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Odour from energy-saving light bulbs

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Odour from energy-saving light bulbs

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Foreword

This project on odour from energy-saving light bulbs has been carried out in the period from March to December 2014.

This report describes the results of the project, including review of previous studies dealing with odour from energy-saving light bulbs. The report describes how smelling energy-saving bulbs were collected from consumers and chemical analyses for release of chemical substances were carried out. The results of the chemical analyses are presented and a risk assessment of selected substances which were released from the analysed smelling energy-saving light bulbs was made.

The project is carried out by FORCE Technology. The chemical analyses of release of substances from energy-saving light bulbs were undertaken by Teknologisk Institut.

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The project was financed by the Danish Environmental Protection Agency.

Conclusion and Summary

Background

During the recent years, both in Denmark and abroad, a discussion has taken place about odour from energy-saving light bulbs, which is released when the light bulb is turned on. The Danish Environmental Protection Agency has received inquiries from consumers who report about unpleasant odour from energy-saving light bulbs and several debate pages show that consumers wonder at the odour and whether it can cause a hazardous effect.

It is unclear what causes the odour and why only some energy-saving light bulbs smell. Furthermore, odour is individual. An odour which is strong for some persons might not be smelled by others.

Purpose

The purpose of this project was to identify which gases smelling energy-saving light bulbs release and to examine whether the substances constitute a health risk for the consumer.

Survey of existing knowledge

Internet searches on various debate pages show that consumers experience that some of the energy-saving light bulbs degas malodorous chemical substances during use. Contributions on Danish, German, English, Swedish and American internet pages were identified so the phenomenon is geographically spread. Some consumers experience the odour as being constant while others have experienced that the odour is decreasing currently with the lamp being turned on. The consumers use different words to describe the odour from the light bulbs, as chemical, poisonous, like a hairdryer, fishlike, like a new car, like in hospital, warm electronic odour etc.

In earlier tests, release of a large number of different substances from energy-saving light bulbs has been identified, especially phenols, glycolic compounds and styrene. In the most detailed test made for the consumer magazine K-Tipp, 126 different chemical substances were identified. Among the most frequently identified substances, substances which are classified as reprotoxic, mutagenic or carcinogenic were found.

The test from K-Tipp is not performed on energy-saving light bulbs already known to be odour releasing but on the contrary on 14 newly purchased light bulbs. If the concentration of the identified substances is compared with their respective odour threshold values, all the 14 tested energy-saving light bulbs might smell because one or more of the substances, which were released from the light bulbs, are measured in concentrations above their odour threshold value.

No risk assessment of the identified levels is made in any of the earlier surveys.

None of the previous examinations concludes about the connection between producer/brand of the energy-saving light bulbs and how much they smell. This indicates that there are no special brands where problems with odour may occur but that odour may occur from a few light bulbs of all brands.

In the survey, more suggestions were given for the cause of the odour:

- The odour may arise as a direct consequence of the degassed substances (as release of phenol and glycol compounds). I.e. the actual released gases smell.

- Another suggestion of the source of the odour is given by US EPA. US EPA suggests that it might be due to the UV radiation which can start a chemical reaction which results in odour (FDA, 2012).
- Some producers have explained the odour as being a result of glue residues etc. which burn off by use of the light bulbs. If this is the case, thus the odour ought to stop after use of the light bulbs for a long period.

Collection of the smelling energy-saving light bulbs
Through a notice on various homepages (among others, the Danish Environmental Protection Agency, Danish Radio News and Ingeniøren (a Danish magazine for engineers)), consumers were invited to get in touch if they had experienced odour from an energy-saving light bulb. Thereafter, the consumers were asked to forward their smelling energy-saving light bulbs. In total, the Danish Environmental Protection Agency received 47 replies and 25 light bulbs were analysed for degassing of selected substances.

Chemical analysis of degassing from smelling energy-saving light bulbs
The most problematic substances identified in earlier studies were also found in the highest concentrations. Therefore, in this survey, for each light bulb only the 10 substances found in the highest concentrations were reported. In addition to this, based on the earlier studies, it was decided specifically to analyse for benzene, N,N-dimethylformamide, cresol and ozone.

In total, 45 different substances which degassed from the analysed energy-saving light bulbs were identified.

The results of the analyses which were made on the collected energy-saving light bulbs showed that all the light bulbs degassed at least three different substances and that one light bulb degassed 16 different substances. The substances degassed in varying concentrations.

In total, nine substances are measured above their odour threshold value. For 24 of the 25 energy-saving light bulbs, there is as a minimum identified one and up to four out of nine substances with concentrations above the odour threshold value. This can explain the reason why the consumers experience that their energy-saving light bulb smells.

Among the degassed substances, the below were especially interesting because they evaporated in concentrations of a factor 10 above their odour threshold value, they have particularly problematic properties, they degassed almost from all the analysed energy-saving light bulbs or because they were found in the highest concentrations:

- 1-Butanol degassed from 21 out of the 25 analysed light bulbs. The substance has no relevant classification for the exposure situation. The highest measured concentration was 2,300 µg/m^3 which is far above the odour threshold value of the substance of 90 µg/m^3.
- Acetic acid degassed from 19 different light bulbs with 1,100 µg/m^3 as the highest concentration. Similarly, the substance has no relevant classification for the exposure situation but degasses in a concentration far above the odour threshold value of the substance of 98-491 µg/m^3.
- Pentanal degassed from 2 different light bulbs with 230 µg/m^3 as the highest concentration which is far above the odour threshold value of the substance of 22 µg/m^3. The substance has no relevant classification for the exposure situation.
- Benzene degassed from 19 light bulbs and has a harmonised classification as carcinogenic. The highest evaporation concentration was measured to be 76 µg/m^3 which is far below the odour threshold value of 4,500 µg/m^3,
- Tetrahydrofuran degassed from 16 different light bulbs and has a harmonised classification as carcinogenic. The highest evaporation concentration was measured to 1,400 µg/m^3 which is far below the odour threshold value of 7,375 µg/m^3.

- Octamethylcyclotetrasiloxane (D4) degassed from 13 different light bulbs and has a harmonised classification as toxic to reproduction. The highest evaporation concentration was measured to be 2,100 µg/m^3. No odour threshold value for D4 has been identified.
- N,N-dimethylformamide degassed from 10 different light bulbs and has a harmonised classification as toxic to reproduction. The highest evaporation concentration was measured to be 670 µg/m^3 which is far below the odour threshold value of 300,000 µg/m^3.
- Phenol which has a harmonised classification as mutagenic and harmful to organs (liver and kidneys) at repeated exposure. In this project, phenol is only identified for one of the 25 analysed light bulbs but many previous tests mention phenol (or phenols) as one of the substances which most frequently evaporate. The highest evaporation concentration was measured to be 510 µg/m^3 which is above the odour threshold value of the substance of 179 µg/m^3.
- Toluene degassed from 3 light bulbs with 600 µg/m^3 as the highest concentration. The substance has a harmonised classification as toxic to reproduction and harmful to organs at repeated exposure. The odour threshold value of the substance is 600 µg/m^3.
- 2-methyl-2-propanol degassed from 2 light bulbs with 6,500 µg/m^3 as the highest concentration. The odour threshold value of the substance is 3,300 µg/m^3.
- Hexamethylcyclotrisiloxane degassed from 12 different light bulbs with 4,800 µg/m^3 as the highest concentration. The substance has no relevant classification for the exposure situation. No odour threshold value is identified for the substance.

The analysis results in this project confirm that the energy-saving light bulbs which smell also release substances in concentrations above the odour threshold value of the substances. If these results are compared with the results from the K-Tipp survey it might indicate that there is a combination of different odour intensity from the light bulbs but also a different sensitivity to odour at the consumers.

Out of the in total 25 analysed light bulbs in the present survey, two light bulbs were identical. The analysis results show that no connection can be seen in relation to degassing of substances for the two light bulbs as 10 out of 15 degassed substances, including the substances which are found in the highest concentration, are not seen for both light bulbs. Two of the same substances which degas from both light bulbs, 1-butanol and benzene are furthermore in very different concentrations.

No general connection between the degassed substances from the energy-saving light bulbs from the same producer is identified.

The K-Tipp survey (K-Tipp (2011), described in section 2.1.2.12) is the survey which till now has carried out the most comprehensive test for degassed substances from energy-saving light bulbs. In the K-Tipp survey, newly purchased energy-saving light bulbs were examined for degassing of substances, light intensity, colour reproduction and many other parameters. The measured concentrations of benzene, N,N-dimethylformamide, octamethylcyclotetrasiloxane (D4) and tetrahydrofuran are higher in this survey than in the K-Tipp study. Phenol was found in one light bulb in this survey which is on level with the result in the K-Tipp survey where on the other hand phenol was identified in all of the analysed light bulbs. Acetic acid was identified in 18 light bulbs out of 25 in this survey while acetic acid did not degas from any light bulb in the K-Tipp survey. A possible explanation of the difference in the measured concentrations in this survey may be that the life span of the light bulbs influences on which substances and in which concentration these degas from the energy-saving light bulbs. It is known that the 14 analysed light bulbs in the K-Tipp survey were quite newly purchased light bulbs which had never been turned on. The age as well as number of lighting hours is not known for the light bulbs which were analysed in this survey. It is possible that old light bulbs degas breakdown products from other substances which might explain why acetic acid is identified in 18 out of 25 analysed light bulbs in this project, contrary to zero light bulbs in the K-Tipp survey. Another possibility may be that the substances change (degrade or react with each other) during the 6 hours they are kept in the tedlar bag during the test. However, this may also occur when they are tested in climatic chambers which is the analytical technical approach that was chosen in the K-Tipp survey as these reactions often take place momentarily. However, it might be conceivably that a possible reaction of the substances is more typical in a closed bag but it is solely a theory which cannot be confirmed on basis of the results in this project.

Assessment of the risk of selected degassed substances

Five of the degassed substances were selected for a health assessment and a risk assessment. These five substances were benzene, N,N-dimethylformamide, octamethylcyclotetrasiloxane, tetrahydrofuran and phenol. The substances were selected due to their health classification where substances classified with harmonised classification as carcinogenic, mutagenic and toxic to reproduction were given the highest priority.

