Incineration plant in Vienna, Austria embellished by F. Hundertwasser

Understanding the Basics:

How Regulation and Industry Innovation Have Eliminated Dioxin Emissions from PVC Production and Waste Incineration

In a recent scientific study carried out under the direction of professor Alfons Buekens, over 200 studies on PVC and dioxins in combustion and fires are reviewed. The overall conclusion is that PVC does not represent a problem in modern municipal solid waste incinerators. Likewise, the European PVC industry accounts for negligible 0.1 % of the total dioxins emitted by human activities. The only remaining issue related to PVC and dioxins is uncontrolled burning of waste, a practice that should be eliminated anyway for reasons unrelated to PVC.

By Tobias Johnsen

vinyl plus
COMMITTED TO SUSTAINABLE DEVELOPMENT

PVC plant, Sweden

PVC manufacturing plants were once blamed for spewing out poisonous dioxins, and labelled "dioxin factories" by Greenpeace. This no longer the case, thanks to a concerted effort by industry and regulators. Today, the European PVC industry accounts for 0.1% of the total dioxins emitted by human activities.

Dioxins. The word in itself sounds ominous. And for the average citizen, dioxins spell trouble. One might remember the Seveso Disaster in 1976, when a chemical factory exploded in northern Italy and exposed the nearby human and animal population to a dioxin-laden cloud. Perhaps an image of the grueling results of the dioxin-contaminated herbicide Agent Orange sprayed by the U.S. in the Vietnam War is conjured. A younger person may recall Viktor Yuschenko, the Ukranian President whose acne-scarred face appeared on the news after he was poisoned by what is widely suspected to have been dioxin in 2004. Horror stories abound, and with good reason. Dioxins encompass a group of chlorinated organic substances with similar chemical structures, known to cause cancers, skin disorders and damage the immune system, among other harmful effects.[1] To make matters worse, dioxins bioaccumulate, are toxic at low levels and do not degrade easily.

Dioxin formation is a complicated matter, explained by different but overlapping theories. The short version is that they are unintended byproducts of industrial processes that contain chlorine, or when chloride matter is burned. This means that both human and non-human activities contribute to dioxin emissions. One side of the coin is thus man-made actions such as industrial production, incineration of waste or even burning wood in the stove to keep warm during winter. The other is forest fires, volcano eruptions and other activities outside the human domain of action.

1 The technical terms are polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), a group of 210 compounds with similar characteristics—the only difference being where on the rings the chlorine atoms are attached.

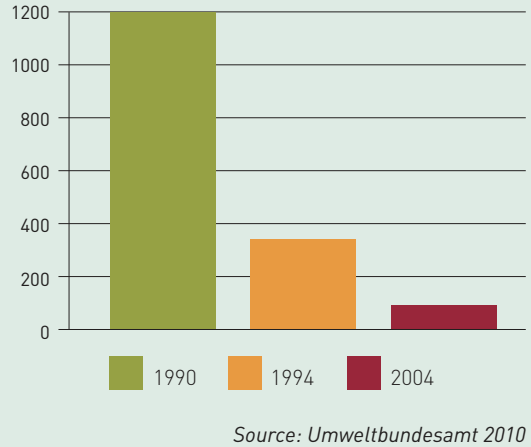
A success story

Naturally, most attention has centered on the dioxins for which humans are responsible. The first concerns date back to the late 1800s, when laboratory workers developed chloracne after being exposed to dioxins. Yet it was not until the aforementioned Seveso Disaster that the issue took forefront. A year later, a Dutch scientist found dioxins in fly ash from municipal waste incinerators in the Netherlands. It became clear that dioxin formation is exacerbated by incomplete combustion, the presence of fly ash or transition metals as catalysts. Also, scientists discovered that dioxins appear whenever carbon, hydrogen, oxygen and chlorine react together at temperatures between 300 and 500 °C. Conversely, dioxins are destroyed above 900 °C.

Through the 1980s and 1990s, dioxins were increasingly put under scrutiny. The main villains were the chemical and steel and iron industries as well as combustion of municipal and chemical waste. Yet the recent history of dioxins, at least in the industrialized world, is actually much more positive. One could go as far as to call it a success story. Since the emission of dioxins from industrial production and waste incineration peaked in the 1980s, authorities and industries have enacted measures that have led to dramatic cuts. In the European Union, industrial emissions have been reduced by up to 90 % since the 1980s. A look at figure 1 shows the impressive progress in Germany, Europe's largest economy. In the US and Japan the reductions are equally remarkable, as documented in figures 2 and 3.

