

REPLACING HAZARDOUS RESIN WITH 3D PRINTING TO MAKE MOULDS

1 General information

Country: Croatia.

Available language: English.

The **sector covered** in this case study is manufacture of perfumes and toiletry preparations.

Tasks covered: handling of chemicals, manufacture.

Worker groups covered (vulnerable groups): all workers (no specific groups) and pregnant workers.

The **purpose of this example of good practice** was to raise awareness and provide training.

The **target groups** are OSH consultants, managers and supervisors.

2 Initiator/organisations involved

LUSH Manufacturing Croatia, Strmec, Croatia.

Occupational Health Service, Samobor, Croatia.

Institute for Medical Research and Occupational Health, Zagreb, Croatia.

3 Description of the case

3.1 Introduction/background

Biological agents: none.

Hazard — physical state: aerosols, gases, liquids, vapours.

Hazard — health effect: allergens, reprotoxic substances, irritants, toxic substances.

Exposure route: inhalation and skin absorption.

Substance description (CAS/EC) (only if possible): epichlorohydrin (106-89-8/203-439-8), bisphenol-A (80-05-7/201-245-8).

The company has been manufacturing handmade cosmetics from fresh organic raw materials since the early 1970s in the UK. The Croatian subsidiary was founded in 2005. LUSH Manufacturing has 457 workers, of whom 65% are women who work in production departments, support and administrative teams. The company has a national licence to use hazardous chemicals.

The basic business principles of the company are environmental protection, human rights protection and animal protection. The company is registered for perfume and toiletry cosmetics production. Production is divided into departments, and each department produces a certain product line (face masks; soaps; massage bars; shower gel, shampoo and creams; cosmetic powders; decorative cosmetics and lip balms; mouth-refreshing tablets; bath balls; bubble bars; and gifts). The production cycle of each department lasts for 2 weeks (10 working days) to ensure the freshness of the products, which have a 3-week expiry date. Within this period, products are produced and distributed, depending on the order. Each department has a manager and the manager's deputy, who are responsible for the production and

the workers. Other activities performed include creative and ethical procurement, environmental protection, research and development, and manufacturing of moulds that are used in production. The moulds are used by hand to shape the finished products. They can be used, on average, three to eight times, or until they are damaged or deformed. Liquid products, such as soaps, are poured into moulds and left for a few hours to harden, while products in the form of paste, such as bubble bars, are shaped inside the mould by hand and then left to harden (see Figure 1). These moulds do not remain on the product as permanent packaging. All products leave the production facilities wrapped in paper only.

Figure 1. Using a mould to make a ball-shaped product.



Previously, moulds were ordered in bulk from the UK on a monthly basis. In the last 3 years, as production has grown, it has been decided to open a mould production department in the Croatian plant. It started production in April 2016, using epoxy resin as a raw material. The mould department used over 300 kg of epoxy resin and over 10,000 kg of polyethylene terephthalate (PET) plastic. Epoxy resin was chosen because it made it possible to develop moulds with very detailed shapes (such as flowers or letters; see Figure 2).

Figure 2. The epoxy mould has the positive shape of the final product.



The process of mould production is the following (see Table 1):

- An initial master mould is made, which has the negative form of the end product (e.g. of the soap). This master mould is sent from the headquarters in the UK.
- Epoxy resin is manually mixed with a curing agent for approximately 10 minutes.
- The resin is left for a few minutes so that all the bubbles can get out.
- The resin is poured into the master mould to take the shape and cure (for about 12-24 hours.)
- After the curing process is completed, this mould, which has a 'positive shape', is removed (see Figure 2).
- The positive moulds are finely ground for a finishing touch and are mounted on a wooden board (see Figure 3).
- A set of positive moulds is used to make the negative moulds of PET (see Figure 4).
- The PET moulds are used in production (see Figure 1.)

Table 1. The process of mould production in the old and the new technology

	Master mould		Positive mould		Production mould
Shape	Negative		Positive		Negative
Lifecycle	Until specific product is produced		Until specific product is produced		Used for three to eight times, until it breaks or loses shape
Original process	Handmade from epoxy resin (not recyclable)	→	Handmade from epoxy resin (not recyclable)	→	Made from PET (recyclable)
New process	Not required any more		3D print from acrylonitrile butadiene styrene (ABS) plastics (recyclable)		Made from PET (recyclable)

'Positive', shape of the final cosmetic product.

Figure 3. Moulds made from epoxy resin.



Figure 4. Moulds used in production are made from transparent PET plastic.



Epoxy resins and polyamine hardeners are highly hazardous compounds. They are moderate to strong irritants and potent occupational allergens. Skin contact with the individual components or the ready-for-use mixed product may lead to allergic contact dermatitis, primarily on the hands or forearms and sometimes on the face. If the curing agents are relatively volatile polyamine hardeners (boiling point below 250 °C), or if the product is applied by spraying, the airways may be affected as well. Workers may be at risk of strong airway irritation and occupational asthma. Epichlorohydrin, one of the constituents of the epoxy resin monomer, is a skin sensitiser but it is also classified as carcinogenic in category 1B (presumed carcinogenic potential for humans), according to the EU classification. However, prior to curing, a high-quality epoxy resin contains only a very low amount of residual epichlorohydrin (<0.001 %). The other constituent of the epoxy resin monomer, bisphenol-A, is a skin sensitiser, reproduction toxin class 2, and a known endocrine disruptor. Although the amount of bisphenol-A in final epoxy products is not known, it is one of the reactants used in the manufacture of epoxy resin monomers, and exposure should be minimised, preferably by using closed production equipment.