The risk assessment of the five selected substances is based on a *worst-case* calculation of the exposure to these substances. In the *worst-case* calculation, among other things, the following is assumed:

- The consumers (both children and adults) sit close to the energy-saving light bulb which is turned on and they inhale the air from the immediate near zone of the light bulb, i.e. a volume of 1 m^3.
- It is assumed that the consumers inhale all the amount of substance which is measured from the degassing of the energy-saving light bulbs during the 6 hours.

Under these conditions, none of the five selected substances constitutes a health problem. Even if energy-saving light bulbs can degas many different chemical substances it is not expected to constitute a health problem as the amount of the individual degassed substances is low and the RCR values of the substances are extremely low (the highest RCR value is 0.009).

However, the risk assessment only applies to health effects where a threshold value can be defined, which is not applicable for the carcinogenic properties of benzene. Thus, even a small exposure to benzene is undesirable. The amount of benzene which is measured as released from the energy-saving light bulbs in this project is small. By way of comparison, the measured amount of benzene in this project is at level with the outdoor air and the concentration of benzene when painting but far below the concentration of benzene which is experienced when filling up with petrol.

1. Introduction

1.1 Background

During recent years, both in Denmark and abroad, smell from energy-saving light bulbs which is released when the light bulb is turned on has been discussed. The Danish Environmental Protection Agency has received inquiries from consumers who report about unpleasant smell from energy-saving light bulbs and several debate pages indicate that consumers wonder at the smell and whether it can result in a hazardous effect.

Both Danish and foreign media have debated what causes the smell and why it arises. Umweltbundesamt (the German Environmental Protection Agency) has dismissed that the gases cause a health risk (Umweltbundesamt, 2011) while the American Food and Drug Administration (FDA, 2012) has the theory that the UV radiation from the energy-saving light bulbs can activate a chemical reaction with odour as the result.

One of the main challenges in relation to finding the reason for the odour is that far from all energy-saving light bulbs smell. Knowledge of any connection between for instance light intensity or producer and which type of bulbs, that smell does not exist. Furthermore, odour is an individual size – something which smells strongly for some persons might not be smelled by others at all.

1.2 Purpose

The present project has the purpose to identify which gasses energy-saving light bulbs can release and investigate whether they constitute a health risk for the consumer.

2. Survey

The survey consists of three sections:

- Literature and internet search
- Contact to the business sector
- Identification and collection of smelling energy-saving light bulbs

Initially, a literature search was made for reports and articles etc. describing smell from energy-saving light bulbs and possible explanations of formation and release of the smelling gases. The search was made as an internet search and basis was both in Danish and international sources. Furthermore, a search among Danish and international scientific publications was carried out but no scientific publications on the subject were identified. In addition to this, a screening and a review of debate pages, consumer inquiries etc. were carried out, by which examples of smelling energy-saving light bulbs were identified. This information which was found through this literature search is described in section 2.1.

Furthermore, the business sector was contacted, i.e. producers of energy-saving light bulbs and trade associations with the purpose to examine whether they knew of odour from energy-saving light bulbs. Information received from the producers is described in section 2.2.

Finally, smelling energy-saving light bulbs were identified and collected. It was possible for consumers during a period to fill in a questionnaire on the Danish EPA's homepage and subsequently send in the smelling energy-saving light bulb which they had in their homes. A link to the questionare on the Danish EPA's Facebook page "Everyday Chemistry" ("Hverdagskemi") was made. The postings on this Facebook page are followed by approx. 7,000 persons. Furthermore, the Danish EPA published a press release which was shown on the website dk.dk/viden (knowledge) and the Facebook page of Ingeniøren (a Danish magazine for Engineers). Thus, it became possible to collect energy-saving light bulbs for chemical analysis. The results of the collection of energy-saving light bulbs from consumers are described in section 2.3.

2.1 Literature and internet search

The internet search was carried out by use of both Danish and foreign/international homepages. Search words in Danish and English like "odour energy-saving light bulbs", "smell light bulbs", "smell CFL" and "emission energy saving light bulbs" were used. Similar German search words were also used as it turned out that several German homepages on the subject were available. Below, a list of examples of debate pages, as a result from the internet search, is shown. On these pages consumers had asked about and discussed smelling energy-saving light bulbs. Subsequently, literature on odour from energy-saving light bulbs was examined. The descriptions were divided into "Debate pages" as well as "Test and articles". Most of the descriptions/examinations were identified on German homepages.

2.1.1 Debate pages

Below a short summary is presented showing the information on odour from energy-saving light bulbs which are discussed on different debate pages. The debate pages might be a discussion forum from consumer to consumer but it might also be answers from a more technical body such as for instance on the Danish website forbrugerkemi.dk (consumer chemistry).

2.1.1.1 Umbra, 12 June 2006: "Umbra on smelly CFLs (and mercury too)"

A consumer writes as he has registered that his recently replaced CFL (Compact Fluorescent Lamp – i.e. energy-saving light bulb) has a strange odour. He asks whether the bulb releases something which he ought to be aware of and whether mercury is released to the air. In the answer it is written that it is unknown whether something smelling is released from the bulb and if so, what this is due to. The only suggestion is that it might come from the plastic around the bulb. However, the attention is drawn to the fact that it is not mercury which is released as it does not smell and is not released from the bulb if it is still intact. (Umbra, 2006).

2.1.1.2 DS forums, 8 August 2008: "Should energy saving light bulbs smell?"

A consumer asks whether it is correct that energy-saving light bulbs may smell or whether something is wrong with the bulb. The odour is difficult to describe but the consumer thinks it is a "strange" odour. Another person has also experienced an odour from his energy-saving light bulbs. A third person has experienced the same and describes the odour as "fishlike" and "unpleasant". (DS Forums, 2008).

2.1.1.3 Forbrugerkemi.dk, question 6 April 2009: "Energy-saving light bulbs smell" (in Danish: "Sparepærer lugter")

Inquiry from a consumer who inform about an energy-saving light bulb which in his opinion releases a "horrible chemical" odour. The odour is experienced as strongest when the light bulb is turned on, but it can also be sensed when the bulb is turned off if the consumer smells at it. The bulb has smelled in this way for several months and the odour does not disappear. The consumer asks if a health risk is connected to the odour and he states that the bulb is of the brand TERO from Kvickly (a supermarket in the COOP group). The answer from Forbrugerkemi is that they have no knowledge whether the released substances were to be hazardous to health and no explanation of the odour. (Forbrugerkemi, 2009).

2.1.1.4 Dk.teknik.elektronik, 2010: Energy-saving light bulbs smell of "hair-dryer" (in Danish: "Sparepærer lugter af "føntørrer"")

Among several consumers, the debate is why energy-saving light bulbs smell and what the odour is due to. One consumer thinks that the energy-saving light bulbs smell as soon as they become warm – also even if more space is made around the bulb. Another thinks that the energy-saving light bulb releases an odour of "hair-dryer" or a weak burnt odour. One consumer has experienced that the light bulb releases an odour which is described as "warm synthetic". (dk.teknik.elektronik, 2010).

2.1.1.5 Eforum, 26 January 2011: "Can a light bulb smell?" (In Swedish: "Kan en lampa lukta?")

A consumer writes because his cohabitee says that her new energy-saving light bulb smells badly. He asks whether it is correct that the light bulb smells. One person suggests that the odour may be caused by warming of the electronics which the energy-saving light bulb contains. Another states that energy-saving light bulbs might smell and that the odour can come from release of ozone. (Eforum, 2011).

2.1.1.6 Forbrugerkemi.dk, question 18 November 2011: ”I would like to know whether the chemical odour which energy-saving light bulbs release is hazardous to health”? (In Danish: ”Jeg vil gerne vide om den kemiske lugt sparepærer afgiver er sundhedsskadelig”?)

Inquiry from a consumer who wants to know whether the chemical odour which energy-saving light bulbs release is hazardous to health. The light bulb is from IKEA and both at home and at work it is observed that the light bulbs release a horrible chemical odour when they are turned on. This has bothered the consumer for quite a long time. The answer gives no explanation of the odour. (Forbrugerkemi, 2011).

2.1.1.7 UK Yahoo answers, 2012. Maintenance and repair: “Why is my light bulb smelling?”

A consumer asks whether others have experienced that their energy-saving light bulbs smell a little like burnt plastic, immediately after it is placed in the lamp. Another consumer answers that he has experienced the same and that the odour is like “the odour of a new car”. (UK Yahoo, 2012).

2.1.1.8 TheGreenLivingForum, 2012: “Do CLF bulbs smell?”

A consumer asks if others have experienced that an energy-saving light bulb smells like medicine. Another recognises the odour as a “warm electronical smell” and suggests that it might be due to the thread. The consumer with the original contribution answers that the odour is more like an odour “at the dentist” or “at the hospital ward”. A third consumer suggests that the odour can come from formaldehyde. A fourth writes that it might come from the condenser in the light bulb. (TheGreenLivingForum, 2012).

2.1.1.9 Gardenweb, 15 May 2012: ”CFL odor”

A consumer inquires as his newly purchased energy-saving light bulb releases a “metallic” smell when it is turned on. He has tried to change the lamp (as the first lamp was made of metal) but the light bulb gives the same smell in the new lamp which is not made of metal. After two days and nights, he writes again because the smell is decreased and it might be due to some production chemicals that have been burnt. (Gardenweb, 2012).

2.1.1.10 Kemikaliedetektiven, 14 August 2012: ”Energy-saving light bulb melted and smelled of chemical” (In Swedish: ”Lågeenergilampa smälte och stank av kemikalier!”)

A concerned consumer makes an inquiry when she experienced a bad odour of chemicals from her energy-saving light bulbs. She tells that due to the chemical odour, she has experienced to become distended, has had low blood pressure and experienced other signs of poisoning. She asks whether this is due to release of phenols (which has a strong odour) or mercury (which does not smell). Other consumers who share her concern about energy-saving light bulbs have answered to her inquiry but no explanation of the odour is stated. (Kemikaliedetektiven, 2012).

