National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

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RIVM letter report 2019-0140
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Colophon

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Synopsis

Microbiological hazards in non-food consumer products

Any infectious disease results from the exposure to a microbiological hazard, like a virus or bacterium. Humans and food are well-known reservoirs of microbiological hazards, but other sources exist. This report describes the results of a literature survey on non-food consumer products as a possible source of microbiological hazards.
Non-food consumer products are products that are commercially available without prescription (pharmaceuticals are excluded) other than food. Examples of such products, cosmetics and personal care products, toys, tattoo inks, but also alternative medicines, garden products like compost and fertilizers, pet animals, detergents and (smokeless) tobacco products are identified as possible sources of microbiological hazards, mainly bacteria.
Although non-food consumer products are used on a large scale, only seven non-food product associated outbreaks of a hazard have been described in the literature. Possibly, exposure to human microbiological hazards via non-food consumer products contributes to a small extent to the overall exposure to human pathogens via all possible routes.

Keywords: infection, public health,

Publiekssamenvatting

Microbiologische gevaren in consumenten producten anders dan voedsel.

Elke infectie is het gevolg van blootstelling aan een microbiologisch gevaar, zoals een virus of bacterie. Microbiologische gevaren zijn overdraagbaar van mens-op-mens of via voedsel, maar kunnen ook via andere bronnen worden overgedragen. In dit rapport wordt verslag gedaan van een literatuur studie naar de rol van consumenten producten (anders dan voedsel) als mogelijke bron van microbiologische gevaren.
Onder dit soort consumenten producten (anders dan voedsel) worden producten verstaan die zonder recept (medicijnen zijn uitgesloten) commercieel verkrijgbaar zijn. Onder andere cosmetica en verzorgingsproducten, speelgoed, tatoeage inkt, alternatieve geneesmiddelen, tuinproducten als compost en mest, gezelschapsdieren, wasmiddelen en tabaksartikelen worden in de literatuur beschreven als potentiële bron van microbiologische gevaren, vooral bacteriën.
Consumenten producten, anders dan voedsel, worden op grote schaal gebruikt. Toch zijn er in de literatuur maar zeven uitbraken van een infectieziekte beschreven waarin dit soort producten een rol hebben gespeeld. Mogelijk spelen consumenten producten anders dan voedsel slechts een bescheiden rol in de verspreiding van infectieziektes.

Kernwoorden: gevaar, infectie, volksgezondheid

Contents

Summary

Any infectious disease results from the exposure to a microbiological hazard, like a virus, yeast, mould or bacterium. Humans and food are well-known reservoirs of microbiological hazards, but other sources exist. This report describes the results of a literature survey on non-food consumer products as a possible source of microbiological hazards.

Non-food consumer products are products that are commercially available without prescription (pharmaceuticals are excluded) other than food. Examples of such products like cosmetics and personal care products, toys, tattoo inks, but also alternative medicines, garden products like compost and fertilizers, pet animals, detergents and (smokeless) tobacco products are identified as possible sources of microbiological hazards, mainly bacteria. Other products, like plants, bulbs and flowers, also have the potential of a source.

Although non-food consumer products are used on a large scale, only seven non-food product associated outbreaks of a hazard have been described in the literature. Possibly, exposure to human microbiological hazards via non-food consumer products contributes to a small extent to the overall exposure to human pathogens via all possible routes.

The Dutch government aims at a full circular economy in 2050. In a circular economy, where the use of virgin or primary ingredients is as low as possible, new risks are introduced: re-use of ingredients from atypical sources introduces new hazards and in circular processes that lack a full microbiological risk-reducing step, accumulation of (microbiological) hazards can occur.

1 Introduction

Any infectious disease results from the exposure to a microbiological hazard. Well-known microbiological hazards are bacteria, moulds, yeasts, parasites and viruses. They have many reservoirs and can survive under many circumstances, for different periods of time. Growth of microbiological hazards however requires sufficient nutrients and water in an environment in which the temperature and pH are neither too high, nor too low. Such conditions are met in humans, plants, animals and many food items. But other growth-supporting sources exist, like non-food consumer products containing water and some (biological) ingredients as source of nutrients.
This report is aimed to identify non-food consumer products with a risk of microbiological contamination. Data on species and level of contamination will also be collected, but are reported separately.
Consumer products are products that are commercially available without prescription. Food, cosmetics, toys, tobacco, garden materials, household items, but also pet animals and ornamental fish can be counted to consumer products as they all are available from commercial shops without prescription. Part of these products will only allow for survival of microbiological hazards, while others can support their growth.
For food, feed, medicinal products, toys and cosmetics specific legislation exists. For products of which the risks are not covered by specific legislation, directive 2001/95/EC must be applied. Product shall mean 'any product which is intended for consumers or likely, under reasonably foreseeable conditions, to be used by consumers even if not intended for them, and is supplied or made available, whether for consideration or not, in the course of a commercial activity, and whether new, used or reconditioned' (directive 2001/95/EC). In this report, a non-food consumer product is any product other than food or medical device that is commercially available for consumers, without prescription.

If a manufacturer or distributor finds out that one of their products on sale is dangerous, they have to inform the competent authority. Competent authorities sent alerts through the rapid alert system for dangerous non-food products - "Safety Gate". Alerts include information about the type of products found, the risks posed and the measures taken at national level to prevent or restrict their marketing.

In this report, the results of a desk study performed on the presence of microbiological hazards in non-food consumer products are shown. Food, feed and medicinal products are not included. The Safety Gate alert system was used as a source of information. Information on microbiological risks linked to non-food consumer products in the European Safety Gate rapid alert system database, is available from: https://ec.europa.eu/consumers/consumers_safety/safety_products/rapex/alerts/repository/content/pages/rapex/index_en.htm.
Next to the Safety Gate rapid alert system, searches for information on microbiological risks linked to non-food consumer products were done in the scientific literature, using Scopus and Embase and two RIVM reports, not available from the above mentioned databases, were included in this desk study.

