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Assessment of chemical constituents of personal care products (PCPs) and their environmental implications: A case of South Africa

Sebatane Sharon Mabitla [a], Natsayi Chiwaye [b], Michael O. Daramola [a,b,*]

[a] Department of Chemical Engineering, Faculty of Engineering, Built Environment, and Information Technology, University of Pretoria, Pretoria, South Africa

[b] School of Chemical and Metallurgical Engineering, Faculty of Engineering and the Built Environment, University of the Witwatersrand, Wits, 2050, Johannesburg, South Africa

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ABSTRACT

Personal Care Products (PCPs) contain a wide range of chemicals which cleanse or enhance one's body appearance. These chemicals are continuously released into the environment, and if not properly regulated, they can be persistent, bioaccumulative and toxic in the environment. These chemicals are discharged into the environment through direct discharge from industries, hospitals, urban/municipal waste, and inefficient wastewater treatment systems. Previously chemicals in PCPs have not been considered harmful, and their effect on water, humans and the environment have not been investigated. However, emerging evidence suggests that some accumulate in body tissues and negatively impact humans and animals, impacting the endocrine systems and the environment since they are continuously being released and may not degenerate easily the environment. The contaminants are thus called emerging pollutants. The aim of this study was to investigate the presence of potentially toxic chemical ingredients of PCPs in South Africa by examining the product labels. A total of 185 PCPs were examined, with 57% of these products classified as skincare, 32% as rinse-off products and 11% as make-up products. Analysis of the database revealed that chemicals which function as fragrances, preservatives and UV-filters were present in 65%, 60% and 58% of the examined PCPs, respectively. Furthermore, the most frequently identified fragrances were limonene (73.33%), linalool (69.17.5%), coumarin (40%), and hexyl cinnamal (38.33%), which are weak allergens. However, alpha-isomethyl ionone and butylphenyl methylpropional are fragrances restricted by the IFRA but were found to be present in over 25 PCPs found in South Africa. This indicates the lack of set rules and regulations around PCP labelling and inconsistency in chemical regulation may promote the distribution of harmful chemicals into the environment.

1. Introduction

The wide environmental occurrence of Personal Care Products (PCPs) is prompted by their daily use in various consumer goods. These products include cosmetics, body washes, perfumes and lotions; which are used to either cleanse or enhance one's body appearance. The great consumption of these products has led to their continuous release into the environment, which consequently threatens ecosystems and human health. The reported health risks associated with chemical ingredients in PCPs (such as ultraviolet (UV) filters, parabens, and phthalates) include potential endocrine disruption and exhibition of estrogenic activity [1,2]. As a result, PCPs are regarded as emerging environmental contaminants; arising from their persistence, exposure potentials, toxicity and environmental accumulation [3,4]. Most of these chemical compounds enter the environment through direct discharge from industries, hospitals, urban waste and inefficient wastewater treatment systems [5]. Upon discharge into aquatic systems, some antimicrobial agents in PCPs such as triclosan have been reported to adsorb onto sediments, thus reducing their polarity [6]. In South Africa, environmentally toxic chemicals such as triclosan and triclocarban are still detected in influent and effluent samples of several wastewater treatment plants [7,8], despite their ban by the Food and Drugs Association (FDA). A recent study conducted by Mhuka and co-workers [9] revealed that one of the largest wastewater treatment plant (WWTP) in Pretoria (Daspoort Wastewater Treatment Works) showed an increase in concentration of triclosan from the influent to effluent samples. These findings indicate the incapability of the WWTPs to eliminate these organic pollutants and such poor removal ratios contribute to the

* Corresponding author. Tel.: +27(0)12 420 2475.
E-mail address: Michael.Daramola@up.ac.za (M.O. Daramola).

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persistence and accumulation of these chemical contaminants into the environment. Furthermore, it is reported that Europe and Canada have banned or restricted about 1500 and 800 chemicals in PCPs, respectively; while only 11 substances are prohibited or restricted in the USA [10].

In light of the above background, it is evident that there are gaps in the proper regulation of PCPs both at national and international levels. Some manufacturers place PCPs in the market with missing ingredient information, thus limiting consumers from making informed decisions upon purchasing the products. The lack of set rules and regulations around PCP labelling and inconsistency in chemical regulation promotes the distribution of harmful chemicals into the environment. The first objective of the current study was to examine PCP ingredients, as listed on the product labels. This task was conducted to identify the presence of environmentally toxic chemicals in PCPs available in South Africa. The second objective was to investigate the existence of PCP ingredients which are prohibited and/ restricted by regulatory bodies/ legislations. The envisioned contribution of this study is to provide consumers with knowledge about emerging contaminants in PCPs and information about harmful chemical ingredients in PCPs. In addition, the developed PCP database can provide South African policymakers and environmental regulatory bodies with critical and relevant information about the occurrence of harmful PCP ingredients in the market.