For one thing, legislation has been passed to make incineration of waste a much cleaner affair. Large, centralized facilities with mandatory technologies to clean flue gas and fly ash have replaced obsolete incineration plants and landfills in many parts of the world. Just as importantly, industries have shown responsibility and done their part to curb emissions.

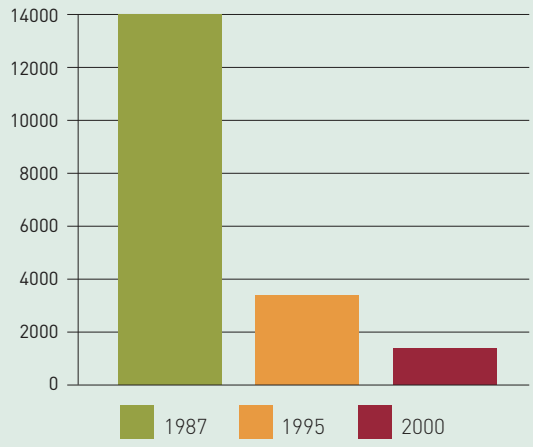
Figure 1
Dioxin emissions in Germany, total annual volume in g I-TEQ



Source: Umweltbundesamt 2010

Germany, which is Europe's largest economy and ranks fourth in manufacturing worldwide, has successfully tackled dioxin emissions.

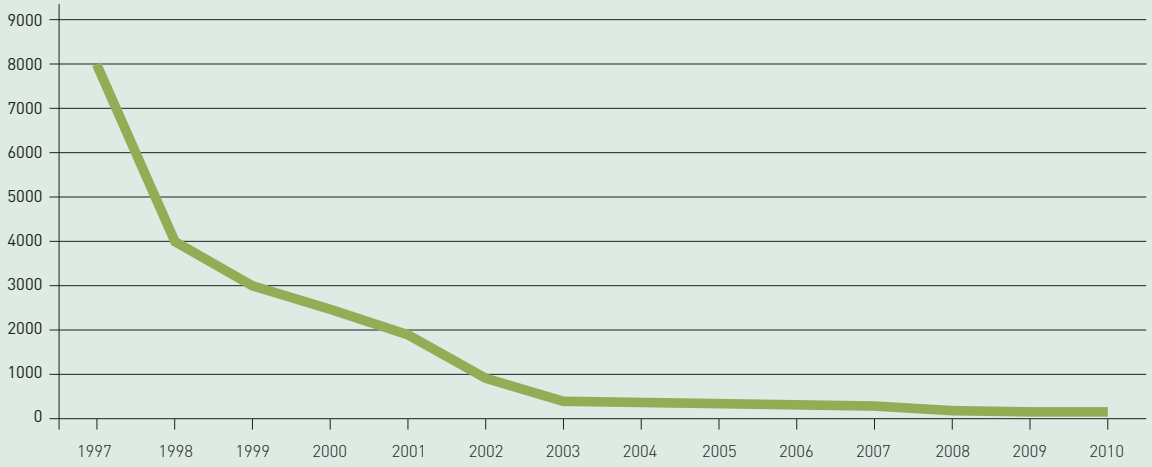
Figure 2
Dioxin emissions in the U.S., total volume in g TEQ



Source: EPA 2006

Until recently the world's largest economy and manufacturing nation, U.S. dioxin emissions have dropped tremendously since the 1980s.

Figure 3
Dioxin emissions in Japan, total volume in g TEQ



Source: Government of Japan 2012

Between 1997 and 2010, Japan's dioxin emissions plummeted.

From "dioxin factories" to clean-tech

PVC and dioxins is a couple with a history, to say the least. In the 1980s and especially in the 1990s, when the debate over dioxins reached a boiling point, PVC was blamed by some as the major culprit for the emissions. Greenpeace summed up the general view in a paper from 1993: PVC manufacturing simply equated "dioxin factories." Or put even more bluntly – if we get rid of PVC, we get rid of dioxins.

The critics had a point, partly because of the material's chemical composition. Since PVC is chlorine-rich it contributes to dioxin emissions when produced and disposed of. However, much has been done on at a European level to make PVC production a cleaner affair. Currently the European PVC industry accounts for around 0.1 % of the total dioxins emitted by human activities.

