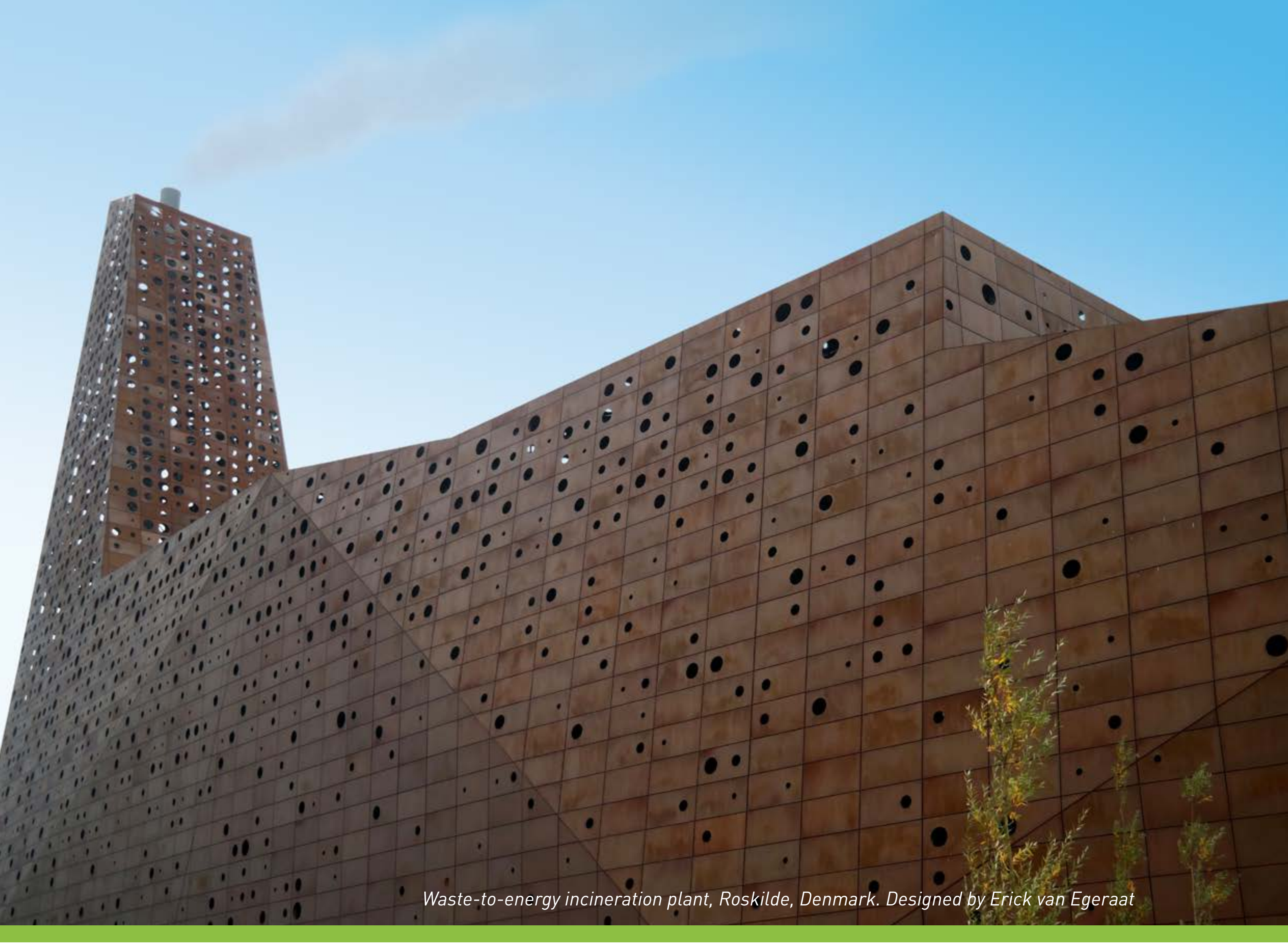

Waste-to-energy incineration plant, Roskilde, Denmark. Designed by Erick van Egeraat

Understanding the Basics:

How Acid Gases from PVC Energy Recovery are Neutralized

Recycling of PVC benefits environment and economy, and through the VinylPlus program recycling rates are increasing year after year. The EU Waste Hierarchy favors incineration over landfilling. Thus, non-recyclable PVC waste should be incinerated with energy recovery. Like all other wastes containing chlorine, e.g. salty foods, PVC generates the acid gas hydrogen chloride (HCl) when combusted in municipal waste incinerators. Yet in modern incineration plants, flue gas cleaning technologies ensure that HCl is neutralized and not emitted into the atmosphere.