2 Method

First, in order to identify consumer products or product categories (other than food) with a microbiological risk, the Safety Gate system was used (selection: all categories, microbiological risks, alerts from all countries, products from all countries).
Next to the Safety Gate system, a general document search was done in Scopus using a query containing ((hazard OR risk OR infection OR safety OR contamination) AND (microbiological OR microbial AND NOT food)) in combination with 'consumer product'.
Subsequently, specific searches on identified products or product groups were done in Scopus. These searches combined a standard query ((hazard OR risk OR infection OR safety OR contamination) AND (microbiological OR microbial AND NOT food)) and the name of the product or product group (cosmetic, toy, tattoo AND ink, herb, alternative OR complementary AND medicine, fertiliser OR fertilizer, ornamental AND fish, pet AND animal, glue, marker, plant OR bulb OR flower, paint, detergent, soil, drugstore AND product, cough AND syrup, tobacco, compost AND consumer).
As a third source of information we used Embase. A similar, specific search strategy as in Scopus was used.
Two RIVM reports, not available via the Safety Gate system or Scopus or embase, were also included.

The products described should be non-food, intended for consumers and commercially available without prescription. The bibliography of selected articles is seperately available from an Endnote database. A separate excel file containing more detailed information (author, year, product group, product, test organism, prevalence, concentration, reporting country and country of origin) is also available.

Note:
The scientific literature might be biased for cosmetics as for cosmetics legal microbiological limits exist.
Some consumer products, like herbs and other biological products used in alternative/complementary medicine, are also used as food. Herbs and such other biological products are included in this study.
Of references on pet animals and ornamental fish, those referring to commercially available pets and fish from pet shops, kennels and shelters, are included.
Searches combining ((hazard OR risk OR infection OR safety OR contamination) AND (microbiological OR microbial AND NOT food)) with either 'marker' (5491 hits), 'plant or bulb or flower' (10413 hits) or 'soil' (8175 hits), resulted in too many hits and are not included in this report.

3 Results

3.1 Identification of non-food consumer products or product groups with a microbiological risk

In the Safety Gate system, most alerts on microbiological risks referred to toys and cosmetics. Other alerts dealt with chemicals. Within the category of toys, soap bubbles/soap bubble toys were most often notified, second in frequency of mentioning were products containing paint (paint, body paint, finger paint, make up, water paint). Other toys mentioned in the rapid alert system were clay and plasticine. All toy products mentioned in the Safety Gate system are aqueous products. Among cosmetics different subcategories could be identified of which skin-care products, hair coloring products and bath products formed the top three of most frequently microbiologically contaminated products. Some cosmetic products were for children. The category of chemicals consisted mostly of tattoo inks. Two liquids for machines producing fog were also found to be contaminated and one single-use tattoo needle system.
The general document search in Scopus on ‘consumer products’ resulted in 560 hits. Most articles described the microbiological quality of cosmetics and personal care products (see 3.2). Other products described were toys (see 3.3), tattoo inks (see 3.4), herbs or alternative/complementary medicine (see 3.5), compost and fertiliser (see 3.6), ornamental fish and pet and companion animals (see 3.7 and 3.8), detergents and washing machines(see 3.9) and (smokeless) tobacco products (see 3.10). Examples of other mentioned products or products groups (see 3.11) were products like decorative contact lenses, contact lens solution, contact lens cases, and teethers. Water filtration systems and water dispensors could also be linked to a microbiological hazard (see 3.14).
The search in Embase did not result in new products or product groups, only few (7) additional references were identified that referred to already identified non-food products or product groups.
In the consulted literature on non-food consumer products, a broad range of microbiological hazards is mentioned (see Annex), both micro-organisms that are mentioned in RAPEX (mainly total aerobic viable count (TAVC), *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Candida albicans*) and other organisms like *Serratia marcescens*.
Other papers containing relevant information focused on the effectivity of preservation systems (Abu Shaqra et al., 2014; Ghalleb et al., 2015; Halla et al., 2018; Periz et al., 2018; Smaoui and Hlima, 2012; Yossa et al., 2017), on RAPEX notifications (Klaschka, 2017; Lundov and Zachariae, 2008; Minghetti et al., 2019; Verdier, 2008; Vincze et al., 2019), on (the development of) resistance to used preservatives (Périamé et al., 2014a, b), on the development of cross-resistance to antimicrobials (Levy, 2002; Orús et al., 2015) and on risk assessment (Pitt et al., 2014; Stewart et al., 2016).
Seven papers described outbreaks. Five outbreaks in a hospital setting are described of which three of *Burkholderia cepacia* (in body milk (Alvarez-Lerma et al., 2008); in wash cloth (Martin et al., 2011) and in

mouth wash (Martin et al., 2012)) and two of *S. marcescens* in hand soap (Rabier et al., 2008) and in baby shampoo (Madani et al., 2011). Skorin (2006) described a multistate outbreak of *Fusarium* in a contact lens solution and Kennedy et al. (2012) reported on tattoo ink as the source of *Mycobacterium chelonae*.

In the next paragraphs, the combined results of the general search on consumer products and of the searches in Scopus and Embase on specific products or products groups is given. The selection of these specific products or product groups is based on the results presented in paragraph 3.1 and on the results of an online brainstorm session (not shown) in the food department.