2. Materials and methodology

The first step involved the development of a database of PCPs found in South Africa. The process involved taking pictures of the ingredients that make up various PCPs, from variant commercial outlets. Furthermore, webshops (online marketing platforms) were used to download datasheets for some of these products. Next, information for each brand type were analysed, and then captured in excel. The PCPs analysed included rinse-off products (shampoos, body washes and cleansers), skincare products (body lotion, hand lotions, face creams and sunscreens) and make-up products (such as foundations and lip balm). As part of this exercise, 185 products were analysed, and their chemical ingredients were listed. However, the developed PCP database is neither deemed complete nor exhaustive. This is because it was developed based on a crude selection of PCPs estimated to be sold in large volumes; according to information provided by shop assistants and authors' own perception.

3. Results and discussion

This section examines the different functions of chemical ingredients of PCPs examined in this study. The database developed included chemicals which function as preservatives, fragrances, and UV filters in PCPs.

3.1. Database analysis of personal care products in South Africa

The developed database of PCP ingredients (as found in South Africa) was made up of a total of 185 personal care products. In summary, the PCPs analysed in this study were divided into three categories i.e. skin care products, rinse-off products and make-up products, as illustrated in Table 1.

In reference to Table 1, it can be observed that skin care products are the largest category, with 57% of the 185 PCPs examined in this study. This category includes a wide range of products from body lotion, hand lotions, face creams and sunscreens. These products are known to contain various UV filters for skin protection, countless fragrances and preservatives to prolong the shelf lives of the products. This is supported by the results in Table 1, with over 80% of the 105 skin care products found to contain UV-filters while approximately 70% of these products contained fragrances. Furthermore, about half (approximately 53) of the 105 skin care products contained chemical ingredients which function as preservatives. On the other hand, rinse-off products do not require UV filters in their formulation due to their short contact time with the skin, while 75% of the examined make-up products contained many chemicals which function as UV-filters. This is owed to the longer contact time of make-up products with one's skin compared to rinse-off products. The next sections examine the frequency of occurrence of specific chemicals in PCPs, which function as preservatives, fragrances, and UV-filters.

3.2. Fragrances in personal care products

Fragrances are generally used in PCPs to provide a pleasant odour and help mask the smell of some ingredients in the product. Table 2 summarises the occurrence of fragrances in PCPs analysed in this study. A total of 16 individual fragrances occurred in a total of 120 PCPs (over 60% of the examined PCPs); with 73 skin care products, 42 rinse off products and 5 make-up products.

It is illustrated in Table 2 that the most frequently identified fragrances were limonene (73.3%), linalool (69.2%), coumarin (40%), hexyl cinnamal (38.3%), benzyl alcohol (35%) and citral (28.3%). These fragrances are reportedly weak allergens this explains their high occurrence in most of the PCPs. Notably, limonene frequently occurs in rinse-off products (90.5%) while linalool occurs mostly in skin care products (68.5%). This is because limonene also acts as a solvent to

Table 2
Frequency of occurrence of fragrances in PCPs classified into skin care, rinse-off and make-up products.

Fragrances	Skincare Products (n = 73)	Rinse-off products (n = 42)	Make-Up (n = 5)	Total (n = 120)	Total %
Benzyl benzoate	15	8	2	25	**20.8**
Benzyl alcohol	27	12	3	42	**35.0**
Benzyl salicylate	22	3	2	27	**22.5**
Amyl cinnamal	5	4	1	10	**8.3**
Alpha isomethyl ionone	19	7	2	28	**23.3**
Citral	29	4	1	34	**28.3**
Citronella	21	7	3	31	**25.3**
Coumarin	31	14	3	48	**40.0**
Eugenol	18	12	1	31	**25.8**
Geraniol	9	17	2	28	**23.3**
Hexyl Cinnamal	22	23	1	46	**38.3**
Limonene	46	38	4	88	**73.3**
Linalool	50	31	2	83	**69.2**
Hydroxycitronella	9	2	1	12	**10.0**
Hydroxyhydrocinnamate	5	3	1	9	**7.5**
Isoeugenol	14	0	0	14	**7.6**
Butylphenyl methylpropinal	19	14	0	33	**17.8**

Table 1
Summary on the frequency of occurrence and proportion of products containing three dominant chemical functions.

