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Review Article

A review on the extensive skin benefits of mineral oil

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Synopsis

This review was initially prepared in 2011 before Professor Johann Wiechers tragically passed away. It has been updated and is being published in his memory. It discusses the importance of mineral oil and its benefits to skin. Its source, structure, properties and efficacy are discussed. Mineral oil has been shown to improve skin softness and barrier function better than some other emollients using the gas-bearing dynamometer and standard water vapour transmission testing as well as *in vivo* studies showing its effects on suppressing trans-epidermal water loss (TEWL). It has also been subjected to the rigour of the newer *in vivo* confocal microscopic measurements now used for testing the performance of moisturizers by following the swelling characteristics of the stratum corneum and been found favourable compared with many vegetable oils. Its introduction as a cosmetic oil was in the late 1800s, and still today, it is used as one of the main components of moisturizers, a true testament to its cost to efficacy window. Naturally, it has physical effects on the stratum corneum, but it is expected that these will translate into biological effects simply through its mechanism of hydrating and occluding the stratum corneum from which many benefits are derived.

Résumé

Cette revue avait été préparée initialement en 2011 avant que le professeur Johann Wiechers décède tragiquement. Elle a été mise à jour et est publiée en son souvenir. Elle discute de l'importance de l'huile minérale et de ses avantages pour la peau. Sa source, la structure, ses propriétés et son efficacité sont discutées. L'huile minérale a été montrée capable d'améliorer la douceur de la peau et du fonctionnement de la barrière cutanée, mieux que certains autres émollients, en utilisant le gaz dynamomètre et les essais de la transmission de vapeur, ainsi que des études *in vivo* montrant ses effets supprimant la perte d'eau transépidermique (PIE). Elle a également été soumise à la rigueur de la nouvelle microscopie confocal *in vivo* maintenant utilisée pour tester les performances des crèmes hydratantes en suivant le gonflement caractéristique de la couche cornée et a été trouvée favorable par rapport à de nombreuses huiles végétales. Son introduction en tant que huile cosmétique date de la fin des 1800 et encore aujourd'hui elle est utilisée comme l'un des principaux composants de crèmes hydratantes, véritable témoin de son rapport coût/efficacité. Naturellement, elle a des effets physiques sur le stratum corneum, mais on s'attend à ce que ceux-ci se traduisent par des effets biologiques tout simplement sur la base de son mécanisme d'hydratation et de l'occlusion du stratum corneum de laquelle de nombreux avantages peuvent être tirés.

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Mineral oil: its source, its connection to the petrochemical industry, the process used to extract it and its usage

It is not known when mineral oil was first produced, but as a derivative of petroleum, it must have been after the discovery of crude oil, but even that is already known for thousands of years. The industrial drilling for petroleum ('petroleum' or rock oil) started around 1852 with production rates increasing exponentially over the first decades. According to generally accepted theory (the biogenic petroleum origin theory), petroleum is derived from ancient fossilized organic materials. Crude oil and natural gas are products of heating ancient organic materials over geological time. Formation of petroleum occurs from the decomposition of organic material at elevated temperatures in the absence of oxygen. Today's oil is formed from the preserved remains of prehistoric zooplankton and algae, which had settled to a sea or lake bottom in large quantities at depths where oxygen is no longer dissolved (the remains of prehistoric terrestrial plants, on the other hand, tended to form coal). Over geological time, the organic matter mixed with mud and was buried under heavy layers of sediment resulting in high levels of heat and pressure. This process caused the organic matter to change, first into a waxy material known as kerogen, which is found in various oil shales around the world, and then with more heat into liquid and gaseous hydrocarbons. This is the crude oil and gas that are being recovered nowadays in oil and gas fields, respectively. Petroleum is thus fossil plankton and algae-derived material and hence a natural material. Its diverse biological origin and the wide variety of conditions under which petroleum is formed explain why petroleum is a complex mixture of many different materials, mainly hydrocarbons. Its generalized weight composition is paraffins (30%; range 15–60%), naphthenes (49%; range 30–60%), aromatics (15%; range 3–30%) and asphaltics (6%; range: remainder). Crude oil therefore needs to be refined before it can be used in modern applications such as petrol for cars, kerosene for planes, lubricants for engines or oil for heating homes, to name but a few.