2.1.1.11 Forbrugerkemi.dk, question 12 July 2013: ”I use exclusively energy-saving light bulbs and have tried many different brands” (In Danish: ”Jeg bruger udelukkende elsparepærer og har forsøgt mig med mange forskellige mærker”)

Inquiry from a consumer who has tried several different energy-saving light bulbs from different brands but she experiences that they all smell as soon as they become warm. She worries about the reason for the odour and asks if it might be due to mercury vapours. In the answer, the consumer does not get a real answer regarding the reason for the odour but it is refused that it is due to mercury vapours as mercury does not smell. (Forbrugerkemi, 2013).

2.1.1.12 Canabis-forum, 2013: ”CFL light bulbs smell”

A consumer writes that he has used energy-saving light bulbs but each of them releases a “stinking smell of burnt plastic”. The person worries about his health and lungs. Another has experienced what is described as a "terribly poisonous" odour from his energy-saving light bulbs. (Canabis-forum, 2013).

2.1.1.13 Summary from the debate pages

Based on contributions on various debate pages, it can be concluded that several consumers experience that an odour is released from energy-saving light bulbs. Contributions are identified on Danish, German, English, Swedish and American internet pages so the phenomenon is geographically widespread. Some consumers experience the odour as being constant while others have experienced that the odour decreases proportionally to the period where the lamp is turned on.

The consumers use different words to describe the odour from the light bulbs but the current experience is that the odour is unpleasant and in many cases, it is described as chemical. On the debate pages, the odour is among other things described as: Chemical, poisonous, like a hair-dryer, fishlike, like a new car, like in a hospital, warm electronic odour etc. These describing words are used in connection with the questionnaire at the homepage of the Danish EPA as inspiration for the consumers when in the questionnaire they were to describe which odour they experience that their energy-saving light bulb releases.

Only in a few cases, official institutions have answered the contributions – otherwise, the debate pages are typically a debate between the consumers. The answers from the official institutions (such as for instance forbrugerkemi.dk) are in general that it is unknown what the reason for the odour is and whether the energy-saving light bulbs degas chemicals in amounts which are hazardous to health.

2.1.2 Tests and articles

Below tests and examinations of energy-saving light bulbs which were identified during the literature search are listed. Most of the examinations and tests are German. For the majority of the identified tests and examinations applies that the amounts of the identified substances which degas are not stated.

2.1.2.1 Öko-test, 2008. Test of energy-saving light bulbs (in Danish: Test af el-sparepærer), April 2008

In connection with a common consumer test of 16 energy-saving light bulbs, it was observed that two of the light bulbs "smelled strangely" when they were turned on. Therefore, an analysis of the vapours which were released from the two energy-saving light bulbs was made. The light bulb of the brand Osram released a glycol compound which has an acidulous odour. The IKEA light bulb turned out to release phenol which is experienced as a kind of "hospital odour". In the examination, it is not specified in which concentrations the substances are found and an assessment whether the substances are hazardous to health were not carried out. (Öko-Test 10, 2008; b.dk, 2008).

2.1.2.2 Test, 2008 Stiftung Warentest, No. 11/2008, 25 October

After reports from consumers concerning odour from energy-saving light bulbs, eight energy-saving light bulbs were tested for emission of VOC (Volatile Organic Compounds). It is not stated which substances that have been tested for, identified or in which concentrations they were found. The existing requirement values for Ecolabel criteria for furniture and wooden furniture were used as threshold limit values. In some cases, these threshold limit values were exceeded. Some of the substances were released in very small amounts but with an odour as the result which is described as being harmless, but annoying for the consumer. It is not further specified what this conclusion is based on. (Stiftung Warentest, 2008).

2.1.2.3 Test, 2010 Stiftung Warentest, No. 4/2010 April

In connection with a test of energy-saving light bulbs, it is reported that several consumers inquire and tell that their energy-saving light bulbs smell unpleasantly. Four of the tested energy-saving light bulbs smell unpleasantly when they are turned on. For the energy-saving light bulb of the brand Osram Delux EL Dimmable, a release of VOC was identified. According to the source, this might be hazardous to health. However, the substances were identified in low concentrations. It is not further specified which substances or in which concentrations the substances are found. (Stiftung Warentest, 2010).

2.1.2.4 JS Online, 2010. Taschler, J., and Content. "No dark, burning secrets to CFLs". 7 November 2010

This article has not focus on odour from energy-saving light bulbs but explains to a higher degree the development of energy-saving light bulbs. Energy-saving light bulbs are now of a much better quality than at the time when they were introduced on the market for the first time. However, it is mentioned in the article that the consumers have to get more used to the new type of bulbs as they "act" differently than the old incandescent bulbs seen in the past. Here the "burnt" odour is mentioned as one of the normal things when the light bulb stops shinning which the consumers have to get used to in connection with the new type of light bulbs. (JS Online, 2010).

2.1.2.5 Kluke, U., 2011. Die Welt. "On energy-saving light bulbs a dark shadow occurs" (in German: "Auf Energisparlampen fällt ein dunkler schatten"). 19 April 2011

A study carried out by a laboratory in Berlin for NDR (a TV station) shows that carcinogenic chemicals from energy-saving light bulbs are released when light bulbs are turned on. No further specification of the carcinogenic chemicals is given. It is stated that the examination confirms that this phenomenon applies to energy-saving light bulbs from at least five large producers. A married couple had written to NDR after they had identified the odour of phenols from energy-saving light bulbs in their home. These two persons work a lot with phenols in connection with their hobby and were thus able to identify the odour of phenols. The examination does not answer the question from where the odour originates but the producers suspect that the odour is caused by glues or other components in the light bulb. (Kluke, U., 2011).

2.1.2.6 NDR-Fernsehen, 2011. "I was surprised at the results" (in German: "Ich war überrascht von den Ergebnissen"). 18 April, 2011

On 18 April 2011, German television, NDR, brought a short feature on odour from energy-saving light bulbs. Jörg Hilbert from Markt.de was interviewed in German television and informed that a viewer had informed per email that his energy-saving light bulb smelled of phenol. As phenol is hazardous to health, Markt.de took the inquiry seriously and made a test of five energy-saving light bulbs from a well-known producer and had them examined by a certified laboratory. At the test, the laboratory found that all the energy-saving light bulbs degassed substances which either are or are suspected of being carcinogenic. In the examination, the carcinogenic substances in question are not specified. Jörg Hilbert states that in reality many of the identified substances ought to be avoided in the indoor climate – although the producers pointed out that the concentrations are low. The measured concentrations are not specified. (NDR-Fernsehen, 2011).

2.1.2.7 NDR.de, 2011. "Poison from energy-saving light bulbs has an impact on the indoor air" (in German: "Gift aus Energiesparlampen belastet Raumluft"), 15 April 2011

NDR refers to a test which has shown that energy-saving light bulbs can release poisonous substances when they are turned on in the home. The poisonous substances in question are not specified. Based on a test performed in a certified laboratory, it turned out that the energy-saving light bulbs release substances which are suspected of having carcinogenic effects. The identified chemicals with carcinogenic effects are not specified. The test showed clearly measurable amounts of phenol which is suspected of being mutagenic. However, the identified amounts of phenol are not stated. Expert in the field, Peter Brown, states it is alarming that phenol is found in these amounts and that they are released during normal use of the energy-saving light bulb. However, a concrete risk assessment of the measured amounts of phenol is not made. Producers of the energy-saving light bulbs have also commented on the test results. One producer thinks that the release must come from the lamp itself and another states that no concentrations are measured in so high amounts that they exceed any legal limits. However, the expert Peter Brown warns that the identified substances might be hazardous to health and carcinogenic even in very low concentrations. (NDR.de, 2011).

2.1.2.8 Wohnungswirtschaft heute, 2012. "The opinion of the Federal Environment Agency in Germany to alleged phenol and aromatic vapours from energy-savining light bulbs" (in German: "Stellungnahme des Umweltbundesamtes zu angeblichen Phenol- und Aromatendämpfen aus Energiesparlampen"

The German Environmental Protection Agency (Umweltbundesamt) comments on emissions of VOC from energy-saving light bulbs based on test performed by NDR (described above). It is described that a degassing test in a climate chamber with new energy-saving light bulbs has been made. Degassing of volatile substances was expected as it is the case for all new products. Where the substances come from is unknown but the German EPA guesses that the evaporation comes from the printed circuit board or the application of glue in the socket of the light bulb.

It is stated that among others, phenol, toluene, naphthalene, styrene, xylene and aldehydes are identified from energy-saving light bulbs when they are turned on. The concentrations of these identified substances are not stated but the German EPA concludes that the concentrations which degas are very low and that there is no reason to fear health effects due to these emissions. The assessment was made based on a comparison of the measured concentrations and applicable threshold limit values. (Umweltbundesamt, 2011; WOWI Heute, 2011).

2.1.2.9 U.S. Food and Drug Administration, 2012. "Radiation-Emitting Products, Compact Fluorescent Lamps (CFLs) – Fact Sheet/FAQ"

9 different energy-saving light bulbs on the American market were examined. UV radiation released from the energy-saving light bulbs was registered. Cracks in the phosphorus coating were observed. These might probably result in a release of UV radiation. It is unknown whether this radiation starts a chemical reaction with a smell as the result (FDA, 2012). However, their statement says that it is a small amount of UV radiation which energy-saving light bulbs release, i.e. an amount which is only measurable with specifically sensitive equipment. The amount of UV radiation is not specified. (FDA, 2012).

2.1.2.10 Baubiologoie Maes, 2013. Maes, W. "The dark sides of the energy-saving light bulbs" (in German: "Die dunklen Seiten der Energiesparlampen"

Wolfgang Maes from the German company Baubiologie Maes which is specialised in indoor climate has prepared a document which summarises a number of problems, such as life span, light shimmer, light spectrum, light intensity, content of mercury and much more, including emission of hazardous substances and smell from energy-saving light bulbs. The document is based on several articles and examinations of energy-saving light bulbs in the period from 2007 to 2013.