3.2 Aims

As epoxy resins are highly hazardous, the company decided that it needed to replace it with a less harmful substance. The substitution can help to prevent long-term chronic health problems that tend to develop in workers who deal with epoxy resin on a daily basis. The production process will become safer and more productive.

3.3 What was done and how?

A working group was formed, which included the managers from the following departments: production, facilities and maintenance, research and development, environmental protection, health and safety, and moulds.

3.3.1 Information gathering

Initially, the following prerequisites of the mould production setup were reviewed: equipment and space, staff, safety and health obligations, support from external safety and health companies, production requirements and so on. The experts did all the necessary inspections and testing to obtain the results that would help provide the best working conditions possible. The safety data sheets for epoxy resin and hardener used in moulds production were reviewed.

3.3.2 Interim measures

The following actions were provided to workers exposed to epoxy resins:

- periodical medical examinations at the occupational health service (every 12 months);
- continuous revision of working clothes and personal protective equipment (including gloves, goggles and facemask with filters) (see Figure 5);
- tailored safety and health training (with an emphasis on working with hazardous substances);
- organised training with the Croatian Institute for Toxicology and Antidoping;
- relocation of pregnant/breastfeeding workers to safer work places for as long as needed, in agreement with the occupational medicine specialist.

Figure 5. Making moulds while using personal respiratory and skin protection.



3.3.3 Substitution

Later, based on all data that were collected, the working group prepared a new solution for the substitution of epoxy with acrylonitrile butadiene styrene (ABS) plastics. A suitable 3D printer and ABS plastics for the moulds production were identified.

ABS plastics are heated to 90 °C for 13-20 seconds in a shaping process. ABS copolymer is a synthetic resin containing less than 0.1% of styrene monomer. ABS is not classified as a hazardous chemical, according to the EU Classification, Labelling and Packaging Regulation. However, heating above 250 °C may release irritating vapour, and dust inhalation or eye contact with ABS may also provoke irritating

effects. This temperature is far above the operating range. Although styrene exposure in relevant concentrations is not expected, periodic measurements of workplace levels is necessary to maximally reduce the exposure to well below the current Croatian occupational exposure limit (100 ppm, 250 ppm short-term exposure limit), especially if there are any changes in the working process. All in all, the ABS copolymer is a clearly less hazardous occupational substance than epoxy resins.

Initially, a Prusa 3D printer was tested to see the results with ABS plastic filament. The proposal was presented to the senior management, who agreed and gave their consent to the investment following the evaluation.

3.4 What was achieved?

First and foremost, the working environment became safer, and solution-focused communication was established. Neither the process nor the production waste is not toxic. The company can and will recycle ABS plastic waste, so it can also reduce total waste.

The biggest outcome of the programme is the safer process, which can help keep workers healthy. Workers can focus more on the job, so productivity is expected to rise. Crucially, workers value the effort, and engagement levels improved.

Some workers are now tracking all data necessary for continuous improvement and are responding to various situations. Communication became bidirectional; workers actively participate in risk management, ask for support and give valuable information to the occupational safety and health experts.

3.5 Problems faced

Primarily, the challenge was to inform and convince workers that all measures are aimed at improving their safety, rather than imposing limiting restrictions and unnecessary rules. This challenge has been successfully overcome through various daily education and information sessions on internal controls and everyday practical examples.

It was a challenge to explain to the senior management why it was necessary to change an efficient process (safety and health issues all complied with regulations), especially given that the parent manufacturer in the UK uses epoxy resin for mould production. The proposal was developed and presented to the senior management in collaboration by research and development and safety and health managers. The main argument in support of it was that the process would be safer in the long term. Additionally, with 3D printing, the company can produce as many identical master moulds as it wants, without the possibility of human error. Following the implementation, the finished products will pass quality control on the first test regarding weight and visual control.

3.6 Success factors and challenges

The following factors contributed to the success of the measure:

- management's commitment: positive attitude towards safety and health issues;
- team work: company managers and senior managers from different departments;
- participatory approach: involvement of everyone in decision making and in finding solutions;
- the workers' education programme;
- strong commitment to quality solutions in every aspect (satisfaction cannot be valued in financial terms, and it can be a challenge to present satisfaction as necessary).
- The challenge now is to maintain the high level of cooperation between the managers in the production, health and safety, and environmental protection departments.

3.7 Transferability

The systematic approach taken by the working group can be transferred to any other company. The method is very suitable for mould making but it can be generalised to higher levels. It may be easier for bigger companies, because they have the expert workers and financial resources at hand.

3.8 Costs and/or economic impacts

No cost-benefit analysis has yet been undertaken to identify if costs have reduced. However, after a reasonable period, such an analysis will be conducted. The price of the 3D printing machine was around EUR 1,000.

3.9 Evaluation

This case study:

- is transferable to other companies/sectors/countries;
- focuses where possible on preventing risk at source;
- includes all relevant parties, especially those who will be affected by the actions;
- comes from a credible source;
- does not include/contain advertisements;
- is innovative/interesting;
- involves a realistic work situation;
- provides a contact for further information.

3.10 Further information

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