REVIEW OF ANALYTICAL METHODS FOR DETERMINATION OF PARABENS IN COSMETIC PRODUCTS

Faris Rudi

Science and Technology Research Institute for Defence (STRIDE), Ministry of Defence, Malaysia
Chemistry Department, Faculty of Science, University of Malaya (UM), Malaysia

Email: faris.rudi@stride.gov.my

ABSTRACT

Parabens are well known preservatives that are widely used in cosmetic and personal care (CPC) products as they have a broad spectrum of antimicrobial properties, as well as being non-sensitising and non-irritating. Over the years, parabens have been considered to be a relatively safe compound. However, a few studies found that parabens might have estrogenic properties and there is an ongoing debate regarding the potential risk of cancer from consuming this product. This paper presents an overview of sample preparation methods, as well as instrumental analysis of current and past researches on the determination of parabens in cosmetic products. It first reviews on sample preparation methods that effectively eliminate complex matrices in cosmetics products, including liquid-liquid extraction (LLE), solid phase extraction (SPE), solid phase microextraction (SPME), dispersive liquid-liquid microextraction (DLLME) and supercritical fluid extraction (SFE). Then, the analytical techniques for the analysis are reported, mainly using high-performance liquid chromatography (HPLC), gas chromatography (GC) and electrophoresis. Research gaps and suggestions for future studies on the detection of parabens in cosmetic products are also given.

Keywords: *Parabens; cosmetic and personal care (CPC) products; complex matrices; sample preparation; analytical techniques.*

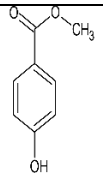
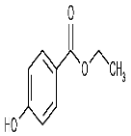
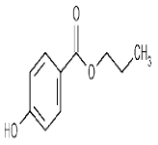
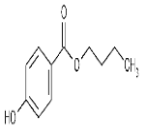
1. INTRODUCTION

Parabens is a group of para-hydroxybenzoic acid esters that is made up of methylparaben (MP), ethylparaben (EP), propylparaben (PP), butylparaben (BP), isobutylparaben (iBP), isopropylparaben (iPP), benzylparaben (BzP) and their sodium salts (Chao *et al*., 2020). Parabens is typically added to cosmetic and personal care (CPC) products as it has broad antimicrobial properties. Furthermore, parabens have characteristics of being odourless, tasteless, inexpensive, stable over a wide range of pH, non-decolourising and adequately soluble in water, which explains the wide range of applications of parabens as preservative (Cabaleiro *et al*., 2014a). While parabens have been known to have low toxicity effect, the increase of alkyl chain in the ester group of parabens contributes to increase in toxicity (Kolatorova *et al*., 2018). In addition, long-chain compounds are not commonly applied to cosmetic products due to lack of solubility (Matwiejczuk *et al*., 2020). The physiochemical properties of the most common parabens used in cosmetic products are shown in Table 1.

Routledge *et al*. (1998) found that a group of parabens, namely MP, EP, PP and BP, have mild estrogenic effects for humans and wildlife. Libei *et al*. (2016) further studied the estrogenic effects of parabens. In addition, findings of parabens in human breast tumours have raised concern on the toxicity of this preservative that leads to the risk of breast cancer (Darbre *et al*., 2004, 2013; Amin *et al*., 2019).

Presently, the European Union legislation has set limits on parabens and their salts for up to 0.4% (w/w) for MP and EP, 0.14% (w/w) for the sum of PP and BP, and 0.8% (w/w) for total parabens concentration in CPC products. Hence, the development of simple and reliable analytical methods to determine parabens is crucial to ensure that CPC products in markets contain parabens values that align with the regulation. A review by Wang & Liu (2007) summarised the sample preparation and instrumental techniques used in determination of parabens in cosmetic products between 1980 to 2007. In addition, Cabaleiro *et al*. (2014) summarised sample preparation methods for up to 2014.

Table 1: Physiochemical properties of the most common parabens used in cosmetics (Matwiejczuk *et al*., 2020).

SPECIFICATION	MP	EP	PP	BP
Chemical formula				
Molecular weight, g/mol	152.16	166.18	180.21	194.23
Cas no	99-76-3	120-47-8	94-13-3	94-26-8
pKa value (indicate the strength of an acid)	8.17	8.22	8.35	8.37
Solubility at 25% (m/m)				
Water	0.25	0.11	0.04	0.02
Propylene glycol	26	20	29	49
Ethanol	32	41	50	68
Melting point, °C	131	117	97	68
Boiling point, °C	275	297	-	-

The objective of this paper is to review the analytical methods that are used for sample preparation and instrumental analysis for determination of parabens in cosmetic products. In addition, it emphasises on the research gaps and suggestions for future studies.

