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NAIL VARNISH PACKAGING AND RESIDUE WASTES: PROBLEMS AND SOLUTIONS

Emily Appleby and Peter J. Shaw *

University of Southampton, Highfield, Campus, Southampton SO17 1BJ, United Kingdom

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ABSTRACT

As global consumption of nail varnish grows, quantities of packaging waste and residues will increase. End-of-use decisions for nail varnish have implications. Residues contain some hazardous substances, whilst packaging has potential for valorization. The extent of problems related to the disposal of end-of-use nail varnish products remains unclear. This study aimed to gain evidence to inform potential management measures. An inventory of hazardous substances in nail varnish products available in the UK was compiled to ascertain their potential for harm to the environment and/or human health. Discarded samples of end-of-use nail varnish products were then collected from volunteers in the UK to determine weights of packaging materials and residues. A parallel survey explored UK consumers' means of disposal and opportunities for positive change. All the brands examined contained at least one hazardous substance; over a hundred hazardous substances were identified in total for the 24 samples audited. Hazards to human health were most common. On average, 7.2g of nail varnish remained in bottles at the point of disposal. Average weights for glass bottles and plastic lids/applicators were 28.5g and 5.6g, respectively. End-of-use products thus generate small quantities of residues and packaging, but the cumulative impacts are potentially substantial. Disposal of end-of-use products with general household waste was evident: this leads to contamination of non-hazardous waste and fails to valorize the materials lost. Collection schemes for end-of-use nail varnish offer a possible way forward, but would benefit from fuller understanding of the potential for consumer engagement.

1. INTRODUCTION

1.1 Cosmetic consumer products

Cosmetics are ubiquitous and utilized every day across the globe for hygiene and beauty. Article 2 of Regulation No. 1223/2009 on cosmetic products (European Commission, 2009) defines them as, 'any substance or mixture intended to be placed in contact with various external parts of the human body…or with the teeth and the mucous membranes of the oral cavity with a view to exclusively or mainly to cleaning them, perfuming them, changing their appearance and/or correcting body odours and/or protecting them or keeping them in good condition' (European Commission, 2009).

Makeup, a sub-group of cosmetics, became popularised in the early 20th century through theatre, ballet and Hollywood (Chaudhri & Jain, 2009). Originally, cosmetic products were predominately available to wealthier members of society, but chemical and business innovation resulted in an increased accessibility for the mass market consumer within Europe and USA (Butler, 2000). There is a growing emerging market in economically-developing countries (Chaudhri & Jain, 2009). Inevitably, the observed increase in consumption of cosmetics is accompanied by increased consumption of resources and generation of waste, with associated adverse impacts upon the environment.

Ensuring cosmetic products are safe for consumer health has long been a priority amongst legislators and traders. Regulation No. 1223/2009 on cosmetic products (European Commission, 2009) bans specified substances from products and ensures product safety checks. However, the environmental impact of cosmetics has, to an extent, been overlooked despite greater awareness in recent years, evidenced by the banning of micro-plastics in popular cosmetic products across Europe (DEFRA, 2018). Across the wide range of cosmetics products, those used for the enhancement of finger and toe nails are of concern due to their potential impacts on the environment.

1.2 Nail varnish

Nail varnish, otherwise known as nail lacquer or nail polish, is a popular cosmetic product applied to nails to deco-

* Corresponding author:
Peter J. Shaw
email: p.j.shaw@soton.ac.uk

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rate them and, in some cases, protect nails (Draelos, 2016). Decorating nails can be traced to as early as 10,000 BC in Ancient Egypt, in which henna or a clay (red ochre) mixed with water were utilized to dye fingernails red, orange or yellow (Chaudhri and Jain, 2009). Similarly, the practice of staining fingernails using gum Arabic, gelatine, beeswax and egg, was present within China in approximately 3000 BC. Despite this long history, the use of products that would be recognised as nail varnish in modern society were not available until the 1920s, and originated from early nitrocellulose-based car paint technology (Draelos, 2016).

Within the last decade the consumption of nail varnish products has grown globally, with the market size reaching US$ 9190 million in 2018, overtaking sales of lipstick to become an economic indicator (Kenton, 2018; Trend, 2019). This trend is predicted to continue, with a compound annual growth rate (CAGR) of 8.5% (Sun et al., 2015). The observed increase in the use of nail varnish products can be attributed to multiple factors, such as increased availability, better quality products coupled with affordable prices and increased disposable income (Kestenbaum, 2017). As a consequence of increased nail varnish purchasing, the volume of nail varnish waste, including the liquid residues and accompanying packaging, has and will continue to increase. Therefore, it is important to understand if, and what, the environmental implications of this waste are and how to manage them.