3.2 Cosmetics and personal care products

3.2.1 Contamination and preservation.

Cosmetics contain water and organic materials making them vulnerable for microbial contamination (Lundov and Zachariae, 2008; Halla et al., 2018). The most frequently isolated micro-organisms from cosmetics are *P. aeruginosa*, *Klebsiella oxytoca*, *B. cepacia*, *S. aureus*, *E. coli*, *C. albicans*, *Enterobacter gergoviae* and *S. marcescens*. Contamination may occur during manufacturing or during use. Contamination during manufacturing happens because of personal contact, the use of contaminated ingredients or via a contaminated production line. The best way to produce safe cosmetics is by the use of good-quality raw materials and GMP in combination with hygienic packaging. Proper physical barriers (a_W, pH, water-in-oil rather than oil-in-water emulsions) and a good preservative system (Halla et al., 2018) further contribute to safe products. Obrębska et al. (2008) also mentioned the application of HACCP.

Campana et al.(2006) tested for total bacterial count, *S. aureus*, *Enterobacteriacea*e and *Pseudomonas* spp. in (91) intact, in-use and end-of-life cosmetic products: emulsions, tensiolytes (bath foam, shampoo, liquid soap) and aqueous pastes (tooth paste). None of the tested products was contaminated before use, but tensiolytes tested positive during and at the end-of-life. The results of challenge tests show that the used preservative systems in body cream and bath foam cause a rapid decline in numbers of *S. aureus* and *P. aeruginosa*. Yossa et al. (2017) performed challenge tests with different bacteria in four different brands of make-up removers. The four brands used different preservation strategies. Not all strategies were as effective and not all strategies were as long lasting. There is a difference in sensitivity amongst tested species. The FDA (Periz et al., 2018) examined cosmetic products that were preserved in a non-traditional way. They checked for pH (all products had a pH between 5 and 9, permissive for microbial growth) and a_W (>0.8 and <0.8). Only eye shadows and eye (liner) pencils had an a_W, <0.7. Despite a low a_W microorganisms were detected. Statistical analyses indicated a positive correlation between dry products and microbial presence. A possible explanation for this could be that preservatives are active against organisms that require a high a_W and that those surviving in low a_W environments (bacilli, *Staphylococci*) are unsensitive to preservatives (Periz et al., 2018).

Resistance of *P. aeruginosa* to preservatives (and antibiotics) was reported by Abu Shaqra et al. (2014). Périamé et al. (2014a, b) point to development of (cross-) resistance. *Enterobacter gergoviae* is a widespread microorganism that is able to survive in many cosmetic products, despite the presence maximum allowed concentrations of preservatives. The resistance is based on membrane modifications (2014a), the presence an enzyme degrading preservatives ánd on the possible presence of an efflux mechanism (2014b).

3.2.2 *Type of cosmetic products.*

Okeke and Lamikanra, (2001) detected bacteria in 29/49 of various, commercially available cosmetic products. Oil-in-water lotions were most likely to be contaminated. *E. coli*, *Pseudomonas spp* and *Bacillus spp*. were most frequently recovered. Abu Shaqra and Al-Groom (2012) evaluated a total of 57 commercially available hair and skin care cosmetics for their microbiological quality (TAVC). More than half of them tested TAVC negative. *P. aeruginosa* and *Bacillus spp* were the most frequently isolated Gram^{-} and Gram^{+} microorganisms. Counterfeit toothpaste from China contained high numbers of *Pseudomonas* and other opportunistic bacteria (Brzezinski et al., 2012).
Moisturizing body milk was identified as the source of infection (*B. cepacia*) in a hospital setting. The organism was detected in unopened bottles (Alvarez-Lerma et al., 2008). Kulkarni et al. (2011) evaluated the microbiological quality of facepacks and cakes. The examined products were heavily contaminated. In a study by Birteksöz et al. (2013), the microbial content and preservative efficacy of various cosmetic products (93), which are produced and sold in markets of Turkey, were investigated. Creams (shaving, moisturizing, face care, depilatory), eye make-up remover and tooth paste tested positive. Numbers and species varied. *S. aureus* was the most common contaminant identified in samples (from six different products) and was followed by *B. cepacia* (from four different products). Gram^{-} -organisms, including *P. aeruginosa* and a yeast (*C. krusei*), were also isolated from samples. *E. coli* and *Salmonella spp* were not recovered from any of the samples. Various unused creams (16/24) from the Iran market tested positive for *S. aureus* and *E. coli* (Behravan et al., 2005). Moisturizing cream samples in Iran appeared to be contaminated (67%) with more than 1000 CFU/mL (Badyeh et al., 2015). All samples contained *Enterobacteriaceae*, *P. aeruginosa* was detected in 4 samples, *S. aureus* in 5 samples. Sainio et al. (2000) examined cellulite creams in Finland. Products were tested for the presence of TAVC, moulds, yeasts, coliforms, *S. aureus* and *P. aeruginosa*. In none of the products, any of these (groups of) organisms was detected (32). Prefabricated wash clothes were contaminated with *B. cepacia* (Martin et al., 2011). Although this organism is considered to be of low virulence, authors mention that they can infect susceptible people in a hospital setting. Quantitative analysis (TAVC) of eye cosmetics (5 products, 2 brands) showed that products from one brand tested negative for bacterial growth, whereas products from both brands were contaminated with low numbers of fungi (Effa et al., 2018). Cosmetics bought between 1995 and 2002 in Bulgaria (Gatseva et al., 2004) were microbiologically tested. In total 919 samples were tested of which 160 products did not comply to the standards. The main contaminant were

Enterobacteriaceae, but standards for yeasts and moulds, *P. aeruginosa*, *S. aureus* and TAVC were also exceeded.