2. TECHNIQUES USED FOR SAMPLE PREPARATION FOR PARABENS DETERMINATION

Generally, cosmetic products contain very complex matrices that demand the use of long steps of sample preparation. There are a number of methods for sample preparation for parabens determination based on simple dilution and homogenisation with a suitable organic solvent, such as methanol (Grzeskowiak *et al*., 2016a), ethanol (Huang *et al*., 2013) and propanol (Memon *et al*., 2005). However, the extracted samples still contain a lot of matrices that might affect chromatography sensitivity. Recently, a number of

methods have been developed to eliminate the matrix effect. Liquid-liquid extraction (LLE) is a method with single or combination of different solvents to extract the parabens that have been used (Gabriella *et al*., 2016a; Nourolhoda *et al*., 2019a). LLE provides simplicity for the extraction process, but there are some disadvantages for this technique, such as emulsion formation and being environmentally unfriendly due to high consumption of organic solvent (Cabaleiro *et al*., 2013). Solid phase extraction (SPE) (Figure 1) is an alternative for LLE that is used for the isolation and concentration of analytes from liquid flowing sample stream by their transfer to and retention (sorption) in a solid phase. This solid phase is then isolated from the sample and the analytes are recovered using liquid elution (Poole *et al*., 2012). Among the SPE cartridges used are C18 (Shen *et al*., 2007a; Uysal *et al*., 2008a) and C8 (Han *et al*., 2008a). However, the drawback of this technique is that it requires a lot of solvent for extraction (Cabaleiro *et al*., 2014b).

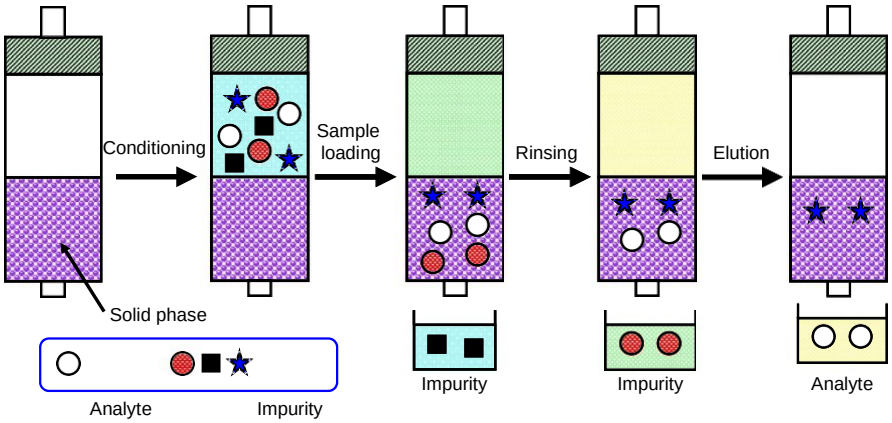


Figure 1: Schematic diagram of the SPE technique (Hiroyuki, 2017).

An alternative for SPE is solid-phase microextraction (SPME) (Figure 2), which reduces solvent consumption and operation time. SPME has two different techniques, which are headspace and direct SPME. For headspace SPME, the sample needs to be brought to equilibrium and the fibre exposed to the headspace of the sample for a period of time. Meanwhile, direct SPME involves immersing the fibre directly into the sample matrix. Direct SPME has been applied mostly for the non-volatile character of parabens (Fei *et al*., 2011a), while we found only one published application of headspace SPME for parabens determination (Yang *et al*., 2010a). The drawback of SPME is the limited number of stationary phases as it covers mostly non-volatile compounds, which poses a problem for volatile compounds (Ocana *et al*., 2015a).

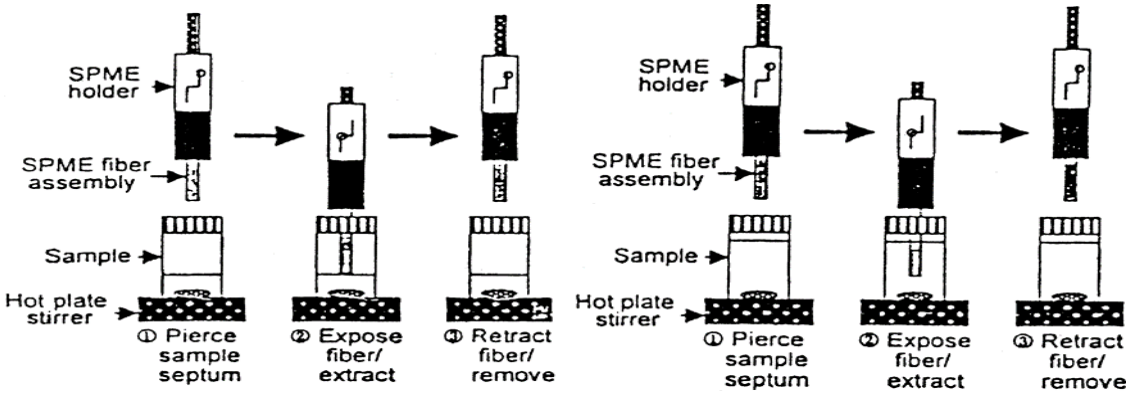


Figure 2: Schematic diagrams of headspace (left) and direct SPME (right) (Jatinder *et al*., 2005).