Again, this is the result of both industry and lawmakers. European PVC resin manufacturers committed as early as 1995 to a charter to tightly limit dioxin emissions during manufacturing, and to periodic verification. Manufacturing is also tightly controlled by Best Available Techniques provisions and EU regulations. And in 2000, representatives from all parts of the production value chain joined forces and formed Vinyl 2010. Inviting representatives from the EU authorities and being externally audited, the partnership continued the 1995 charter and set a number of new, ambitious sustainability goals to be met by 2010 on a voluntary basis. Having met all goals, the partnership decided to continue under the new moniker VinylPlus, with new targets for 2020. In regard to dioxins, VinylPlus "will help to ensure that persistent organic compounds do not accumulate in nature and that other emissions are reduced."[2] As such, the real problem is not on the manufacturing side – it is what happens to the PVC when it leaves the factory, and especially when burned in uncontrolled settings.

2 VinylPlus 2011

Incineration plant, Denmark

In modern, centralized waste incinerators, dioxin formation is no longer a problem. Due to its high chlorine content, PVC has taken much flak for contributing to dioxin emissions when incinerated. However, science documents that the volume of chlorine in the waste has far less influence on dioxin formation than factors relating to the combustion process, namely temperature, residence time and oxygen concentration.

PVC plant, Norway

Uncontrolled combustion – the main issue

PVC is ubiquitous. Highly flexible, cost-effective and easily manufactured, the plastic is used for building materials, medical devices, cable sheathing and auto parts to name just a few examples. Though the European PVC industry has done much to increase recycling, most still end up as waste which has to be disposed of one way or another. While PVC accounts for only 0.7 % of the total waste handled by municipal incinerators, the material contributes 40 to 70 % of the chlorine input. Thus, the groundwork is laid for high dioxin emissions. When treated properly, however, PVC waste is not an issue.

In a new, yet unpublished scientific study funded by the European Council of Vinyl Manufacturers and conducted by researchers at Zhejiang University in China – under the direction of renowned professor Alfons Buekens – over 200 studies on PVC and dioxins in combustion and fires are reviewed. The overall conclusion is that PVC does not represent a problem in modern municipal solid waste incinerators. Here, the high temperatures, controlled oxygen levels and technologies to clean fly ash and flue gas ensure that dioxins are eliminated and that chlorine can be extracted either as hydrogen chloride soluble in water or as neutral salt. Further, while PVC's chlorine content does influence the formation of dioxins, other factors relating to the combustion process, such as temperature, residence time and oxygen concentration, are far more important. In other words, there is not a reciprocal relationship between the chlorine content and dioxins. If all PVC was eliminated from the waste, dioxins would still be formed. This is in line with both the European Commission's 2000 *Green Paper on Environmental Issues of PVC* and previous research. Clearly, the main issue is what happens outside the modern municipal waste incinerators.

Backyard burning in Puerto Galera, Philippines

Open "backyard" burning of household trash is bad for the environment and should be eliminated. It produces dioxins, in part due to the chlorine content in the trash. Though the chlorine-rich PVC contributes, dioxins would still be emitted if the plastic was excluded from the waste: most household trash contains chlorine, especially in the form of common salt. Other byproducts of open burning include particle pollution and cancer-causing polyliclc aromatic hydrocarbons.

Medical waste burned onsite

One aspect is medical waste. PVC only accounts for 5 to 15 % of all medical waste but represents a serious problem if burned onsite. The often small and outdated furnaces at hospitals are simply not equipped to handle dioxins nor other forms of air pollution for that matter. Traditionally, onsite incineration has been regarded as an effective and sanitary way of disposing the often-contaminated medical waste, but the practice is in fact a major dioxin emitter. And with the rapidly increasing volume of medical waste worldwide, the authors stress that the shift to centralized incineration plants should be accelerated. However, this is mainly a problem in developing and BRIC countries. In the U.S. and European Union for instance, medical waste incineration is subject to strict regulation. Additionally, an increasing focus on the possibility to recycle PVC medical devices will in the future probably reduce the amount of PVC medical waste being incinerated.