	Products Examined	Products containing fragrances	Products containing preservatives	Products containing UV filters
	Number (%)	Number (%)	Number (%)	Number (%)
Skin care products	105 (57)	73 (69.5)	53 (50.5)	92 (88)
Rinse-off products	60 (32)	42 (70)	51 (85)	0
Make-up products	20 (11)	5 (25)	7 (35)	15 (75)
Total	**185**	120(65)	111(60)	107 (58)

enhance the cleaning properties of a product. These results are comparable with the study conducted by Panico et. al [11]. In the study, cosmetics used in Italy were examined and limonene fragrance also occurred mostly in rinse-off products (76.9% of 112 examined rinse-off products).

Fragrances such as alpha-isomethyl ionone and butylphenyl methylpropional are restricted by the International Fragrance Association (IFRA) but were found to be present in over 25 PCPs in this investigation. Based on these findings, it can be concluded that frequently used fragrances have the potential to contaminate aquatic systems due to their potential high discharge into the environment through wastewater. These chemicals are reportedly skin sensitizers; hence they are restricted. In addition, alpha-isomethyl ionone is toxic to aquatic life with long lasting effects while butylphenyl methylpropional has the potential to affect fertility and can cause harm to a fetus during pregnancy.

3.3. Preservatives in personal care products

Preservatives are used in PCPs to prevent the growth of harmful bacteria and fungi, thereby increasing the shelf life of a product. Table 3 summarises the occurrence of 13 commonly used preservatives in Personal Care Products.

In reference to Table 3, it can be concluded that Phenoxyethanol (47.8%) is the most dominant preservative used in PCPs found in South Africa as analysed in this study. In reference to Table 3 above, phenoxyethanol was found in 35 skincare products and also in 5 make-up products. These results reveal that phenoxyethanol was found present in 66% of the skincare products and 71% of make-up products examined this study. The second most dominant preservative used is sodium benzoate (36%) and followed by potassium sorbate (33.3%).

Notably, triclosan and triclocarban were not found in any of the examined products. This is despite the high levels of triclosan and triclocarban concentrations reported across South Africa [8,7]. These levels range between triclosan concentration of 2.01 and 17.6 mg/L influent and 0.990 to 13.0 mg/L effluent of samples collected from several wastewater treatment plants (WWTPs) across Gauteng [8]. Furthermore, triclocarban concentrations were 0.0860–2.84 mg/L and $< LOD - 1.89$ mg/L for the influent and effluent, respectively [8]. In a recent study, Bakare & Adeyinka [7] continued to evaluate the occurrence and fate of triclosan and triclocarban in Durban Metropolis (South Africa), and the influent concentration levels of triclosan and triclocarban were found in the ranges of 1.903 to 73.462 μg/L and 0.320 to 45.26 μg/L, respectively. These studies validate the fact that these chemical preservatives are still used in South African products despite their ban by the FDA [12]. In the past, these chemicals were commonly found in PCPs such as soaps, toothpastes, and detergents, but have been banned due to issues of endocrine disruption and antimicrobial resistance. In this context, it is highly likely that triclosan and triclocarban are still used as preservatives in these but excluded from the ingredient lists of PCPs investigated in this study. This strong assumption is validated by the fact that PCPs are widely recognised as the primary source of i.e., triclosan in wastewaters [14,15]. However, other minor sources of triclosan in wastewaters may be consumer products such as acrylics, veterinary, medical and household products [16]. These findings strengthen the need for more stringent regulations on product labelling, product testing and hazardous chemical regulation of PCPs and other products of concern in South Africa.

In addition, due to the global burden of antimicrobial resistance (AMR) it is important that environmental data or environmental risk assessments for chemical preservatives are prioritised in Cosmetic Product Regulation. This is because cosmetic preservatives are often evaluated for human health and subsequently approved without evaluation of their environmental fate. However, emerging evidence that suggests that low concentration exposures of these chemicals have the potential to contribute to AMR [13].