Mineral oil, which is the topic of this report, is a complex mixture of highly refined saturated hydrocarbons, which are derived from petroleum through various refining steps and subsequent purification by acid or catalytic hydrotreatment [1]. As the most purified form of petroleum that exists, mineral oil is not merely a by-product of petroleum but a specifically isolated and prepared fraction of petroleum with highly specialized product applications, among others, in food, cosmetics and pharmaceutics (for more details, see the next subsection). A complex series of processing steps is needed to produce mineral oils with the physical properties and the level of purity required for use in cosmetics, food and pharmaceuticals. Crude petroleum oils are distilled and processed by various methods to make finished mineral oils. Distillation of the crude oil produces fractions that differ in boiling range, average molecular weight and viscosity. The fractions obtained following distillation can be further refined by solvent extraction that removes polar and polycyclic compounds. The refining process used to make the mineral oil discussed in this report consists of treatment with sulphuric acid or hydrogenation (i.e. treatment with hydrogen in the presence of a catalyst at high pressure and temperature). Both processes are designed to remove polycyclic aromatic hydrocarbons, which are believed to be responsible for the historical finding of carcinogenicity of rodents after treatment with petroleum derivatives [2]. Refined mineral oil is composed of two hydrocarbon types: parraffinics, which are branched-chain alkanes, and naphthenics, which are alkanes containing one or more saturated cyclic structures. For the non-chemist readers of this report, alkanes are saturated hydrocarbons, chemical compounds that consist only of the elements carbon (C) and hydrogen (H). In mineral oil, especially, the longer-chained hydrocarbons are present. The parraffinics (i.e. the saturated straight-chain or branched hydrocarbons) are characterized by a higher viscosity and cloud point than the naphthenics (the cyclo-paraffinic hydrocarbons) that are characterized by their non-waxy nature.

The two hydrocarbon types can be separated via distillation and other physical processes. The ratio of these two chemical families and their molecular weight determines the physical properties of the resulting oils. Because of their complex chemical compositions, mineral oils are classified by their viscosities. Medicinal, cosmetic and food-grade oils are highly refined white mineral oils with a carbon number range from 15 to 25 for light and 25 to 50 heavy oils [2].

Mineral oil has been used in cosmetics for more than a hundred years, but the exact date of the introduction of mineral oil in cosmetics could not be found. It has also been used in electrical and food applications [3,4]. As extreme refining of crude petroleum is necessary, its introduction is estimated to have been around 1870–1880, as around that time the production of mineral oil was high enough at low costs. This combination of high production at low cost is probably also the reason why it was used as a cheaper alternative for vegetable oils. Table I lists a number of differences and similarities between vegetable oils and mineral oils used in cosmetics. This table indicates that both types of oil have their advantages and disadvantages. Although both products are nature-derived, the chemical process of manufacturing mineral oil is such that it does not meet the standards of 'naturals' in cosmetics. However, its 'inertness' makes it an extremely safe chemical that can even be used in food and pharmaceuticals. One can conclude from this that when mineral oil is used, it is more often than not used at high percentages in the formulations in which it is included.

Mineral oil is used in many topical applications and with added fragrance is marketed as baby oil. Although baby oil is primarily marketed as a generic skin ointment, other applications exist in common use. It is often used on infant 'diaper rashes' to ease the inflammation. Similarly, it may alleviate mild eczema, particularly when the use of corticosteroid creams is not desirable. Mineral or baby oil can also be employed in small quantities (two to three drops daily) to clean inside ears.

Mineral oil: its structure and properties

Mineral oil is known under many different names. The reason for this is probably historical as the product was created long before common nomenclature was implemented. Synonyms include heavy mineral oil, light mineral oil, liquid paraffin, liquid petrolatum, mineral oil mist, paraffin oil, paraffinum liquidum, petrolatum liquid, petroleum oil, white mineral oil and white oil. To avoid any confusion, this mixture of hydrocarbons will be referred to in this report as mineral oil. It is known by CAS as 8012-95-1; 8020-83-5 (wh.); 8042-47-5 (wh.); 39355-35-6; 79956-36-8; 83046-05-3; EINECS/ELINCS 232-384-2; 232-455-8 (wh.); INS905a.

According to the Specialty Chemicals Source Book, 4th Edition [5], the definition of mineral oil is '*a liquid mixture of hydrocarbons obtained from petroleum by intensive treatment with sulphuric and oleum, or by hydrogenation, or a combination, and consisting predominantly of saturated C15–C50 hydrocarbons*'. It is a colourless, transparent, oily liquid that is odourless and tasteless. It is insoluble in water and ethanol, soluble in benzene, ether, petroleum ether, carbon disulphide and volatile oils. Its density is 0.83–0.86 kg L^{-1} for the light mineral oil variant and 0.875–0.905 kg L^{-1} for the heavy mineral oil variant. Its flashpoint is 229°C (or 444°F), whereas its surface tension is <35 dynes cm^{-1}. The LD_{50} (oral, mouse) is 22 g kg^{-1}, whereas the highly purified food grades are

