Per- and Polyfluorinated Compounds in Menstrual Products and its Relationship with Natural Labeling

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ABSTRACT

Per- and Polyfluorinated compounds (PFAS), also known as "forever chemicals," gain their name from their persistence in both the environment and the human body. From pots to drinking water to period products/menstrual products, PFAS are found in seemingly every product both in and out of markets, yet PFAS in period products is of particular interest within this study due to its potential for harm. Due to the permeability of the vaginal mucosa and the misleading labeling of packaging, numerous people are being exposed to these compounds unknowingly, and thus their large range of potential side effects. Alongside the lack transparency within the composition of period products and the unknowing addition of PFAS through manufacturing and a lack of oversight, labels like "natural" and "non-toxic" lose their meaning. This study is performed to heighten awareness to this issue to potentially promote change in both transparency policy with "medical devices" and consumer/brand awareness of their products. This study attempts to show the lack of relationship between labeling and PFAS detection in menstrual products through an analysis of data from a Mamvation study alongside product listings on common consumer sites. By showing the lack of relationship, this study helps initiate an important discussion that can be used to spur change within accepted systems (such as United States policy on labeling and a lack of transparency and knowledge of product production chains behind brand names.

Introduction

For 2023, the projected sales price of period products within the United States is $52 billion, which is about $160 per person in the US (Petruzzi, 2022). Despite being considered as necessities by most in the western world, public knowledge of the chemicals and materials used to make period products seems sparce. With vague labeling, high prices, and unprovable claims of non-toxicity, there is a lack of transparency within feminine hygiene products that is aided by their labels as medical device—a label that allows them to avoid releasing a full materials and ingredients list within the United States (Segedie, 2022). This transparency problem is compounded when these manufacturing companies are unknowingly subjecting their customers to chemicals with potentially harmful and potent side effects.

PFAS, also known as per- and polyfluorinated substances, are a group of chemicals known as "forever chemicals." This title stems from the strength of the carbon-fluorine bonds that compose these compounds (EREF Staff, 2021). Due to the electronegativity difference between carbon and fluorine, fluorine carries a partial negative and carbon carries a partial positive, which creates a polar bond that pulls the atoms closer together. Compared with carbon-hydrogen bonds (that make up most organic molecules), the carbon-fluorine bond is strong due to its electrostatic properties and shorter bond length. Bond strength can be measured using bond dissociation energy, which is the energy required to break a bond into its atomic pieces. For comparison, carbon-hydrogen bonds require 413 KJ/mol to break, while the carbon-fluorine bond requires 485 KJ/mol to break: this is a relatively large difference considering the order of magnitude of the units used (Song & Le, 2023). Due to the comparatively large amount of energy needed to break the carbon-fluorine bonds and the number of these bonds present in one compound, PFAS can survive for prolonged periods of time and accumulate in both landfills and the body for years: in fact, PFAS mostly leave the human body through urine rather than breaking down within the body (Pennsylvania Department of Health, 2023).