3.4. UV filters in personal care products

PCPs contain UV filters in order to protect one's skin from the harmful effects of UV light, which can potentially cause skin cancer and/or wrinkling. UV filters were used in 58% of the PCPs examined in this study. Products which contain UV lights were found to be skincare products (particularly sunscreen) and make-up products. In summary, UV filters were found in 75% of the make-up products examined and 88% of the skincare products examined in this study. There were no UV filters found in the rinse-off products examined in this study. This is due to the short contact time of these products with the skin, wherein products are washed off immediately after application. The common UV filters include benzophenone-3 (57%), octycrylene (27%), ethylmethyl methoxycinnamate (45%) and lastly homosalate (5%), which was mainly found in anti-ageing face screens. Moreover, it is important to note that PCPs analysed in this study comprise of many skincare products (57% of the examined products), particularly sunscreens and face creams. Therefore that supports the high frequency of occurrence of UV filters analysed in this study.

However, UV filters such as homosalate, benzophenone and octocrylene are suspected to have endocrine–disrupting properties and are currently prioritised for further assessment by several regulatory bodies such as the Cancer Association of South Africa (CANSA) and the USA (FDA).

4. Conclusions

A database of the constituent chemical ingredients of PCPs, as found in the South African market has been created. Analysis of the database revealed that there are predominant chemicals which function as preservatives, fragrances, and UV-filters in the formulation of these PCPs. Results reported in this study provide evidence that some of the PCPs available in the South African market contain ingredients that are

Table 3
Frequency of occurrence of preservatives in PCPs classified into skin care, rinse-off and make-up products.

Preservatives	Skincare Products (n = 53)	Rinse-off products (n = 51)	Make-Up (n = 7)	Total (n = 111)	Total%
Methyl paraben	14	6	4	24	**21.6**
Triclocarban	0	0	0	0	**0.0**
Propyl paraben	12	2	3	17	**15.3**
Ethyl paraben	10	3	1	14	**12.6**
Butylparaben	9	0	2	11	**9.9**
Potasium sorbate	11	25	1	37	**33.3**
DMDM Hydantoin	2	5	0	7	**6.3**
Sodium benzoate	16	23	1	40	**36.0**
Benzoic acid	4	2	0	6	**5.4**
Phenoxyethanol	35	13	5	53	**47.8**
Imidazolidinyl urea	4	2	1	7	**6.3**
Triclosan	0	0	0	0	**0.0**
Methylchloroisothiazolinone/ Methylisothiazolinone	0	16	0	16	**14.4**

reportedly harmful to the environment and restricted by regulatory bodies. These include harmful fragrances such alpha-isomethyl ionone and butylphenyl methylpropional, which were found to be present in over 16% of the studied PCPs. These fragrances are reportedly skin sensitizers and toxic to aquatic life. On the other hand, there are fragrances such as limonene and linalool, which were found to be present in over 70% of the examined PCPs. These fragrances are reportedly weak allergens and that rationalizes their predominant use in the formulation of PCPs. Furthermore, endocrine-disruptive preservatives such as triclosan and triclocarban are omitted from ingredient labels of some PCPs but continue to be detected in the effluent of multiple WWTP in South Africa, despite their ban. This study has therefore revealed some inconsistencies and gaps in chemical regulation of PCPs in South Africa. Therefore, this study strengthens the need for more stringent regulations on product labelling, product testing and hazardous chemical regulation of PCPs in South Africa. Such detailed information on product information will not only ensure adherence to environmental regulations but will also provide useful information to consumers about the quality and health effects of the products they use in their daily lives.

Future work will involve conducting chemical analysis of the PCP ingredients, as found in the developed database. In that case, QSAR models will be applied to predict the environmental fate of these chemicals from their inherent physicochemical properties. Furthermore, chemicals identified to be persistent, bioaccumulative and toxic by the QSAR model will be prioritised and used as a basis for the development of an optimum wastewater treatment system, capable of effectively removing harmful PCP contaminants. It is also recommended that more studies are conducted on alternative substances against potentially dangerous PCP ingredients, to ensure greener chemistry designs. Moreover, it is critical that PCP manufacturers do not prioritise preservation and attractiveness of their products (with fragrances/ colourants) at the expense of environmental conservation and human protection.

CRediT authorship contribution statement

Sebatane Sharon Mabitla: Conceptualization, Data curation, Investigation, Methodology, Validation, Writing – original draft. **Natsayi Chiwaye:** Investigation, Methodology, Supervision, Visualization, Writing – review & editing. **Michael O. Daramola:** Conceptualization, Supervision, Visualization, Resources, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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