1.3 Potential impacts of nail varnish disposal

The formulation of nail varnish varies between products, however the overarching composition is typically 70-80% volatile solvent, 15% nitrocellulose and differing quantities of a diverse range of other substances (Trend, 2019). Some of the ingredients contained within nail varnish products are classified as hazardous substances, i.e. have "… the potential to cause harm to humans, animals and the environment" (Institute of Hazardous Material Management, 2004).

The presence of some hazardous substances, such as toluene and formaldehyde, has undergone scrutiny (Quach, 2015; Sainio et al., 2006; Yokota et al., 2007). Attention thus drawn to the presence of such substances in nail varnish products has resulted in (1) toluene and formaldehyde being omitted from these products and (2) customers avoiding products containing these substances. However, nail varnish may still contain hazardous substances and many consumers may be unaware of this situation. Furthermore, many nail varnish bottles do not exhibit hazard symbols or information to inform consumers of a product's hazardous nature. Consumers themselves thus have to check a product's material safety data sheet for information, which can be hard to obtain (Environment Agency, 2014a). This is particularly problematic when consumers dispose of nail varnish.

Nail varnish products can be classified as hazardous waste or hazardous household waste if they contain hazardous substances under legislation (Table 1) and therefore require special disposal with strict control measures, similar to other hazardous wastes, as described by the Hazardous Waste Directive 2008 (Table 1; European Commission, 2018a). Moreover, it is 'illegal to mix a hazardous waste with either non-hazardous or another hazardous waste' under the Hazardous Waste (England and Wales) Regulations 2005, thus incorrect disposal is an offence (Environment Agency, 2014a). Regulatory controls for hazardous substances, however, do not apply to all sectors. For example, domestic waste is excluded from controls specified by The Hazardous Waste (England and Wales) Regulations 2005 unless "it comprises asbestos waste or is collected separately." (United Kingdom Government, 2005).

Despite this situation, hazardous components of household waste are poorly understood. There is a general consensus that amounts are small, thus disposal risks can be assumed to be negligible (Slack et al., 2005). There are concerns, however, that this assumption is not supported by robust evidence (Slack et al., 2005). Furthermore, as the consumption of nail varnish and other household products increases, the quantities of hazardous substances in the household waste stream will likely increase (Inglezakis and Moustakas, 2015).

There is a lack of literature pertaining to the environmental impacts associated with hazardous waste contamination of household waste streams. However, Slack et al. (2005) suggested that hazardous substances from improperly disposed hazardous waste can lead to hazardous leachate from landfills causing water pollution, and identified a need for research to quantify contamination resulting from household waste. Research pertaining to household hazardous waste has explored identification, volumes and sources of household hazardous wastes rather than the impacts associated (e.g. Slack et al., 2004, 2009). The volume of hazardous waste will inevitably increase and understanding these wastes is important for their effective management.

In addition to concerns regarding the fate of hazardous substances in nail varnish, there are implications regarding the fate of nail varnish packaging. As "high end" products (i.e. relatively small quantities of product at relatively high price), packaging is designed partly to ensure safe containment of the product and partly by the desire for the product to be attractive to customers. The quantity of

TABLE 1: Legislation relating to hazardous substances in the UK context.

Legislation	Notes
Hazardous Waste Directive 2008/98/EC	Defines hazardous waste as waste that has substances that are " harmful to human health or the environment" (HSE, 2019)
Hazardous Waste (England and Wales) Regulations 2005	Defines hazardous waste. States "It is illegal to mix a potentially hazardous waste with either a non-hazardous waste or another hazardous waste" (EA, 2014a)

packaging relative to the quantity of the product tends to be rather high and there is potential to recycle packaging materials.

1.4 Aims of the study

In view of the background to and content of nail varnish products, this study aimed to elucidate (1) the hazardous substances contained within nail varnish, in order to gain an understanding of the hazardous substances that could arise and contaminate household waste streams, and (2) the quantities of packaging associated with end-of-use or end-of-life nail varnish products and thereby the opportunities for recycling and implications of failure to do so, and (3) consumer behaviours relating to disposal of nail varnish products with a view to identify opportunities and challenges to improve management of residues and packaging. On the basis of information acquired, the study provides commentary on means to effect positive change.