PFAS, especially as they build up within the body, have been associated with certain health risks: delayed mammary gland development in unborn children, reduced response to vaccines in unborn children, low birth weight in unborn children, obesity in unborn children, early puberty onset in unborn children, increased miscarriage risk, low sperm count and mobility, thyroid disease, increased cholesterol levels, breast cancer, liver damage, kidney cancer, inflammatory bowel disease, testicular cancer, increased time to pregnancy, and pregnancy induced hypertension (pre-eclampsia) (Fenton, Ducatman, Boobis, DeWitt, Lau, Ng, Smith, & Roberts, 2020). However, like all chemicals, many of these side effects are proposed in a precautionary manner based off associative studies rather than causational ones. The study of the effects of PFAS is being aided by animal studies, but Jennifer Seed (branch chief with the EPA Office of Pollution prevention and Toxics) reveals that there is a lot of "variation in the speed with which humans and Labatory animals can eliminate PFOA (a PFAS compound)" (Seed, as cited in Betts, 2007). In further provocation, there is a lack of understanding why these difference between species occurs on a biological level according to Chirstopher Lau, a lead research biologist with the EPA National Health and Environmental Effects Research Labatory (Lau, as cited in Betts, 2007). Thus, there are a plethora of unknowns when it comes to the causes of these proposed side effects and the strength of association they have with PFAS, especially since human studies are likely confounded with existing conditions and environmental exposure (also it is unethical to purposefully expose people to PFAS with the knowledge that they are associated with adverse health effects). Animal studies using mice exposed to PFOA (perfluorooctanoic acid—a PFAS compound), such as the one done by Chester E Rodriguez, R Woodrow Setzer, and Hugh A Barton (2009) reveal some of these side effects. For example, this animal study revealed that there is a difference in PFOA life span between species (monkey, mice, female rat, male rat, and humans), and it reveals an association with adverse prenatal effects. The main effects revealed through laboratory animal studies (rates, mice, and monkeys) (after oral exposures to PFAS) include developmental toxicity, liver toxicity, and immune system toxicity. As seen in rats, PFAS has been associated with pregnancy loss, weight deficits, delayed mammary gland differentiation, delayed eye opening, and sexual maturation. In rats and monkeys, repeated oral exposure to PFAS is liver enlargement due to build up of PFAS chains within the organ (Rodriguez, n.d.). PFAS structure can resemble fatty acid structure (expect hydrogen is replaced with fluorine), and the liver is the central organ for fatty acid metabolism (Rodriguez, n.d.). One major difference though is that PFAS cannot be metabolized like fatty acids can, due to the strong C-F bond. The last major effects include immune system suppression, decreased spleen and thymus weight, and decreased immunoglobulin response (Rodriguez, n.d.). However, while these studies relieve that there is likely an association between PFAS and the side effects mentioned, it is important to consider that these results are limited in their application to humans due to the lack of knowledge or explanation for the differing characteristics of PFAS between specie.

PFAS compounds also pose environmental risk and harm. Due to their presence in a wide range of products and the disposable-inclined mindset adopted by many people in western countries, PFAS end up in landfills and disposal sites, polluting the soil and water. Since PFAS are unable to break down naturally, they end up back into the water and food supply, further exposing both wildlife and people to its adverse effects (United States Environmental Protection Agency, 2023). Many of its environmental effects are currently unknown, such as its effect when vaporized into the air, posing even more potential risk (Wisconsin Department of Natural Resources, n.d.).

If PFAS have adverse effects on both the body and environment, why are they still used in a vast variety of products? From pots to napkins to shampoo to period products, PFAS can be found in practically every product imaginable. One property of this chemical family is that it can be used to create products that resist heat, oil, stains, grease, and water (Kluger, 2023). The stability of the fluorine backbone of PFAS create a hydrophobic and lipophobic (oil-repelling) molecule due to the net polarity of the chemicals being relatively low (since many of the dipole moments cancel or are at least mitigated due to the position of the carbon-fluorine bonds). Thus, they are sometimes used in period products for their stain and water-resistant properties (water-resistance can help prevent leakage during use) (Beins 2023). While PFAS compounds might be used intentionally due to some of their physical properties, sometimes PFAS are byproducts of production. Due to their use in many machines, gloves, lubricants, etc. (that touch the final product—including packaging), PFAS addition could be presence in products without company knowledge (Koll & Sheldon, 2023). Also, outsourcing and renting of materials creates even more potential for unknown exposure, since many period product brands do not actually own the equipment, they use or sometimes leave the whole manufacturing process up to a separate company (Segedie, 2022). This creates a disconnect between the marketing of products and the materials being used, which is concerning because any error or miscommunication between the materials and chemicals used can translate into dangerous chemicals being found in products that are then mismarketed to the consumers. In combination with the lack of forced transparency with materials and chemicals used in period products (within the United States), it is seemingly impossible to avoid PFAS and other harmful chemicals, especially within feminine hygiene products.