Dispersive liquid-liquid microextraction (DLLME) is an alternative technique to SPE and SPME, in which sorbent is dispersed into the sample matrix (or its extract), with the close contact that is obtained between the sorbent particles and the analyte favouring the kinetics of the sorption (Alberto *et al*., 2019). DLLME (Figure 3) involves the extraction and simultaneous concentration of the desired analyte from an aqueous solution using a small amount of organic solvent. It is an extraction technique that offers higher efficiency with only microvolume of solvent (Hongmin *et al*., 2014; Hwang *et al*., 2018). Dyia *et al.* (2018) used DLLME for extraction of methyl parabens from cosmetic products. Additionally, supercritical fluid extraction (SFE) is another extraction method for parabens determination that does not need any sample pretreatment (Lee *et al*., 2006a). SFE is well known as green technology by using CO_2 as the extraction solvent (Figure 4). Despite the benefit of SFE requiring no solvent to be used at all, it needs to be operated at high pressure (Puah *et al*., 2005).

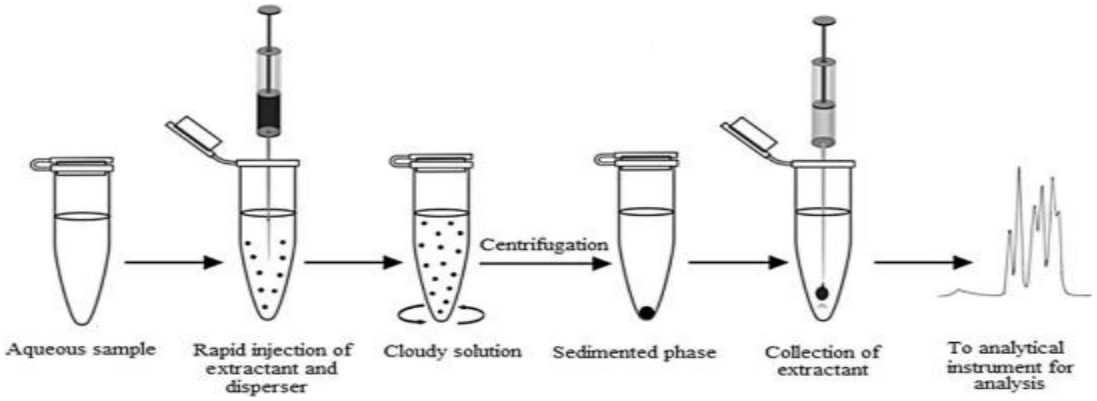


Figure 3: Steps in the DLLME technique (Ahmad et *al*., 2015).

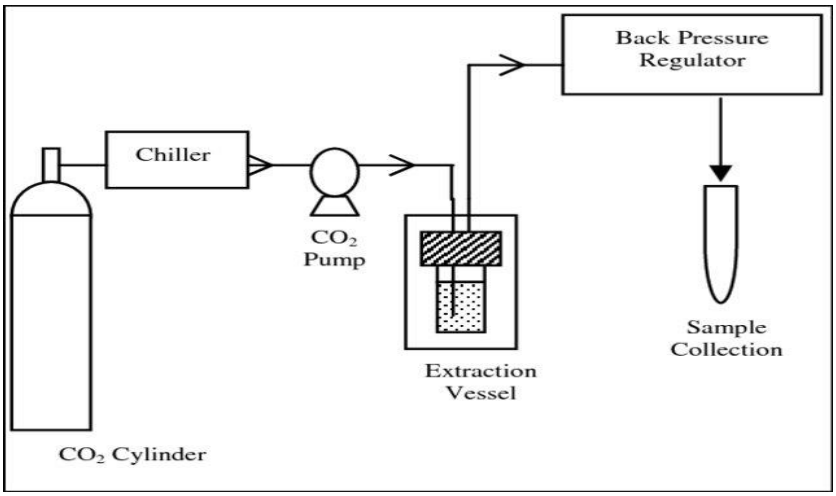


Figure 4: Simplified flow diagram of SFE (Puah *et al*., 2005).

3. SUMMARY OF ANALYTICAL TECHNIQUES USED AND RESULTS FROM LITERATURE

The last few years have seen a number of determination and analytical techniques being developed for parabens determination. High-performance liquid chromatography (HPLC) is the most common analytical technique used, followed by gas chromatography (GC) and electrophoresis.

