

## ORIGINAL ARTICLE OPEN ACCESS

# Results of GC–MS Analyses of 40 Extracts of Diabetes Devices

Emma M. van Oers<sup>1</sup> | Anton C. de Groot<sup>2</sup>  | Patrick Verolme<sup>3</sup> | Norbertus A. Ipenburg<sup>2</sup>  | Thomas Rustemeyer<sup>2</sup> 

<sup>1</sup>Amsterdam University Medical Centers, Amsterdam, the Netherlands | <sup>2</sup>Dermato-Allergology and Occupational Dermatology, Amsterdam University Medical Centers, Amsterdam, the Netherlands | <sup>3</sup>NEDLAB, Middelharnis, the Netherlands

**Correspondence:** Anton C. de Groot ([antondegroot@planet.nl](mailto:antondegroot@planet.nl))

**Received:** 26 July 2025 | **Revised:** 22 August 2025 | **Accepted:** 10 October 2025

**Funding:** This investigation was made possible by a grant from the Dutch Diabetes Research Foundation (Project number 2024.30.002).

**Keywords:** acrylates | allergens | colophonium | diabetes devices | gas chromatography—mass spectrometry | GC–MS | glucose sensor | insulin pump | isocyanates | phenolic chemicals

## ABSTRACT

**Background:** Diagnostic patch testing in patients with suspected allergic Contact Dermatitis from glucose sensors, insulin pumps, and infusion sets is seriously hampered by a lack of information on the chemical composition of these diabetes devices.

**Objectives:** To identify the chemicals present in diabetes devices.

**Materials and Methods:** Forty acetone extracts of 27 devices (10 sensors, 3 patch pumps, 12 infusion sets and 2 single adhesives) were investigated by gas chromatography—mass spectrometry.

**Results:** Two hundred eighty four individual chemicals were identified. All 40 extracts contained one or more chemicals that were previously identified as allergens in diabetes devices causing allergic Contact Dermatitis. Fourteen of 27 devices (52%) contained one or more acrylates, 8 (30%) colophonium derivatives, all 27 (100%) one or two phenolic allergens (2,4-di-*tert*-butylphenol, *p-tert*-butylphenol, butylated hydroxytoluene), and 9 (33%) 1-hydroxycyclohexyl phenyl ketone. None of the other chemicals were well-known haptens, with the exception of bisphenol A, which was present in half of the extracts, in some cases in very high concentrations.

**Conclusions:** All products investigated contained chemicals already known to be sensitizers in diabetes devices. The data can help determine the relevance of positive patch tests, facilitate targeted patch testing with potential allergens and aid in advising safer alternatives for sensitized patients.

## 1 | Introduction

Skin complications related to the use of glucose sensors and insulin pumps are common in children and adolescents [1], as well as in adults [2]. The prevalence of dermatitis, which may be irritant or allergic in nature, varies across studies and is estimated to range from approximately 5% to over 10% [3]. Although the exact incidence and prevalence of allergic contact dermatitis (ACD) remain unknown, 45%–60%

of patients referred to university hospitals for suspected ACD are diagnosed with allergic reactions to their diabetes devices [3, 4].

Unfortunately, the diagnostic patch testing process is significantly hindered by the lack of information regarding the chemical composition of diabetes devices. Unlike cosmetics and topical medications, the specific substances they contain are typically not labelled and may be altered without prior notice [3]. Moreover,

This is an open access article under the terms of the [Creative Commons Attribution-NonCommercial-NoDerivs](https://creativecommons.org/licenses/by-nc-nd/4.0/) License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

© 2025 The Author(s). *Contact Dermatitis* published by John Wiley & Sons Ltd.

**TABLE 1** | Names of sensors, pumps and infusion sets, sample (extract) numbers and batch numbers.

Sample (extract) number	Name of device	Batch number (LOT)
1	Accu-Chek SmartGuide (adhesive)	4000002301
2	Accu-Chek SmartGuide (housing)	4000002301
3	Dexcom ONE+ (adhesive)	1524118005
4	Dexcom ONE+ (housing)	1524118005
5	Dexcom G6 (adhesive)	5348921
6	Dexcom G6 (housing)	5348921
7	Dexcom G7 (adhesive)	1824225005
8	Dexcom G7 (housing)	1824225005
9	Freestyle libre 2 (adhesive)	7588801
10	Freestyle libre 2 (housing)	7588801
11	Freestyle libre 3 (adhesive)	T60002460
12	Freestyle libre 3 (housing)	T60002460
13	Glunovo (adhesive)	S240930132
14	Glunovo (housing)	S240930132
15	Guardian 4 (adhesive)	HG8AUH1
16	Guardian 4 (housing)	HG8AUH1
17	Simplera Sync (adhesive)	HG88G56
18	Simplera Sync (housing)	HG88G56
19	CareSens Air (adhesive)	240326B001
20	CareSens Air (housing)	240326B001
21	Dana-i Soft Release O (infusion set)	860544239
22	Dana-I Easy Release (infusion set)	240719
23	Minimed Mio Advance (infusion set)	6001563
24	Minimed Mio 30 (infusion set)	6007609
25	Minimed Sure-T (infusion set)	6009329
26	Minimed Quick set (infusion set)	6008084
27	Minimed Extended (infusion set)	6009113
28	Omnipod 5 (adhesive)	PH1K06032431
29	Omnipod 5 (housing)	PH1K06032431
30	Omnipod DASH (adhesive)	PD1K03272431

(Continues)