The prevalence of PFAS in products of a vast variety may lead one to question why the focus of this study is on period products specifically. The reason lies within the particular risk posed by these chemicals within menstrual products. Period products are in direct contact with the vulvar and vaginal mucosa—two areas that are especially permeable due to the "absence of keratin and a loosely packed, less structured lipid barrier" and "the thinner, inner epithelium [creating] a shorter distance for penetration of substances" (Farage, 2019). Keratin is a protein found in hair, nails, and the epidermis of the skin that prevents external environmental substances from entering the body and internal bodily components from leaving (Cleveland Clinic, 2022). Lipid barriers act as a membrane, separating the chemical environments and concentrations of the different substances found on either side of the membrane: a "loosely structured lipid barrier" means that the membrane is not preventing as many things from entering and leaving the body (Farage 2019). Epithelium is a type of tissue that lines every surface of the body (internal and external) (epidermis is a specific example of epithelial); a thinner epithelium further contributes to the increased permeability of the vulva area since there are plainly less barriers that compounds need to surpass to enter or leave the body (Cleaveland Clinic, 2021). This permeability in addition to direct contact with the vaginal orifice means that chemicals in period products can and are directly absorbed into the body. According to Rhode Island Department of Health (2017), exposure to PFAS "in drinking water should not be higher than 70 parts per trillion," which becomes concerning when compared with the data shown below (for PFAS concentration found in period products) that is in the order of magnitude of part per million (keeping in mind that there is a difference in bodily uptake between direct consumption and bodily contact). In conjunction with the fact that "Around 22 items of sanitary protection are used per cycle and around 11,000 will be used in a lifetime," PFAS exposure from period products is extremely concerning, especially in the context of their potential health effects (Absorbent Hygiene Product Manufacturers Association, n.d.). If around "11,000" period products are used by one person throughout their lifetime, then around 11,000 products per person who mensurates ends up in landfills or other disposal sites where the PFAS within the product can seep into numerous places, including arable soil and drinking water reserves—leading to further PFAS exposure to more people (including those without periods).

The natural progression of this observation is learning how to avoid these chemicals, especially within mensural products. However, due to unknown additions of PFAS within products, vague labeling, and transparency laws, product labeling is of little aid to this goal. Therefore, the purpose of this study is to show the lack of relationship between product labeling and PFAS content within period products, in order to bring awareness to this issue.

Question and Hypothesis

What is the relationship between PFAS-containing period products and their labeling as natural?

Due to PFAS often being present as a byproduct of production and their advantageous characteristics, there is no relationship between labeling and PFAS content within period products.

Data Table

PFAS Detected compared with Natural Labeling by Product and Brand

Brand	Type of Product / Product Name	PFA (ppm) (organic fluoride)	Natural or non-toxic or free of PFAS (specially) (yes or no)
Medline Contour	Plus bladder pads	11	no
My box Shop	100% US Organic Top sheet panty liners	11	yes
Natra Touch	Natural bamboo charcoal panty liners	20	yes
NIIS GIRL	Bamboo charcoal luxury black pads	19	yes
Always	No feel protection Thin Liners	21	no
Always	Discreet 360 Form fit maximum underwear	15	no
Always	Anti-bunch extra protection liners	15	no
Amazon	Basic daily pantiliners long length	12	no
Attn	Grace light absorbency liners	19	yes
Carefree	Acti-fresh unscented daily liners	17	no
Claene	Organic cotton cover liners	22	yes
Cora	The-got-you-covered liner organic cotton top sheet	30	yes
Equate (Walmart)	Options liners light bladder leakage protection	21	no
Honey pot	100% organic cotton cover everyday liners	38	yes
Prevail	Incognito liners	51	no

