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ASBP The Alliance for Sustainable Building Products

WHAT'S IN MY UPVC WINDOW?

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1.0 Introduction: What is uPVC and how do we make it?

As a reminder, uPVC stands for Unplasticised Polyvinyl Chloride. How many consumers or indeed construction professionals know this? And have they considered how uPVC is manufactured?

Time for some basic chemistry; Poly(vinylchloride) (PVC) is produced by the polymerisation of vinyl chloride monomer, which is in turn derived from ethylene dichloride. Ethylene dichloride is obtained from the reaction of ethylene with chlorine, with the ethylene being obtained by steam cracking of hydrocarbons derived from fossil oil reserves.

Chlorine is produced from brine (salt solution) by the chlor-alkali industry. Total chlorine production in Europe was nearly 9.7 million tonnes in 2016, with the largest single end use (33%) being for PVC production. Demand for PVC products in Europe is close to 5 million tonnes per annum, with window profiles accounting for 28% or 1.4 million tonnes.

The vast majority of chlorine (85%) used in UK PVC manufacture and 95% of chlorine added to the UK drinking water supply, is manufactured in Runcorn, Cheshire, in a plant formerly owned by ICI and now owned by Ineos.

1.1 Manufacturing chlorine is highly energy intensive

Manufacturing chlorine is highly energy intensive as the CEO from Ineos commented in 2013. Such (energy) costs are particularly important for Ineos. Its Runcorn plant, which provides the chlorine for 95% of Britain's water, "consumes as much energy as Liverpool", says Ratcliffe. "We are one of the largest industrial consumers of both electricity and gas in the UK outside of the power generation sector". [1]

Jim Ratcliffe may not be a household name. But it's hard to find another British industrialist who, in 15 years, has built a business from scratch into a global $43bn (£27.5bn) operation, employing 3,500 people across the UK. Ineos have since opened an energy from waste plant on site and in July 2016, Ineos suggested they would be putting in thirty planning applications to frack in England by the end of the year. However, by September, these plans appear to have been downgraded, with Ineos stating it hoped to lodge just five applications by the end of 2016.

2.0 The toxic history of the site in Runcorn

Friends of the Earth produced in 2016 an excellent briefing on Ineos. [2]

Back in February 2000, the Guardian broke the news under the headline Toxic Shock that a chemical known as HBCD had leached from a dump within the ICI facility in Runcorn, Cheshire.

The village of Weston, population around 1,000, with its good housing, good schools, good church and people, is deep in this nightmare. Ever since ICI knocked on 120 doors along Weston Road in the first week of January, the stress levels have been rising. So far, 19 out of 104 properties in the street tested near the two linked waste tips have proved positive for HCBD, and more than 50 people have been evacuated to local hotels.

The bulk of the several million tons of waste in the two quarries is rubble, lime, chlorinated solvents, chemical catalysts and general industrial waste. But also known to be dumped were large amounts of highly toxic mercury, sodium, perchlorethylene, trichlorethylene, carbide and lime slurry, and thousands of unmarked steel drums whose contents are unknown. The site made chlorine gas during the second world war, then helped make atomic bombs. More recently, it was one of the world's largest producers of CFCs - the propellants and coolants that destroy the ozone layer. It is now one of Britain's greatest producers of deadly cancer-causing dioxins and is hounded by Friends of the Earth for its pollution record.

The following year in May, 2001 the Guardian ran a follow up article;

A further 200 homes were vacated voluntarily after ICI offered to buy any house in the village, even though HCBD was detected at dangerously high levels only in the original 26. The chemical came from industrial waste from ICI's Runcorn factory which it dumped in disused quarries 25 years ago. Gas was detected in boreholes in December 1999. North Cheshire health authority tested 70 people evacuated from the homes with high levels of HCBD; half had kidney abnormalities.