**TABLE 1** | (Continued)

Sample (extract) number	Name of device	Batch number (LOT)
31	Omnipod DASH (housing)	PD1K03272431
32	Tandem t:slim X2 AutoSoft 90 (infusion set)	6006588
33	Tandem t:slim X2 VariSoft (infusion set)	6004348
34	TouchCare SmartOne Nano 200 U (adhesive)	S18A9DS23
35	TouchCare SmartOne Nano 200 U (housing)	S18A9DS23
36	mylife Orbit Micro YpsoPump (infusion set)	861046496
37	mylife Orbit Soft YpsoPump (infusion set)	860739601
38	mylife Ypsopump inset (infusion set)	6009364
39	Medtronic Oval Tape (adhesive, overtape)	246990
40	TouchCare Nano 300 U Demo Kit 'hypoallergenic' (adhesive)	Unknown

some manufacturers are unwilling to provide detailed—or any—information about the materials used. This complicates targeted patch testing with potential allergens, correct interpretation of positive test results, and the ability to counsel patients on safe alternative devices [5].

Previous chemical analyses of diabetes devices that caused ACD have led to the identification of both new and known allergens. However, most of these studies were limited in scope, examining only a few devices or specific components [5–7]. We have analysed a large number of commonly used glucose sensors, insulin pumps, and insulin infusion sets using gas chromatography–mass spectrometry (GC–MS).

## 2 | Materials and Methods

Acetone extracts were prepared from the vast majority of diabetes devices available on the Dutch market in April 2025. In total, 40 extracts were obtained from 27 products: 10 sensors (adhesive, housing), 3 patch pumps (adhesive, housing), 12 infusion sets, and 2 additional adhesives. The names of these devices, the parts used for extraction and their batch numbers are shown in Table 1. The 40 extract samples were analysed using GC–MS to identify and quantify the extracted compounds. A detailed description of the preparation of the extracts and of the chemical analyses is available as [Supporting Information \(Data S2\)](#).

**TABLE 2** | List of chemicals which had a quantity of > 50 µg/mL in one or more extracts.

Chemicals	CAS numbers <sup>a</sup>	For explanation see note
8-Azabicyclo[3.2.1]octane-8-carboxaldehyde	56771-95-0	S12 [102] <b>(1/2)</b>
Benzenepropanoic acid, 3,5-bis(1,1-dimethylethyl)-4-hydroxy-, octadecyl ester		S23 [56] <b>(1/1)</b>
Bisphenol A	80-05-7	S31 [2028]; S34 [1518] <b>(2/20)</b>
Bisphenol A diacetate	10192-62-8	S31 [208] <b>(1/1)</b>
3-Buten-1-ol, trimethylsilyl ether	25195-89-5	S40 [113] <b>(1/2)</b>
Butyl acetate	123-86-4	S7 [536]; S8 [561]; S16 [448] <b>(3/3)</b>
Butylated hydroxytoluene	128-37-0	S26 [53]; S33 [65] <b>(2/6)</b>
2,4-di- <i>tert</i> -Butylphenol	96-76-4	S7 [83]; S8 [80]; S16 [63] <b>(3/36)</b>
<i>p-tert</i> -Butylphenol	98-54-4	S2 [178]; S10 [208]; S12 [164]; S14 [126]; S18 [85] <b>(5/8)</b>
Butylphosphonic acid, 4-isopropylphenylethyl ester		S31 [334] <b>(1/1)</b>
(1 <i>S</i> ,2 <i>E</i> ,4 <i>S</i> ,5 <i>R</i> ,7 <i>E</i> ,11 <i>E</i> )-2,7,11-Cembratriene-4,5-diol		S32 [62] <b>(1/2)</b>
3β,5α-Cholestan-3-ol, 4,4-dimethyl—	2550-84-7	S32 [191] <b>(1/10)</b>
2-[1-(4-Cyano-1,2,3,4-tetrahydronaphthyl)]-propanenitrile	57964-39-3	S25 [58] <b>(1/1)</b>
9,19-Cycloergost-24(28)-en-3-ol, 4,14-dimethyl-, acetate		S17 [143] <b>(1/1)</b>
Decanoic acid, 2-ethylhexyl ester	73947-30-5	S34 [321] <b>(1/1)</b>
26-Dehydroxy-dihydropseudoprogenin-25-ene		S39 [133] <b>(1/2)</b>
Dihydroabietic acid	19407-37-5	S32 [265] <b>(1/1)</b>
1,6-Dioxacyclododecane-7,12-dione	777-95-7	S10 [78]; S12 [81]; S20 [60] S25 [75]; S26 [54]; S33 [75] <b>(6/20)</b>
<i>cis</i> -13-Docosenamide	112-84-5	S36 [191]; S38 [74]; S39 [78] <b>(3/4)</b>
<i>cis</i> -11-Eicosenamide	10436-08-5	S11 [57]; S13 [53]; S15 [68]; S20 [68] <b>(4/8)</b>
<i>cis</i> -11-Eicosenamide ester		S27 [86] <b>(1/1)</b>
2-Ethylhexanol	104-76-7	S5 [216]; S6 [62]; S7 [67]; S17 [66]; S19 [91]; S24 [55]; S26 [64]; S28 [96]; S29 [65]; S30 [106]; S33 [104]; S35 [67]; S39 [62]; S40 [281] <b>(14/23)</b>
2-Ethylhexyl propylphosphonofluoridate		S31 [226] <b>(1/10)</b>
13α-Ethyl-13-methylpodocarpin-18-oic acid methyl ester	33892-02-3	S32 [148]; S35 [610] <b>(2/4)</b>
Formic acid, 2-propylpentyl ester		S10 [67] <b>(1/3)</b>
D:B-Friedo-B':A'-neogammacer-5-en-3-ol	1615-94-7	S20 [67] <b>(1/2)</b>
Glutaric acid, butyl 2-ethylhexyl ester		S31 [105] <b>(1/3)</b>
Glutaric acid, di(2-propylpentyl) ester		S31 [157]; S34 [716] <b>(2/11)</b>
1-Heptanol, 2,4-dimethyl—	98982-97-9	S32 [60]; S35 [89] <b>(2/2)</b>
1-Heptanol, 6-methyl—	1653-40-3	S9 [98]; S11 [121] <b>(2/7)</b>
Hexadecanoic acid, butyl ester	111-06-8	S34 [690] <b>(1/1)</b>
1-Hydroxycyclohexyl phenyl ketone	947-19-3	S4 [174] <b>(1/10)</b>