HPLC is a specific form of column chromatography that is generally used in chemical analysis to identify, separate and quantify analytes. It operates at high pressure that pumps the sample (analyte) dissolved in a solvent (mobile phase) through a column with an immobilised stationary phase (Figure 5). The properties of the sample, mobile phase and stationary phase determine the retention time of the analyte, whereby analytes that have strong interactions with the stationary phase will elute for a longer period (Olga & Karin, 2017). HPLC allows for samples to be analysed without any derivatisation step since it is suitable for non-volatile compounds. This advantage contributes to the determination of parabens in cosmetic products in a short time as compared to other analytical techniques. Table 2 sums up the techniques and results for determination of parabens in cosmetic products using HPLC. Until now, HPLC ultraviolet detector (HPLC-UV) is the most used analytical technique for this type of parabens determination. Memon *et al*. (2005) successfully detected parabens with range of detection limit between 25-250 ng mL^{-1} using this technique. In addition, other detectors used for this technique are fluorescent detector (HPLC-FD) (Grzeskowiak *et al*., 2016b), diode array detector (HPLC-DAD) (Fei *et al*., 2011b; Nourolhoda *et al*., 2019b), mass spectrometer single quadrupole (HPLC-MS) (Lee *et al*., 2006b) and mass spectrometer triple quadrupole (HPLC-MS/MS) (Gabriella *et al*., 2016b).

Gas chromatography (GC) is a separation technique used to isolate volatile components of analytes in the mixture based on the differences in the mode of partitioning between mobile and stationary phases. The injected sample is then vaporised and transferred to a column by a mobile phase (Figure 6). The column that is packed with a finely divided solid or coated film is a stationary phase. The analyte interaction that occurs at the column results in the separation of the analyte of interest. The analyte then is eluted to the detector for signal generation (Rahman et al., 2015). Table 3 summarises the GC techniques with flame ionisation detector (GC-FID) (Hongmin *et al*., 2014; Dyia *et al*., 2018) and mass spectrometer detector (GC-MS) (Shen *et al*., 2007b; Yang *et al*., 2010b). Generally, GC-MS and HPLC-MS offer the same advantages, such as identification of analytes with low detection limit, which allows for the study of very low level of parabens in cosmetic products. GC-MS has some advantages as compared to HPLC-MS, in particular higher resolution, lower solvent of waste production and lower cost. However, GC-MS requires longer sample preparation time as the sample needs to be derivatised, which also raises the possibility of errors occurring during the derivatisation (Ocana *et al*., 2015b).

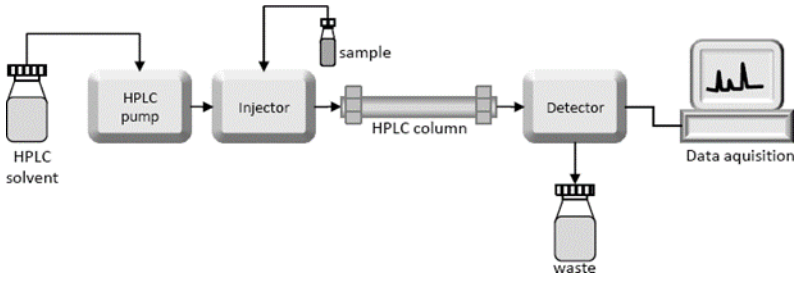


Figure 5: Schematic diagram of HPLC (Sylwester, 2013).

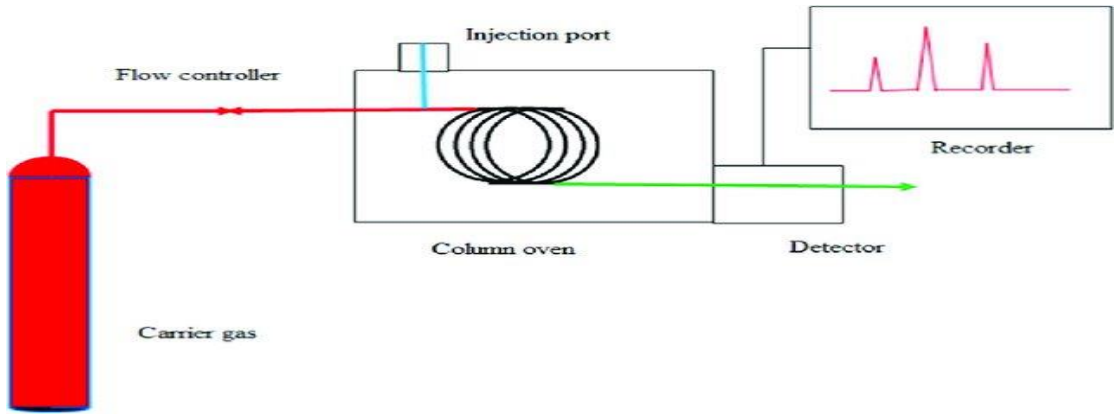


Figure 6: Schematic diagram of GC (Mallaiah, 2018)

Table 2: HPLC techniques for the determination of parabens in cosmetic products.