In the document it is described that in May 2008 the German consumer magazine Stiftung Warentest had an article on the subject that more and more persons complain about bad odours from energy-saving light bulbs. In 2008 Stiftung Warentest has similarly performed measurements of energy-saving light bulbs for the German consumer magazine Öko-Test where odour from energy-saving light bulbs was observed as well. Stiftung Warentest describes that the test room smelled intensively of chemistry and that the persons who carried out the test had eyes which watered as a result of the test. Therefore, Stiftung Warentest carried out another test of two energy-saving light bulbs from Osram and IKEA and identified degassing of phenol and glycol in the inhalation air in the room. It is stated that the threshold limit values for the substances in the room were exceeded. The amount of released phenol and glycol is not specified.

In another test with five energy-saving light bulbs performed by Stiftung Warentest, carcinogenic substances such as phenol, styrene and tetrahydrofuran were identified. The amounts were not specified. In these tests they show that the gases come from the light bulb sockets. Stiftung Warentest contacted the producers to inquire from where the gases came. The producers supposed that the gases originate from "harmless soldering and glue residues" and stated that the smell disappears quickly. However, Stiftung Warentest describes examples of the contrary, i.e. that the smell continues – also after weeks and months.

In the document, it is concluded that nobody exactly knows the cause of the odour and no comprehensive examinations are completed to find out which substances that degas and how dangerous these odours are. (Maes, W., 2013).

2.1.2.11 Stiftung Warentest, test 4/2014. "Theme package light bulbs. Test of LED, halogeneous and energy-saving light bulbs" (in German: "Themenpaket Lampen. Test von LED-, Halogen- und Energiesparlampen")

This comprehensive test/article from Stiftung Warentest is a complete test of different kinds of light bulbs, including energy-saving light bulbs. Smell from energy-saving light bulbs is described very shortly. Stiftung Warentest states that energy-saving light bulbs can release caustic gases which do not only release an unpleasant smell but after a short time the eyes and throat also smart. In the examination, the gases in question are not specified. Stiftung Warentest states that they have tested some hundred light bulbs in their many tests of light bulbs but not all the light bulbs smell. It is only in a few cases that they have been able to prove a clear release of odour. In a previous test with a few light bulbs, increased concentrations of readily volatile substances were demonstrated but the substances in question are not specified. Stiftung Warentest states that under normal ventilation conditions, a risk of an acute health hazard is not present. (Stiftung Warentest test 4, 2014).

2.1.2.12 Test, K-Tipp No. 11/2011, Swiss consumer magazine

In this test, 14 energy-saving light bulbs which are commonly available on the Swiss market have been tested by the consumer magazine K-Tipp. The basis of this test was not odour from energy-saving light bulbs as far more parameters were included in the test, such as light intensity, life span etc. The test is carried out by the ALAB analysis laboratory in Berlin and is the most comprehensive test report which has been identified in this survey. The detailed analysis results from the test are not open to the public but the project group obtained admission to them through contact to the analysis laboratory. The measurements were carried out as a climate chamber test where the energy-saving light bulbs had burnt for 7 days. (K-Tipp, 2011; ALAB, 2011).

The test included release of approximately 200 different chemical substances by use of the light bulbs of which 126 of the examined substances were detected in one or several light bulbs. The test was carried out in the period from 17 June to 10 August 2011. All the examined energy-saving light bulbs generated electromagnetic fields and released harmful chemicals. The 14 examined energy-saving light bulbs have all a light intensity of 11 watt and were assessed in relation to durability, energy efficiency, loss of light intensity, colour reproduction, start-up time etc. K-Tipp concludes that it is alarming that all the energy-saving light bulbs release harmful gases to the environment and generate electrosmog. No risk assessment of the released chemicals from the energy-saving light bulbs has been prepared. (K-Tipp, 2011; ALAB, 2011). All the test results for the 126 identified substances are shown in Appendix 1:.

It must be noted that in this test carried out for K-Tipp, all the light bulbs were turned on for 7 consecutive days in climate chambers with a volume of 22.5 litres with an air exchange of 0.5 per hour. No reason for this long burning period has been given. (K-Tipp, 2011; ALAB, 2011). This condition has also been criticised by the producers as being an unrealistically long burning period but given the constant air change, it is a kind of steady state measurements which have been undertaken.

The test results of the identified released gases are shown in Table 13 in Appendix 1: where all the 126 identified substances are stated. Table 1 below lists the substances which in this K-Tipp survey were identified in concentrations above 20 $\mu g/m^3$ and which either were classified (with the below classifications) or which were identified in concentrations above the odour threshold value, in total 21 substances.

For all the 126 identificed substances in this test, the harmonised classification has been listed as well as their notified self-classification if no harmonised classification of substance is available for the substance. The listed self-classification has not been evaluated. Please notice that there may be differences of opinion concerning the classification between the different notifiers. The complete classification is not noted, but only whether the substance has one of the below classifications as these classifications are regarded to be most relevant in relation to an assessment whether the substances can constitute a health risk.

- Carc. 1A, 1B og 2 (carcinogenic),
- Muta. 1A, 1B og 2 (mutagenuc),
- Repr. 1A, 1B og 2 (toxic to reproduction),
- Resp. Sens. 1, 2 og 3 (respiratory sensitising), and
- STOT RE 1, 2 og 3 (damaging for a spcific target organ at repeated exposure (Specific Target Organ Toxicity Repeated Exposure)).

Furthermore, the lowest odour threshold value of the substances is stated if it was found in the literature. References to the individual odour threshold limits are marked with footnotes in the table. It must be noted that odour threshold limits are subjective and it will depend on the individual person when the odour is experienced. However, in the table, the lowest odour threshold limit which has been reported in the individual sources is stated.

Furthermore, the threshold limit in the working environment is stated for the substances if such a limit is available.

Finally, for all the identified substances it is stated in how many light bulbs (out of the 14 tested light bulbs) the substance is identified as degassed from.

In the table, the following markings are used:

- Light green backgroud colour: The substance is relevant because it appears in a concentration where it might be smelled, i.e. the concentration is higher than the odour threshold limit.
- **Bold type**: The substance is relevant because it has one of the above classifications.
- *Italics and underlined text*: The substance is relevant because it appears in high concentrations (> 50 $\mu g/m^3$).

As described, the basis of this test was not odour but on the contrary other parameters. However, the results from the survey confirm that all the 14 tested energy-saving light bulbs might smell due to the fact that one or more of the identified substances which emit from the bulbs are measured in concentrations above the respective odour threshold limit (see Table 1) when comparing with the odour threshold limit (as stated in Table 1). It is especially the substances m/p-cresol, phenol and 1-butanol where concentrations are identified from several of the 14 tested light bulbs which are above the stated odour threshold limit for the substance.

Substance name	CAS No.	Harmonised classification	Relevant notified self-classification	Odour threshold value* (µg/m^3)	No. of light bulbs where the substance is identified	Lowest value meas. (µg/m^3)	Highest value meas. (µg/m^3)	Occup. threshold limit value
Phenol	108-95-2	Muta. 2 STOT RE 2	-	179[3]	14	52.8	730	1 ppm 4 mg/m^3
1-butanol	71-36-3	None relevant	None relevant	90[1]	14	8	449	50 ppm 150 mg/m^3
Tetrahydrofuran	109-99-9	Carc. 2	-	7,375[3]	14	25	355	50 ppm 148 mg/m^3
Toluene	108-88-3	Repr. 2 STOT RE 2	-	600[2]	14	8	237	25 ppm 94 mg/m^3
Styrene	100-42-5	None relevant	Carc. 2 STOT RE 1	160[1]	13	1	209	25 ppm 105 mg/m^3
2-(-2-metoxyetoxy)ethanol	111-77-3	Repr. 2	-		2	6	178	10 ppm 50 mg/m^3
n-butanal	123-72-8	None relevant	None relevant	28[1]	14	2	165	-
Diisobutyl-phthalate	84-69-5	Repr. 1B	-		9	1	139	- 3 mg/m^3
m-/p-xylene	1330-20-7	None relevant	STOT RE 2	78[2]	10	1	118	25 ppm 109 mg/m^3

Substance name	CAS No.	Harmonised classification	Relevant notified self-classification	Odour threshold value* (µg/m^3)	No. of light bulbs where the substance is identified	Lowest value meas. (µg/m^3)	Highest value meas. (µg/m^3)	Occup. threshold limit value
Ethylbenzene	***100-41-4***	***None relevant***	***Carc. 2*** ***STOT RE 2***	***2,000***[1]	***8***	***1***	***113***	***50 ppm*** ***217 mg/m^3***
N,N-Dimethyl-formamide	***68-12-2***	***Repr. 1B***		***300,000***[3]	***14***	***2***	***108***	***10 ppm*** ***30 mg/m^3***
n-hexanal	*66-25-1*	*None*	*None relevant*	*58*[1]	*14*	*1*	*90*	*-*
n-pentanal	*110-62-3*	*None*	*None relevant*	*22*[1]	*14*	*1*	*88*	*50 ppm* *175 mg/m^3*
TXIB	***6846-50-0***	***None***	***STOT RE 2***		***9***	***1***	***83***	***-***
Ethylenglycol	***107-21-1***	***None relevant***	***Muta. 1B*** ***Repr. 1B*** ***STOT RE 1 og 2***	***62,500***[3]	***6***	***6***	***71***	***10 ppm*** ***26 mg/m^3***
Octamethylcyclo-tetrasiloxane (D4)	***556-67-2***	***Repr. 2***	***-***		***9***	***1***	***65***	***-***
n-heptanal	*111-71-7*	*None*	*None relevant*	*23*[1]	*13*	*1*	*53*	*-*
n-octanal	124-13-0	None	None relevant	7[1]	14	1	48	-
n-nonanal	124-19-6	None	None relevant	14[1]	14	2	45	-

Substance name	CAS No.	Harmonised classification	Relevant notified self-classification	Odour threshold value* (µg/m³)	No. of light bulbs where the substance is identified	Lowest value meas. (µg/m³)	Highest value meas. (µg/m³)	Occup. threshold limit value
Benzene	71-43-2	Carc. 1A Muta. 1B STOT RE 1	-	4,500 [1]	12	1	20	0,5 ppm 1,6 mg/m³
m/p-cresol	108-39-4 /106-44-5	None relevant	Repr. 2/None relevant	1 [3]	14	1.5	20.0	5 ppm 22 mg/m³

TABLE 1
SELECTED TEST RESULTS (K-TIPP, 2011) – TEST OF 14 ENERGY-SAVING LIGHT BULBS AND IDENTIFICATION OF CHEMICALS RELEASED FROM THE LIGHT BULBS. THE SUBSTANCE CLASSIFICATION FROM ECHA'S C&L INVENTORY DATABASE IS LISTED AS WELL AS ODOUR THRESHOLD VALUES FOR SUBSTANCES WHERE AN ODOUR THRESHOLD VALUE HAS BEEN IDENTIFIED. SELECTED SUBSTANCES, I.E. SUBSTANCES MEASURED IN CONCENTRATIONS ABOVE 20 µG/M³ AND EITHER CLASSIFIED OR MEASURED IN CONCENTRATIONS ABOVE THEIR ODOUR THRESHOLD VALUE ARE LISTED IN THE TABLE.