By Tobias Johnsen

vinyl plus COMMITTED TO SUSTAINABLE DEVELOPMENT

Window profiles ready for mechanical recycling. With a market share of almost 40 %, PVC is the most used plastic material in building and construction. Window profiles, pipes, doors, cables, flooring, roofing membranes and other long-lasting applications are often made of PVC. These are easy to collect and recycle into new products.

With good reasons, proper waste management stands central in countries that can allocate the necessary resources. In short, humans and environment suffer when waste is disposed of improperly. Backyard burning of household trash emits dioxins, carcinogenic polyaromatic hydrocarbons and particle pollution. Neither is landfilling a good solution, for several reasons. It takes up space; a scarce resource in densely populated areas. It produces the powerful greenhouse gas methane, which is far more potent than CO_2. Fires are common, causing the same pollution as backyard burning. Also, problematic substances can leach into the groundwater if the landfill is not properly managed.

And not least, trash is a valuable and recoverable resource. These issues are well recognized in the European Union. According to the EU waste hierarchy, the best waste management options are prevention, reuse and recycling, in that order. Next is recovery, or incineration, and lastly landfilling. Of course, the first three options are preferable, but for some types of waste recycling and reusing are neither economically, practically nor hygienically sound. Further, there are simply limits to how many times a material can be recycled. In these instances, incineration presents itself as the best, though not perfect, solution.

PVC can be incinerated with energy recovery. There will be a need for this in future, but the volume should be much smaller as recycling is scaled up.

VinylPlus, the sustainable development programme of the European PVC industry, registered a record 481,018 in 2014 – keeping the industry on track to meet the challenge of recycling 800,000 tonnes per year by 2020.

Incineration 101

Incineration dates back thousands of years, but the practice did not mature until the end of the 19th century. In order to deal with the mountains of foul-smelling, disease-causing and obnoxious waste, fast-growing cities in the industrialized world found incineration to be a smart alternative to landfills. Basically, waste combustion reduces the volume by approximately 90 % and produces heat, which can potentially be recovered. Unfortunately, sterile yet troublesome residues are also generated, in form of bottom ash and flue gas containing heavy metal-laden dust particles, acid gases and products of incomplete combustion, e.g. dioxins. Historically, these processes were poorly understood, and for a long time waste combustion remained a dirty affair. For instance, around 1920 a newly built plant outside Den Haag closed down shortly after its inauguration due to air pollution.

As concerns over environmental degradation from incineration mounted in the 1960s, development of air pollution control technologies took off. Today, strict regulatory regimes exist in Europe and elsewhere that mandate cleaning of flue gas. Moreover, most European plants now recover the heat from the combustion process as electricity, and in some countries—namely in Scandinavia—also as district heating. Currently, these waste-to-energy plants supply 14 million European households with electricity and another 14 million with heating. With the EU moving away from landfilling, the forecast for waste-to-energy plants looks bright. However, critique of incineration is still being voiced.

PVC waste: a cause of controversy

One of the most controversial subjects is PVC. A versatile, durable, safe and cost-effective material, PVC has been in use for over 50 years and is currently the third most used plastic worldwide. Its applications are endless: from medical devices such as tubing and blood bags over food packaging to auto parts and construction materials like piping and windows. While the European PVC industry has enacted considerable measures to increase recycling, the material still must be disposed of eventually. Some kinds of waste are also unsuitable for recycling because it would consume more resources in separation and cleaning than are saved. For these as well as the reasons mentioned in the introduction, incineration of PVC waste is preferable over landfilling. However, incineration of PVC waste has been under scrutiny for decades. A key aspect is dioxins, which is beyond the scope of this article but covered elsewhere by VinylPlus. Another is hydrogen chloride, or HCl. Unlike other plastics, PVC is mainly derived from common salt (57 %). (The remaining 43 % comes from oil or gas). On one hand, this makes the material less dependent on fossil fuels than other plastics. But on the other, the high chlorine content has raised concerns. When incinerated, chlorine is converted into HCl. Since HCl is an acid gas, incineration of PVC waste have for decades been blamed for contributing to acid rain. Likewise, PVC has been linked to excessive investment costs in air pollution control devices as well as corrosion of the boilers that recover energy. The following statement from NGO Healthcare Without Harm sums up the anti-PVC position succinctly: *"Burning PVC … produces hydrochloric acid, or HCl. In addition to being a dioxin precursor, and a contributor to acid rain, HCl wreaks havoc on the pollution control equipment and the incinerator itself, where it can 'eat' the chrome plating off the machinery."*[1]

1 Patton, "The Campaign for Environmentally Responsible Health Care" http://www.chem.unep.ch/pops/POPs_Inc/proceedings/slovenia/patton.html.