Technique	Parabens	Sample	Extraction method	Mobile phase	Stationary phase	Detection limits	Reference
HPLC-FD	MP, EP, PP, BP	Tonics & micellar water	LE	Gradient methanol / water	C18	0.007-0.014 µg mL^{-1}	Grzeskowiak *et al*. (2016)
HPLC-UV	MP, EP, PP, BP	Shampoo, hand lotion, creams & bath foam	LE	Isocratic water / propanol	C18	25-250 ng mL^{-1}	Memon *et al*. (2005)
HPLC-DAD	MP, EP, PP, BP	Sunscreens, lotions & creams	SPME	Acetonitrile /water	C18	0.12-0.15 µg mL^{-1}	Fei *et al*. (2011)
HPLC-DAD	MP, EP, PP, BP	Toothpaste & mouthwash	LE	Gradient methanol / water	C18	0.0004-0.001 µg mL^{-1}	Nourolhoda *et al*. (2019)
HPLC-MS/MS	MP, PP	Serum	LLE	Gradient methanol / acetonitrile	C18	1-20 ng mL^{-1}	Gabriella *et al*. (2016)
HPLC-MS	MP, EP, PP, BP	Lanoline cream, skin milk & cream	SFE	Gradient methanol / water	C18	4.7-19.3 ng/g	Lee *et al*. (2006)

Table 3: GC techniques for the determination of parabens in cosmetic products.

Techniques	Parabens	Sample	Extraction method	Detection limits	Reference
GC-FID	MP	Sunscreens	DLLME	0.082 µg mL^{-1}	Dyia *et al*. (2018)
GC-FID	MP, EP, PP, BP	Face masks, moisture cream, face cream & hair cream	DLLME	2.0 – 9.5 µg g^{-1}	Hongmin *et al*. (2014)
GC-MS	MP, EP, PP, BP	Homemade cream	SPME	0.001-0.015 µg L^{-1}	Yang *et al*. (2010)
GC-MS	MP, EP, PP, BP	Cosmetics	SPE	0.1-5.0 µg Kg^{-1}	Shen *et al*. (2007)

Electrophoresis refers to the movement of particles through a stationary fluid under the influence of an electric field. The principle of electrophoresis is the existence of charge separation between the surface of particle and fluid that surrounding it. An applied electric field acts on the resulting charge density, resulting in the particles migrating and the fluid around particles to flow (Scott & Curtis, 2000). Electrophoresis provides a simple, fast and sensitive technique for parabens determination in cosmetic products. However, for BP, it can only be separated by varying the pH value or methanol percentage in the buffer solution (Labat *et al*., 2000). There are two techniques for electrophoresis, which are capillary electrophoresis (CE) and micellar electrokinetic chromatograph (MEC). The set up for CE is shown in Figure 7. A microcapillary is stretched between two reservoirs that are filled with buffer solution. The analyte is introduced at one end of the capillary in the form of a plug that travels down the capillary due to electrophoretic mobility. The difference in the electrophoretic mobility of the analyte causes it to separate and travel to the detector (Sandip, 2005). For MEC (Figure 8), the surfactant is added to the buffer solution with concentration above the critical micellar concentration. The separation is based on the differences in the distribution constant between two phases migrating at different velocities due to the electrokinetic effects, resulting in micelles being formed (Hancu *et al*., 2012). Table 4 shows a summary of CE and MEC techniques used for determination of parabens in cosmetic products.

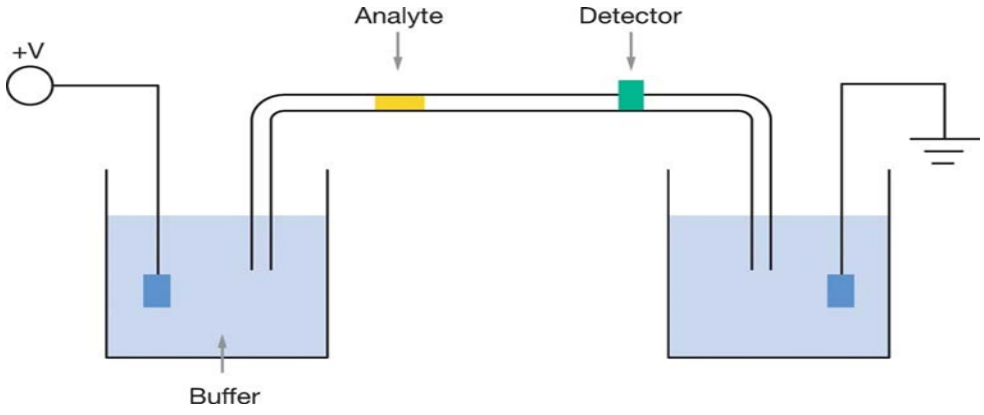


Figure 7: Schematic diagram of CE (Sandip, 2005).