(Continues)

TABLE 2 | (Continued)

Chemicals	CAS numbers <sup>a</sup>	For explanation see note
2-(4'-Hydroxyphenyl)-2-(4'-methoxyphenyl)-propane		S31 [253] <b>(1/1)</b>
Isobornyl acrylate	5888-33-5	S2 [75] <b>(1/2)</b>
Isopimaric acid methylester	1686-62-0	S1 [163] <b>(1/1)</b>
Methyl abietate	127-25-3	S1 [215] <b>(1/1)</b>
Methyl dehydroabietate	1235-74-1	S13 [177]; S31 [68] <b>(2/3)</b>
Methyl dihydroabietate	67893-02-1	S1 [1990] <b>(1/1)</b>
4-Methyldocosane	25117-30-0	S31 [66] <b>(1/2)</b>
2,2'-Methylenebis(6- <i>tert</i> -butyl-4-methylphenol)	119-47-1	S1 [366] <b>(1/2)</b>
2-Methyl-4- <i>tert</i> -octylphenol	2219-84-3	S25 [56] <b>(1/1)</b>
Methyl 8-pimaren-18-oate	3582-25-0	S1 [370] <b>(1/1)</b>
7-Methyl- <i>Z</i> -tetradecen-1-ol acetate	959269-58-0	S35 [111] <b>(1/2)</b>
Methyl tetrahydroabietate	19941-28-7	S1 [137] <b>(1/2)</b>
2-[4-Methyl-6-(2,6,6-trimethylcyclohex-1-enyl)hexa-1,3,5-trienyl]cyclohex-1-en-1-carboxaldehyde		S17 [60] <b>(1/1)</b>
Nonadecanamide	58185-32-3	S36 [166] <b>(1/19)</b>
18-Norabietane	2221-95-6	S13 [450]; S27 [624]; S39 [89] <b>(3/5)</b>
Octadecanoic acid, butyl ester		S34 [1087] <b>(1/1)</b>
9-Octadecenamide	3322-62-1	S4 [98]; S7 [51]; S16 [59]; S21 [74]; S23 [69] <b>(5/17)</b>
9-Octadecenoic acid ( <i>Z</i> )-, methyl ester	112-62-9	S25 [52] <b>(1/1)</b>
Octanoic acid, 2-ethylhexyl ester	63321-70-0	S34 [908] <b>(1/4)</b>
Octanoic acid, 2-octyl ester	2306-88-9	S31 [392] <b>(1/1)</b>
<i>tert</i> -Octyldiphenylamine	4496-45-1	S3 [55]; S4 [102]; S7 [58]; S8 [133] <b>(4/4)</b>
4,4'-di- <i>tert</i> -Octyldiphenylamine	15721-78-5	S4 [531]; S8 [317]; S9 [1586]; S5 [1852] <b>(4/5)</b>
Phenol	108-95-2	S6 [146]; S16 [63]; S29 [51]; S31 [57]; S35 [53] <b>(5/10)</b>
2-Propyl-1-pentanol	58175-57-8	S8 [56]; S16 [58] <b>(2/7)</b>
Pyrrolidine,1-(7-oxo-2,4,6-trimethylheptanoyl)—		S34 [549] <b>(1/1)</b>
Stigmastane	601-58-1	S25 [55] <b>(1/2)</b>
Tetratetracontane	7098-22-8	S20 [95]; S21 [67] <b>(2/3)</b>

Note: Extracts in which chemicals were identified (for conversion of numbers to device names: see Table 1); [quantity in  $\mu\text{g/mL}$ ]; (number of samples containing  $> 50 \mu\text{g/mL}$ /total number containing the chemical, in bold).

<sup>a</sup>Most CAS registry numbers have been retrieved from PubChem (<https://pubchem.ncbi.nlm.nih.gov/>) or from the NIST Chemistry WebBook (<https://webbook.nist.gov/>); they were not checked by the Chemical Abstract Service ([www.cas.org](http://www.cas.org)).

### 3 | Results

In the 40 extracts of the sensors, pumps and infusion sets, 284 individual chemicals were identified. These are shown in alphabetical order in the Supporting Information (Table S1) with their CAS numbers, the extracts in which they were present and quantities in  $\mu\text{g/mL}$ . 162 of the 284 compounds (57%) were found in a single extract only, 47 (17%) in two, and 36 (13%) in 3–5 extracts. Nine of the chemicals were identified in  $> 15$  extracts: 1-tridecene ( $n = 37$ ), 2,4-di-*tert*-butylphenol ( $n = 36$ ),

1-dodecene ( $n = 35$ ), 4-hydroxy-4-methyl-2-pentanone ( $n = 26$ ), 2-ethylhexanol ( $n = 23$ ), bisphenol A ( $n = 20$ ), 1,6-dioxacyclopentane-7,12-dione ( $n = 20$ ), nonadecanamide ( $n = 19$ ), and 9-octadecenamide ( $n = 17$ ).