Clearly, the critique has some justification. But as the next part hopefully will show, a lopsided stance toward PVC waste incineration is not grounded in facts.

Residues: incineration's unpleasant companion

As mentioned earlier, incineration produces bottom ash and flue gas. The first makes up about 90 % of the waste output, most of which can and be reused with little treatment as a civil works material. Some countries display quite impressive figures: in the Netherlands and Denmark the percentage of reused bottom ash hovers at 90 %. Residues from flue gas cleaning are more problematic. These consist of heavy metal-laden fly ash and acid gases, mainly in form of HCl and SO_2. In order to meet severe emission standards, all EU incineration facilities must have at least one flue gas cleaning system installed to collect the fly ash and neutralise the acid gases. Though they come in a variety of configurations, overall two different types of cleaning systems exist: wet or semi-dry/dry. In the EU, residues are classified as hazardous. The lion's share end up in depleted salt mines, as they are considered safe sites for long-term waste disposal.

The role of PVC

Municipal solid waste composition varies greatly across the EU. Generally speaking, it includes refuse collected by municipal authorities from a wide range of sources, e.g. households, public institutions and businesses. Currently, about a quarter of the waste is incinerated, while the rest is either landfilled, or recycled or composted. Of the total waste incinerated, PVC's contribution is a mere 0.7 % on average. Because of the plastic's high chlorine content, about half of the chlorine in the waste can be attributed to PVC. The other major source is putrescibles—popularly speaking salt-containing food—and to a minor extent paper, textiles and other types of trash. Of the total residues produced

Air pollution control residues in big bags from an incineration plant in Denmark awaiting disposal. These neutralisation residues are normally disposed of in German saltmines. Promising new technologies will in future limit the residues to be disposed of.

in European municipal waste incinerators, PVC accounts for less than 1.5 %. With regard to bottom ash, PVC's contribution is negligible. In fact, the presence of PVC in the waste stream is beneficial, as the chlorine contributes to reduce the heavy metal content in the bottom ash. HCl helps to volatilize the metals, which are transported to the fly ash instead. Environmentally, this is the best solution, since the problematic metals become concentrated at minimal volume.

The heart of the matter is flue gas cleaning residues, of which PVC accounts for approximately 10 %. However, the story is not as simple as it appears. As mentioned earlier, fly ash contains heavy metals, which may cause leaching problems and are harmful to the environment. Today, PVC's contribution to heavy metals in the fly ash is marginal. This was not always the case. Traditionally, heavy metals such as cadmium and lead were used as stabilizers in PVC. In 1993 for instance, the plastic contributed to 11 % of the cadmium load and 1 % of the lead load in the waste. Yet in 2000, the European PVC industry set up the Voluntary Commitment, also known as Vinyl 2010. Here it was agreed upon to phase out cadmium by 2001. Under the renewed commitment VinylPlus, in force from 2010, lead is to be phased out by the end of 2015. Indeed, the industry is shifting from heavy metal-based stabilizers to non-hazardous substances.

Neutralisation of HCl is the main issue, but again cautiousness must be applied before drawing conclusions. First of all, the flue gas cleaning system in place largely determines how much residue is generated—and also how much can be attributed to PVC. The wet process is both the most effective and least harmful to the environment. Here the HCl is scrubbed with an alkaline solution, which is subsequently washed and released as ecologically harmless wastewater. The semi-dry and dry systems

	Increase in flue gas cleaning residue due to PVC waste (weight %)
Wet process	+5 %
Semi-dry process	+19 %
Dry process	+20 %

Table 1. Source: Hjelmar 2002

produce significantly more residue material, as seen in table 1. Fortunately, the wet process is the most widely used air pollution control system in Europe. Thus, PVC waste is an issue when incinerated. But as such the real culprit is the chlorine, not PVC. Studies have shown that removing PVC from the waste stream does not eliminate the need for neutralisation of HCl. In other words, as long as the salt-containing foods we throw out end up being incinerated, HCl will continue to be an issue.