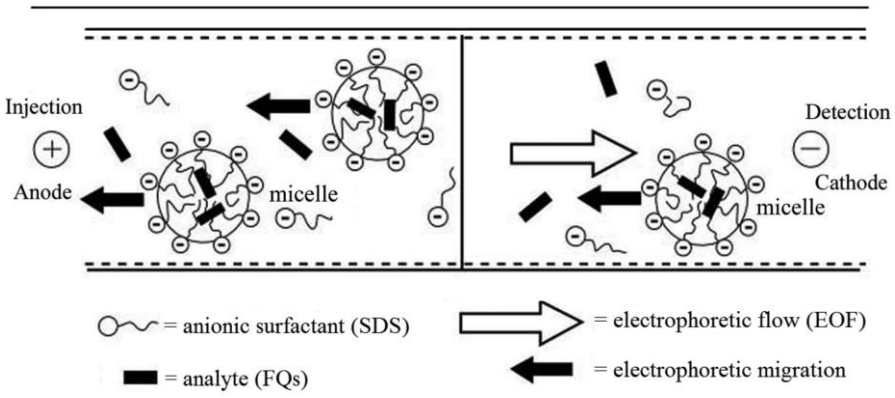


Figure 8: Schematic diagram of MEC (Hancu *et al*., 2012).

Table 4: Electrophoresis techniques for the determination of parabens in cosmetic products.

Techniques	Parabens	Sample	Extraction method	Carrier buffer	Voltage	Detection limits	Reference
CE	MP, EP, PP, BP	Shampoo, hair dyes, tooth paste & gel	SPE	20 mM borate, 10 % (v/v) MeOH	20 kV	1.42-2.86 µM	Uysal *et al*. (2008)
MEC	MP, EP, PP, BP	Cream, lotion, moisturiser	LE	1.0 mM phosphate buffer, 10% (v/v) ethanol	12.5 kV	0.48-1.52 µg mL^{-1}	Huang *et al*. (2013)
MEC	MP, EP, PP, BP	Cream, lotion, gel	C8	20 mM sodium tetraborate (pH 9.3, 100mmol/L SDS)	15 kV	0.07-0.1 µg mL^{-1}	Han *et al*. (2008)

4. CONCLUSION

This paper reviewed the sample preparation methods and analytical techniques for determination of parabens in cosmetic products. A number of sample preparation methods have been developed to effectively eliminate complex matrices in cosmetics products, including SPE, SPME, DLLME and SFE. SPE techniques have the potential to be used as an extraction technique as it offers fast and effective results. Meanwhile, SPME offers low solvent use and fast extraction time. DLLME, on the other hand, has the potential to be chosen as an effective technique as it is suitable for very low limit of parabens in cosmetic products. Finally, SFE provides an extraction technique without any use of solvent. However, it must operate at high pressure.

HPLC, GC and electrophoresis are among the analytical techniques used for parabens determination in cosmetic products. HPLC offers sample treatment without any derivatisation steps and is suitable for most non-volatile compounds. Hence, it is the commonly used analytical technique for parabens determination in cosmetic products. GC, on the other hand, is more suitable for volatile compounds, as well as provides simplicity and fast analysis time as compared to HPLC. Finally, electrophoresis offers fast and simple analysis for parabens determination in cosmetic products.

Suggestions for future studies to improve the sensitivity of parabens determination in cosmetics are:

(1) Possibility to apply nanomaterials as an extraction technique that allows for matrix clean up without decrease in sensitivity.
(2) Developing an electrochemical sensor for selective detection of parabens.

REFERENCES

Ahmad, W., Al-Sibaai, A.A., Bashammakh, A.S., Alwael, H. & El-Shahawi, M.S. (2015). Recent advances in dispersive liquid-liquid microextraction for pesticide analysis. *Trends Anal. Chem*, **72:** 18-192.

Alberto, C., Soledad, C. & Rafael, L. (2019). Dispersive micro-solid phase extraction. *Trends Anal. Chem*, **112:** 226-233.

Amin, M.M., Maryam, T., Asfane, C., Elham, A., Majid, H., Karim, E., Roya, K., Sedigheh, K. & Marjan, M. (2019). *Biomed Environ Sci*, **32:** 893-904.