The quantity of the compounds in the extracts ranged from 1 to 2028  $\mu\text{g/mL}$ . These values can be converted to ppm (parts per million) by multiplying them by a factor of 1.264, based on the density of acetone (0.791  $\text{g/mL}$ ). Fifty-nine of the 284 chemicals (21%) were classified as “high quantity compounds”,

**TABLE 3** | The 15 chemicals with the highest quantities.

Chemical	Quantity ( $\mu\text{g/mL}$ )
Bisphenol A	2028 and 1518
Methyl dehydroabietate	1990
4,4'-di- <i>tert</i> -Octyldiphenylamine	1852 and 1586
Octadecanoic acid, butyl ester	1087
Octanoic acid, 2-ethylhexyl ester	908
Glutaric acid, di(2-propylpentyl) ester	716
Hexadecanoic acid, butyl ester	690
18-Norabietane	624 and 450
13 $\alpha$ -ethyl-13-Methylpodocarpin-18-oic acid methyl ester	610
Butyl acetate	561
Pyrrolidine,1-(7-oxo-2,4,6-trimethylheptanoyl)—	549
Octanoic acid, 2-octyl ester	392
Methyl 8-pimarene-18-oate	370
2,2'-Methylenebis(6- <i>tert</i> -butyl-4-methylphenol)	366
Butylphosphonic acid, 4-isopropylphenylethyl ester	334

(arbitrarily) defined as those chemicals with quantities of  $> 50 \mu\text{g/mL}$  (63.2 ppm) in one or more extracts. These compounds are shown in Table 2 in alphabetical order with their CAS numbers, the extracts in which they were identified and quantities in  $\mu\text{g/mL}$ . The 15 chemicals with the highest concentrations in the extracts, headed by bisphenol A (2028 and 1518  $\mu\text{g/mL}$ ) and methyl dehydroabietate (1990  $\mu\text{g/mL}$ ) are shown in Table 3.

Data on chemicals that have previously been identified as allergens in diabetes devices [5–7] and structurally related compounds (acrylates, phenolic compounds, isocyanates) or derivatives (colophonium-) is shown in Table 4. Isobornyl acrylate was found in 2 extracts, of which one had a relatively high (75  $\mu\text{g/mL}$ ) amount. There were 5 other acrylates, of which 2 were identified in one extract and 2 in two extracts each (one also containing isobornyl acrylate); 2-ethylhexyl acrylate was present in 9 extract samples. Their concentrations were relatively low, with a maximum of 21  $\mu\text{g/mL}$  for tetrahydrofurfuryl acrylate.

Of colophonium-related chemicals, methyl dehydroabietate, the only established allergen of this class in diabetes devices, was found in 3 extracts in concentrations ranging from 49 to 177  $\mu\text{g/mL}$ . We identified 8 other colophonium-derived compounds, which as a group were present in 7 different extract samples. In 11 of 16 identifications, their quantities were high, ranging from 89 to 1990  $\mu\text{g/mL}$ , median 265 (Table 4).

The previously established phenolic allergens butylated hydroxytoluene, 2,4-di-*tert*-butylphenol and *p*-*tert*-butylphenol were found in 6 (of which 2 were high quantity), 36 (3 were high quantity) and 8 (5 were high quantity) extracts, respectively. We identified 8 related phenolic compounds, including bisphenol A, which was present in 20 extracts, in 2 cases in extremely high quantities (2028 and 1518  $\mu\text{g/mL}$ ) (Table 4).

Of the group of isocyanates, previously identified allergens were not found, but 2 others were detected in 5 samples, albeit at low concentrations. The allergen 1-hydroxycyclohexyl phenyl ketone (synonym: 1-benzoyl cyclohexanol) was found in 10 extract samples in quantities ranging from 5 to 174  $\mu\text{g/mL}$  (Table 4).

A list of samples with product names and the established allergens found therein is provided in Table 5.

All 40 product extracts contained one or more established allergens, most often 2,4-di-*tert*-butylphenol ( $n = 36$ ). Eighteen products contained 1 established allergen, 19 contained two, and in three extracts 3 allergens were found to be present. Isobornyl acrylate, an allergen which has caused an epidemic of allergic contact dermatitis in the past [5] was present in one sensor. Other acrylates (not previously identified as allergens in diabetes devices) were present in 5/10 sensors, 2/3 patch pumps and 5/12 infusion sets.

Colophonium-derivatives, a class of chemicals frequently reported to be responsible for ACD to sensors and pumps, were found in 5/10 sensors, 2/12 infusion sets and an additional adhesive used to aid in the adherence of transmitters and sensors of the same brand. One or more of the phenolic sensitizers were present in all 40 extracts: 2,4-di-*tert*-butylphenol (all products except 3 infusion sets and one patch pump), *p*-*tert*-butylphenol (6/10 sensors, 2/3 patch pumps) and butylated hydroxytoluene (1/10 sensors, 4/12 infusion sets, 1/3 patch pump). Isocyanates were found in only 5 products (4/10 sensors, 1 adhesive) and the previously identified sensitizer 1-hydroxycyclohexyl phenyl ketone (1-benzoyl cyclohexanol) in 3/10 sensors, 4/12 infusion sets and the 2 additional adhesives (Table 5).

