Gas evolution during FDM 3D printing and health impact

Dott. **Fabrizio Merlo**, fabrizio@3dsafety.org
Dott.Ing. **Stefano Mazzoni**, stefano@3dsafety.org

undertaken with **WASP Project by CSP Srl**, www.wasproject.it

Why shall we talk about this topic?

In recent years we are seeing the exponential diffusion of 3D printers, that quickly became popular as they allow the production of small prototypes series with costs and production time that are becoming smaller day after day. For example, more and more often you can find these devices in the meeting rooms of large and small professional firms or in the bedrooms or in the small garage of some the youngs (and not so youngs) makers that tries to develop his small and big dreams, using additive manufacturing also.

Thanks to an intensive cooperation with WASP (www.wasproject.it) we have been able to deepen the "collateral damage" of 3D printing in terms of healthiness of the workplace; in fact WASP is always driven by a high sensitivity to ecology in its projects and when we proposed them to carry evaluation tests, the company has provided its products and knowledges.

FDM technology 3D printers use plastic materials in the form of solid filament which, passing through an extruder at a certain temperature, stratifies the material to form the desired object. One of the many printing settings is the melting temperature, that can be set up over 260°C. The melting process of the plastic filaments emits both **gaseous substances**, commonly indicated with the term VOC (Volatile Organic Carbon), and **nanoparticles** of various size of the order of several tens of nm.

The object of the research has focused on the qualitative assessment and not just the formation of molecules and nanoparticles that persists in the environment, referring to the main existing literature available about this subject.

Some studies conducted since the mid-90s [1,2], have shown that in the process of melting and machining the of plastic materials particles and gaseous substances harmful to human health are generated in the surrounding; for example ammonia, hydrogen cyanide, phenol, benzene, etc.

During a laboratory test [3] where it was monitored the variation in the concentration of VOCs during the printing process of plastics and studies have shown, for example, that ABS is more toxic than the PLA, but that the PLA under certain conditions is not free of emissions harmful to health, especially if melted at temperatures over 200°C [4-6]. At the same time the same material emits substances in quantities significantly different from one supplier to another, even if used in the same printer, printing the very same model at the same parameters of speed and temperature.

Another critical issue is connected to the high concentration of ultrafine particles (several billions of ultrafine particles per minute for single print job), with sizes less than 0.1 microns, smaller then a ten-millionth of a meter, so small that can be absorbed directly by the pulmonary alveolus and from the epidermis.

One laboratory experiment [7] has compared the amount of nanoparticles produced in the case [A] of two printers run with only PLA filaments with the case [B] composed of the same two printers together with three printers working with ABS filaments. The result of this comparison is that the concentration of particles emitted in the second case [B] varies from about 3 to 30 times the concentration of particles emitted by printers working only with PLA filaments. The test also wanted to highlight how, after switching off the printers, the decay time, the time necessary to halving the concentration of the particulate spread in the environment, would vary according to the size of the nanoparticles; it takes from 10 to 30 minutes to get a room "sufficiently" healthy.

Using PID PhotoIonization Detectors it was possible quantitatively detect the VOC pollution from PLA, Nylon, ABS, polystyrene and PET bought from different manufacturers, obtaining confirmations of what mentioned above.

What are the effects on human health?

Both the gaseous molecules and the nanoparticles are inhaled by humans through the olfactory system. The ultrafine particulate is deposited mainly in the cells of the respiratory organs and through the olfactory nerves of the nasal mucosa it reaches the brain. The single exposure through the skin allows a partial absorption.

Recent studies [8-11] have highlighted how nanoparticles are able to enter into human blood system in less than a minute. Once absorbed in the respiratory tract, skin and gastro-intestinal tract, the particles may reach the systemic circulation and migrate successively in different organs and tissues: in particular the organs that appear to be most vulnerable are the liver and the spleen, which perform a job of filtering toxic substances in the human body, aggravating their functionality.

The most common diseases caused by the absorption of the gaseous substances (VOC) and of the nanoparticles produced during the printing process are those in the lungs (bronchitis, tracheitis, asthma etc.), and they may trigger some forms of cancer. Various studies [11-14] have shown that **these diseases are related to oxidative stress caused by emissions of toxic substances that affect human cells accelerating their aging**.

What to do? What are some solutions?

In these months we have decided to raise awareness and makers on this issue, also through the creation of a project called "3D Safety" (www.3dsafety.org) where institutional and private players and the makers community will be involved in raising properly those who want to approach safely the 3D printing technology,and where will be offered new technical solutions that will be shortly introduced in Italian WASP printers.

So far it is already possible to give some tips and suggestions, such as using the printers in ventilated places, even better if provided with an air exchange system with a primary power of at least 3 volumes of the room per hour (eg. a room of 100 m^3 should have an air exchange system that allows at least 300 m^3/h of treated air).

For those printers with closed cabinet, the 3D Safety team is studying some solution based on activated carbon filtration, selected according to the type of print material; In fact, PLA, ABS and Nylon not emit all the same type of substances therefore they need proper filters, that have to able to adsorb the VOCs depending on the type of plastic material used.

If the above is certainly interesting in terms of absorption of gas molecules, the same technology cannot be used to neutralize of the ultrafine particulate, where activated carbon is not effective.

During past months our team has designed and realized the first prototypes of a synthesis of technologies that will lead to a positive impact both on the front of the neutralization of the molecules both and the reduction of the nanoparticles, with extremely limited costs with the hope for a rapid diffusion not only in the maker community.

On **saturday October 17th in Rome during Maker Faire 2015 at 3.00 pm, room 4,** will be held a speech about this topics. The main purpose is start to inform people about 3D printing pollution and smart behaviors to avoid it.

Let's follow us!

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