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Mini review

Dermal uptake of petroleum substances

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HIGHLIGHTS

- Dermal absorption of aromatic hydrocarbons is higher than that of paraffinics.
- Dermal absorption of petroleum hydrocarbons from aqueous solutions highly overestimates that from petroleum products.
- Absorption studies should be conducted under "in use" scenarios.
- Dermal exposure to petroleum hydrocarbons will not cause systemic toxicity under normal working conditions.
- More studies on dermal absorption of petroleum substances across compromised skin are needed.

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ABSTRACT

Petroleum products are complex substances comprising varying amounts of linear and branched alkanes, alkenes, cycloalkanes, and aromatics which may penetrate the skin at different rates. For proper interpretation of toxic hazard data, understanding their percutaneous absorption is of paramount importance.

The extent and significance of dermal absorption of eight petroleum substances, representing different classes of hydrocarbons, was evaluated. Literature data on the steady-state flux and permeability coefficient of these substances were evaluated and compared to those predicted by mathematical models.

Reported results spanned over 5–6 orders of magnitude and were largely dependent on experimental conditions in particular on the type of the vehicle used. In general, aromatic hydrocarbons showed higher dermal absorption than more lipophilic aliphatics with similar molecular weight. The results showed high variation and were largely influenced by experimental conditions emphasizing the need of performing the experiments under "in use" scenario. The predictive models overestimated experimental absorption. The overall conclusion is that, based on the observed percutaneous penetration data, dermal exposure to petroleum hydrocarbons, even of aromatics with highest dermal absorption is limited and highly unlikely to be associated with health risks under real use scenarios.

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1. Introduction

Petroleum substances comprise a wide range of materials that are prepared from crude oil by distillation and – in most cases – subsequent treatments to remove unwanted constituents, such as sulfur, unsaturated and (polycyclic) aromatic compounds, to obtain products with the desired specifications. Petroleum substances range from very light products, such as petroleum gases and low-boiling point naphthas (gasoline), via products such as kerosines and gas oils (diesel), to heavier products such as lubricating oils and petroleum waxes. With exception of petroleum gases and, to some extent gasolines, for which the major route of exposure is through inhalation, dermal exposure is the predominant route of exposure for petroleum substances, both for workers in occupational settings and for consumers. As a consequence, the hazardous properties of petroleum substances are routinely tested in animal studies following dermal application. It is obvious that systemic adverse health effects caused by these materials would require their dermal penetration and subsequent systemic uptake.

Petroleum products are complex substances comprising varying amounts of linear alkanes (paraffins), branched alkanes (isoparaffins), alkenes (olefins), cycloalkanes (naphthenes), and aromatics. Table 1 lists the relative contribution (in weight percentage) of these five different classes of hydrocarbons in recent refinery samples of the various categories of petroleum products, such as gasoline, diesel, kerosene and lubricating oils. As indicated, most petroleum products heavier than gasoline are processed, for instance by hydro-treatment, to reduce the amount of aromatics. The aromatics are saturated in this process, leading to naphthenics. Olefinic compounds are concomitantly turned into saturated compounds and therefore virtually absent in heavier products. The total percentage of constituents as listed in Table 1 does not add up to 100% for the heavier petroleum products since the data have been generated using two-dimensional gas chromatography which is limited to the analysis of constituents up to a molecular mass of about 450–500, which corresponds to a carbon number of about 30. This corresponds rather well with the molecular size limit for dermal penetration. For instance, for petrolatum (petroleum jelly) and even more for paraffin waxes, which are both used in cosmetics, the dermal penetration is expected to be very limited as the molecular weight of most of the constituents is too high. This is reflected in the low overall percentage of constituents in Table 1.

The various constituents of petroleum substances may penetrate the skin at different rates and may also influence each other's penetration. For proper evaluation of the toxic hazard data of petroleum substances obtained mainly from dermal exposure studies in experimental animals, reliable data on dermal absorption is of paramount importance. Considering that all petroleum substances are made up of several hundreds to many thousands of individual constituents, this is obviously a difficult task. Therefore, marker compounds for certain classes of hydrocarbons are used. These markers should represent a relevant constituent of the petroleum products, which may be for instance the most abundant constituent, the most hazardous constituent or a typical constituent representing a class with similar physico-chemical properties. For instance, benzene is quite often used as a representative marker for gasoline due to its carcinogenic properties although it is usually present in concentrations well below 1%. Another useful marker for gasoline is toluene, which is usually present in much higher concentrations and would represent the 'aromatics' which are probably the most hazardous subset of constituents in gasoline. Similarly, for kerosene usually a paraffins or isoparaffins compound is used as a marker as they are representative for the most relevant health hazard associated with dermal exposure (skin irritation). As indicated by these two examples, various individual petroleum substances have different hazardous properties. For instance, low-boiling point naphthas (gasolines) may have a depressing effect on the central nervous system causing dizziness whereas the main effects of kerosene concern local skin effects. In addition, the benzene in gasoline represents a carcinogenic hazard (IARC, 1987) but it is unclear whether this would also apply following dermal exposure to gasoline. However, the different health hazards associated with the various categories of petroleum

Table 1
Composition of petroleum hydrocarbons (from C_4 to C_{30}) in terms of paraffinics (alkanes), olefinics (alkenes), naphthenics (cycloalkanes) and aromatics (mono- and polycyclic aromatics). Values represent typical range (average; median) in weight (%). The weight percentages are based on 2D-GC analysis (Edam et al., 2005) with correction for the variations in response of the flame ionization detector arising from the different hydrocarbon functionalities (Sternberg et al., 1962).

Category	*N*	Paraffinics	Iso-paraffinics	Olefinics	Naphthenics	Aromatics	Carbon range
Low-boiling point naphthas (gasolines)	6	5–24 (17; 20)	25–62 (34; 30)	1-36 (9; 3)	2–33 (11; 7)	2–56 (27; 25)	C4–C12
Kerosines	13	9–19 (17; 18)	21–33 (28; 28)	Low	28–64 (37; 35)	6–30 (19; 20)	C6–C17
Gas oil (diesel)	54	10–22 (16; 16)	14–28 (20; 21)	Low	27–45 (36; 36)	13–47 (26; 26)	C9–C30
Cracked gas oil	7	2–8 (4; 4)	5–19 (12; 14)	Low	4–41 (15; 10)	55–89 (71; 68)	C9–C30
Heavy fuel oil	9	0.2–11 (5; 3)	0.2–21 (6; 4)	Low	0.7–20 (10; 10)	2–45 (19; 19)	>C8
Unrefined/acid-treated oils	6	1–14 (9; 10)	2–22 (16; 14)	Low	3–24 (14; 17)	3–49 (31; 42)	C15–C50
Highly refined base oils	3	1–10 (4; 1)	2–22 (9; 2)	Low	12–50 (26; 15)	Low	C12–C50
Other lubricating base oils	14	1–25 (9; 9)	2–33 (17; 20)	Low	5–58 (33; 34)	0–36 (15; 15)	C12–C120
Residual aromatic extracts	1	1	1	Low	3	8	>C25
Paraffin and hydrocarbon waxes	2	6–9 (7; 7)	0–1(0.6; 0.6)	Low	0–1 (0.2; 0.2)	0	C12–C85
Petrolatum	2	4–12 (8; 8)	6–12 (8; 8)	Low	13–28 (21; 21)	0	C12–C85