Last Object	Last pad reusable menstruation pad	17	yes
Maxim Hygiene	Organic cotton ultra-thin contour pads	27	yes
Rael	Organic cotton cover panty liners	15	yes
Softly*	100% organic cotton cover pads	154	yes
Veeda	natural cotton liners	11	yes
Wise	Leak-proof everyday pads for bladder protection	13	yes
Wombilee	Organic cotton surface with wings biodegradable pads	13	yes
Le Fresh	Organic cotton large pads	None detected	yes
Live Better (CVS)	Organic cotton pantiliners	None detected	yes
Livlit	Organic cotton cover pads	None detected	yes
Lola	Utra thin liners made with 100% organic cotton	None detected	yes
Natracare	panty liners	None detected	no
OrganYc	Feminine care liners light flows	None detected	no
Sandis	Organic cotton panty liners	None detected	no
August	Liners	None detected	no
Always	Maxi pad with flex-wings	None detected	no
Carefree Breathe	Ultra-think pads overnight	None detected	no
Depend silhouette	Invisible comfort and protection maximum absorbency underwear	None detected	no
Kindfully made	Bamboo based pad liners	None detected	no

L.	100% pure cotton ultra-thin pads	None detected	no
L.	Life proof incontinence liners	None detected	no
Poise	One 2-in-1 liners	None detected	no
Poise	Daily liners discreet bladder protection	None detected	no
Prevail	Daily ultra-thin pads for bladder leaks	None detected	no
U by Kotex	Security light days liners	None detected	no
Seventh generation	Chlorine-free liners	None detected	no
Stayfree	Maxi all-in-one regular pads	None detected	no
Tena	Intimates liners	None detected	no
Up and up (target)	Regular liners unscented	None detected	no
maxim	Hygiene organic cotton cardboard applicator tampons	28	no
organYc	Complete protection tampons (made with organic cotton)	24	no
Playtex SPQRT	Regular and super tampons	19	no
Tampax	Cardboard applicator unscented tampons	23	no
Up and Up (target)	Regular tampons	23	No (no fragrances, bleach, dyes)
Daye	CBD-filled tampons	None detected	yes
Love begins with L	Organic cotton tampons	None detected	yes
O.B.	fluid lock regular tampons	None detected	No (environmentally friendly)
Playtex	Simply gentle glide ultra-absorbency tampon	None detected	No (no BPAS)

Tampax	Pearl leak guard protection jumbo tampons	None detected	No (no BPAS, dyes, fragrances, etc.)
Tampax	200% organic cotton core tampons	None detected	yes
U by Kotex	Click with comfort flex for your perfect fit compact Unscented Tampons	None detected	no
Veeda	100% natural cotton regular tampons	None detected	yes
Honey Pot	Organically grown tampons	None detected	yes
Live Better (CVS)	Organic cotton tampons regular	None detected	yes
Lola	Super tampons made with 100% organic cotton	None detected	yes
O.B.	Organic 100% organic cotton regular Tampons	None detected	yes
OI Girl	Organic regular tampons	None detected	yes
My Box	Shop 32 organic tampons	None detected	yes
Natracare	Organic tampons with applicator	None detected	yes
Seventh Generation	Organic cotton tampons	None detected	yes
TOP	Organic cotton tampons with plant-based compact applicator	Not detected	yes
Viv for your V	Organic cotton tampons with plant-based applicator	Not detected	yes

(Segedie, 2022)
*This is an outlier.
This data has been collected from studies done by Mamavation and an EPA (Environmental protection Agency)-certified lab, and the data considered here does not include any reusable period underwear. (data about the labeling of the product has also been found from commercial sites)

Graphical Review

Figure 1: Brands compared with the number of products tested, whether those products had PFAS detected, and whether those products were labeled as natural

Figure 2: Types of products versus PFAS detected versus whether the product was labeled as natural