Cabaleiro, N., Calle, I. D., Bendicho, C. & Lavilla, I. (2013). Current trends in liquid-liquid and solid-liquid extraction for cosmetic analysis: a review. *Trends Anal. Chem.*, **5:** 323-340.

Cabaleiro, N., Calle, I. D., Bendicho, C. & Lavilla, I. (2014). An overview of sample preparation for the determination of parabens in cosmetics. *Trends Anal. Chem.*, **57:** 34-46.

Chao, L., Xinyi, C., Yi, C. & Chunyang, L. (2020). Parabens concentrations in human fingernail and its association with personal care product use. *Ecotoxicol. Environ. Saf.*, **202:** 110933.

Darbre, P.D. (2013). Underarm cosmetics and breast cancer. *J. Appl. Toxicol.*, **23:** 89-95.

Darbre, P.D., Aljarrah, A., Miller, W.R., Coldham, N.G., Sauer, M. J. & Pope, G.S. (2004). Concentrations of parabens in human breast tumours. *J. Appl. Toxicol.*, **24:** 5-13.

Doron, S., Friedman, M., Falach, M., Sadovnic, E. & Zvia, H. (2001). Antibacterial effect of parabens against planktonic and biofilm streptococcus sobrinus. *Int. J. Antimicrob. Agents*, **18:** 575-578.

Dyia, S.M., Nurul, A.H., Shakirah, H. & Izhan, W.N. (2018). Extraction of methylparaben in cosmetic using dispersive liquid-liquid microextraction based on solidification of floating organic drop coupled with gas chromatography flame ionization detector. *Malayisan J. Anal. Sci*, **21:** 1289-1298.

European Commission. (2014). *Commission regulation (EU) No. 1004/2014 of 18 September 2014 amending annex V to regulation (EC) No. 1223/2009 of the European Parliament and of the Council on Cosmetic Products (Text with EEA Relevance)*. Publication Office of the EU, Brussels, Belgium.

Fei, T., Haifeng, L., Ding, M., Ito, M. & Lin, J.M. (2011). Determination of parabens in cosmetic products by solid-phase microextraction of poly (ethylene glycol) diacrylate thin film on fibers and ultra-high-speed liquid chromatography with diode array detector. *J. Sep. Sci*, **34:** 1599-1606.

Gabriella, P.T., Nayara, K.S.S., Ana, C.A. & Isarita, M. (2016). Determination of parabens in serum by liquid chromatography tandem mass spectrometry:Correlation with lipstick use. *Regul. Toxicol. Pharmacol*, **79:** 42-48.

Golden, R., Gandy, J. & Vollmer, G. (2005). A review of the endocrine activity of parabens and implications for potential risks to human health. *Crit. Rev. Toxicol*, **5:** 435-458.

Grzeskowiak, A.Z., Werner, J., Skowron, M.J. & Goslinska, B.C. (2016). Determination of parabens in cosmetic products using high performance liquid chromatography with fluorescene detection. *Anal. Methods*, **8:** 3903-3909.

Han, F., He, Y.Z. & Yu, C.Z. (2008). On-line pretreatment and determination of parabens in cosmetic products by combination of flow injection analysis, solid-phase extraction and micellar electrokinetic chromatography. *Talanta*, **5:** 1371-1377.

Hancu, G., Rusu, A., Simon B., Boia, G. & Gyeresi, A. (2012). Simultaneous separation of ciprofloxacin, norfloxacin and ofloxacin by micellar electrokinetic chromatography. *J. Braz. Chem. Soc.*, **10:** 1889-1894.

Hiroyuki, K. (Eds.) (2017). *Liquid Chromatography, 2nd Ed.* Elsevier, Amsterdam, Netherlands.

Hongmin, W., Jinjuan, Y., Hanqi, Z. & Yuhua, S. (2014). Ultrasonic nebulization extraction assisted dispersice liquid-liquid microxtraction followed by gas chromatography for the simultaneous determination of six parabens in cosmetic products. *J. Sep. Sci.*, **37**: 2349-2356.

Huang, J.Q., Hu, C.C. & Chiu, T.C. (2013). Determination of seven preservatives in cosmetic products by micellar electrokinetic chromatography. *Int. J. Cosmet. Sci.;*, **35:** 346-353.

Hwang, T.Y., Kin, C.M. & Shing, W.L. (2018). A review on extraction solvents in the dispersive liquid-liquid microextraction. *Malaysian J. Anal. Sci.*, **22:** 166-174.

Jatinder, S.A., Ashok, K.M., Varinder, K. & Phillipee, S.K. (Eds). (2005). *Critical Review in Analytical Chemistry*. Taylor & Francis, Oxfordshire, UK

Kolatorova, L., Vitku, J., Hampl, R., Adamcova, K., Skodova, T., Simkova, M., Parizek, A., Starka, L. & Duskova, M. (2018). Exposure to bisphenols and parabens during pregnancy and relation to steroid changes. *Environ. Res.*, **163:** 115-122.