Table I Differences and similarities of vegetable oils and mineral oils. It should be taken into account that there are many different vegetable oils, so only a range can be given, whereas the properties of mineral oil can be described more accurately

	Vegetable oils	Mineral oil
Origin	Plant-derived	Animal-derived (fossil plankton and algae)
Production volume	Low to medium	High
Production cost	Medium to high	Low
Physical appearance	Yellowish to brown	Colourless
Chemical treatment during manufacturing	Mainly pressing (fixed oil) or heating (volatile oils)	Sulphuric acid and/or hydrogenation
Chemical stability	Often sensitive to oxidation and occasionally to light	Inert
Biological activity	Variable, depending on active ingredients	Gut: laxative Skin: moisturization
Toxicology	Variable, depending on active ingredients	Non-toxic, GRAS (Generally Regarded As Safe)

described in the same Specialty Chemicals Source Book [5] to be of low toxicity. Many uses are known, of which the most common have already been described previously but others include protectant, binder, extender, pharmaceutical vehicle, corrosion inhibitor, viscosity modifier in metal treatment, etc. It is FDA approved for ophthalmics, orals and topical and is listed in many different pharmacopeia. It is sold by more than 45 different suppliers, many of which are known in the cosmetic industry and is sold under at least 123 different registered trade names [5].

The popularity of mineral oil as a cosmetic ingredient emerged in the last quarter of the nineteenth century because of its low cost and abundant supply. In the first quarter of the twenty-first century, we see a 'Back-to-Nature' movement that is purely based on the perception of the consumer that anything derived from nature is better, safer and more efficacious, whereas anything synthetic is chemical, dangerous and toxic. Table II therefore lists the efficacy/capacity of vegetable oils and mineral oil for a series of physical and biological parameters. Again, as with Table I, the reader should keep in mind that '*the*' vegetable oil does not exist and that therefore only a range can be given for 'vegetable oils'.

Based on the findings in this table, the differences between vegetable oils and mineral oil are only marginal. The efficacy of mineral oil is mainly 'external', *that is*, on top of the skin (where it leads to emolliency and skin moisturization via occlusivity), whereas vegetable oils as a class of chemicals are smaller and, even within a single oil, more chemically diverse; hence, they offer less occlusivity but a higher biological efficacy in specific applications (such as skin whitening, anti-itch, etc.). The sensory profile of mineral oil has been well described through the work of Wiechers and co-workers [6–8].

Efficacy of mineral oil

Skin moisturization: Blank [9] first identified the importance of water in softening the stratum corneum but excluded the benefits of oils having this effect. Peck and Glick [10] came to similar conclusions demonstrating that mineral oil had no effect on the hardness of the stratum corneum. Similarly, Rieger and Deem [11] found that mineral oil alone had no effect on stratum corneum extensibility, but they did show its effects on reducing water loss *in vivo* much like the early studies of Powers and Fox *in vivo* [12]. The interpretation of the original studies on stratum corneum flexibility was erroneous as the authors did not take the effect of mineral oil as a mildly occlusive agent into account. In fact, it was not the mineral oil that improved stratum corneum flexibility but the water that was trapped because of the occlusive property of mineral oil.

Table III Mean values and standard deviations of TEWL values obtained previous to treatment and 30-min post treatment for all applied substances

	TEWL values (g hm^{-2})		
Applied substance	Previous to treatment	30-min post treatment	Significanc *P*
Jojoba oil	11.82 ± 2.18	11.82 ± 2.68	>0.05
Soybean oil	10.78 ± 2.03	9.88 ± 2.06	<0.05
Avocado oil	11.70 ± 1.61	9.93 ± 2.22	<0.05
Paraffin oil	11.95 ± 1.54	10.70 ± 1.78	<0.05
Almond oil	11.82 ± 1.35	10.67 ± 1.54	<0.05
Petrolatum	10.95 ± 2.1	5.08 ± 1.78	<0.05

Although new mechanisms of action of active ingredients are being identified all the time, emolliency, occlusion and humectancy are the mainstay of action of moisturizers. Mineral oil possesses the first two of these benefits. Occlusion will deliver the greater efficacy as it helps to retain water in the skin rather than just masking superficial problems. To obtain occlusion from a cosmetic ingredient, two aspects are important: alkyl chain length and distribution as well as substantivity [13].