Not only cosmetic and personal care products with a high water content are susceptible to microbiological contamination. Unused toothbrushes are not always sterile (Do Nascimento et al., 2012) and tampons (Briancesko et al., 2018) are frequently (93%) contaminated with low numbers of bacteria; pathogens were detected in 6% of the samples. In $CaCO_3$ powder, an ingredient of cosmetics like toothpaste and foundation, low numbers of TAVC, bacilli and actinobacteria were detected (Di Maiuta and Schwarzentruber, 2011).

3.2.3 *Outbreaks of pathogenic species.*

Cosmetic and personal care products were identified as the source of infection in five outbreaks pathogenic microbial species. Body milk (Alvarez-Lerma et al., 2008), wash cloths (Martin et al. 2011) and mouth wash (Martin et al. 2012) were the source of *B. cepacia. S. marcescens* was involved in outbreaks via the use of hand soap (Rabier et al., 2008) or baby shampoo (Madani et al., 2011).

3.3 Toys

Although microbiologically contaminated toys are frequently reported in the Safety Gate system, the search in the scientific literature yielded only one relevant publication. Soap bubbles from China were found to be contaminated with *P. aeruginosa* (Amoruso et al., 2015). The use of untreated water in the production of soap was probably the original source of *Pseudomonas*.

3.4 Tattoo ink

Verdier (2008) compared the national (France) and EU RAPEX system dealing with tattoo-related notifications and reported on the sterility of 26 ink samples that were tested (according to the French system) for sterility. Three samples were non-sterile. Minghetti et al. (2019) also reported on RAPEX alerts. From 2007 to 2017, 190 tattoo inks were withdrawn from the market of which 10% for microbiological reasons. The most frequently found pathogen was *P. aeruginosa*. In a paper by Bonadonna (2015), the literature on microbial contamination of tattoo inks is surveyed. The real incidence of infective complications after tattooing is not known because most subjects return to their tattoo parlour rather than consulting their own physician. Tattoos represent a risk for bacterial, viral and fungal infections. Most of the infections are caused by improper use of hygiene regimens, but inks can also be contaminated (Bonadonna, 2015). Nho et al. (2018) reported on a microbiological survey in the USA. In 49% of tattoo ink and permanent make up (PMU) unopened samples (85 tested), a microbiological contamination was detected. In 16 inks, the number exceeded 10^3 colony forming units (cfu)/mL. Hogsberg et al. (2013) checked tattoo ink in Denmark. 58 Unopened stock bottles with tattoo ink were microbiologically tested of which 6 were found to be contaminated with pathogenic and non-pathogenic bacterial species. Numbers varied from 100 to > 500 cfu/mL. Moulds and yeasts were not found. Inks were purchased via the internet from different countries.

Outbreaks
One tattoo ink related outbreak is described in the literature (Kennedy et al, 2012). Premixed tattoo ink (ink plus distilled water) was identified as the source of *Mycobacterium chelonae*.

3.5 Herbs or alternative or complementary medicine

Herbs and other biological products are used as food but also in alternative / complementary medicine. This paragraph reports on publications dealing with commercially available herbs and other biological products sold as and used in alternative / complementary medicine.

The microbial load of medicinal plants used in plant-based herbal medicinal products can be high. This microbial contamination reflects the environmental conditions, as the highest risk of contamination is in the field and during harvesting (Ghisleni et al. 2016). *S. aureus* and *Salmonella* are usually absent, but other pathogenic species can be detected (Guédon et al., 2007). Kneifel et al. (2002) reviewed the scientific literature and showed that various plant species carry bacteria belonging to aerobic, mesophilic species. More specifically, *Enterobacteriaceae* and coliform species can be found. Reported numbers vary heaviliy. Moulds and yeasts are also detectable, but not as often.
Among the possible moulds and yeasts in 15 different medicinal herbs that were collected from 3 different regions in China, Zheng et al. (2017) showed *Aspergillus* and *Penicillium* genera as the predominant contaminants. Mycotoxin producing strains were present (aflatoxin). Herbs from China were also tested in Germany (Melchart et al., 2016) and Italy (Mazzanti et al., 2008). In Germany, Chinese medicinal herbs at a hospital for traditional Chinese medicine were screened for TAVC, Y&M, *Salmonella* and *E. coli*. Some samples (2/23) showed microbiological contamination. *Salmonella* was not detected. In Italy, a too high number of TAVC (above 10^5 cfu/g according to the European Pharmacopoeia) was detected in 1 out of 27 samples of Chinese herbs. *E. coli* and *Salmonella* were not detected.
Reports on the microbiological quality of ingredients of alternative medicine are also available from other countries. Noor et al. (2015) gave an overview of the prevalence of pathogenic microorganisms in different pharmaceutical products from the Bangladesh market and point to the risk of antimicrobial drug resistant bacteria (among which *S. aureus*, the one frequently found in cosmetics). Antacids commonly available in drugstores in Bangladesh contained *S. aureus*. *Pseudomonas*, *E. coli*, and *Salmonella* were absent (Urmi and Noor, 2014). Limyata and Juniar (1998) examined raw materials as an ingredient of traditional medicine in Indonesia. Their investigation showed that samples of ingredients of Jamu Gendong (JG) and of JG were heavily contaminated with bacteria, moulds and yeasts. Indicators for fecal contamination were detected (coliform) and some samples contained pathogenic species, like *S. aureus*, *Salmonella* and *Vibrio spp*. In Serbia, dried medicinal drugs were most often infected with moulds, mainly *Fusarium*. Potentially pathogenic bacterial species were also detected, among which *E. coli*, *Bacillus* and *Clostridium* (Stevic et al., 2012). Herbs from the local market in Kenya appeared to be