Full data of all 40 extracts with chemicals, CAS numbers, and quantities can be found in the Supporting Information (Data S1). Different colours show classes of previously reported allergens, related chemicals (cyanates, phenolic compounds, colophonium-related, isocyanates) and high quantity compounds.

#### 4 | Discussion

To the best of our knowledge, this is the first large-scale study investigating the ingredients of glucose sensors, insulin pumps, and insulin infusion sets. An important finding is that all 40 extracts of 27 products (10 sensors, 3 patch pumps, 12 infusion sets, and 2 adhesives) each contained one or more chemicals previously identified in diabetes devices as causes of allergic contact dermatitis. Fourteen of these 27 devices (52%) contained one or more acrylates, 8 (30%) colophonium derivatives, all 27 (100%) one or two of the phenolic allergens

**TABLE 4** | List of known allergens and related chemicals identified in extracts of sensors/pumps/infusion sets.

Chemicals	CAS numbers <sup>a</sup>	For explanation see note
Acrylates		
Known allergens in diabetes devices		
Isobornyl acrylate	5888-33-5	S1 [4]; S2 [75]
Related compounds		
2-Ethylhexyl acrylate	103-11-7	S7 [1]; S11 [1]; S17 [2]; S23 [1]; S24 [2]; S26 [1]; S28 [4]; S30 [3]; S33 [7]
6-Methylheptyl acrylate	54774-91-3	S5 [2]; S15 [1]
Pentadecyl acrylate	43080-23-5	S5 [7]; S25 [18]
Tetrahydrofurfuryl acrylate	2399-48-6	S2 [21]
Tridecyl acrylate	3076-04-8	S4 [3]
Colophonium-compounds		
Known allergens in diabetes devices		
Methyl dehydroabietate	1235-74-1	S13 [177]; S27 [49]; S31 [68]
Related compounds		
Dihydroabietic acid	19407-37-5	S32 [265]
13 $\alpha$ -Ethyl-13-methylpodocarpan-18-oic acid methyl ester	33892-02-3	S13 [18]; S32 [148]; S35 [610]; S39 [39]
Isopimaric acid methylester	1686-62-0	S1 [163]
Methyl abietate	127-25-3	S1 [215]
Methyl dihydroabietate	67893-02-1	S1 [1990]
Methyl 8-pimaren-18-oate	3582-25-0	S1 [370]
Methyl tetrahydroabietate	19941-28-7	S1 [137]; S39 [10]
18-Norabietane	2221-95-6	S1 [48]; S13 [450]; S15 [20]; S27 [624]; S39 [89]
Phenolic compounds		
Known allergens in diabetes devices		
Butylated hydroxytoluene (synonym: 2,6-di- <i>tert</i> -Butyl-4-methylphenol)	128-37-0	S12 [4]; S25 [30]; S26 [53]; S32 [53]; S33 [65]; S35 [32]
2,4-di- <i>tert</i> -Butylphenol	96-76-4	S1 [24]; S2 [27]; S3 [27]; S4 [36]; S5 [23]; S6 [21]; S7 [83]; S8 [80]; S9 [35]; S10 [22]; S11 [36]; S12 [25]; S13 [18]; S14 [19]; S15 [33]; S16 [63]; S17 [24]; S18 [28]; S19 [33]; S20 [27]; S21 [30]; S22 [35]; S23 [36]; S24 [29]; S25 [23]; S27 [29]; S28 [31]; S29 [37]; S30 [30]; S31 [33]; S34 [33]; S36 [26]; S37 [27]; S38 [40]; S39 [17]; S40 [37]
<i>p-tert</i> -Butylphenol	98-54-4	S2 [178]; S6 [2]; S10 [208]; S12 [164]; S14 [126]; S18 [85]; S29 [3]; S35 [16]
Related compounds		
Bisphenol A	80-05-7	S6 [7]; S7 [28]; S8 [31]; S9 [19]; S10 [18]; S11 [40]; S12 [39]; S14 [23]; S15 [10]; S21 [8]; S22 [23]; S23 [7]; S25 [6]; S26 [3]; S29 [4]; S30 [20]; S31 [2028]; S34 [1518]; S38 [16]; S40 [23]
Bisphenol A ester		S16 [12]
Bisphenol A diacetate	10192-62-8	S31 [208]
2,4-Dimethyl-6- <i>tert</i> -butylphenol	1879-09-0	S1 [7]

(Continues)

TABLE 4 | (Continued)

Chemicals	CAS numbers <sup>a</sup>	For explanation see note
2,2'-Methylenebis(6- <i>tert</i> -butyl-4-methylphenol)	119-47-1	S1 [366]; S2 [5]
2-Methyl-4- <i>tert</i> -octylphenol	2219-84-3	S25 [56]
Phenol	108-95-2	S6 [146]; S12 [22]; S16 [63]; S20 [34]; S21 [32]; S29 [51]; S31 [57]; S35 [53]; S36 [13]; S37 [24]
Isocyanates		
Known allergens in diabetes devices		
None		
Related compounds		
3-Isopropenylcumyl isocyanate	2094-99-7	S7 [2]; S11 [2]; S40 [15]
Tetramethyl- <i>m</i> -xylylene diisocyanate	2778-42-9	S9 [4]; S4 [9]
Other compounds		
Known allergens in diabetes devices		
1-Hydroxycyclohexyl phenyl ketone (synonym: 1-benzoyl cyclohexanol)	947-19-3	S3 [38]; S4 [174]; S7 [32]; S15 [39]; S25 [5]; S26 [6]; S33 [5]; S38 [5]; S39 [6]; S40 [25]
Related compounds		
1-Hydroxycyclohexyl phenyl ketone ester		S16 [17]

Note: Extracts in which chemicals were identified (for conversion to device names: see Table 1); [quantities in µg/mL]; quantities > 50 µg/mL in bold.