2. MATERIALS AND METHODS

2.1 Overview

Data collection was undertaken in two phases. The audit of hazardous substance in nail varnish products was carried out first. In addition to providing information in focus, this audit also informed completion of the risk assessment and Control of Substances Hazardous to Health (COSHH) assessment for the subsequent evaluation of nail varnish packaging and residues in the laboratory. A questionnaire survey was undertaken to determine consumers' disposal behaviours, as well as their receptiveness to potential management initiatives or interventions. All elements of this study involving human subjects (sections 2.3 & 2.4) received ethical approval from the University of Southampton (reference number ERGO II 47510). All data collection focused on nail varnish products available in the UK. Samples of nail varnish packaging and residues were provided by citizens living in the UK. The questionnaire survey was distributed only to UK residents.

2.2 Audit of hazardous substances in nail varnish products

In order to ascertain an indicative profile of the types of hazardous substances contained within nail varnish products and their associated hazards, an on-line audit of ingredients contained within nail varnish products was performed (February to March 2019). Boots the Chemists Ltd (trading as Boots) and Superdrug Stores plc. (trading as Superdrug) are the UK's largest and second largest pharmacy, health and beauty chains respectively, each with a wide range of self-application nail varnish products (Boots UK, 2018; Superdrug, 2019). One nail varnish product from each brand sold by these stores was selected for this audit. Lists of products for each brand sold by each store were located on the stores' websites and the first pigmented product listed for each brand on the website was selected for scrutiny. The full list of contents provided within the description of each product was used as the basis for the hazardous substances audit. Any brands in which a list of contents could not be obtained were omitted from the study.

An internet search for a Material Safety Data Sheets (MSDS) for each ingredient present in the randomly selected nail varnish for each brand was conducted. If a Material Safety Data Sheet with a hazard statement was found, the ingredient was considered a hazardous substance and recorded. The associated hazard(s), both physical and health, were recorded for each ingredient. A matrix then was constructed to map hazard statements in relation to brand. This matrix was used to determine the number of brands containing each hazardous substance, and the percentage of brands audited that contained each hazardous substance.

2.3 Packaging and nail varnish residues

A combination of opportunistic and convenience sampling was used to obtain unwanted bottles of nail varnish from individuals in Southampton and London over a five month collection period (Lavrakas, 2008) from November 2018 to March 2019. A modified triple rinse procedure, originally used to clean pesticide containers, was utilized to remove residues of nail varnish from nail varnish packaging. This method was selected as it is an accepted, widely used cleaning method and it is suitable for glass and plastic containers used for nail varnish (Miles et al., 1983). All work had to be carried out within a fume cupboard due to the presence of volatile substances within the nail varnish residues.

Each bottle of nail varnish was weighed prior to the triple rinse procedure, using a balance to three decimal place accuracy. The nail varnish bottle was inspected for any hazardous warning information and/or disposal information. All symbols and information were recorded. The volume of the product displayed on the bottle was recorded. The bottle was then inverted for one minute with the lid tightly secured. The nail varnish residues were then decanted into a lidded waste container until drips of residues were no longer observed. An aliquot of 2ml of acetone (ca. 10% of the average volume contained in nail varnish products) was pipetted into each bottle. Acetone was selected as the bottle cleaning agent because the main constituents of nail varnish are organic compounds and acetone is an effective organic solvent (Remler, 1923). Once the lid was firmly re-secured, the nail varnish bottle was shaken vigorously by hand for 30 seconds and the mixture decanted into the waste container. The presence of metal balls, which facilitate mixing of the nail varnish prior to use, was recorded. The addition of acetone in 2ml increments was repeated twice more, or until nail varnish residues were no longer evident by visual inspection. In the vast majority of cases, there were no visible residues remaining after three rinses. A paper towel was used to remove nail varnish residues from the brush applicator. If nail varnish residues remained on the brush applicator, the brush was cleaned by immersion in 5ml of acetone until residue were no longer present upon visual inspection. Once all residues of nail varnish were removed from the brush applicator, 5ml of distilled water was pipetted into the nail varnish bottle and the lid re-secured. The bottle was vigorously shaken for 30 sec-

onds and the liquid discarded. The lid was then removed from the nail varnish bottle and the bottle was weighed. The plastic lid/brush applicator was also weighed. Although some brush bristles can be natural animal hair, all brushes within this study were assumed to be synthetic plastic fibres as nail varnish brushes produced for the mass market predominately consist of plastic bristles. The metal ball in one nail varnish was captured and weighed. Descriptive statistics for both glass and plastic packaging were calculated, and the ratio of glass to plastic packaging derived.