Figure 3: PFAS containing Products versus Labeling as natural

Discussion of Trends and Data Collection

The first graph under the graphical review section compares the number of products tested with the number of products with PFAS and the number of products labeled as natural (by brand). This comparison is used to question whether detected PFAS products tended to come from a few brands or not and whether these brands tended to advertise themselves as "natural" or "non-toxic." It should be noted here that this graph cannot be used to make generalized statements about any particular brands due to a small sample size of one to four products being tested from each brand. 15 of the 43 brands shown in this graph sell products with PFAS and products that are labeled as "natural" (note that the products labeled as natural may or may not have PFAS). This reveals that it is not uncommon for brands to label their products (or even potentially their brand image) as "natural" while still selling products that contain PFAS, suggesting that judging brands by their public image and other products should be avoided. Additionally, this graph shows the prevalence of PFAS within period products since 26 of 43 brands (some of these brands being the most common and most available ones used within United States stores, including grocery store brands like Up and Up, Equate, and Live Better) had at least one product with detectable levels of PFAS.

The second graph under the graphical review section compares the total number of products tested with the number of products labeled as natural and the number of products with detected PFAS (by type of period product). As aforementioned, the products shown with the natural label may or may not be the same products as those detected with PFAS. This graph was utilized to question whether there is any relationship between the types of period products and detectable PFAS. Looking at the ratios between products with PFAS and total products tested, pads had 7/15, tampons had 5/23, liners had 14/28, and underwear had 1/2. Excluding tampons, each product has almost a 1 in 2 ratio, suggesting that there is not a strong relationship between one product type and PFAS detection. On the other hand, it is interesting to point out that there is a comparatively lower ratio between products with detected PFAS, and total tested for tampons. However, as mentioned prior, it should be noted that generalizations should be avoided (especially for underwear which has a sample size of 2 products) due to the low sample size of the data. This graph was then used to compare the number of products labeled as natural with product type to question whether one type of product was more susceptible to the "natural" label than others. Looking at the ratio between the number of products labeled as natural and the total number of products tested, pads had 8/15, tampons had 15/23, liners had 10/28, and underwear had 0/2. These ratios reveal that tampons and pads (within the sample tested) tended to be labeled as natural more often than liners. Due to the manner in which tampons are inserted, it would be logical that people might be more concerned over the composition of their tampons than things that solely touch the skin like liners. While pads and liners sit similarly on the skin, the duration of time in which people wear the products may also possibly affect the level of public concern. These predictions can help assess brand awareness of the public's desires or criteria for period products. This is important because if products are misbranded then not only is the consumer deceived monetarily but they are also deceived in terms of health risks—especially if they have picked a certain product to avoid chemicals like PFAS. Additionally, if brands are aware that there is concern about the composition of certain period products, then bringing awareness to certain materials or chemicals (like PFAS) can help incite change within manufacturing.

In graph three, the total number of products with PFAS is compared with the number of products with both PFAS and natural labels. Unlike the other two graphs, this graph shows the relationship between labeling and PFAS detected. The prevalence of blue lines (number of products labeled as natural that also contain PFAS) indicates that many products labeled as natural do contain PFAS. Yet again, the vitality of taking note of the low sample size throughout the data analysis cannot be overstated. Thus, while this data does depict that most brands (14/24) have natural proclaiming products with detectable PFAS, the data does not show any causation or trends for companies/brands as a whole. Therefore, there seems to be no relationship between labeling and detectable PFAS; products with PFAS are labeled both as natural and "unnatural." As discussed within the introduction, this is likely due to lack of awareness of manufacturing tools and processes by brands, the inclusion of PFAS as a byproduct of production, and the advantageous properties of PFAS within products.