<sup>a</sup>Most CAS registry numbers have been retrieved from PubChem (<https://pubchem.ncbi.nlm.nih.gov/>) or from the NIST Chemistry WebBook (<https://webbook.nist.gov/>); they were not checked by the Chemical Abstract Service ([www.cas.org](http://www.cas.org)).

2,4-di-*tert*-butylphenol, *p*-*tert*-butylphenol and butylated hydroxytoluene, and 9 (33%) 1-hydroxycyclohexyl phenyl ketone (1-benzoyl cyclohexanol).

When comparing this data to that of previous analytical studies and information obtained from manufacturers [5], in which acrylates (especially isobornyl acrylate [IBOA]) and colophonium derivatives were the most frequently identified allergens, it appears that the use of IBOA has largely been abandoned by manufacturers of diabetes devices, undoubtedly driven by the many reports of cases of ACD to this chemical. Only one of the products still contained IBOA. Yet, one or more other acrylates (2-ethylhexyl, 6-methylheptyl, pentadecyl, tetrahydrofurfuryl, tridecyl) were present in over half of the 27 devices, mostly in very low amounts of 1–3 µg/mL (1.3–4 ppm), but in 2 extracts in concentrations of 18 and 21 µg/mL (23 and 27 ppm). Colophonium derivatives were still present in 30% of the products, often in large amounts. Of the 9 colophonium-related chemicals seen in our analyses, 8 have not previously been identified in diabetes devices (Table 4). The phenolic allergens up to recently [7] were infrequently identified as a cause of allergic contact dermatitis, but as a group were now present in all extracts and may therefore be chemicals of interest. The same goes for 1-hydroxycyclohexyl phenyl ketone. This compound has been reported as an allergen only once by its presence in the glue of 3 insulin infusion sets in 1995 [8], but was present in 9 of 27 devices.

Eight of the devices that we analysed have been investigated by others before (Table 6). The same trend as described above is visible here. In all cases, our results were very different from earlier observations: IBOA, nor other well-defined acrylate sensitizers or isocyanate allergens were identified by us. The most important allergenic chemicals were now the phenolic compounds, 1-hydroxycyclohexyl phenyl ketone and possibly the non-IBOA acrylates.

We suggest that most changes are the result of reformulating by the manufacturers as a reaction to reports of allergic contact dermatitis and the identification of specific sensitizers. However, batch variations and especially differences in analytical protocols may also be likely explanations for different results in our and previous studies. The possibility that (certain) chemicals could not (always) be identified as a result of the protocol we chose cannot be excluded.

In addition, some of the previous studies may have looked for specific chemicals such as acrylates and colophonium derivatives only, thereby missing other (potentially) allergenic ingredients.

One of the aims of our study was to identify chemicals which may act as (undetected) allergens in these diabetes devices. With the exception of the chemicals already known to be sensitizers (Table 4), not one of the 284 chemicals found in the extracts is an established and frequent allergen. Yet, contact allergy to

**TABLE 5** | Established allergens in the sensors/pumps/instillation sets investigated, and related chemicals.

Extract no.	Name of device	Established allergens identified in each extract and quantity in $\mu\text{g/mL}$						Related and other chemicals <sup>a</sup>
		DTBP	IBOA	PTBP	BHT	HCPK	MDHA	
1	Accu-Chek SmartGuide (adhesive)	24	4					Colophonium-compounds; phenolics
2	Accu-Chek SmartGuide (housing)	27	75	178				Acrylate; phenolic
3	Dexcom ONE+ (adhesive)	27				38		
4	Dexcom ONE+ (housing)	36				174		Acrylate; isocyanate
5	Dexcom G6 (adhesive)	21						Acrylates
6	Dexcom G6 (housing)	21		2				Phenolics
7	Dexcom G7 (adhesive)	83				32		Phenolic; isocyanate; acrylate
8	Dexcom G7 (housing)	80						Phenolic
9	Freestyle libre 2 (adhesive)	35						Phenolic; isocyanate
10	Freestyle libre 2 (housing)	22		208				Phenolic
11	Freestyle libre 3 (adhesive)	36						Phenolic; acrylate; isocyanate
12	Freestyle libre 3 (housing)	25		164	4			Phenolics
13	Glunovo (adhesive)	18					177	Colophonium-compounds
14	Glunovo (housing)	19		126				Phenolic
15	Guardian 4 (adhesive)	33				39		Acrylate; phenolic; colophonium-compound
16	Guardian 4 (housing)	63						HCPK-ester [17]; phenolics
17	Simplera Sync (adhesive)	24						Acrylate
18	Simplera Sync (housing)	28		85				
19	CareSens Air (adhesive)	33						
20	CareSens Air (housing)	27						Phenolic
21	Dana-i Soft Release O (infusion set)	30						Phenolics
22	Dana-I Easy Release (infusion set)	35						Phenolic
23	Minimed Mio Advance (infusion set)	36						Acrylate; phenolic
24	Minimed Mio 30 (infusion set)	29						Acrylate
25	Minimed Sure-T (infusion set)	23			30	5		Acrylate; phenolics
26	Minimed Quick set (infusion set)				53	6		Acrylate; phenolic
27	Minimed Extended (infusion set)	29					49	Colophonium-compound