contaminated with (according to the WHO standards) too high numbers of TAVC, coliform, *E. coli*, *S. aereus* and moulds and yeasts (Kaume et al. 2012). Antimalaria herbs available in Nigeria harbor a large number of micro-organismen. Most frequently detected species are *Bacillus spp*. yeasts and moulds. Pathogenic species, like *P. aeruginosa*, *E. coli* O157 and *S. aureus* were present (Tatfeng et al., 2009). Products available from the Brasilian market, randomly collected in street markets and stalls were tested for the presence of filamentous fungi in samples of the tea herbs *Peumus boldus* Molina (boldo leaf), *Pimpinella anisum* (anise) and *Matricaria chamomilla* (wild chamomile). Toxigenic fungi such as *Aspergillus* spp., *Penicillium* spp. and *Fusarium* spp. were found, the first being present in all plant samples. The fungi *Exophiala* spp. and *Fonsecaea* spp., which are clinically significant as they can cause mycoses, were also identified (Santos et al., 2013). In medicinal plants in Pakistan, high TAVC and coliform numbers were found. Samples also tested positive for *E. coli* (23/45) and *Salmonella* (13/45). Fungi were detected in all samples (Khanzadi, 2012). Commercially available herbs in India (5 species) were analysed (1 sample per species) for TAVC and pathogenic species *E. coli*, *Salmonella*, *S. aureus* and *P. aeruginosa* and tested against WHO limits. 4 out of 5 of the samples had a higher TAVC than allowed, but none of the samples tested positive for any of the pathogens (Khurana et al., 2011).
Not all investigated products carried microbiological hazards. Polish sage grown in different systems met the WHO microbiological standards (Seidler-Lozykowska et al., 2015). And essential oils used in complementary therapies bought in UK retail outlets tested negative for any bacterial species or any fungus (Maudsley and Kerr, 1999).

3.6 Compost or fertilizer or fertiliser

In garden shops, several types of compost and fertilizers (non-composted organic material) are available. Organic material is a potential source of various microbiological hazards. The hazards in compost depend on the type of sorting and method of composting (Deportes et al., 1995). Routes of exposure to hazards in compost or fertilizers are by hand/mouth or dust/aerosols.
In this paragraph, an overview is given of literature on microbiological hazards in compost and fertilisers. As the origin of compost and fertilizers available in gardenshops is not often mentioned, literature on compost and fertilizers in general and not specifically on compost and fertilizers for the consumer market was surveyed.

Compost of digestate
Bonetta et al. (2011; 2014) analysed samples of bovine manure and digestate from an anaerobic digester. Digestate is seperated in a solid and liquid fraction. Most bacteria are concentrated in the solid fraction. Digesting results in lower counts, but *Salmonella* and *L. monocytogenes* were still present in digestate samples. Govasmark et al. (2011) tested for the presence *B. cereus* and *E. coli* in the liquid fraction of digestate of anaerobically digested organic and industrial food waste. This fraction contained *B. cereus* in 10% of the samples. VTEC tested negative.

Compost of sludge
Direct application of sludge as fertilizer is not recommended as various potentially pathogenic bacterial species, among which *E. coli*, *C. perfringens*, *Pseudomonas*, *Staphylococcus* and *Enterococcus* are detected (Popova et al., 2017). In Egypt, sewage sludge was contaminated with fecal coliform, *Salmonella*, *Shigella* and nematodes (El-Naim et al., 2004). Additional processing is required to obtain a safe product. In the USA, two types of sludge are identified: class A and B. A is processed and safe to use, class B solids are not processed and maybe need to be handled with care (Lewis and Gattie, 2002). Composting sludge declines the numbers of pathogens (El-Naim et al., 2004). The decline in numbers of pathogens during composting of sewage sludge was also observed by Moretti et al. (2015). However, fecal *Streptococci* and enteric bacteria can be found in composted sludge. Parasites (*Toxocara*) survive longest in compost.

Compost of pulp and paper
Pulp and paper mill biosolids can be used as fertilizer. Detection rates for pathogens (*Salmonella*, *Campylobacter*, *Shigella*, *Cryptosporidium* and *Giardia*) ranged from 5 to 25% (Flemming et al., 2017). Also *E. coli* can be detected (Croteau et al., 2007). However, none of the *E. coli* isolates contained any of the STx encoding genes. In compost containing various proportions of paper and cardboard, fruits and vegetables and green waste were composted, survival of *Salmonella* was observed after three months. *E. coli* and *L. monocytogenes* did not survive for three months (Lemunier et al., 2005).

Compost of manure
Manure is a potential source of zoonotic agents like *Salmonella* and *E. coli*. Composting of manure has a risk reducing effect (Bonetta et al., 2011; Cancelado et al., 2014) but does not always result in a safe product (Bonetta et al., 2011), similar to composting of sewage sludge (see above).

Compost of other biosolids.
Legionella and free-living amoeba (host of *Legionella*) can be detected in compost made of non-specified organic material. They can spread via aerosols (Conza et al., 2013).

Fertilisers
Fertilisers consist of non-composted organic material of various origin. As fertilisers do not receive the risk-reducing composting treatment, their use means a microbiological risk. Hazards that can be present are the same as in compost, but probably in higher concentration. In addition, hazards that normally do not survive during composting can form a risk. Such risk is mentioned by Gomez et al. (2018). *Histoplasma capsulatum*, the fungal causative agent of histoplasmosis, inhabits soils rich in phosphorus and nitrogen that are enriched with bird and bat manure. Cases and outbreaks due to the presence of the fungus in these components have been reported. Authors examined 239 samples of which 25 (10.5%) were positive. Grinten and Spijker (2018) refer to the risk of transmission of *Clostridium* via struvite, a nitrogen/phosphorus rich by-product from waste water treatment plants.