First of all, the molecules must all align and in doing so, form a tight 'palisade' that prevents the passage of other molecules. This can be achieved by having straight alkyl chains of the same length. In contrast to vegetable oils where the molecules can be extremely diverse, mineral oil is almost nothing else but straight-chain alkyl chains. The difference between light and heavy mineral oil (the low- and high-viscosity variants, respectively) is that the light variant contains more cyclic (saturated) molecules that prevent the consistent build-up of the palisade. Light mineral oil is therefore less occlusive than heavy mineral oil. But the presence of (only) straight alkyl chains alone is not enough. If there are different alkyl

Table II Comparison of vegetable oils and mineral oil for a series of physical and biological parameters. Note that only ranges can be given for vegetable oils as this is an extremely diverse group. Although exceptions will always exist, care has been taken to list the 'average' vegetable oil

Parameter	Vegetable oils	Mineral oil
Occlusivity	Medium at most because of chemical diversity	High (because of alignment of straight alkyl chains)
Emolliency (the degree to which the oil provides softness to the skin)	Variable	High
Blocking pores (acne inducing)	Rarely	Not (based on experimental findings)
Moisturizing (increasing moisture content of skin)	Variable, mainly medium, but biologically active ingredients can deliver improved moisturising with time (after weeks of treatment)	Medium
Skin elasticity (increasing the flexibility of skin)	Low	Low
Substantivity (extent to which a chemical remains on the skin)	Extremely variable, from very low to very high	Medium
Skin penetrability	Variable, but on average some penetration because of smaller chemical structures than mineral oil	Low to extremely low because of molecular size of the alkyl chains

chains with different chain lengths, this also allows for the existence of 'holes' in the palisade fence. Heavy mineral oil may be predominantly straight-chain alkyl chains, but the chain length is highly variable, ranging from 25 to 50 carbon atoms. This is the reason that the occlusive nature of mineral oil is good, but not perfect.

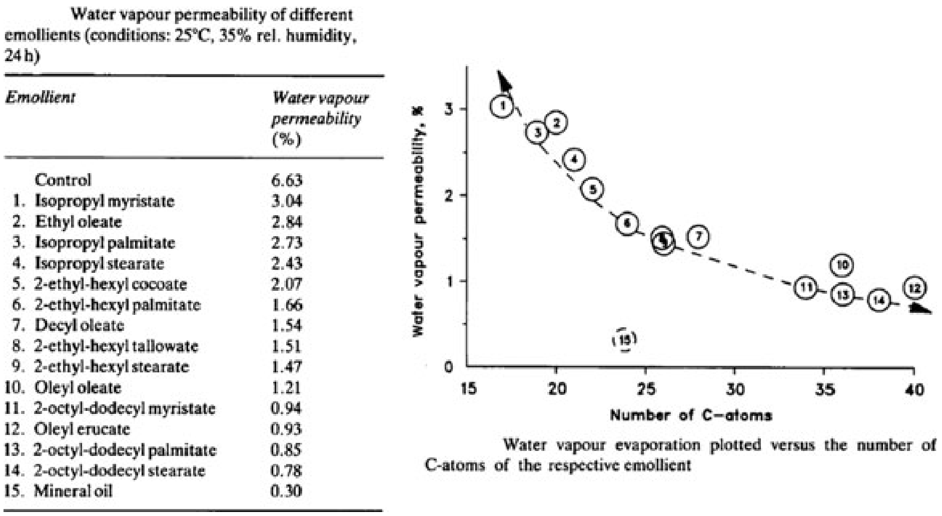
The second aspect is the substantivity of the occluding oil. If the molecule penetrates the skin very well, the palisade disappears very quickly, so the resulting occlusion is not very high. This removal from the site of application is mainly caused by diffusion, both into the skin (skin permeability) as well as lateral diffusion on top of the skin. This is easily understood from the waxy nature of the latter. The viscosity of this waxy material is that high that it has no lateral diffusion and it is too big to penetrate, whereas mineral oil has some lateral diffusion but hardly any skin penetration. A disadvantage of vaseline petroleum jelly, however, is its unfavourable sensory profile. It is an effective moisturizer but absolutely not an elegant product. Mineral oil seems to be at the optimum of two opposing forces: it still has enough substantivity and occlusivity left to create skin moisturization but not enough substantivity to become unacceptable from a sensory point of view. Most other commonly used cosmetic emollients are too light (i.e. not viscous enough) to have this degree of substantivity, or if viscous, they are not sufficiently regularly shaped to allow the 'palisade' formation. Fixed vegetable oils, however, tend to be a little bit heavier, and they may also hydrate skin to some extent, provided they are used in high enough concentrations. And this introduces the final proviso: concentration. You may have an oil that is sufficiently straight chained to give the 'palisade' structure and sufficiently substantive to provide occlusivity, but if this oil is only present at small amounts in a formulation, there is still not enough occlusivity.