THE TABLE IS SORTED AFTER DESCENDING CONCENTRATION.

* IT MUST BE NOTED THAT AN ODOUR THRESHOLD VALUE HAS BEEN LISTED FOR THE SUBSTANCES WHERE SUCH A VALUE HAS BEEN AVAILABLE IN THE OPEN TECHNICAL LITERATURE.
1 – DANISH EPA, 2003
2 – WOLKOFF ET AL., 2006
3- JON H. RUTH, 1986

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[1] Jon H. Ruth. Odor Threshold and Irritation Levels of Several Chemical Substances: A Review. Journal of American Industrial Hygiene Association (47) 1986. 142-151.

2.1.2.13 Summary of existing tests

Five real chemical analyses of gases from smelling energy-saving light bulbs have been identified. In the described tests, different energy-saving light bulbs in a number from 2 up to 16 of varying brands, light intensity etc. were analysed. The substances which degas from the energy-saving light bulbs are identified as phenols (are identified in all tests), styrene, glycol compounds etc. In addition to this, a few test laboratories measure UV radiation released from the light bulb. Common for all tests is that no one has made a risk assessment of the released substances from the energy-saving light bulbs but it is described that substances classified as carcinogenic are released which potentially might constitute a risk for the consumer.

The most detailed test is made for the consumer magazine K-Tipp where the release of approximately 200 different chemicals was tested. The survey carried out by K-Tipp shows that a number of substances among the most frequently identified substances are classified as reprotoxic, mutagenic or carcinogenic. The test from K-Tipp is not performed on light bulbs which were known for releasing odour but on the contrary on 14 different newly bought energy-saving light bulbs. However, the results from the survey confirm that if compared with the odour threshold limit (as stated in Table 1), all the 14 tested energy-saving light bulbs might smell due to the fact that one or more of the identified substances which emit from the light bulbs are measured in concentrations above their respective odour threshold limit (see Table 1).

2.1.3 Summary of literature and internet search

Based on the internet search, it can be concluded that some energy-saving light bulbs degas chemicals during use with odour as a result. Release of a number of different substances from the energy-saving light bulbs, especially phenols, glycol compounds and styrene, has been identified. The release of phenol has been identified in several of the surveys. Release of carcinogenic substances (however, not all the surveys indicate specifically which substances) has been identified. No risk assessment of the identified levels has been made in any of the surveys.

None of the surveys gives any conclusions on the relation between producer/brand of the energy-saving light bulbs and the level of the odour from these light bulbs. This indicates that there are not any special brands with problems with odour but that odour can occur for a few light bulbs of all brands.

In the surveys, several suggestions of the reason for the odour have been given:

- The odour can arise as a direct consequence of the degassed substances (like at release of phenol and glycol compounds), i.e. it is the actual released gases which smell.
- Another suggestion of the origin of the odour is given by US EPA. US EPA suggests that it may be due to the UV radiation which can start a chemical reaction that results in odour (FDA, 2012).
- On their homepages, some producers have explained the odour as being a result of glue residues etc. which burn off by use of the light bulbs. In these cases, the odour ought to stop after long-term use of the light bulbs.
- Other producers suggest that the complaints of odour from energy-saving light bulbs are due to the possibility that it is a new type of light bulbs and that the consumers are to get used to the “different odour”. However, this theory does hardly last so many years after the energy-saving light bulb has been introduced when complaints of odour still exist.

2.2 Contact to the industry

The below organisations and companies have been contacted with the purpose to get an explanation of the odour problems from energy-saving light bulbs which some consumers can experience from energy-saving light bulbs. In addition to this, the producers were asked what their opinion is regarding odour from energy-saving light bulbs – i.e. whether this is a comprehensive problem and what the reason for the odour is.

Producers of energy-saving light bulbs:

- Phillips
- Osram
- Megaman
- IKEA
- COOP (TERO)

Furthermore, the trade organisation Dansk Energi (Danish Energy) has been contacted but they were not in possession of any information on odour from energy-saving light bulbs.

Out of the five contacted producers, three answered the inquiry. The general response is that they do not know anything about the phenomenon regarding odour from energy-saving light bulbs and that they have not received any inquiry from their customers dealing with odour.

Of possible explanations of the circumstance why odour from energy-saving light bulbs can arise, a suggestion from a producer is that it may be a short circuit which can result in a burnt odour. However, this occurs very rarely according to the producer. Another suggestion is that it is probably cheap/bad models which may smell, which are produced of either bad material or produced of recycled material containing impurities.

A producer explains that the phenomenon odour (described as “cat piss”) has periodically been complained for light sources which are used at very high temperatures. However, these odour problems are exclusively seen at incandescent bulbs and halogen bulbs but have never been complained for energy-saving light bulbs. For incandescent bulbs and halogen bulbs it is known that the odour comes from the putty material which binds the mounting and the bulb.

None of the producers was in possession of energy-saving light bulbs which smell and thus they have not been able to give input to this project in the form of smelling light bulbs. Smelling energy-saving light bulbs are therefore exclusively obtained directly through consumers for the analysis phase in the project.

2.3 Identification and collection of smelling energy-saving light bulbs

In this section it is described how smelling energy-saving light bulbs have been collected from consumers.

2.3.1 Purpose

The purpose of the identification and the collection was to obtain smelling energy-saving light bulbs from the consumers which in the next phase of this project are to be analysed for the release of hazardous substances. The collection of the smelling energy-saving light bulbs is exclusively made on the basis of the consumers’ own assessment whether the energy-saving light bulb smells, how it smells and how strongly it smells etc.

The first step in the collection of the smelling energy-saving light bulbs was to apply to consumers and to disseminate the message about the survey. The following means were used to disseminate the message about the survey:

- Notice on the homepage of the Danish EPA
- News on various homepages

2.3.2 Notice on the homepage of the Danish EPA

On their homepage, the Danish EPA created a questionnaire in the period from mid May 2014 to mid July 2014 which applied to the consumers who have experienced that one or more of their energy-saving light bulbs smelled.

Through the questionnaire of the Danish EPA (see Appendix 2:), the consumers could report if they had experienced that an energy-saving light bulb smelled during use. They were to fill in a questionnaire and describe the odour with words like “chemical”, “poisonous” etc., the strength of the odour (on a scale from 1 to 5 where 1 is weak and 5 is strong), when the odour arises (number of minutes after the lamp is turned on). After this they were to state whether they still were in possession of the smelling energy-saving light bulb and if so whether they were interested in participating in the survey by forwarding the smelling energy-saving light bulb to the project group.

Subsequently, inquiry was made to the consumers who had filled in and sent in the questionnaire with the purpose to collect the smelling energy-saving light bulbs and finally to have these light bulbs analysed for the release of hazardous chemical substances.

2.3.3 News on various homepages

To disseminate the news about the survey, a notice was made on the Danish EPA’s Facebook page ”Everyday Chemistry”[2] (“Hverdagskemi”). On this page, a teaser was posted to all the persons who “follow” the page, i.e. about 7,000 persons. This text invited consumers to enter the homepage of the Danish EPA if they had experienced a smelling energy-saving light bulb and were interested in participating in the survey of the Danish EPA. When the consumer clicked on the link they entered the homepage of the Danish EPA where they could answer a couple of short questions about the smelling energy-saving light bulb by filling in a form.

Furthermore, the Danish EPA released a press release which was taken up by Denmark’s Radio (Danmarks Radio) and brought on their home page ”Knowledge”[3] (”Viden”) under the subject Environment (Miljø). The news was also shared on the Facebook page of “Ingeniøren”[4] (the Danish magazine for Engineers) and on the homepage of FORCE Technology under ”News”[5] (“Nyheder”). Besides through their Facebook page, the Danish EPA shared the news about the survey via their homepage under ”Nyheder”[6] (“News”). The news about the project was furthermore sent to “Forbrugerrådet” (the Danish Consumer Council).

2.3.4 Result of the inquiries from consumers

In total 47 consumers filled in the form on the homepage of the Danish EPA. Of these 42 were interested in having their energy-saving light bulb examined. Out of the 42, 7 consumers did not fill in sufficient contact information. A parcel was sent to each of the remaining 35 consumers. They were asked to return the parcel with the smelling energy-saving light bulb so the light bulb could be analysed in the next phase of the project. Each light bulb was given a number between 1 and 35.

The consumers have used the following words to describe the odour from the energy-saving light bulbs: Chemical, poisonous, burnt, strange, like in a hospital, burnt printed circuit board, electric installations, chlorine, sour, old, sweet, of hair-dryer, burnt plastic and solar heat burnt. The describing word which is used by most consumers is that the energy-saving light bulb smells chemically.