At this stage ICI, it seems, began an exit strategy from this site, to remove the risks of future liabilities and connections with such a severe toxic shock. ICI sold its Runcorn chlorine plant to Ineos Chlor in 2001, but retained a stake in the site. In July 2003, ICI and Ineos agreed a deal to modernise the chlorine facility next to the Manchester Ship Canal in an attempt to make it more environmentally friendly. The deal comprised £45m from Ineos, £60m from ICI and financial assistance from the Government. This was in addition to the original £100m loan facility ICI had previously agreed to provide, as part of the sale of 85% of the business three years ago. Government support may be explained by the fact that Ineos had cut about 400 jobs at Runcorn, since taking over from ICI in January 2001.

In 2004, ICI transfered its 15% stake in chlorine producer Ineos Chlor to the Ineos group and wrote off all its £100m loan; basically this was ICI cutting and running.

According to the FOE 2016 report, the toxic dump that was the source of the HBCD, now apparently has no legal owner, according to the land registry.

3.0 Mercury

The Runcorn plant used mercury filters until very recently and had a permit to allow 20.64 tonnes of mercury to be emitted to the air between 1997 and the end of 2020. At the beginning of 2005, 8.764 tonnes of this allowance had been used.

Up until last year, the Runcorn plant had used mercury filters to produce chlorine. Now finally, the last mercury filter for chlorine production on this site has ceased operations. The Environment Agency ruled a while back that this process must stop across the UK by the end of 2017. So no more mercury filters.

That said, the plant has now got to be decommissioned.... and the long term effects of the mercury that has been dumped up until now, is a clear health hazard. It collects in the sludge and silt, which is then washed away in the Mersey.

4.0 uPVC and toxicity in fires

Because of the high chlorine content, unplasticised PVC products will self-extinguish if the source of flame is removed and they form a char rather than burning droplets. In a fire situation, PVC will emit a range of toxic gases, which include carbon monoxide, hydrogen chloride (HCl), dioxins, polycyclic aromatic hydrocarbons, as well as fine particles contributing to heavy smoke formation (Levchik and Weil 2005, Stec et al. 2013).

"Although the inhalation of toxic smoke is the biggest killer and the largest cause of injury in fires, it is very much the neglected area of fire science and fire safety engineering. It was concluded that having toxicity data required by the Construction Products Regulation would ensure data was available for engineering calculations. In the absence of toxicity labelling within the Construction Products Regulations, cooperation between competitor organisations, such as fire test laboratories and between fire safety engineering consultancies, would be the best way to secure publicly available data and hence ensure the life safety in the event of a fire" [4]

4.1 2017 fire in Milton, Stoke on Trent

On 5th February 2017, the Mirror reported; [5]

Six crews dashed to Hanbury Plastics centre in Milton, Stoke-on-Trent, at 9.30am yesterday after the service received 78 calls in ten minutes about the blaze. Graham Shaw, 63, said: *"It questions whether the plastic factory should be built so close to residential properties. It is the most smoke I have ever seen. The question is whether it is toxic."*

The photo of the fire above, surely answers this question.

4.2 Hazards of PVC fires on fire-fighters

An excellent white paper from Perkins and Will and the US' Healthy Building Network entitled *'What's new (and what's not) with PVC'* (November 2015) includes a quote from Richard Duffy, International Association of Fire-fighters;

"Exposure to a single PVC fire can cause permanent respiratory disease. Due to its intrinsic hazards, we support the efforts to identify and use alternative building materials that do not pose as much risk as PVC to fire-fighters, building occupants and communities". [6]

4.3 Is uPVC more toxic in fires than wood?

It is known that exposure to burning PVC does affect the respiratory system (Markowitz, 1989) mainly due to the production of hydrogen chloride gas. Carroll (2001) compared wood and PVC as sources of dioxin emissions in house fires, finding that PVC emitted about 10-20 times more dioxins than wood under the same combustion conditions. This paper gives references to other papers where dioxin emissions from the combustion of wood are reported. Many of the studies of PVC combustion investigate controlled burning, which does not represent the conditions that might occur in a real fire. ASBP is working with partners to update this test.