Strubmann *et al.* [14] used polytetrafluoroethylene membranes to mimic skin and examined the effects of a variety of emollients on its water vapour permeability in which mineral oil was shown to be very occlusive compared with other 'fluid' emollients (Fig. 1). Fromder *et al.* [15] also compared a variety of emollients/gelatine mixtures for their occlusive properties in which mineral oil performed very well. However, it must be borne in mind that real skin was not used in either of these examples. Indeed, comparing the efficacy from the *in vitro* data to the *in vivo* TEWL measurements, the performance of all the emollients was less with mineral oil reducing baseline transepidermal water loss (TEWL) by 16% (for comparison, petroleum jelly reduced TEWL by 43%). Tsutsumi *et al.* [16] demonstrated *in vivo* using TEWL that mineral oil gave an occlusivity to forearm skin of about 25% at and above 2 mg cm^{-2}, similar to the work of Osborne and Gerraughty [17]. Lieb *et al.* [18] provided even better occlusivity from mineral oil in hamster skin *in vitro*. Changing the viscosity of the mineral oil can improve efficacy. By reducing its diffusion, even greater efficacy has been reported by Morrison with gelled mineral oils [19]. The rationale for these effects was already explained previously.

Mineral oil, Johnson's Baby Oil as reported by Jolly and Sloughfy [20], has been used to treat dry skin. However, to date, it has been reported to have similar efficacy to other oils [21–23]. Nevertheless, the barrier effects of mineral oil can also be observed in the skin's susceptibility to stinging from lactic acid. Sahlin *et al.* [24] have reported that increasing the concentration of mineral oil in formulations containing the same concentration of lactic acid tended to decrease the stinging effect thereof, as the concentration of mineral oil increased from 10% to 50%. This suggests that the lactic acid was less capable of penetrating the additional barrier created by the mineral oil. The results of this experiment are shown in Fig. 2.

Mineral oil has many applications in bath oils. Knox *et al.* [25] described superior water dispersible bath oils in 1958. Taylor [26] went on to prove that mineral oil type bath oils are better absorbed into skin than vegetable oils. Stolar [27] came to similar conclusions but also found that mineral oils with increasing viscosities (and therefore reducing naphthenic content) deposited less onto skin *in vivo*. *In vivo*, mineral oil binds to skin better than vegetable oils, whereas Bollinger *et al.* [28] and Knox *et al.* [25] found conflicting results *in vitro* with the latter studies correlating with *in vivo* findings.

Improvements in skin softness are an additional benefit that consumers can perceive from the application of oils. These improvements can be measured objectively using sensitive biomechanical techniques. Using the Dermaflex, Overgaard and Jemec [29]



Water vapour permeability of different emollients (conditions: 25°C, 35% rel. humidity, 24 h)

Emollient	*Water vapour permeability* (%)
Control	6.63
1. Isopropyl myristate	3.04
2. Ethyl oleate	2.84
3. Isopropyl palmitate	2.73
4. Isopropyl stearate	2.43
5. 2-ethyl-hexyl cocoate	2.07
6. 2-ethyl-hexyl palmitate	1.66
7. Decyl oleate	1.54
8. 2-ethyl-hexyl tallowate	1.51
9. 2-ethyl-hexyl stearate	1.47
10. Oleyl oleate	1.21
11. 2-octyl-dodecyl myristate	0.94
12. Oleyl erucate	0.93
13. 2-octyl-dodecyl palmitate	0.85
14. 2-octyl-dodecyl stearate	0.78
15. Mineral oil	0.30

Water vapour evaporation plotted versus the number of C-atoms of the respective emollient

Figure 1 Water vapour transmission rates of various emollients from ref. 11.

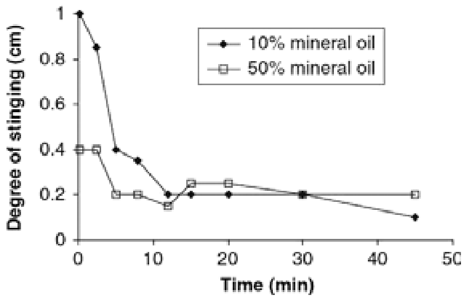


Figure 2 Degree of perceived stinging with time from 15% lactic acid in the o/w emulsion with 10% mineral oil and the one with 50% mineral oil. The degree of stinging was marked on a 9-cm visual analogue scale. Median values, $n = 19$. Tendency to significant differences between maximum degree of stinging ($P = 0.077$), whereas less significance in the area under curve (AUC; $P = 0.251$) was seen between the two formulations.