Volumes of nail varnish residues were obtained by first determining the density of nail varnish. A full nail varnish bottle, with a known volume, was weighed, 5ml of nail varnish was removed using a pipette, the bottle lid was re-secured and the bottle re-weighed. The residue in each bottle was used, in conjunction with the full volume, to calculate the percentage of waste nail varnish product remaining in the bottle.

2.4 Consumer questionnaire

A questionnaire was designed comprising closed and open questions to determine (1) awareness that nail varnish contains hazardous substances, (2) individuals' current disposal of nail varnish products, (3) how awareness of nail varnish's hazardous nature could change future disposal behaviours, and (4) consumers' receptiveness to potential management initiatives or interventions.

Questionnaires were completed using online methods and on a face-to-face basis. Individuals were only permitted to participate if older than 18 years, were fully capable to give consent, lived within England and used nail varnish products. Participants in the consumer questionnaire comprised a convenience sample and were recruited (1) via social media for online surveys, and (2) by approaching members of the public in Southampton city centre for face-to-face surveys. Participants recruited via social media comprised acquaintances and contacts of the researchers: participants in face-to-face interviews were all unknown to the researcher and duplicated responses are therefore unlikely. All consumer questionnaires were completed over the period March to May 2019.

Descriptive statistics were derived to profile the demographics of the population sample and responses related to awareness of nail varnishes hazardous nature, nail varnish disposal at end-of-use or end-of-life, and receptiveness to collection schemes.

TABLE 2: Hazardous substances present within the majority of nail varnish brands audited. CI indicates "colour Index" (pigment) substances (N=24).

Hazarous substances	Percentage of brands present in
Butyl acetate, Ethyl acetate, Nitrocellulose	100
Isopropyl alcohol, Trimellitic Anhydride	90-99
Acrylates Copolymer, Adipic Acid, Titanium Dioxide (CI 77891), Acetyl Tributyl Citrate, Neopentyl glycol, Yellow 5 lake (CI 19140)	80-89
Red Iron Oxide (CI 77491)	70-79
Aluminium Powder (CI 77000), Black iron oxide (CI 77499), Red 6 (CI 15850)	60-69
Benzophenone-1, Red 7 lake (CI 15850), Stearalkonium hectorite, Styrene	50-59

3. RESULTS

3.1 Hazardous substances in nail varnish products

The online hazardous substance audit was completed for samples of 24 nail varnish brands. All nail varnish brands were found to contain at least one hazardous substance and 107 hazardous substances were identified in total across all brands. The number of hazardous substances per brand ranged from 10 to 45. Several hazardous substances were noted to be present in the majority (>50%) of products sampled (Table 2).

Seven of the hazardous substances found in the majority of products (Table 2) are utilized for pigmentation and are accompanied by a five digit CI (Colour Index) code. The remaining substances are utilized within nail varnish as a solvent, suspension agent, adhesive, film former or stabilizer.

Table 3 lists the hazard statements present for all of the 24 brands of nail varnish audited. The hazards identified concern human health hazards. Hazard statements that were not present for all of the brands audited mainly concerned hazards to human health. Only one hazard to the environment was recorded: 'harmful to aquatic life with long lasting effects' was stated for over 90% of the products examined.

3.2 Packaging and nail varnish residues

Product residues and packaging (glass and plastic) were considered in relation to the volume of product as sold (Figure 1). In total, 59 end-of-use nail varnish bottles were analysed, from 28 different nail varnish brands. For

TABLE 3: Stated hazards present for all nail varnish brands audited (N=24).

Stated hazards	
Above 22°C explosive vapour/air mixtures may be formed	May cause eye irritation
Acute toxicity (oral, dermal, inhalation)	May cause skin irritation
Combustible	Nasal irritation
Cough when inhaled	Nausea if ingested
Difficulty breathing if inhaled	Nausea if inhaled
Dizziness if inhaled	Sore throat if inhaled
Drowsiness if inhaled	Unconscious if ingested
Flammable. Headache if inhaled	Unconscious if inhaled
Highly flammable	Vapour/air mixtures are explosive
Irritation of eyes	Vomiting if ingested
Irritation of skin	

some of the brands within this sample, more than one bottle was thus collected. Of the sample, 35 nail varnish bottles displayed a hazard warning and/or disposal information. A flammable warning symbol or written warning was present on 31 of the 59 bottles (59%). A recycling symbol was shown on only two nail varnish bottles, and a recycling symbol coupled with a 'Don't put in a general waste bin' symbol was present on only one bottle. One bottle alone had a 'Don't put in a general waste bin' symbol. No hazardous warning/symbols or disposal symbols/information were present on 24 of the 59 bottles (41%).