(Continues)

TABLE 5 | (Continued)

Extract no.	Name of device	Established allergens identified in each extract and quantity in µg/mL						Related and other chemicals <sup>a</sup>
		DTBP	IBOA	PTBP	BHT	HCPK	MDHA	
28	Omnipod 5 (adhesive)	31						Acrylate
29	Omnipod 5 (housing)	37		3				Phenolics
30	Omnipod DASH (adhesive)	30						Acrylate; phenolic
31	Omnipod DASH (housing)	33					68	Phenolics
32	Tandem t:slim X2 AutoSoft 90 (infusion set)				53			Colophonium-compounds
33	Tandem t:slim X2 VariSoft (infusion set)				65	5		Acrylate
34	TouchCare SmartOne Nano 200U (adhesive)	33						Phenolic
35	TouchCare SmartOne Nano 200U (housing)			16	32			Colophonium-compound; phenolic
36	Mylife Orbit Micro YpsoPump (infusion set)	26						Phenolic
37	Mylife Orbit Soft YpsoPump (infusion set)	27						Phenolic
38	Mylife Ypsopump inset (infusion set)	40				5		Phenolic
39	Medtronic Oval Tape (adhesive)	17				6		Colophonium-compounds
40	TouchCare Nano 300U Demo Kit 'hypoallergenic' (adhesive)	37				25		Isocyanate; phenolic

Abbreviations: BHT, Butylated hydroxytoluene; DTBP, 2,4-di-*tert*-Butylphenol; HCPK, 1-Hydroxycyclohexyl phenyl ketone (1-benzoyl cyclohexanol); IBOA, Isobornyl acrylate; MDHA, Methyl dehydroabietate; PTBP, *p*-*tert*-Butylphenol.

<sup>a</sup>See for details the [Supporting Information](#) (Data S1).

bisphenol A, which was found to be present in our investigation in half of the extracts and sometimes at very high concentrations, has been observed repeatedly. Therefore, we consider bisphenol A as a chemical of interest and have added it (1% pet.) to our Diabetes device screening series [9].

When looking for possible new allergenic culprits, it may have some merit to focus on frequently identified chemicals or the compounds with the highest quantities in the extracts (Table 3). However, whether these are merely harmless chemicals used in the production of the devices flushed out by our acetone extraction process or may be chemicals of interest from an allergological point of view (and may therefore be suitable candidates for targeted patch testing), cannot be determined at this moment.

The data presented in Table 5 and the [Supporting Information](#) (Data S1) can help dermatologists establish the relevance of

positive patch tests observed in patients with allergic reactions to one or more of the 27 products investigated by us. The information can equally assist in choosing safe(r) alternatives for patients in whom device-related allergens have been demonstrated [9]. It may be prudent to avoid all products in which the sensitizer was identified. However, whether the chemicals that show (very) low concentrations in the extracts can and will induce ACD in individual sensitised patients, cannot reliably be predicted.

Finally, the data presented here may also aid in targeted patch testing in patients with demonstrated contact allergy to a sensor, pump or infusion set (e.g., by positive reactions to the adhesive, scrapings or extracts, or by emergence of classic ACD upon repeated applications), but who had no positive patch tests to device-related allergens, by consulting the full GC-MS analysis of the incriminated product in the [Supporting Information](#) (Data S1).

**TABLE 6** | Comparison between previous chemical analyses and the analytical data in this study<sup>a</sup>.

Allergens identified in previous studies [5–7]	Allergens identified in this study
Dexcom G6 sensor	
Isobornyl acrylate (IBOA)	2,4-di- <i>tert</i> -Butylphenol
Methyl dehydroabietate	<i>p-tert</i> -Butylphenol
2,2'-Methylenebis(6- <i>tert</i> -butyl-4-methylphenol) monoacrylate	2 non-IBOA acrylates
Dexcom G7 sensor	
Methyl dehydroabietate	2,4-di- <i>tert</i> -Butylphenol
Dicyclohexylmethane-4,4'-diisocyanate	1-Hydroxycyclohexyl phenyl ketone
Isobornyl acrylate (IBOA)	1 non-IBOA acrylate
FreeStyle Libre 2 sensor	
Butylated hydroxytoluene	2,4-di- <i>tert</i> -Butylphenol <i>p-tert</i> -Butylphenol
Guardian 4 sensor	
Isobornyl acrylate (IBOA)	2,4-di- <i>tert</i> -Butylphenol
<i>N,N</i> -Dimethylacrylamide	1-Hydroxycyclohexyl phenyl ketone
1,6-Hexanediol diacrylate	Colophonium-derivative UNDER 1 non-IBOA acrylate
MiniMed quick-set infusion set	
Isobornyl acrylate (IBOA)	Butylated hydroxytoluene
4,4'-Methylene diphenyl diisocyanate	1-Hydroxycyclohexyl phenyl ketone 1 non-IBOA acrylate
Minimed sure-T infusion set	
Isobornyl acrylate (IBOA)	Butylated hydroxytoluene
4,4'-Methylene diphenyl diisocyanate	2,4-di- <i>tert</i> -Butylphenol 1-Hydroxycyclohexyl phenyl ketone 1 non-IBOA acrylate
Mylife Ypsopump Orbit infusion set	
Isobornyl acrylate (IBOA)	2,4-di- <i>tert</i> -Butylphenol
Dicyclohexylmethane-4,4 diisocyanate	
Omnipod DASH pump	
Colophonium derivatives	Methyl dehydroabietate 2,4-di- <i>tert</i> -Butylphenol One non-IBOA acrylate (very low amount)

<sup>a</sup>Differences in the results between this and the previous studies can be the result of changes of composition over time, batch variations and differences in protocols used for extraction and GC-MS analyses.