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[2] https://m.facebook.com/Hverdagskemi

[3] http://www.dr.dk/Nyheder/Viden/Miljoe/2014/05/19153921.htm

[4] https://m.facebook.com/ingeniorendk

[5] http://www.forcetechnology.com/da/Header/News/News/lugter-din-sparep%C3%A6re.htm)

[6] http://mst.dk/service/nyheder/nyhedsarkiv/2014/maj/pm-lugt-fra-sparepaerer/

To the question how bad the odour from the energy-saving light bulb is experienced on a scale from 1 (weak) to 5 (strong), the consumers describe it from 2 to 5. The majority describes the odour as being strength 4, thus relatively strong-smelling. However, it must be noted that this is the consumers' own assessment of the odour and it may be assumed that the consumers who are most annoyed by the odour from energy-saving light bulbs are also those who have chosen to participate in this survey.

The consumers state that the odour from the energy-saving light bulbs arises in the period from a few seconds after the light bulb is turned on and upto 1 hour after the light bulb is turned on. Most consumers state that the odour arises when the energy-saving light bulb has been turned on for 5-20 minutes.

In the below table (Table 2), the information from the consumers is reported. It must be noted that not all 47 consumers who filled in the form on the homepage of the Danish EPA with a description of the odour participated in the survey by sending in their smelling energy-saving light bulb.

Light bulb no.	Description of the odour	How bad is the odour? (1 – 5)	When does the odour arise?
1	burnt strange	3	20 minutes
2	like in hospital	3	1 minute
3 a-c	burnt printed circuit board	4	1 hour
4	sweet chemical	5	10 minutes
5	chemical plastic	2	20 minutes
6	chemical burnt sweet	3	20 minutes
7 a-b	chemical electric installations	3	5 minutes
8	sweet chemical	3	20 minutes
9	chemical burnt	4	5 minutes
10	chemical	3	1 minute
11 a-b	chemical	3	30 minutes
-	chemical a little burnt	2	5 minutes
12	chlorine	2	30 minutes
13	chemical poisonous burnt	5	1 minute
14	burnt	2	5 minutes
15	chemical	4	*

Light bulb no.	Description of the odour	How bad is the odour? (1 – 5)	When does the odour arise?
-	chemical poisonous	3	5 minutes
16	chemical	5	*
17	chemical poisonous	4	*
18	poisonous burnt	4	5 minutes
19	chemical burnt	5	2 minutes
-	burnt poisonous	*	*
20	chemical	2	*
-	sour old burnt	4	*
21 a-b	chemical sweet	3	5 minutes
22	chemical burnt	3	20 minutes
23	chemical sweet	4	5 minutes
24	burnt plastic	4	5 minutes
-	burnt	4	2 minutes
25	burnt	2	5 minutes
26 a-b	hair-dryer sweet burnt	3	10 minutes
-	chemical	5	*
-	sweet chemical	3	*
-	burnt sweet	3	3 minutes
27	burnt chemical	4	10 minutes
28	chemical	4	2 minutes
29	chemical poisonous	4	1 minute
30	chemical poisonous	5	5 minutes
31	burnt hair-dryer	4	1 minute
-	poisonous	4	3 minutes
32	solar heat burnt	4	1 minute
33	chemical poisonous	4	10 minutes

Light bulb no.	Description of the odour	How bad is the odour? (1 – 5)	When does the odour arise?
-	burnt chemical	2	1 minute
-	burnt chemical	3	*
34	sweet	4	1 minute
35	chemical	3	1 minute
-	chemical	5	1 minute

TABLE 2
ANSWERS FROM ALL THE 47 CONSUMERS WHO FILLED IN THE QUESTIONNAIRE ON THE HOMEPAGE OF THE DANISH EPA. NOT ALL THE PERSONS WHO ANSWERED THE QUESTIONNAIRE HAD ENERGY-SAVING LIGHT BULBS WHICH THEY COULD FORWARD TO THE SURVEY (MARKED WITH"-"). NOT ALL CONSUMERS STATED WHEN THE ODOUR AROSE OR HOW BAD THEY EXPERIENCED THE ODOUR (MARKED WITH"*").

2.3.5 Result of the collection from the consumers

35 consumers received a parcel so they could forward their smelling energy-saving light bulb. This resulted in a total of 37 energy-saving light bulbs being received from 30 consumers as some of the consumers sent more than one light bulb. However, one of the energy-saving light bulbs was broken during transport.

The 36 undamaged energy-saving light bulbs were from 15 different producers and in total 28 different types of energy-saving light bulbs. Besides producer, the energy-saving light bulbs varied in light intensity (watt) and shape (spiral, pearshaped, columnar etc.).

5 types of the forwarded energy-saving light bulbs were "repeats" where producer/brand, light intensity and shape were identical. Thus, a total of 28 different energy-saving light bulbs was registered, several of them of the same brand/producer, but with variations in the model, shape and/or light intensity.

There is thus no immediate pattern in either brand/producer, light intensity or shape of the light bulbs when it comes to odour from energy-saving light bulbs.

On receipt of the energy-saving light bulb, brand and light intensity (watt) were registered. A picture of the energy-saving light bulb was taken as documentation and subsequently a gift voucher for a new light bulb was returned to the consumer as a compensation of the forwarded energy-saving light bulb.

It is to be noted that the gift voucher was not "promoted" during the process. The text solely said that the consumers "were to get a compensation for their expenses". This means that no consumers should have forwarded their light bulbs on purpose and "claimed" that it smelled in order to get a financial profit. Gift vouchers which were sent to the consumers exclusively covered the consumer's expenses of the light bulbs which were sent in.

It is also to be noted that the age of the received energy-saving light bulbs is unknown. Therefore, the theory that the odour was due to degassing of glue residues from the energy-saving light bulb cannot directly be confirmed or disconfirmed in this project. According to this theory, the degassing from the energy-saving light bulb has to be strongest at the beginning of the life of the energy-saving light bulb where evaporation of possible residues of solvents from the glue will be strongest.

2.4 Energy-saving light bulbs sent for analysis

In total 36 smelling energy-saving light bulbs were collected from the consumers of which 5 light bulbs were repeats (identical). It was decided that 3 of these 5 repeats were to be analysed to assess whether the light bulbs had comparable emission profiles.

Thus, 34 energy-saving light bulbs were sent to chemical analysis at Danish Technological Institute for measurement of degassing of selected substances. However, at the receipt, several of the energy-saving light bulbs could no longer be turned on and therefore only analyses of 26 energy-saving light bulbs have been made and of these there was only one repeat.

3. Degassing test and chemical analyses

3.1 Selection of substances to be analysed

The analysis programme was determined based on the results of the survey and especially the comprehensive K-Tipp test of energy-saving light bulbs which is presented in Appendix 1: and Table 1. In the previous examination with degassing from energy-saving light bulbs, a number of volatile and semi-volatile organic substances have been detected. All these substances would be able to be detected through the already chosen sampling and analysis method for the present project (see the detailed descriptions of test and analysis programme below).

As the most problematic substances identified in the K-Tipp test were also found in the highest concentrations it was decided that the 26 energy-saving light bulbs were to be analysed for the 10 substances which were found in the highest concentrations – measured through a semi-quantitative analysis. The decision from the start not to determine which specific substances to be identified gave the possibility to see which substances that actually were released from the light bulbs in the highest concentrations.

Furthermore, it was decided that analyses for the below three substances for all 26 energy-saving light bulbs were to be carried out. The reason is that these substances are problematic but that they were not found in the highest concentrations in the K-Tipp test (see Table 1).

- Benzene – the substance has a harmonised classification of concern (Carc. 1A and Muta. 1B) and it has a low threshold limit value in the working environment. In the K-Tipp test, benzene was degassed from 12 of 14 analysed light bulbs and was present in relatively low concentrations – seen in relation to the measured concentrations of all substances (however, above 20 µg/m^3).
- N,N-dimethylformamide – the substance has a harmonised classification of concern (Repr. 1B) and it has a low threshold limit value in the working environment. In the K-Tipp test, the substance was degassed from 14 of 14 light bulbs and was present in relatively low concentrations (however, above 20 µg/m^3).
- Cresol – the substance has a harmonised classification of concern (Repr. 2). In the K-Tipp test, cresol was degassed from 14 of 14 light bulbs and the substance has an extremely low odour threshold limit, i.e. the substance can cause that the energy-saving light bulbs smell.

Finally, all the 26 light bulbs were also analysed for release of ozone.

Thus, the test programme was determined to include degassing test with sampling of volatile and semi-volatile organic substances (the 10 substances which are degassed in the highest concentration as well as benzene, N,N-dimethylformamide, cresol and ozone).

3.2 Degassing test

The energy-saving light bulbs were mounted separately in tedlar bags of 10 litres with clean air. The energy-saving light bulbs were mounted on a stand so that the light bulbs hung freely in the tedlar bags without any contact between the energy-saving light bulbs and the tedlar bags. After 5.5 burning hours, a sampling of the air around the energy-saving light bulbs on adsorption tubes for determination of volatile and semi-volatile organic substances was made. The sampling was terminated after 6 burning hours. The used adsorption tubes were ATD tubes with mixed bed consisting of Tenax TA® and Carbograph™. The 6 burning hours were chosen as a worst-case exposure time (see the section on exposure scenario in chapter 4.3.1).

After 6 burning hours, a sampling of the air around the energy-saving light bulbs was made for determination of ozone on tubes for direct measurement of the type ”Dräger, Ozone 0.05/b” with a measuring range of 0.5 to 0.7 ppm.

Testing for blank for the air in the tedlar bags were made before mounting of the energy-saving light bulbs. The temperature in the test room was 20 – 23 °C with only slight variations.

3.3 Analysis of ATD tubes

A screening analysis was made of the sampling tubes from the sampling in the tedlar bags for volatile and semi-volatile organic substances with semi-quantitative determination of the up to 10 components which were found in the highest concentration. At the same time as the screening, all the tubes were furthermore analysed semi-quantitatively for a content of benzene, cresol and N,N-dimethylformamide (DMF).