The mean mass of nail varnish residue within the donated nail varnish bottles was 7.2g ± 0.5g; the range of residue mass (maximum-minimum) was 14g. The mean mass of glass for glass bottles was 28.5g ± 1.1g, and the range (maximum-minimum) was 32.12g. The mean mass of plastic contained in nail varnish bottles was 5.6g ± 0.3g and the range of plastic packaging (maximum-minimum) was 8.4g. It was also noted that quantities of packaging and residues were not necessarily related to product volume. Products of 9ml, for example, were noted to have higher levels of residues than some larger products and also had relatively high weights of glass and plastic packaging (Figure 1). The ratio of residues to product volume was also highest for products of 9ml (Figure 1).

3.3 Consumer disposal behaviours and collection scheme receptiveness

The total number of respondents was 109; of these, 3 participated in the survey via face-to-face interviews and 106 took part in the on-line survey. All respondents identified themselves as female and were predominately aged 18-25 years (42%). Self-application of nail varnish products (as opposed to use of professional services) was reported by 96% of respondents; 59% of respondents stated that they were aware that nail varnish contains hazardous substances.

The number of nail varnish bottles reported to be disposed by respondents within a year ranged from 0 to 15; most respondents (55%) claimed to dispose of nail varnish once a year or less often. The majority of respondents (86%) dispose of nail varnish bottles with residues of less than 30% of the initial product volume; 29% of respondents claimed to discard bottles containing less than 10% of the original product volume and a further 29% claimed to discard bottles with less than a fifth of the original product.

At the point of disposal, most (85%) respondents appear not to check the safety or disposal information of products; only 14% do. The method of nail varnish disposal at end-of-life or end-of-use varies with the volume of residue (Figure 2).

The majority of respondents expressed an interest in participating in a nail varnish collection scheme (89%). Respondents indicated a wide range of incentives or initiatives that would potentially encourage them to participate in scheme(s) to collect nail varnish residues and packaging of which the most likely to appeal to consumers was the offer of monetary incentives in the form of discounts for further purchases (Figure 3).

4. DISCUSSION

The hazardous waste audit revealed that all nail varnish brands audited contained hazardous substances to varying degrees (Table 2), confirming that nail varnish, depending on its content, is classified as hazardous waste at the point of disposal. Due to its hazardous nature, nail varnish should in principle not therefore be mixed with other waste materials (Table 1), although the Hazardous Waste

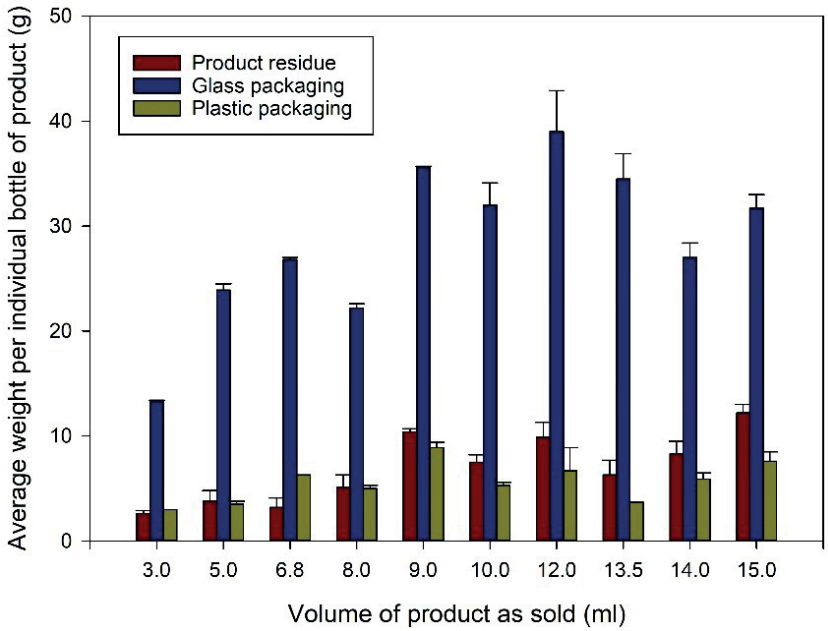

FIGURE 1: Descriptive statistics (mean ± standard error) for nail varnish end-of-use residues and packaging. Data are grouped by product volume as sold; only data for samples with three or more of the same product volume are shown. Products of 6.8ml, 9.0ml and 13.5ml each comprised samples of only one brand.

