds, so they all get converted in formic acid,” said Asst Prof Soo, though he added that the main by-product is still carbon dioxide.

“For the carbon dioxide that is produced, there are ways to capture it instead of releasing to the atmosphere. Already in existing industrial processes, carbon dioxide can be converted to carbon monoxide, which can be combined with hydrogen to produce syngas, which is similar to methane gas, useful for power generation or to be further refined into synfuel (like petrol)."

While the project so far has involved laboratory work, he said there should be little issue producing formic acid on a larger scale. However, he admitted that they have yet to trial their research on actual plastic waste, so it remains to be seen whether contaminants will affect the results.

Aside from NTU’s scientists, only Cambridge University has conducted similar research.

small part of the reaction.

It also uses the heavy metal cadmium as a catalyst, which he says is as toxic as lead.

Asst Prof Soo stressed that there are no toxic components, or harsh pre-treatments, involved in his project.

The entire process for the Cambridge system is much slower, too. Even after one week, only about half of the plastic is converted into chemicals, he said.

Furthermore, the result from the Cambridge system does not produce pure formic acid, but a "complex mixture", he said.

The downside about NTU's system is that the catalyst is dissolved, which makes it hard to be reused.

WHAT NEXT?

For now, the project is not commercially viable.

However, Asst Prof Soo reckons that with the right amount of funding and manpower, the project could be completed in five years.

The project team is also pursuing other improvements to the process that could see other chemical fuels being produced, such as hydrogen gas.

Another improvement is finding ways to use electricity, instead of sunlight, to jump-start the chemical reaction.

"I don't want to create stuff that only works in Singapore," said Asst Prof Soo.

He said while some countries may lack sufficient sunlight, they may make up for it with other renewable energy sources such as wind or hydropower.

Asst Prof Soo also envisions a future where a treatment plant could be built on Pulau Semakau which would treat plastic waste on a large scale.

If all goes according to plan, it may even pave a way to transit from fossil fuels to hydrogen fuel, which emits zero emissions when burned.