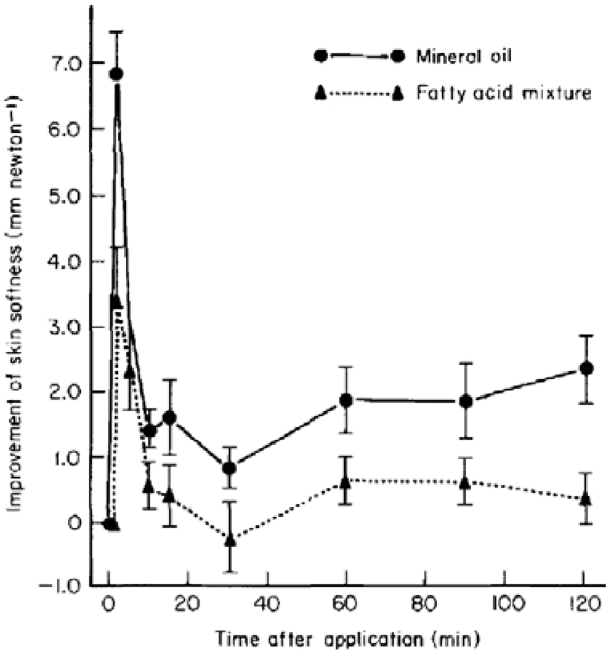


Figure 3 Improvement in skin softness after application of an emulsion containing fatty acids or mineral oil from ref. 30.

showed the positive effects on improving skin extensibility for mineral oil, which lasted longer than treatment with water alone. Increased skin extensibility means a more flexible or elastic skin, a skin that can be stretched further but will still return to its original position. The highly sensitive gas-bearing electrodynamometer has also been used by Maes *et al.* [30] to discriminate the effects of emollients on stratum corneum *in vivo*. Applied in emulsions, mineral oil was shown to induce greater skin softness compared with wax esters, triglycerides and fatty acids (Fig. 3). This effect may relate to its superior effects as an occlusive ingredient.

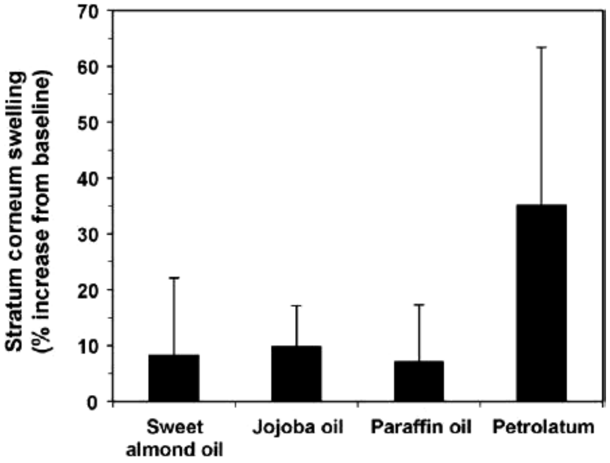


Figure 4 Increase in stratum corneum thickness (a measure for water uptake of the stratum corneum) because of the application of two vegetable oils and mineral oil (paraffin oil). Taken from ref. 33.

Very long chain hydrocarbons have been reported by Brown *et al.* [31] not to penetrate the skin to any large degree. Using radiolabelled hexadecane ($C_{16}H_{34}$) and docosane ($C_{22}H_{46}$) as *n*-alkanes of different chain length, they found that when applied in mineral oil, they hardly penetrated beyond the stratum corneum layer of pig skin *in vitro* with only 1.2% and 2.1% of the applied dose being in the epidermal and dermal layers. There was no penetration into the receptor fluids. Thus, these studies indicate the safety of these ingredients. However, it must be borne in mind that straight-chain alkanes were used in these studies and that branched together with cyclic alkanes are also found in mineral oil, and their delivery characteristics may be different.

Backhouse *et al.* [32] came to similar conclusions regarding the limited penetration of mineral oil into skin. Stamatas *et al.* [33] have also shown limited penetration of mineral oil into the stratum corneum. Using their method of *in vivo* Raman spectroscopy, they also showed an increase in stratum corneum thickness of around 10% further demonstrating the effect of occlusion leading to the reported effects on skin softness discussed previously. Figure 4 illustrates the results of this investigation. When using vegetable oils (in this study, sweet almond oil and jojoba oil) and mineral oil (called paraffin oil in this publication), the increase in stratum corneum thickness (which is a measure for its water uptake) is increased to the same extent, namely 10%. The application of petrolatum, which is much more occlusive, results in a significantly larger increase in stratum corneum thickness.