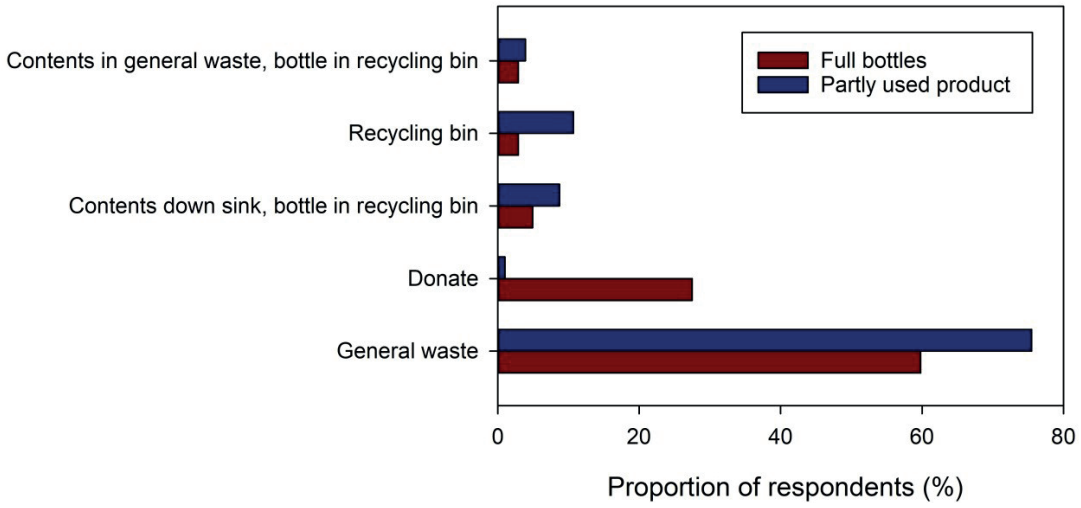

FIGURE 2: Disposal methods employed by respondents as stated in responses to the questionnaire survey. "Full bottles" refers to nail varnish products that are discarded without having been used; "partly used product" refers to nail varnish products that have been used but contain some residues. Items places in either recycling bins or discarded as general waste comprised bottles containing residues or unused product. "Donate" includes giving to known persons or organizations (N=109).

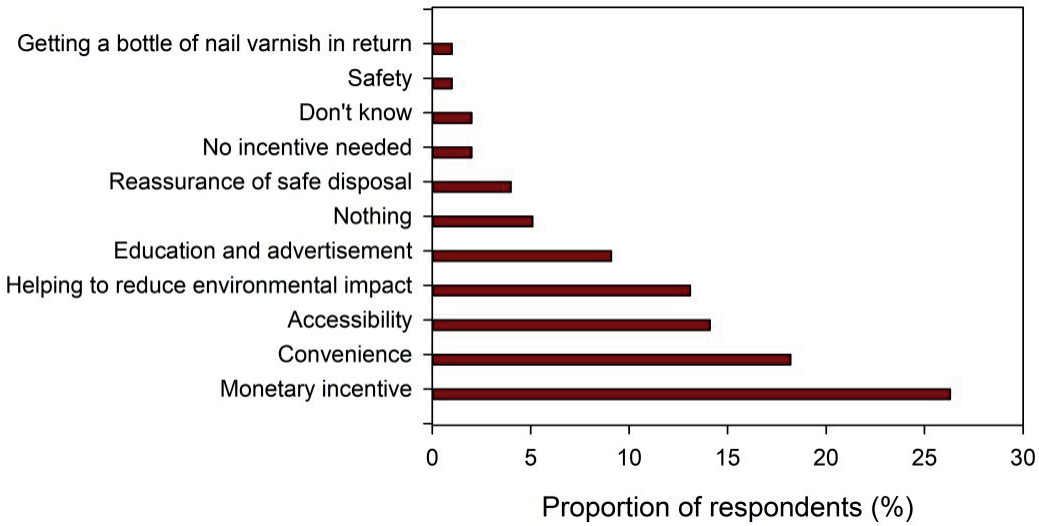

FIGURE 3: Suggestions for incentives likely to encourage engagement of consumers in nail varnish collection schemes, as identified via questionnaire surveys (N=109).