The method only includes components which can be collected, desorbed and analysed on ATD tubes with adsorption material consisting of Tenax TA® combined with Carbograph™. Adsorption material for the ATD tubes is determined from the expected, relevant substances exposed during the survey. It is not possible to identify for instance inorganic substances, volatile aldehydes and isocyanates.

3.3.1 Analysis method – screening analysis at GC/MS

The ATD tubes are extracted by automatic thermal desorption (ATD) and the analysis is carried out by gaschromatografy with mass selective detection (ATD/GC/MS). The mass spectra of the components are compared with the mass spectrum from the MS library from NIST[7]. At the screening, semi-quantitative results are calculated for the up to 10 most dominant substances towards the internal deuterated standard (Toluene-d_8). The selected specific substances from the survey, benzene, cresol and N,N-dimethylformamide, were determined semi-quantitatively.

Testing for blank was included in all analysis operations.

The detection threshold limit values are 1-100 ng/tube dependent on the individual substances. The results of the degassing in the tedlar bags are reported in µg/m³ and represent the concentration in the bag.

3.4 Ozone

The tubes for direct measurement of the type ”Dräger, Ozone 0.05/b” were read according to the instructions from the supplier. The adsorption material in the tubes for direct measurement changes colour from light blue to white at the presence of ozone after the following reaction: O_3 + Indigo → Isatin.

The detection limit is 0.1 mg/m³.

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[7] National Institute of Standards and Technology

The results of the degassing in the tedlar bags are reported in µg/m³ and represent the concentration in the bag.

3.5 Analysis results

A large number of substances have been detected from the degassing of the energy-saving light bulbs. A number of the substances are seen in more of the samples but generally quite a variation between the identified substances for the different energy-saving light bulbs is found.

All the analysis results of the analyses at GC/MS as well as the results of the readings of Dräger tubes for the energy-saving light bulbs are given in Appendix 3:.

An analysis of 26 energy-saving light bulbs has been made but one light bulb stopped functioning 2.5 hours after the start of the analysis and therefore, only analysis results for 25 energy-saving light bulbs are presented here. In total 45 different substances were identified in the 25 analysed energy-saving light bulbs. All the energy-saving light bulbs degassed at least three different substances and one light bulb degassed 16 different substances in total. It has to be noted that neither cresol nor ozone was identified above their detection limits for any of the 25 analysed energy-saving light bulbs.

In Table 3, analysis results are stated for substances which

- are found in concentrations above its odour limit,
- are classified as carcinogenic, mutagenic, toxic to reproduction or harmful to a specific target organ,
- are found in high concentrations (i.e. above 50 ppm) or
- have been identified in 6 or more of the 25 analysed energy-saving light bulbs

The harmonised classification of the substances is found by use of ECHA C&L database (2014). A classification is assessed as relevant in this project if it may have an effect which is hazardous to health, as described in section 2.1.2.12. A possible self-classification is not included in the table. This means that in Table 3 the full classification is not noted but only whether the substance has one of the harmonised classifications which are considered to be most relevant in relation to the exposure and assessment of whether the substances can constitute a risk for the health (i.e. Carc., Muta., Repr., Resp. Sens. and STOT RE).

The DNEL value of a substance gives the concentration where a health effect is not expected (for that matter, see chapter 4.2), and the values are found in ECHA's database of registered substances (ECHA RSD, 2014). It has to be noted that the DNEL values in question are stated by the companies (the registrants) and that ECHA has not checked whether the calculated DNEL values are correct. The DNEL values are here used to assess whether the degassed concentrations are unproblematic (if the measured concentrations are lower than the DNEL values). This gives a possibility of a relatively quick indication of the risk of more substances without being obliged to make an actual health assessment of all the substances.

When possible, the odour limits of the substances are identified through accessible literature on the internet. For the individual substances, the number of light bulbs is stated in which the substance is measured as well as the highest measured concentration. Finally, the threshold limit value of the substances in the working environment is stated in Table 3, if available. It is seen from Table 3 that none of the relevant emitted substances is measured in concentrations above the threshold limit value in the working environment. The threshold limit value in the working environment is an average value for a working day of 8 hours where the measured degassed concentrations are the total concentration collected during 6 hours.

The corresponding information is stated in Appendix 4: for all the substances which emitted from the examined energy-saving light bulbs.

Substance name	CAS No.	Harmonised classification[1]	DNEL-value (inh.)[2] (µg/m^3)	Odour threshold value (µg/m^3)	Identified in no. of bulbs	Highest concentration measured (µg/m^3)	Occupational threshold limit value (µg/m^3)
2-Methyl-2-propanol	78-83-1	None relevant	-	3,300[4]	2	6,500	150,000
Hexamethylcyclotrisiloxane	541-05-9	None	64,000 (for "workers")	-	12	4,800	*Does not exist*
1-Butanol	71-36-3	None relevant	55,000	90[4]	21	2,300	150,000
2-Ethyl-1-hexanol	104-76-7	None	2,300	500[4]	6	2,100	*Does not exist*
Octamethylcyclotetrasiloxane (D4)	556-67-2	Repr. 2	13,000	-	13	2,100	*Does not exist*
Decamethylcyclopentasiloxane	541-02-6	None	17,300	-	7	1,800	*Does not exist*
Tetrahydrofuran	109-99-9	Carc. 2	62	7,375[5]	16	1,400	148,000
Acetic acid	64-19-7	None relevant	N/A	98.2-491[6]	18	1,100	25,000
N,N-Dimethylformamide	68-12-2	Repr. 1B	15,000	300,000[5]	10	670	30,000
1,2-Dichloropropane	78-87-5	None relevant	14,440	1,165[3]	6	660	350,000
Toluene	108-88-3	Repr. 2 STOT RE 2	56.5	600[7]	3	600	94,000
Phenol	108-95-2	Muta. 2 STOT RE 2	1,320	179[5]	1	510	4,000
Styrene	100-42-5	None relevant	-	160[4]	1	250	105,000
Butanal	123-72-8	None relevant	No DNEL value liste d in ECHA RSD	28[4]	6	230	*Does not exist*
Pentanal	110-62-3	None	-	22[4]	2	230	175,000
Hexamethyldisiloxane	107-46-0	None	13,300	-	1	210	*Does not exist*
Acetone	67-64-1	None relevant	200.000	31,000[3]	8	170	600,000
Methylvinylketone	78-94-4	None	Not registered in ECHA	-	6	160	*Does not exist*

Substance name	CAS No.	Harmonised classification[1]	DNEL-value (inh.)[2] (µg/m^3)	Odour threshold value (µg/m^3)	Identified in no. of bulbs	Highest concen-tration measured (µg/m^3)	Occupational threshold limit value (µg/m^3)
			RSD				
1-Chloro-2-propanol	127-00-4	None	Not registered in ECHA RSD	-	6	140	*Does not exist*
Benzene	71-43-2	Muta. 1B Carc. 1A STOT RE 1	No DNEL value liste d in ECHA RSD	4,500[5]	19	76	1,600
Propyleneglycol	57-55-6	None	50.000	-	8	73	*Does not exist*
2-Propenal	107-02-8	None relevant	200 (for "workers")	370[3]	2	39	120

TABLE 3
SELECTED SUBSTANCES FROM THE RESULTS OF THE CHEMICAL ANALYSIS OF THE LIGHT BULBS WHERE CLASSIFICATION IS RELEVANT OR WHERE THE CONCENTRATION IS ABOVE THE ODOUR THRESHOLD OF THE SUBSTANCE. THE HIGHEST MEASURED CONCENTRATION HAS BEEN CONVERTED FROM THE TEDLAR BAG (µG/1O L) TO µG/M^3.

1 ECHA C&L, 2014.
2 ECHA RSD, 2014.
3 DANISH EPA, 2008.
4 DANISH EPA, 2003.
5 RUTH, 1986.
6 DANISH EMERGENCY MANAGEMENT AGENCY, 2013A.
7 WOLKOFF ET AL., 2006.
8 DANISH EMERGENCY MANAGEMENT AGENCY, 2013B.
9 DANISH WORKING ENVIRONMENT AUTHORITY, 2007.
- VALUE HAS NOT BEEN POSSIBLE TO IDENTIFY OR HAS NOT BEEN ESTABLISHED.
N/A NO THRESHOLD EFFECT AND/OR NO DOSIS RESPONSE INFORMATION AVAILABLE.

3.6 Analysis of the results

From Table 3 it can be seen that 9 substances are measured in concentrations above their odour threshold value which most probably can explain the odour from the energy-savining light bulbs. These nine substances are:

- 1-butanol
- 2-ethyl-1-hexanol
- 2-methyl-1-propanol
- Butanal
- Acetic acid
- Phenol
- Styrene
- Toluene

Furthermore, light bulbs from the same producer have been analysed to assess whether a connection between degassing of substances from energy-saving light bulbs from the same producer exists.

3.6.1 Substances above the odour threshold value

1-butanol was degassed from 20 of the 25 analysed light bulbs of which the concentration from 9 light bulbs was on or above the odour threshold value (**Fejl! Henvisningskilde ikke fundet.**). Thus, 1-butanol may cause that consumers experience that some of the energy-saving light bulbs smell.