## 5 | Limitations

Our data cannot be used to determine the quantities of the chemicals present in the actual products, nor the levels in the extracts that would ensure the safe use of the device in sensitized patients. As a consequence of using an internal standard in the chemical

analyses, 100% reliable identifications were not possible. For the same reason, the quantities of the identified chemicals in the GC-MS analyses, mentioned both in the article and in the Supporting information files, should not be regarded as absolute quantities but rather as semi-quantitative, indicative concentrations. See Materials and Methods for more information.

## Author Contributions

Emma van Oers: conceptualization, investigation, data curation, writing – original draft. Anton de Groot: conceptualization, methodology, visualisation, writing – original draft, writing – review and editing. Patrick Verolme: methodology, investigation. Norbertus Ipenburg: project administration, writing – review and editing. Thomas Rustemeyer: supervision, writing – review and editing.

## Conflicts of Interest

The authors declare no conflicts of interest.

## Data Availability Statement

Most data that support the findings of this study are available in the [Supporting Information](#) of this article.

## References

1. A. K. Berg, S. Passanisi, T. von dem Berge, et al., “SKIN-PEDIC: A Worldwide Assessment of Skin Problems in Children and Adolescents Using Diabetes Devices,” *Hormone Research in Paediatrics* (2025): <https://doi.org/10.1159/000545428> Epub ahead of print.
2. J. Ulriksdotter, T. Sukakul, M. Bruze, N. Hamnerius, M. Mowitz, and C. Svedman, “A Cross-Sectional Study Demonstrating a High Prevalence of Skin Rash to Diabetes Medical Devices: An Underestimated Problem,” *Journal of Diabetes Science and Technology* (2025): 19322968251336261, <https://doi.org/10.1177/19322968251336261> Epub ahead of print.
3. L. B. von Kobyletzki, J. Ulriksdotter, T. Sukakul, et al., “Prevalence of Dermatitis Including Allergic Contact Dermatitis From Medical Devices Used by Children and Adults With Type 1 Diabetes Mellitus: A Systematic Review and Questionnaire Study,” *Journal of the European Academy of Dermatology and Venereology* 38, no. 7 (2024): 1329–1346, <https://doi.org/10.1111/jdv.19908>.
4. L. B. von Kobyletzki, J. Ulriksdotter, E. von Kobyletzki, M. Mowitz, J. Jendle, and C. Svedman, “Insulin Pump Therapy and Adverse Skin Reactions With Focus on Allergic Contact Dermatitis in Individuals Living With Diabetes Mellitus: A Systematic Review and Clinical-Based Update,” *Journal of Diabetes Science and Technology* 18, no. 6 (2024): 1300–1312, <https://doi.org/10.1177/19322968241252613>.
5. A. De Groot, E. M. van Oers, N. A. Ipenburg, and T. Rustemeyer, “Allergic Contact Dermatitis Caused by Glucose Sensors and Insulin Pumps: A Full Review: Part 1: Sensors and Pumps, Adverse Cutaneous Reactions, Allergens, and Diabetes Devices Causing Allergic Contact Dermatitis,” *Contact Dermatitis* 92, no. 2 (2025): 87–112, <https://doi.org/10.1111/cod.14698>.
6. F. Sexton, J. O’ Mahony, S. Sumera, et al., “Culprit Allergens in Diabetes Technology-Associated Allergic Contact Dermatitis: Investigation Remains Challenging,” *British Journal of Dermatology* 26 (2025): ljaf245, <https://doi.org/10.1093/bjd/ljaf245>.
7. E. Dendooven, T. Naessens, K. Foubert, N. Hermans, and O. Aerts, “Tert-Butylhydroquinone and Tert-Butylcatechol Positivity as Warning Lights of Skin Sensitization to Tert-Butylphenol Derivatives in Adhesives and Diabetes Devices,” *Contact Dermatitis* 91, no. 5 (2024): 387–391, <https://doi.org/10.1111/cod.14670>.
8. A. M. Busschots, V. Meuleman, N. Poesen, and A. Dooms-Goossens, “Contact Allergy to Components of Glue in Insulin Pump Infusion Sets,” *Contact Dermatitis* 33, no. 3 (1995): 205–206, <https://doi.org/10.1111/j.1600-0536.1995.tb00554.x>.
9. A. De Groot, E. M. van Oers, N. A. Ipenburg, and T. Rustemeyer, “Allergic Contact Dermatitis Caused by Glucose Sensors and Insulin Pumps: A Full Review. Part 2. Case Reports and Case Series, Clinical Features, Patch Test Procedures, Differentiation From

Irritant Dermatitis, Management of Allergic Patients and (Proposed) Legislation,” *Contact Dermatitis* 92, no. 3 (2025): 164–175, <https://doi.org/10.1111/cod.14697>.

## Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** Supporting Information. **Data S2:** Supporting Information. **Table S1:** Alphabetical list of all chemicals identified with CAS numbers, presence in extracts of sensors/pumps/infusion sets and quantities.