Other
In order to increase crop yield, research has started/intensified on the application of plant-growth promoting bacteria (PGPB), also called bio-pesticides. The bacterial genera used as PGPB include potentially pathogenic species (*Bacillus*, *Pseudomonas, Burkholderia*). Several authors (Cook et al., 1996; Ferreira et al., 2019; Heydari and Pessarakli, 2010) mention that the safety of PGPB is not guaranteed and that it is important to have a method available that can be used to distinguish between pathogenic and non-pathogenic species (Sundh et al., 2011).

3.7 Ornamental fish

Ornamental fish are identified as a source of both pathogenic and antimicrobial drug resistant (AMR) bacterial species.

Pathogenic species
Ornamental fish species are a source of *Vibrio cholerae* and *V. mimicus* (Zago et al., 2017). In aquarium water of two fish species, bacterial species were detected with the potential to cause disease in fish and men: *Legionella pneumophila* and *V. cholerae* (Smith et al., 2012). Motile *Aeromonas* species are opportunistic human pathogens that can be detected in zebrafish (Hossain et al., 2018). Other opportunistic human pathogens like *Mycobacteria* can also be found in ornamental fish in pet shops (Macri et al., 2008; Kusar et al., 2017).

AMR species
Some papers in the scientific literature report on the presence of AMR bacteria in ornamental fish. AMR *Aeromonas* isolates (Dobiasova et al., 2014; Hossain et al., 2018; Verner-Jeffreys et al., 2009) were found in both fish and carrier water. Gallani et al. (2016) reported on freshwater angelfish as a source of multidrug resistant *Citrobacter freundii*.

3.8 Pets or companion animals

Pets or companion animals can be bought from pet shops, breeders/kennels and animal shelters, and as such, they can be considered as consumer products. Feed for non-food producing animals does not have to comply to (EC) No. 183/2005, so feed can be considered a consumer product as well.
Microbiological hazards in feed (and toys) for non-food producing animals were already described by DeJonge, (2017). The most relevant pathogenic species identified in feed and pet toys was *Salmonella*, a finding that was also recently reported by Davies et al. (2019).
In this paragraph, the emphasis is on literature focusing on pathogenic and AMR hazards in pets and companion animals available from pet shops, breeders/kennels and animal shelters.

Pathogenic species
Litwin (2003) gives an overview of potential microbiological hazards transmissible via pets. The paper describes the diagnostic methods for various pathogens and some prevalence data. *Campylobacter* can be found in healthy dog puppies (29%). *Brucella canis* tested serologically positive in 30% of dogs. *Salmonella* was found in 27,6% of tested dogs. Relevant zoonotic hazards in cats are *Bordetella*, *Helicobacter*, *Francisella*, *Toxoplasma* and *Yersinia*. But also *Chlamydia psittaci*,

Coxiella burnetii can be detected in cats. In a study by Ogden et al. (2009) on the presence of *Campylobacter jejuni and C. coli* in animals, a prevalence of <5% in dogs and cats was found. Chinchillas tested positive for *P. aeruginosa* (Hirakawa et al., 2010). *Enterococcus faecalis, E. faecium and E. avium* were found in the feces of dogs and cats in Portugal (Rodrigues et al., 2002). And in dogs at animal shelters in the USA (Leahy et al., 2016), the prevalence of *Salmonella* was low. Pigeons and pet birds on breeding establisments showed a high prevalence of the facultative pathogenic yeast *Cryptococcus neoformans* (Kielstein et al., 2000). Birds are also a potential source of *C. psittaci* (Litwin, 2003).
Other pets (rats, mice, guinea pigs and hamsters) are susceptible to infections with hazards like *Salmonella* and *Leptospirosis*. Rabbits can carry *Francisella* and *Yersinia* (Litwin, 2003). However, mice bought from commercial pet shops were screened for 47 microbiological agents, among which viruses, parasites , bacteria and fungi. None of the human pathogenic species (Hantavirus, Lymphocytic choriomeningitis virus, *Salmonella* or dermatophytes) were detected in mice (Hayashimoto et al., 2015).
Reptiles and amphibians can be carrier of *Salmonella*. Imported Russian tortoises were shown to be a reservoir for *Salmonella* in Poland. Nowakiewicz et al. (2012) identified 56 strains of which 30 belonged to *S. enterica subsp enterica*. *Salmonella* spp. occurred in red-eared (*Pseudemys scripts elegans*) turtle eggs imported into Canada from Louisiana (D'Aoust et al., 1990; Shane et al., 1990). *S. poona* and *S. arizonae* were frequently encountered in both fertile eggs and packaging moss. Turtles hatched in the laboratory from affected lots of eggs shed *Salmonella* in tank water for up to 11 months. In excreta from chameleons *S. Tel-el-kebir* was detected. This *Salmonella* strain caused disease in a 3-month old child in the UK (Willis et al., 2002).