Labat, L., Kummer, E., Dallet, P. & Dubost, J.P, (2000). Comparison of high-performance liquid

chromatography and capillary zone electrophoresis for the determination of parabens in cosmetic product. *J. Pharm. Biomed. Anal.*, **23:** 763-769.

Lee, M.R., Lin, C.Y. & Tsai, T.F. (2006). Simultaneous analysis of antioxidants and preservatives in cosmetic by supercritical fluid extraction combined with liquid chromatography-mass spectrometry. *J. Chromatogr. A*, **1120**: 244-251.

Libei, S., Tong, Y., Jilong, G., Zhaobin, Z., Ying, H., Xuan, X., Yingli, S., Han, X., Junyu, L., Desheng, Z., Linlin, S. & Jun, L. (2016). The estrogenicity of methylparaben and ethylparaben at doses close to the acceptable daily intake in immature Sprague-Dawley rats. *Sci. Rep.*, **6:** 25173.

Mallaiah, M. & Venkat, R.G. (2018). Data on acetic acid-methanol-methyl acetate-water mixture analysised by dual packed column gas chromatography. *Data Brief*, **18:** 947-960.

Matwiejczuk, N., Gallicka, A. & Brzoska, M.M. (2020). Review of the safety of application of cosmetic products containing parabens. *J. Appl. Toxicol.*, **40:** 176-210.

Memon, N., Bhanger, M.I. & Khuhawer, M.Y. (2005). Determination of preservatives in cosmetics and food samples by micellar liquid chromatography. *J. Sep. Sci*, **28:** 635-638.

Nourolhoda, R. & Zarrin, E. (2019). Curcumin loaded magnetic graphene oxide solid-phase extraction for the determination of parabens in toothpaste and mouthwash coupled with high performance liquid chromatography. *Microchem. J.*, **148:** 616-625.

Ocana-Gonzalez, J.A., Villar-Navaro, M., Ramos-Payan, M., Fernandez-Torres, R. & Bello-Lopez, M.A. (2015). New developments in the extraction and determination of parabens in cosmetic and environmental samples. A review. *Anal. Chim. Acta*, **858:** 1-15.

Olga, E.P. & Karin, S. (2017). High performance liquid chromatography (HPLC)-based detection and quantification of cellular c-di-GMP. *Methods Mol Biol*, **1657: 33**-43.

Poole, C.F. & Poole, S.K. (Eds). (2012). *Comprehensive sampling and sample preparation*. Academic Press, Cambridge, Massachusetts.

Puah, C.W., Choo, Y.M., Ma, A.N. & Cheng, H.C. (2005). Supercritical fluid extraction of palm carotenoids. *Am. J. Environ. Sci*, **4:** 264-269.

Rahman, M.M., Abd El-Aty, A.M., Choi, J.H., Shin, H.C., Shin, S.C. & Shim, J.H. (Eds) (2015). *Analytical Separation Science*. Wiley-VCH Verlag GmbH & Co. KGaA.

Routledge, E.J., Parker, J., Odum, J., Ashby, J. & Sumpter, J.P. (1998). Some alkyl hydroxyl benzoate preservatives (parabens) are estrogenic. *Toxicol. Appl. Pharmacol.*, **153:** 12-19.

Sandip Ghosal. (2005). Electrokinetic flow and dispersion in capillary electrophoresis. *Annu. Rev. Fluid. Mech.*, **38:** 309-338.

Scott, R. R. & Curtis, A.M. (2000). Electrophoresis techniques. *Sep. Purif. Methods*, **29:** 129-148.

Shen, H., Ying, L., Cao, Y., Pan, G. & Zhou, L. (2007). Simultaneous determination of phthalates and parabens in cosmetic products by gas chromatography/mass spectrometry coupled with solid phase extraction. *Sepu*, **25:** 272-275.

Sylwester Czaplicki. (Eds). (2013). *Column chromatography*. IntechOpen,

Uysal, U.D. & Gurayb, T. (2008). Determination of parabens in pharmaceutical and cosmetic products by capillary electrophoresis. *J. Anal. Chem*, **63:** 982-986.

Wang, P. & Liu, Y. (2007). Cosmetic preservatives and analysis methods used in China. J. *Environ. Health*, **24:** 557-559.

Yang, T.J., Tsei, F.J., Chen, C.Y., Cherng, T.C. & Lee, M.R. (2010). Determination of additives in cosmetic by supercritical fluid extraction on-line headspace solid-phase microextraction combined with gas chromatography-mass spectrometry. *Anal. Chim Acta*, **668:** 188-194.