Sulphur dioxide—a much larger problem
Perhaps more attention should be directed toward SO_2, which is a much larger problem than HCl. And here PVC bears no responsibility. SO_2, or sulphur dioxide, is an acid gas formed when sulphur-containing waste such as putrescibles, paper, rubber and plasterboard is incinerated. Especially in regard to acid rain, SO_2 has a worse track record than HCl. Since the debate over acidification of the environment raged in the 1960s, 1970s and 1980s, sulphur emissions have been cut dramatically in Europe, in practice eliminating the problem. Flue gas cleaning in waste incineration plays a central role. But on the flipside, S02 is harder to neutralize than HCl and therefore generates excessive amounts of residue.

New technologies
Moreover, promising new technologies are changing how residues are treated. The traditional neutralisation method was based on the use of hydrated lime, which required disposal at hazardous waste sites. Yet an increasing number of incinerators, especially in Germany, now recover the chlorine as commercial grade HCl to be used for a wide range of purposes. Worth mentioning are also the Neutrec, Solvair and Halosep projects. In the Neutrec process, sodium bicarbonate acts to neutralize the acid gases, which are subsequently converted into recoverable salts. The only solid residue is insoluble phase. Taking this a step further, the Solvair process recovers the insoluble phase to make sodium carbonate, a raw material in glass production. The purpose of the Halosep project is to recover the HCl and limit the residues to be disposed of. While Halosep is still in its pilot phase, the results so far are promising.

Costly and complicated corrosion

Another central element in the discussion over PVC waste relates to corrosion. In waste-to-energy plants, corrosion of the steam-producing boilers is a persistent concern. A very costly affair, corrosion is also highly complicated and not fully understood. Though there is wide agreement that HCl has a stimulating effect. Again, the problem is the chlorine, which would exist in the waste even if German chemist Fritz Klatte had not patented PVC a hundred years ago. However, the exact influence of chlorine is unknown. Studies show that burning wood with a chlorine content a hundred times lower than typical waste results in the same corrosion found in municipal solid waste incinerators. Also in play are a host of other parameters including sulphur, temperature, water content of the flue gas and boiler surface material. Thus, the verdict on PVC and corrosion is still up in the air.

About 40 % of all plastics-based medical devices are made from PVC, most of which are incinerated after use. Despite this high percentage, the PVC used for the manufacture of medical devices only makes up 1 % of the total PVC raw material production. Yet this 1 % is used quite efficiently. For instance, it only takes 4 to 5 tonnes of medical grade PVC to produce 80,000 blood bags. Also within the medical device area, mechanical recycling of PVC is increasing. For instance, recycling projects are taking place in the UK, Australia, New Zealand and Thailand.

The bigger picture

Taken all this into account, the question is whether it makes sense to avoid incineration of PVC waste, as some has suggested. For others, the only solution is to ban PVC products altogether. Common sense should guide the discussion, and this is not always the case. Consider the following: if the main problem seems to be chlorine, why is chlorine-rich table salt not prohibited? Limiting the intake would also benefit public health as well as the bloating budgets of the European health care systems. Such a statement is bogus but nevertheless falls in line with much of the PVC-bashing. The pros and cons should be weighed before deciding whether PVC should be kept out of incinerators. Yes, PVC waste does produce HCl when combusted. However, modern municipal waste incinerators, which also generate power for millions of European households, are equipped with air pollution control systems to neutralize the acid gas. Not least because of such efforts, acid rain is no longer a real concern in Europe.

Yes, PVC waste does contribute to the amount of residue to be disposed of. Yet the most common flue gas cleaning systems in Europe—the wet—also generate the smallest amount of residue. Here, PVC waste accounts for approximately 5 %, which is washed out and released as ecologically harmless wastewater. Also, new technologies can recover the HCl and help reduce the residues to be disposed of. Besides, even if no PVC waste reached the incinerator, the flue gas would still need treatment—not least because of the SO_2. And in regard to corrosion, PVC's impact can be kept under control by appropriate operation.

Incineration of PVC waste is thus not unproblematic, which the European PVC industry is well aware of. For this reason, VinylPlus has set ambitious goals to increase recycling: by 2020, 800,000 tonnes should be recycled per year. Clocking in at 481,018 tonnes for 2014, the industry is more than halfway only four years into the program. As the EU waste hierarchy signifies, this is the way to go.

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