AMR species
AMR microbiological hazards originating from companion animals that can have an adverse effect on humans are MRSA, methicillin-resistant *Staphylococcus pseudointermedius*, VRE, ESBL- or carbapenemase-producing *Enterobacteriaceae* (CRE; Pomba et al., 2016). In Europe (France, Germany, Spain), the prevalence of CRE in companion animals (dogs, cats, horses) was less than 1% (Köck et al., 2018). In the Netherlands, the prevalence of AMR *E. faecium* in dogs in the Netherlands is high (25.6%; Van den Bunt et al., 2018). Authors mention that there is only a small phylogenetic linkage between pet and human isolates. In kennel dogs (bitches and puppies) in Italy multi-drug resistant *S. pseudintermedius* was found (Corro et al., 2018). Dogs and cats from pure-breed kennels were tested for the presence of methicillin-resistant *Staphylococcus haemolyticus* (MRSH). Only dogs tested positive for MRSH (Ruzauskas et al., 2014). Kennel dogs in Lithuania were carrier of methicillin-resistant *S. pseudintermedius* (Ruzauskas et al., 2015). In other publications, multidrug-resistant *Clostridium difficile* (in healthy pets in Chinese pet shops; Wei et al., 2019), MRSA (in dogs from an animal shelter; Huang and Chou, 2019) and AMR *E. coli* (in pet birds; Nakamura et al., 1980) are mentioned.

3.9 Washing machines and detergents

Washing machines

Although laundering should mainly remove stains and dirt from used and worn textiles, the elimination of microbial contamination is an important aim of the laundry process as well. While industrial and institutional laundering employs standardized processes using high temperatures (i.e. 60°C and above) and bleaching agents to ensure a sufficient hygienic reconditioning of textiles, self-service laundering processes are less defined.

The strive for energy efficiency of household appliances has resulted in a decrease in washing temperatures in Europe during the last decades and convenience aspects led to an increased use of liquid detergents that do not contain bleach which in turn impacts the antimicrobial efficacy of domestic laundering (Bockmühl, 2017). Laundering at low temperature (<40°C), however, is not optimally effective in hygiene. Indeed, washing machines (powder drawer, softener drawer and rubber seals) tested positive (25.3%) for *Candida parapsilosis* (Dogen et al., 2017). Also in Slovenia, fungi were isolated from residential washing machines. In 55/70 tested machines, fungi were isolated. Opportunistic species of both *Fusarium* and *Candida* were detected (Babic et al., 2015). Nix et al. (2015) showed that the microbial community inside washing machines appeared to be highly diverse with Proteobacteria as the main prokaryotic and *Basidiomycota* and *Ascomycota* as the main fungal colonizers. So, if consumers that make use of self-service laundries apply similar washing conditions as consumers do at home, then washing machines in self-service laundry facilities are a potential source of microbiological hazards.

Detergents

Bacterial species can be a source of appropriate enzymes to degrade stains and soils (Berg et al., 2017). Cleaning products that include microbes as active ingredients are increasingly used in various settings. These microbial-based cleaning products (MBCPs) are also known as environmentally-friendly, biodegradable or non-toxic. MBCPs can contain potentially pathogenic species, among which *Bacillus* (Tayabali and Ashby, 2018). The use of *Bacillus*-based cleaning products could lead to exposure via inhalation, although Berg et al. (2017) conclude that a *Bacillus*-based carpet cleaning product presents a low potential for inhalation exposure with minimal risk of adverse effects.

3.10 Tobacco

Cigarettes

Cigarettes are colonized by a wide array of potentially pathogenic microbes, like *B. cepacia*, *Clostridium* and *P. aeruginosa* (Sapkota et al., 2010). The health consequences however are unclear as it is not known whether or not bacteria can survive the smoking/burning process of cigarettes. Exposure can also occur via tobacco flakes on cigarette filters. Analysis showed that bacteria with haemolytic activity were present on these flakes, but further identification of isolates was not done (Pauly et al., 2008).

Smokeless tobacco
In moist, dry and chewing smokeless tobacco products (snuff), bacteria can be detected (Han et al., 2016; Tyx et al., 2016; Smyth et al., 2017). Moist snuff exhibited higher levels of bacteria than dry (snus) and some chewing products. Among the species were *Bacilli* and *Staphylococci* (Han et al., 2016) and *Burkholderia* (Smyth et al., 2017). These are of concern for two reasons: opportunistic infections and their ability to reduce nitrate into nitrite, an important step in the formation of carcinogenic nitrosamines. Using NGS in combination with 16S rDNA analysis revealed the presence of *S. aureus*, *Corynebacteriaceae*, *Enterobacteriaceae* and *Lactobacilli* (Tyx et al., 2016). Authors also detected the presence of nitrate reductase genes, whose products can contribute to the formation of carcinogenic nitrosamines.

Water pipes
Safizadeh et al. (2014) detected contaminants like *Staphyloccoccus, Streptococcus* and *E. coli* in 83% of the examined different parts of waterpipes. Hani et al., (2018) found more than 40 bacterial species, among which pathogenic species: *Flavobacterium*, *Halomonas*, *S. aureus* and *Pseudomonas*. Other pathogenic and/or antibiotic resistant species (*B. cereus*, and *L. monocytogenes*) were detected by Masadeh et al. (2015).

3.11 Other products

In this paragraph, other products or products groups that were identified in this desk study on microbiological hazards in commercially available non-food consumer products are described.

Contact lens systems
Approved, unapproved and decorative lenses showed microbiological contamination (Land et al., 2018). A contaminated contact lens solution appeared to be the source of infection in an outbreak of *Fusarium* (Skorin, 2006).

Filtered water dispensors
Activated carbon blocks for the Point of Use filtration of tap water become contaminated during their use. As a consequence, the number of bacteria in the effluent can be higher than in the influent (Wu et al., 2017). This was confirmed by the results of a study by Girolamini et al. (2019). None of the input water samples tested positive for any of the pathogens, but *P. aeruginosa* was detected in 20/93 samples of output water. Three other output samples were contaminated with other pathogens (*E. coli*, *S. aureus*, *Enterococci*).