5.0 Procurement and the Precautionary Principle

The Healthy Building Network highlights in its 2015 white paper;

"Perkins+Will, an international architecture practice with about 1,000 architects, who have included PVC in its Precautionary List as a substance for which to seek alternatives."

5.1 The Precautionary Principle

In short, the meaning of the Precautionary principle may be described as "better safe than sorry". Since chemicals are so infinitely difficult to assess and the potential hazard may be so severe, a precautionary perspective is essential. By eliminating hazardous substances you are also eliminating the risk for them to do any harm. The guiding principle in this approach is called the Precautionary Principle. In 1992, the United Nations adopted the following definition of the principle: *"where there are threats of serious or irreversible damage to the environment, lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation"*.

6.0 End of life issues for PVC

The presence of cadmium and lead-based stabilisers in PVC products has resulted in concerns with respect to recycling, since these 'legacy' stabilisers will continue to appear in products even though they have been theoretically phased out. It is not known at present how this situation will be resolved. There is an EU derogation in place allowing for cadmium levels of 0.1% in rigid PVC products containing recovered PVC, which is due to be reviewed at the end of 2017. No doubt the PVC industry will argue for an extension of the derogation.

6.1 Recycling rates for uPVC

The PVC industry claims to recycle PVC windows but in reality this encompasses only a tiny percentage according to the Scottish Civic Trust.

In reality uPVC is rarely recycled and when it is the uPVC degrades so that a window frame can only contain a small percentage of recycled material. The process requires the addition of yet more chemical additives and stabilisers and is actually more expensive than producing new uPVC. 82% of uPVC goes to landfill 15% of uPVC is incinerated. Only 3% of uPVC is recycled. [7]

7.0 uPVC Windows and the BRE Green Guide

There is only one domestic uPVC window listed on the BRE Green Guide, which scores A. [8] It scores badly for Climate Change (D), Water Extraction (E), Fossil Fuel Depletion (E) and Waste Disposal (C), yet is still rewarded a Summary Rating of A. It is not clear how this is possible? ASBP would intuitively challenge the A+ ratings for toxicity.

There is one commercial PVC-U Window listed on the BRE Green Guide which scores A+. [9] The functional unit for this commercial windows is 1m^2, as opposed to 1.82m^2 for the domestic uPVC window.

It is noted that it scores an A+ for waste disposal. Ii is also noted the GWP figure is 120 kg CO^{2}e and so proportionally much lower than the 310 kgCO2e figure for the above. The recycled content is stated at 15%. It is notable that the functional unit here does not state that the window should be openable. And so in this case, it is likely it has no steel reinforcing or hardware, which explains the lower kg CO^{2}e number.

ASBP queried these issues with Dr Shamir Ghumra, BRE in February 2017 and he kindly sent back the BRE 2014 report, *FB66 Environmental Impact of Windows*. [10] A few issues leapt out;

Table 4 is quite misleading at it implies that the lowest Green Guide rating for uPVC is A and A+. This is surely because there is only one uPVC entry for each category.

In 4.4 it claims that BPF have provided evidence to BRE that the UK has achieved a recycling rate of 50%. The authors have been unable to locate a breakdown of recycling rates in the UK, but this rate seems high. The BPF has no up to date UK figures. The Green Guide assumes 15%. The Scottish Civil Trust suggest 3%.

8.0 Conclusions and next steps

On a positive note, we are pleased that the team from the Royal College of Physicians and the authors of *Every Breath We Take* in 2016, are now following up with a report on indoor air quality, which will push forwards the whole subject of good indoor air quality. Healthy products that contribute to indoor air quality, is a major theme of work for ASBP.

It is clear from the above that the ramifications of the selection of uPVC windows are considerable. Friends of the Earth must be commended for their excellent briefing. We will contact them to see if we might collaborate on some monitoring.

With advances in timber window science and in particular thermally modified wood extending the life of timber windows, the choice is clear.

We now intend to do the following:

8.1 Investigate methodologies and costs to conduct an accelerated ageing chamber study for uPVC window(s), to monitor and measure any off-gassing into the indoor environment.