Backyard burning

Another major concern is backyard burning of household trash, a widespread practice in the developing world and rural parts of the U.S. Whether burned in a stove, open barrel or furnace, this is a fail-safe dioxin generator due to the low combustion temperatures, poor air distribution and presence of chlorine from PVC and other sources, especially common salt. Other byproducts of backyard trash-burning include particle pollution, cancer-causing polycyclic aromatic hydrocarbons and harmful volatile organic compounds. In fact, the U.S. Environmental Protection Agency has categorized the practice as a serious health hazard.

Cable burning

In poor parts of the world it is still common to burn the plastic coating around cables to recover valuable copper wiring. PVC is a popular material for cable coating, due to its low cost, high flame resistance and electrical insulation. With chlorine, a catalyst (the copper) and carbon (the coating) present – in combination with the uncontrolled nature of the fire – cable burning will result in considerable dioxin formation. Fortunately, the practice is waning but still a problem that must be tackled.

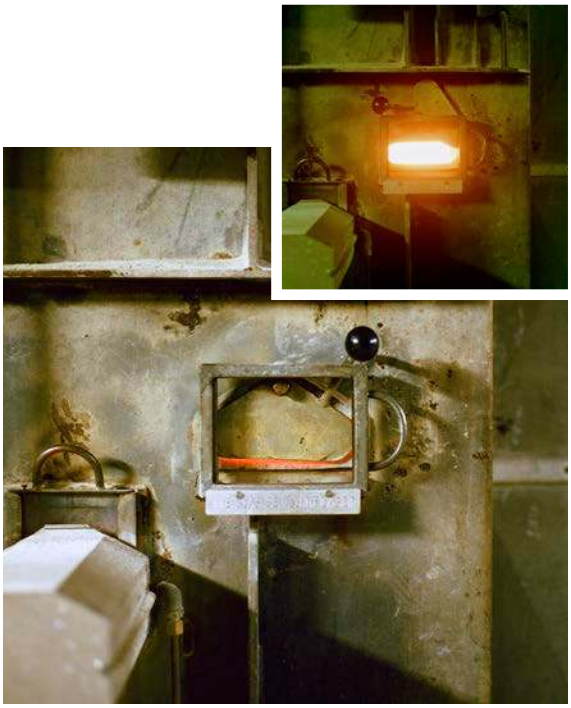
Landfill fires

Landfilling encompasses a common but highly problematic way to handle trash, not least because of fires above and below ground. Of the two, subsurface fires are the most problematic since they have temperatures ranging from 80 to 230 °C, far below municipal waste incinerators. Usually, PVC – in form of flooring, cable wires, pipes and rigid foils – contributes to about 40 % of the chlorine content in landfills, thereby facilitating dioxin formation. The combination of low temperatures, high chlorine content, incomplete combustion; heterogeneous, compacted and poorly mixed materials, moisture, and lack of oxygen make subsurface landfill fires a fertile breeding ground for dioxins. However, more studies are needed to assess the combined effects. Policies to discourage landfilling of waste have been in place in the EU and other developed parts of the world for many years, with some success e.g. in Germany. More should be done, be it only because landfilling plastics is a waste of non-renewable resources.

House fires

Houses are increasingly equipped with PVC, in form of piping, flooring, window frames, wire insulation etc. This poses a problem in the event of fire. However, PVC is not the only culprit here. Since many other building materials contain chlorine, they will inevitably generate dioxins when burned uncontrolled. In fact, the authors point to several studies which show that the potential for dioxin formation is similar for PVC and wood. In terms of general toxicity and fire, the hydrogen chloride released by PVC is considerably less dangerous than the acrolein and hydrogen cyanide released by wood, nylon, leather and wool. Also, the high chlorine content of PVC reduces ignitability and heat generation. The material thereby possesses much valuable self-extinguishing properties in case of fire.

Incineration plant, Denmark



The scientific verdict and the next steps

The scientific verdict by professor Buekens and his colleagues is pretty clear: when properly incinerated, PVC waste is not problematic. Removing the material from the waste would not make incineration a dioxin-free affair. Dioxin formation happens in landfill fires or when burned in obsolete plants or out in the open. These practices should be eliminated, not only because of dioxins, but also to curb carcinogenic polyaromatic hydrocarbons. As mentioned earlier, dioxin emissions during the production of PVC is a marginal problem. However, VinylPlus is committed to continue the positive development when it comes to manufacturing, recycling and waste management.

Incineration plant, Denmark

Tobias Johnsen is a Master of Arts and writes for VinylPlus

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