In this process of interacting with the stratum corneum lipids, mineral oil, like all other oils, will disrupt its structure to some extent. However, when examined by electron microscopy as reported by Warner *et al.* [34], a more homogeneous structure than that present in soap-induced dry skin was found.

However, Patzelt *et al.* [35] found minimal penetration of mineral oil and other oils into the stratum corneum (Fig. 5) and that mineral oil's behaviour on suppressing TEWL was similar to vegetable oils, but that jojoba oil was the worst performing vegetable oil tested (Table III).

Mineral oil and comedogenicity

'Acne cosmetica' was coined in the early 1970s to describe the association between cosmetic use and acne breakouts. A variety of

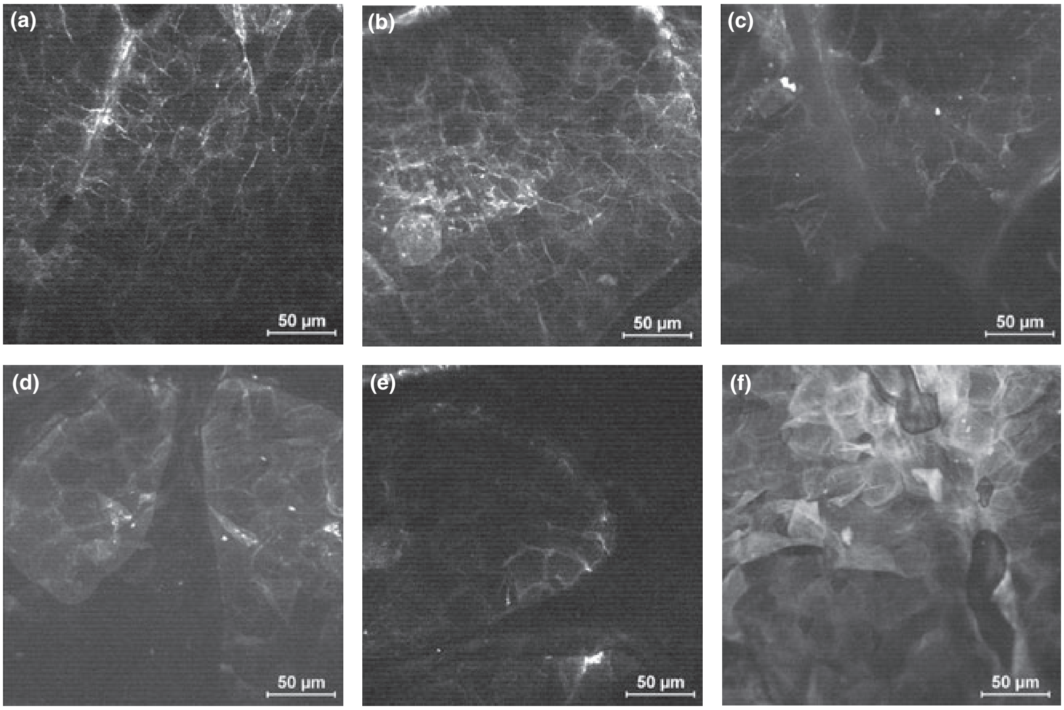


Figure 5 Distribution of soybean oil (a), almond oil (b), jojoba oil (c), avocado oil (d), paraffin oil (e) and petrolatum (f) on skin and in upper most layers of the stratum corneum analysed by fluorescence laser scanning microscopy from ref. 35.

oils, including mineral oil, at the time were thought to be inducing this effect by blocking pores. Animal models were quickly developed. Fulton [36] described the comedogenicity of an extensive list of commonly used ingredients in skincare products of which mineral oil was reported to be mildly comedogenic but nowhere near as much as other ingredients. Conflicting results were found by Mills and Kligman [37] in their rabbit and human models, in which mineral oil was reported not to be comedogenic. The American Academy of Dermatology proposed guidelines to try to interpret the differences in the animal to human data, and they concluded that 1–2 comedones in animal testing would be unlikely to be an indicator of comedogenicity in humans [38]. This is precisely the comedogenic activity of 100% mineral oil reported in five studies, *that is*, zero. Furthermore, DiNardo tested in humans the formulations containing mineral oil up to 30% and found that there was no comedogenicity potential of mineral oil [39]. A wide series of products were tested that showed a comedogenic activity in the same range as the negative control. The overall conclusion is that mineral oil is not comedogenic. But this article also reveals that there is a difference between animal models and human models: the rabbit model is much more prone to comedogenicity than the human model, but all the earlier data that condemned mineral oil originate from animal models, a situation scientists even say will be difficult to correct [39].