(Bio-) toilets
Dry-composting toilets are a practical solution in areas with inadequate sewage disposal and where water is limited. Redlinger et al. (2001) analysed the reduction of coliforms. Desiccation in combination with solar exposure is responsible for the decrease and for the final quality. Most of the compost resulting from such toilets, however, is not of the highest quality (Mexican standards). Nakagawa et al. (2006) tested survival of viruses in bio-toilet matrices (feces, urine, sawdust). Solids

were spiked with two types of viruses. In the worst case scenario, a storage time of 260 days is required for an acceptable risk level. Warm-water bidet toilets are equipped with a device that sprays warm water on the external genitalia and anus after urination or defecation. The warm water is either held in a tank or produced on demand using a water heater. Spray waters from both types showed low bacterial contamination. But *P. aeruginosa* was detected (Iyo et al., 2018).

Cough syrups, paint and paper products

Cough syrups can be contaminated. *B. subtilis*, *Micrococcus fulvum*, and *S. epidermidis* were the most commonly recovered bacteria. *Aspergillus niger*, *A. fumigatus*, *Penicillium notatum*, *Mucor sp*., and *A. flavus* were the most frequently isolated fungi. Tested samples however contained viable microbial loads within the acceptable limits according Pharmacopeia specifications. (Al-Kaf et al., 2015).
Obidi et al. (2009) evaluated the microbial quality of paints and paint products. Bacteria (*Bacilli* and *E. coli*) and fungi (*Aspergillus* and *Penicillum*) were detected. Initial numbers were low but numbers increased in time.
Paper and paperboard can be a source of microorganisms (Guzinska et al., 2012). The origin of the contamination is not obvious, but starch, used in the paper industry as reinforcement is conducive to growth of microorganisms. Paper and paperboard might also be contaminated during processing by the use of recirculated processing water.
In a product recall advertisement in the Child Health Alert magazine, teethers filled with liquid were reported to be possibly contaminated with *Pseudomonas* (Anonymous, 2006).

4 Discussion en conclusions

A consumer product is any product other than food or medical device that is commercially available for consumers, without prescription. They should be safe in many aspects. In this study, Scopus, Embase and the RAPEX system were used for the identification of microbiologically unsafe non-food consumer products or product groups. Some of the queries used in Scopus and Embase yielded too many results (both relevant and non-relevant). The queries focused on markers, plants, bulbs or flowers and soil. The results of these queries could not be analysed within the period of this project and are not included in this report. However, markers, plants, bulbs or flowers and soil need to be considered as risky, as they contain sufficient water and/or nutrients to support growth of microbiological hazards.
In the scientific literature, cosmetic items (rich in water and containing natural ingredients) were the most frequently mentioned products. Contamination of water-rich products can originate from one of the (natural) ingredients, or is the result of poor hygiene during handling and processing. Few examples of microbiologically contaminated low-water products were found in the scientific literature: tampons, tobacco, toothbrushes, paper and board and $CaCO_3$.
In RAPEX, most microbiological alerts referred to cosmetics and water-containing toys contaminated with TAVC, *E. coli*, *P. aeruginosa*, *S. aureus* and *C. albicans*, most likely because legal limits are set for these hazards. The RAPEX system has some limitations: there is no information on prevalence, only those non-food products that have cross-border effects are reported and there might be a sampling bias (mainly products that are subjected to specific EU legislation are reported (cosmetics, toys)). Furthermore, different countries might use different strategies/methods for the detection of microbiological hazards and have different notification strategies (Vincze et al., 2019). Klaschka (2017) analysed RAPEX alerts (on cosmetics) from between 2006 and 2015 and concluded that RAPEX contributes to product safety, but the system does not cover all dangerous products, as there are simply too many.

Other microbiological hazards.
Besides opportunistic pathogenic microorganisms, non-food consumer products are also linked to other potential microbiological hazards, like hazards with increased resistance to common preservatives, or with cross-resistance to antimicrobial compounds and allergens (Lundov et al., 2009). In one paper, the presence of nitrate reductase positive microorganisms is mentioned as a risk. It is not clear to what extent these nitrate reductase positive organisms in tobacco contribute to the overall health risk of smoking, but in smokeless tobacco these organisms contribute to the formation of carcinogenic nitrosamines. Pet animals and ornamental fish can be a source of antimicrobial resistant microorganisms, but their relevance for public health is not clear.

Other, non-reported products.
From the online brainstorm session at our department some additional potentially contaminated products were mentioned that did not pop-up

in the scientific literature. Searches for bait (fly-mades, worms) did not result in relevant publications. Drugstore products other than cough syrup with a microbiological risk (like nose/ear/eye sprays, liquid skin, (toilet) air refreshers/conditioners) were not (found to be) reported. In supermarkets and in public spaces during summer times, the temperature of the air is cooled by spraying water. This can form a risk, but no information on this potential risk was found.

Conclusion:
The use of or contact with non-food consumer products can result in an infection. Cosmetics and soap containing toys are the most frequently mentioned non-food consumer products in RAPEX. Cosmetics are also frequently mentioned in the scientific literature as a source of human pathogens. Although products like cosmetics and toys are used on a large scale, only seven outbreaks have been described in the literature, of which five were in a hospital setting. Possibly, exposure to human microbiological hazards via non-food consumer products contributes to a small extent to the overall exposure to human pathogens via all possible routes.

Future developments.
In a circular economy, the use of virgin or primary ingredients is as low as possible. Instead, pre-used, recycled materials become an ingredient of products. Compost is a well-known re-use example (Longhurst et al., 2019), paper is recycled and becomes paper again and pre-used plastics become a foodcontact product or toy. A circular economy introduces new risks: re-used ingredients from sources with new hazards replace traditional ingredients with known microbiological hazards. In addition, in circular processes that lack a full microbiological risk-reducing step, accumulation of (microbiological) hazards can occur (Quik et al, 2018).

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