The following is abstracted from *Photostabilization of poly(vinyl chloride) – Still on the run by* Emad Yousif, Ali Hasan, 2015. [11]

Long term exposure to sunlight leads to the degradation of plastic materials. UV energy absorbed by plastics can excite photons, which then create free radicals. While many pure plastics cannot absorb UV radiation, the presence of catalyst residues and other impurities will often act as free radical receptors, and degradation occurs. It only takes a very small amount of impurity for the degradation to occur. In the presence of oxygen, the free radicals form oxygen hydroperoxides that can break the double bonds of the backbone chain leading to a brittle structure. This process is often called photo-oxidation. However, in the absence of oxygen there will still be degradation due to the cross-linking process.

Poly(vinyl chloride) has poor light stability in the wavelength range of 253–310 nm, presumably due to the presence of unsaturated (C C) bonds, carbonyl, hydroperoxide, and hydroxyl groups in polymer chains. The relative activity of one or another chromophore in initiating PVC photodegradation is determined primarily by two factors: their ability to absorb UV light in the wavelength range under consideration and their participation in the formation of active particles (radicals) which cause degradation of the polymer chains. The alkene unsaturated (C C) bonds (both internal and terminal) cannot be the primary initiators of PVC photodegradation under the action of sunlight with $(\lambda > 250)$ *nm because they absorb only the UV light at* $(\lambda < 200)$ *nm. The absorption by conjugated (C C) bonds (dienes, trienes, etc.) shifts toward the longer wavelengths. The color changes from white to yellow, brown, and finally to black while the properties of the material deteriorate.*

The question here is does this degradation lead to any offgassing?

Our academic review found little testing in this area but no reported effects on IAQ. ASBP has within its network, a range of experts in the field of indoor air quality testing. It is proposed that ASBP will send this report to the following experts. We will ask them for comment on the following:

1. Are they aware of any such testing?
2. What would be the process and parameters for testing?
3. What would be the likely costs for 1,2 and 5 tests?
4. For UV coatings, what is their life time; do they degrade?
5. Propose a range of sample tests; different sources/grades/coatings;

- Dr Derrick Crump, IEH Consulting
- Tim Robinson, Waverton Analytics
- Les Keeper, CEO, Prism Analytical Technologies
- Dr Volker Gutzeit, Head of Technology, Sentinel Haus Institute

8.2 Investigate methodologies and costs for an uncontrolled burn test to monitor and measure off-gassing into the indoor environment.

In a fire situation, PVC will emit a range of toxic gases which include carbon monoxide, hydrogen chloride (HCl), dioxins, polycyclic aromatic hydrocarbons, as well as fine particles contributing to heavy smoke formation (Levchik and Weil 2005, Stec et al. 2013).

It is proposed that the above experts, as well as TRADA, comment and responses are collated on:

- Are they aware of any such testing?

- What would be the process and parameters be for such testing?
- What would be the costs for 1,2 and 5 tests?

8.3 IAQ testing and surface testing; uPVC related fire incidence

Tim Robinson at Waverton Analytics calibrated markers for IAQ and surface tests to use after the Milton, Stoke on Trent fire. We were too late to carry out tests for this fire but aim to respond to the next one.

8.4 Kent Fire and Rescue

Simon Corbey, Director, ASBP has contacted Graham Day at Kent Fire and Rescue, to understand from their experience the implications of fire and uPVC windows. They are running a contaminants project looking at exposure to toxins for Firefighters and a collaboration with the Kent Fire and Rescue Service can be explored.

8.5 BRE Green Guide and EPD

Although it is now widely accepted that the Green Guide has many failings, it is still widely referenced in planning and used within BREEAM. Jane Anderson is an ASBP board member and Life Cycle Analysis expert and co-author of the Green Guide. It is proposed that Jane will review this output and then lend some comment.

For regular updates on our work, please sign up to our monthly newsletter on our website - http://www.asbp.org.uk.

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