To analyze the full validity of the data and trends discussed, this paper also comments on the original Mamavation study and their manner of testing. The company notes that they send the tested products to an "EPA-certified laboratory [to look] for indications of PFAS." To do this, "they do not look for PFAS compounds directly, because that is simply impossible. There are over 12,000 PFAS compounds and assays available for less than 100 compounds [available] in a really good commercial lab" (Segedie, 2022). Thus, they use marker testing to detect the presence of organic fluorine (a marker for PFAS since all PFAS are comprised of carbon-fluorine bonds). Specifically, they determined the total fluorine by "oxygen flask combustion and ion-selective electrode," then they identified the amount of free fluorine ions in the product by "ion-selective electrode" (if the lab detected 10ppm or greater) (Segedie, 2022). Lastly, they took the difference between these two measurements: In simpler language, the lab determined the total fluorine presence in a sample then the number of free (unbonded) fluorine ions and took the difference in order to predict the amount of bonded fluorine within the compound (since carbon-fluorine bonds comprise PFAS, the fluorine within PFAS should not be free ions). While this is an efficient way to quickly test consumer products, PFAS are not the only fluorine containing compounds; therefore it is possible that the "PFAS detected" in the study may also include the fluorine content from other "fluoropolymers, pharmaceuticals, and common hydrofluorocarbon refrigerants, such as 1,1,1,2-tetrafluoroethane (commonly known as R-134a) and 2,3,3,3-tetrafluoropropene (commonly known as HFO-1234yf)" (Segedie, 2022). Thus, it is not unlikely that the PFAS detected an overestimation. In contrast, due to the number of carbon-fluorine bonds within PFAS, it is likely that most of the organic fluoride detected came from PFAS and not other compounds.

Conclusion and Future Implications

As more testing and studies are performed on PFAS, it is being revealed that these compounds seem to not only be dangerous to the human body but also to the environment. However, their useful properties and accidental inclusion lead to a high prevalence of these compounds within practically every product and resource--even drinking water. But due to the permeability of vaginal skin and disposability of period products, PFAS within period products is of particular concern for both health and environmental reasons. Through data collected by Mamavation, it can be claimed that there is no relationship between a product being labeled as "natural" and that product's potential to include PFAS. Thus, not only are these compounds being revealed as dangerous (or at least unideal), but they are being included in products without consumer awareness and without any reliable way of avoiding them.

A problem discussed within the previous section is the small sample size of the Mamavation study, which can be generalized to this topic as a whole. The limited number of studies done, and the limited number of products tested limit the reliability of the data discussed and restrict the generalizability of the results discussed, making it difficult to make any overarching claims or conclusions about this subject. Consequently, there is certainly future potential for more research that tests more products, repeats studies on tested products, and develops more methods that can more reliability test for PFAS (maybe as more is learned about these compounds, it will become possible to identify a particular PFAS compounds that tend to be within these products, allowing for these tests/procedures to become more specific and reliable).

The implications of studies and analyses of this topic is increased awareness that can potentially incite change in both United States laws and product/material composition. Brands market to consumers, so if more consumers begin to care about PFAS content within their products, brands will have increased incentive to ensure the production of PFAS-free products. An example of this can be seen with a chemical known as dioxins, which often are added when period products are bleached with chlorine compounds. As more was learnt about the high toxicity of these compounds (linked to cancer, reproductive harm, endocrine disruption, and more) and how they end up in period products, an effort was made to change manufacturing practices (Segedie, 2022). Since dioxins are created in trace amounts during bleaching (and not added intentionally), companies have begun to stop bleaching their products and advertising them as so (likely increasing their brand customer trust and overall sales). Hence why bleaching with chlorine compounds has been largely abandoned by the late 1990s in favor of a chlorine-free bleaching process (Dudley, Nassar, Hartman & Wang, n.d.). Additionally, as this disparity between labeling and composition becomes more apparent, people can potentially charge their government with increasing transparency within not just period products but potentially all products. Afterall having "medical devices and products" becoming health risks is simply counterintuitive, and not something that should be hidden under vague labeling and "protective" laws.

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