(England and Wales) Regulations 2005 (UK Government, 2005) stipulate that controls on hazardous wastes in domestic waste would not apply unless separate collection for nail varnish residues were in place. We contend that waste management authorities should ideally implement systems to capture and separate nail varnish waste from household waste to ensure safe disposal with minimal environmental impact.

The number of hazardous substances varied greatly between brands. Only three hazardous substances (Butyl acetate, Ethyl acetate and Nitrocellulose) were present within 100% of the brands audited (Table 2). Consequently, the number and type of hazardous substances that would contaminate waste varies greatly, but the highest volume associated with these will most likely be the aforementioned three substances. Most of these hazards are related to human health and fewer are associated with environmental harm. Arguably, the hazardous substances that raise the most concern for waste management coordinators, particularly with respect to contamination, are combustible, flammable and explosive substances. Fire is a common and detrimental hazardous event within waste management (Oygard et al., 2005). The presence of these substances could cause, accelerate or intensify such events, potentially causing injury, death, air, soil and water pollution, and resource consumption (Martin et al., 2016; Weichenthal et al., 2015).

Substances that are 'harmful to aquatic life with long lasting effects' are of potential concern, as hazardous substances possessing this property could accumulate in landfill leachate and potentially damage aquatic life if the leachate enters a watercourse (Salem et al., 2008). Further

research into the quantities of such hazardous substances within nail varnish residues and the mean volume of nail varnish remaining in disposed bottles, in concert with knowledge of disposal, could contribute to better understanding of the risks in this regard. Product-specific information would be needed to achieve this due to the variable hazardous substance content of nail varnish products. Moreover, research into the actual volume of nail varnish needed to cause aquatic harm is also required if the possible impacts from nail varnish waste at current waste volumes are to be determined.

The low quantities of residues relative to original product volumes (Figure 1) may be interpreted as an indication that the volumes of nail varnish waste and associated risks are negligible. However, the cumulative volumes of nail varnish in waste are currently unknown. If it is assumed that the risks of hazardous substances increases with their quantity, the risk associated with hazardous substances in nail varnish remains unknown. Given the widespread use of nail varnish and its predicted increase, any risks are likely to be of concern when aggregated to population level and likely to increase. Arguably, identifying the extent of this issue is a matter of urgency, particularly in light of likely increases in use.

If a precautionary approach were to be adopted, means would be implemented to (1) avoid the placement of nail varnish residues containing hazardous substances with other household waste, and (2) capture associated packaging to facilitate recycling of glass and plastics. A possible solution would be to capture and separate nail varnish waste from households for safe treatment: establishing a nail varnish collection scheme, similar to reverse logistic collection programmes in the USA (USEPA, 2019), offers potential in this regard. However, the success of such schemes relies heavily on their economic viability. This requires high participation rates and for the collected material to have profitable market value (Pulidindi & Chakaborty, 2018; Tonglet et al., 2004).

Glass and plastic are the main component materials of nail varnish product packaging: the mean glass and plastic was found to be 3.5g and 0.65g per ml or product. The market value of recycled glass is growing, particularly clear glass of which most nail varnish bottles are composed (WRAP, 2019). Moreover, glass is considered an endlessly closed loop material as it can be recycled endlessly, but its quality does not depreciate significantly when recycled. The value of plastic packaging may be lower than glass, as the value of plastic varies with plastic resin type. The mass of plastic available to recycle is also lower than glass (Figure 1). Further analysis and research needs to be undertaken to establish the actual value of glass and plastic contained in nail varnish products, in conjunction with participation models for a collection scheme.

