How the kilogram has put on weight

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Using a state-of-the-art Theta-probe XPS machine experts at Newcastle University, UK, have shown the original kilogram is likely to be tens of micrograms heavier than it was when the first standard was set in 1875. And they say a suntan could be the key to helping it lose weight.

Post-Christmas and most of us are feeling the over-indulgence. But take heart - experts at Newcastle University, UK, have shown even the kilogram itself has put on weight. Using a state-of-the-art Theta-probe XPS machine – the only one of its kind in the world – the team have shown the original kilogram is likely to be tens of micrograms heavier than it was when the first standard was set in 1875.

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The original kilogram – known as the International Prototype Kilogram or the IPK – is the standard against which all other measurements of mass are set. Stored in the International Bureau of Weights and Measures in Paris, forty official replicas of the IPK were made in 1884 and distributed around the world in order to standardise mass. The UK holds replica 18 at the National Physical Laboratory (NPL).

But despite efforts to protect the IPK and its duplicates, industrialisation and modern living have taken their toll on the platinum-based weights and contaminants have built up on the surface. Now Professor Peter Cumpson and Dr Naoko Sano have used cutting-edge X-ray Photoelectron Spectroscopy (XPS) to analyse surfaces similar to the standard kilogram to assess the build-up of hydrocarbons – and how to

remove them.

Publishing their findings this month in the journal of *Metrologia*, they reveal how giving the kilogram a suntan could be the answer to helping it lose weight. "Statute decrees the IPK is the kilogram," explains research lead Peter Cumpson, Professor of MicroElectroMechanical Systems (MEMS) at Newcastle University. "It doesn't really matter what it weighs as long as we are all working to the same exact standard - the problem is there are slight differences. Around the world, the IPK and its 40 replicas are all growing at different rates, diverging from the original.

"We're only talking about a very small change – less than 100 micrograms – so, unfortunately, we can't all take a couple of kilograms off our weight and pretend the Christmas over-indulgence never happened.

"But mass is such a fundamental unit that even this very small change is significant and the impact of a slight variation on a global scale is absolutely huge. There are cases of international trade in high-value materials - or waste - where every last microgram must be accounted for.

"What we have done at Newcastle is effectively give these surfaces a suntan. By exposing the surface to a mixture of UV and ozone we can remove the carbonaceous contamination and potentially bring prototype kilograms back to their ideal weight."

The kilogram is one of the seven SI base units from which all other units can be derived and is the only one which is measured against a physical object – the IPK – all others are standardised against known constants.

The Newcastle team are now moving on to study the addition of mercury from the atmosphere, something Professor Cumpson first identified while working at the NPL in the 1990's. But it is the development of

techniques such as XPS which has allowed them to accurately measure how the build up of chemicals such as hydrocarbons can be most effectively removed.

Newcastle University hosts the £3million National XPS service funded by the Engineering and Physical Sciences Research Council (EPSRC).

Using a Theta-probe XPS machine – the only one of its kind in the world - Professor Cumpson and Dr Sano showed how the UV/ozone wash could be used to remove contamination without damaging the platinum surface. "The Theta probe allows us to look at the composition of very thin layers by measuring the angle at which the electrons emerge from it," explains Professor Cumpson.

"Rather like an MRI scanner, it takes a cross section of the material but at an atomic level. The second part of the machine is the Argon cluster ion gun – which fires charged 'droplets', each containing about a thousand Argon atoms – and it is this which makes the Newcastle machine unique.

"The Argon cluster ion gun allows us to analyse organic materials without damaging the inorganic surface, in this case the platinum alloy."

Work is underway internationally in several National Measurement Institutes to find an alternative to the IPK – a standardised value for the kilogram that is not based on a matchbox- sized piece of metal. But until then, the prototype kilograms are what the world relies on for its mass scale.

"If the kilogram does put on weight then it's imperative that we understand exactly how the IPK is changing," says Professor Cumpson.

More information: "Stability of reference masses V: UV/ozone

treatment of gold and platinum surfaces." Peter Cumpson and Naoko Sano. *Metrologia*. January 2013.

Provided by Newcastle University

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