Mineral oil: UVB irradiation and photocarcinogenesis

As mineral oil has a high refractive index close to that of skin, it actually improves the optical behaviour of skin, *that is,* it allows slightly more light to penetrate into the skin rather than the skin reflecting it.

Several publications have reported on the effects of emollients increasing skin UV sensitivity and thereby photocarcinogenesis. The most relevant publication to mineral oil is that from Kligman and Kligman [40]. The latter studies have only been conducted in mice, are of limited size, and the human relevance has not been determined. Although animal studies cannot be ignored, they are still insufficient as a risk assessment tool [41]. The hairless mouse model used is a mutant mouse that is highly sensitive towards the development of skin tumours, and the decades' long-term usage of moisturizers without any relationship to tumour development exemplifies the lack of relevance of these mouse models. Nevertheless, the studies are in the public domain. Equally, they are contradictory in that acute application of mineral oil increased UVB-induced damage, but chronic applications actually provided protection against UV. The human studies show that typical moisturizers containing 10% mineral oil or glycerol decrease the minimal erythemal dose (MED) of skin to UVB irradiation by 5–7.6% (i.e. they make the skin slightly more sensitive to UV) [42]. However, to put this in context, shaving or using an exfoliating treatment such as sponges or cosmetic uses of alpha hydroxyacids is reported to decrease MED by approximately 12–13.2%. Although this may sound rather dramatic, it should also be realized that the average MED increase between January and April was 14% [43]. However, Schleider *et al.* [44] reported that mineral oil only had a small effect (5–13% reduction of MED), whereas peanut oil and corn oil had no effect and petrolatum was actually beneficial. Equally, Hudson-Peacock *et al.* [45] found a reduction in MED by 16% for mineral oil. Conversely, Behrens-Williams *et al.* [46] found that an emulsion containing 35% mineral oil, 30% cetylstearyl alcohol and vaseline had no effect on UVB-induced erythema, and Otman *et al.* [47] found that a variety of mineral oil-containing emulsions decreased the sensitivity to UV, but it should be realized that these formulations also contained soft paraffin waxes.

The consensus of evidence of the effects of UV irradiation and mineral oil in humans is that mineral oil has a slight, reducing effect on the MED of skin of an order similar to that of glycerol because of its refractive index. Its long-term usage suggests that any detrimental effect on skin is probably minor and only as severe as the changes in sun sensitivity that occurs between the seasons.

Conclusion

Mineral oil is a complex mixture of highly refined saturated branched-chain and napthenic hydrocarbons. Poly aromatic hydrocarbons (PAHs) that are known carcinogens are not present in mineral oil. The different grades are classified by their viscosities because of their complex compositions. They are used in many industrial, mechanical, medicinal, food and cosmetic applications.

Mineral oil is an efficacious skin moisturizer providing occlusivity and emolliency. Its occlusive effects lead to increases in stratum corneum water content by reducing transepidermal water loss. Through this mechanism, mineral oil is used to treat dry skin conditions in both leave-on and wash-off applications. It has been shown to improve skin softness better than wax esters, triglycerides and fatty acids. Its effect is largely confined to the epidermal layers, and as a result of its limited penetration, it is considered to be a very safe ingredient for cosmetic use.

Early animal studies suggested that mineral oil was comedogenic, but the evidence (using more recent human models) and consensus of opinion is now the opposite. However, because of its high refractive index, it actually improves the optical behaviour of skin, and as more light can now enter the skin, it has a slight reducing effect on skin MED. This effect, however, is no more than that of other cosmetic treatments and no different to seasonal effects on lowering MED. Recent animal studies have suggested that emollients including mineral oil may contribute to UV-induced photocarcinogenesis. However, these studies were of a very limited size and conducted in a mutant mouse that is highly sensitive to UV. Nevertheless, the relevance of these studies to human use of mineral oil is limited as there is no evidence to tumour development.

Comparisons with vegetable oils have been made wherever possible throughout this report. The main difference between vegetable oils and mineral oil is the wide variety of chemistry that may be present in vegetable oils (such as unsaturated, aromatic groups), whereas mineral oil contains mainly straight-chain hydrocarbons. As a consequence, the reasons for using vegetable oils and mineral oil are very different. Vegetable oils are used in cosmetics in relatively small amounts to obtain a specific effect of a specific ingredient with, for instance, a specific receptor in the skin. A very precisely defined chemical structure is necessary to achieve such a specific effect. Mineral oil is typically used in much higher concentrations for its emolliency, the soft skin feel that it provides to a formulation. This is a physical effect and not a biological effect. Another reason for using mineral oil is its occlusivity, which again is a physical effect and not a biological effect, although this does result in a biological effect: skin moisturization and a dampening of inflammatory responses.

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