In tandem with systems and facilities for the collection of end-of-use nail varnish products, due consideration is needed with regard to the treatment of the residues and packaging collected. First, residues must be separated from packaging to enable recycling of glass and plastic. Given the risks to human health associated with substances in nail varnish residues (Table 3), exposure of processing operatives to residues should be minimised or avoided by the pre-treatment of contaminated packaging prior to recycling operations. Use of suitable solvents (e.g. acetone; Remler, 1923) combined with a rinsing procedure (Miles et al., 1983) could provide a suitable means to remove residues. We note that such procedures have two key weaknesses (1) manual operations of this nature (see section 2.3) are onerous and time-consuming and do not offer a viable prospect at scale, and (2) waste products in the form of a mixture of acetone, water and nail varnish are generated. Larger-scale and automated cleaning operation may be technically feasible, but the treatment of large volumes of washing residues is potentially problematic. In addition to the hazardous substances contained in nail varnishes, acetone itself is a hazardous substance and should be treated and/or disposed of as such. Waste acetone can be recycled and reused (Weires et al., 2011), but residues of nail varnish product would nonetheless remain. Landfill has been used widely as a disposal route for hazardous substances and may offer an option for nail varnish washing residues, but seepage or leakage of hazardous substances from landfills poses a risk (Slack et al. 2005). We note that in the case of nail varnish residues, the majority of hazards are to human health rather than to the environment (Table 3). Incineration – thermal destruction - of hazardous wastes arising from nail varnish residues and the cleaning of packaging might present the best opportunity for their disposal (Dempsey & Oppelt, 2015).

Ultimately, efforts to enhance recycling of glass and plastic packaging necessitate participation by consumers. Responses to the questionnaire survey indicate that engagement in collection schemes might be fostered by making available monetary incentives. Arguably, it is difficult to envisage how such schemes would operate given the often infrequent need to dispose of end-of-use or end-of-life products. Over half of the questionnaire respondents reported discarding nail varnish once a year or less often (section 3.3) and the monetary incentive would have to be commensurate with the monetary value of the product and materials. Convenience and accessibility were highlighted as important facets of collections schemes (Figure 3). Collection schemes could, for example, utilize collection facilities located in high street retail outlets. Convenient locations of this type may foster high participation rates; collection points do not have to be located at the place of purchase. Means to foster high levels of participation should recognise convenience and availability (Ongondo and Williams, 2011). Studies of nail varnish collections schemes already implemented, such as those in the USA, could be used to guide research and to design collection schemes within the UK. We recommend that researching, investing in and implementing such schemes should commence sooner rather than later, given the potential risks identified. Moreover, we propose that efforts to change consumer efforts and behaviour should consider waste avoidance as a priority in accordance with the aims and principles of the waste hierarchy (Williams, 2015). As a priority, full use of nail varnish products should be promoted to avoid generating residues. If achievable, elimination of residues (see Figure 1) would simultaneously make

fuller use of the energy and resources consumed in the manufacturing, packaging and distribution of nail varnish products, whilst reducing the volume of residues requiring treatment and disposal.

Finally, we note that the hazardous nature of substances used in nail varnish (Table 3) imply that nail varnish residues potentially constitute hazardous waste. In principle, therefore, separation of nail varnish waste from other household waste streams along with safe treatment may be legally required (Table 1). Even if further research into the hazardous nature of nail varnish waste were to determine that the risks to human health and environmental risk posed by nail varnish waste are negligible and specialised treatment is neither warranted nor economically viable, there remains a need for a management system to capture resources that would otherwise be wasted (Tudor et al., 2011). The importance of recovering materials used for the packaging of products for reuse or recycling has become increasingly important, evidenced by the implementation of producer responsibility through the Packaging and Packaging Waste European Directive (94/62/EC), amended in 2015 (European Commission, 2018b; Environment Agency, 2014b). Consequently, establishing a collection scheme for end-of-use nail varnish to reuse and recycle the plastic and glass within nail varnish bottles would contribute to efforts towards circular economy approaches within the nail varnish industry.

5. CONCLUSIONS

The global consumption of nail varnish products will likely continue to grow, inevitably producing higher volumes of nail varnish waste. Due to the hazardous substances used for its production, it is likely that all nail varnish waste produced is potentially hazardous waste: waste management systems to capture and separate nail varnish waste from household wastes are required. However, there remain unknowns regarding the volume and composition of nail varnish waste generated, the hazardous substances within this nail varnish waste, and the associated risks.

In order to successfully implement an appropriate management scheme for end-of-use nail varnish residues and packaging, there is a need to understand consumer awareness regarding both the hazardous nature of substances present in nail varnish products and the presence of recyclable packaging materials. Information regarding the hazardous nature of waste, the impact of nail varnish waste and how to dispose of it correctly are of potential benefit. Accurate estimates of the volumes and type of nail varnish waste that requires disposal would also assist in efforts to establish suitable collection systems. Furthermore, implementing a nail varnish management scheme, such as a collection scheme, is not just a matter of immediate human health and environmental impacts but also sustainable consumption. Implementing a nail varnish collection scheme would facilitate the capture of resources such as plastic and glass, reducing the waste of both upstream and material resources. However, more research is required to establish the actual value of resources.

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