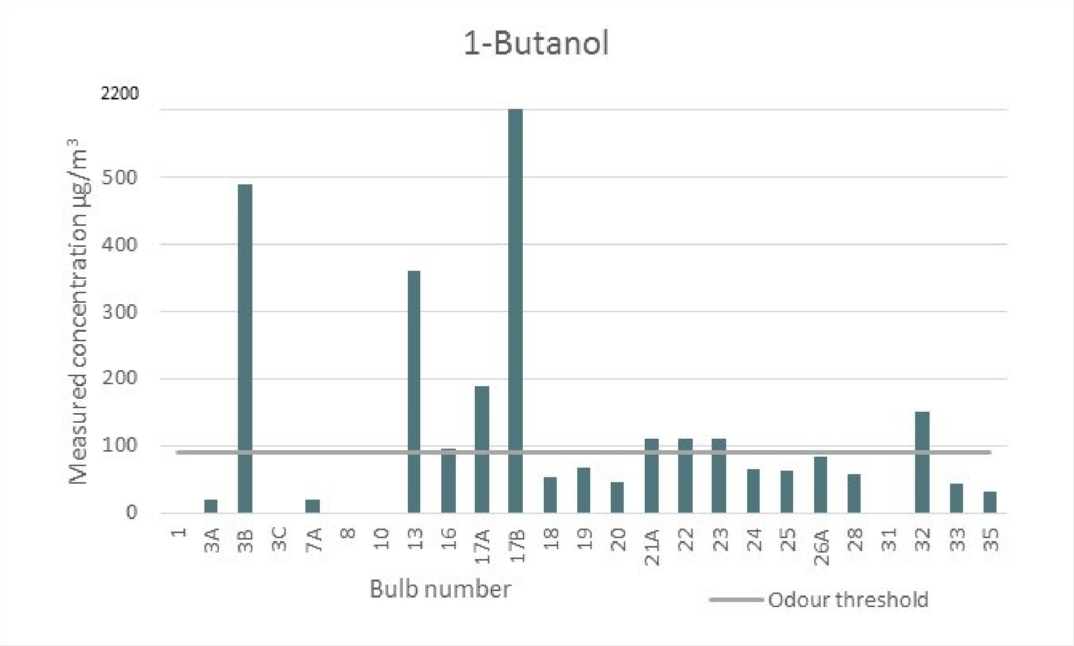


FIGURE 1
EMISSION OF 1-BUTANOL FROM ENERGY-SAVING LIGHT BULBS DURING 6 LIGHTING HOURS
NOTE THAT LIGHT BULB 17B DEGASSED CONSIDERABLY LARGER AMOUNTS THAN THE OTHER LIGHT BULBS

2-Ethyl-1-hexanol was degassed from 6 different light bulbs and from all the light bulbs the concentration was somewhat above the odour threshold value (Figure 2). Therefore, 2-ethyl-1-hexanol may also cause that consumers experience that their energy-saving light bulb smells.

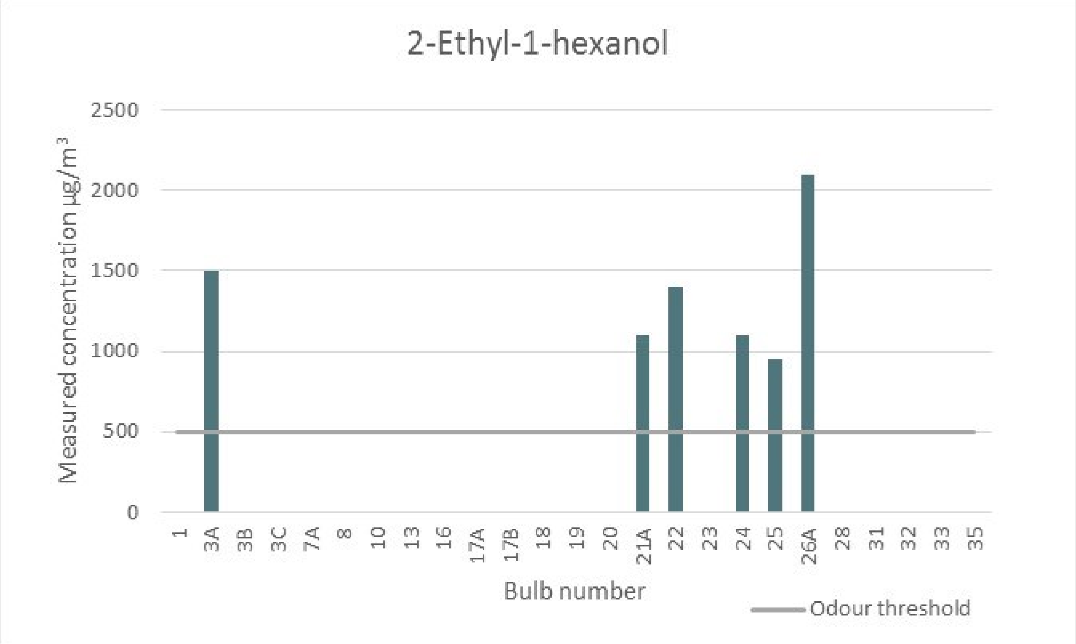


FIGURE 2
EMISSION OF 2-ETHYL-1-HEXANOL FROM ENERGY-SAVING LIGHT BULBS DURING 6 LIGHTING HOURS

2-Methyl-1-propanol degassed from two light bulbs. From one of the light bulbs it was far above the odour threshold value and for the other light bulb the concentration was far below (Figure 3). Therefore, 2-Methyl-1-propanol may be the reason that one consumer experienced an odour from his light bulb.

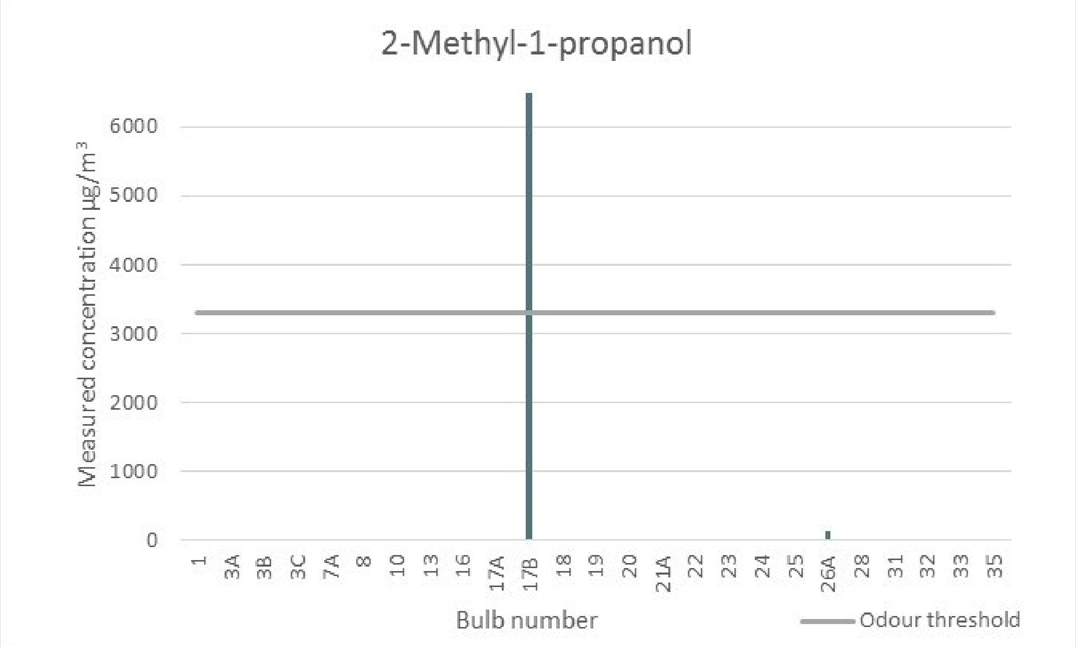


FIGURE 3
EMISSION OF 2-METHYL-1-PROPANOL FROM ENERGY-SAVING LIGHT BULBS DURING 6 LIGHTING HOURS

Butanal degassed from six different light bulbs and as it can be seen from Figure 4 all the concentrations were above the odour threshold value. Thus, the reason why consumers have experienced that their energy-saving light bulbs smell may also be due to degassing of butanal.

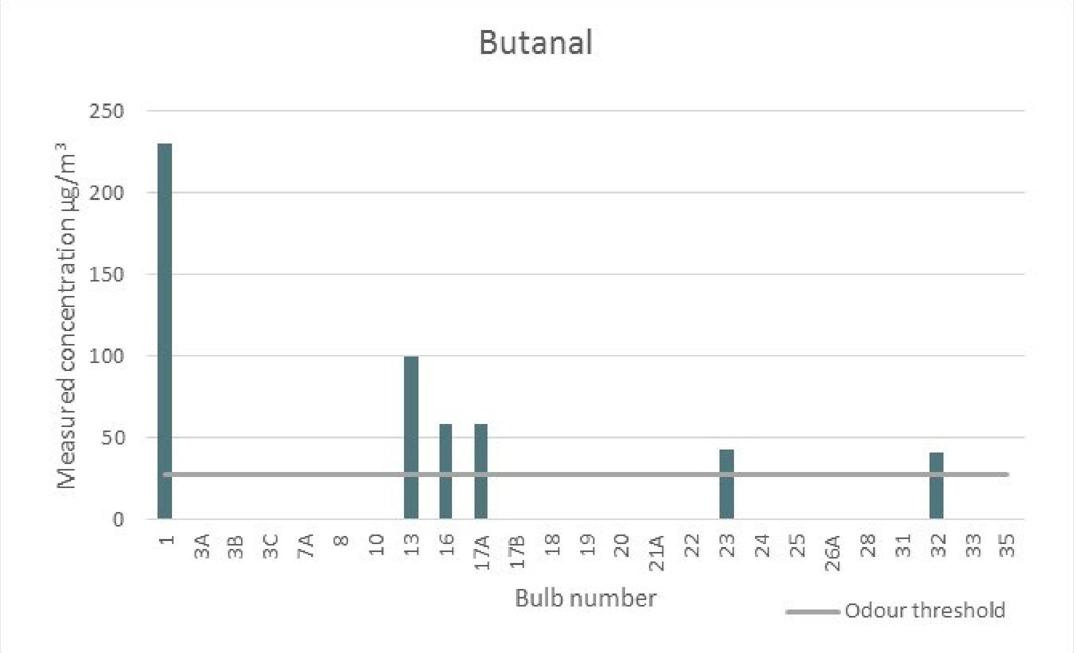


FIGURE 4
EMISSION OF BUTANAL FROM ENERGY-SAVING LIGHT BULBS DURING 6 LIGHTING HOURS

Degassing of acetic acid was measured in the analyses from 18 light bulbs. As it can be seen from Figure 5, the concentration of acetic acid from all 18 light bulbs was on or above the odour threshold value. Therefore, it is possible that acetic acid also was the reason why consumers experienced that the light bulb smelled.

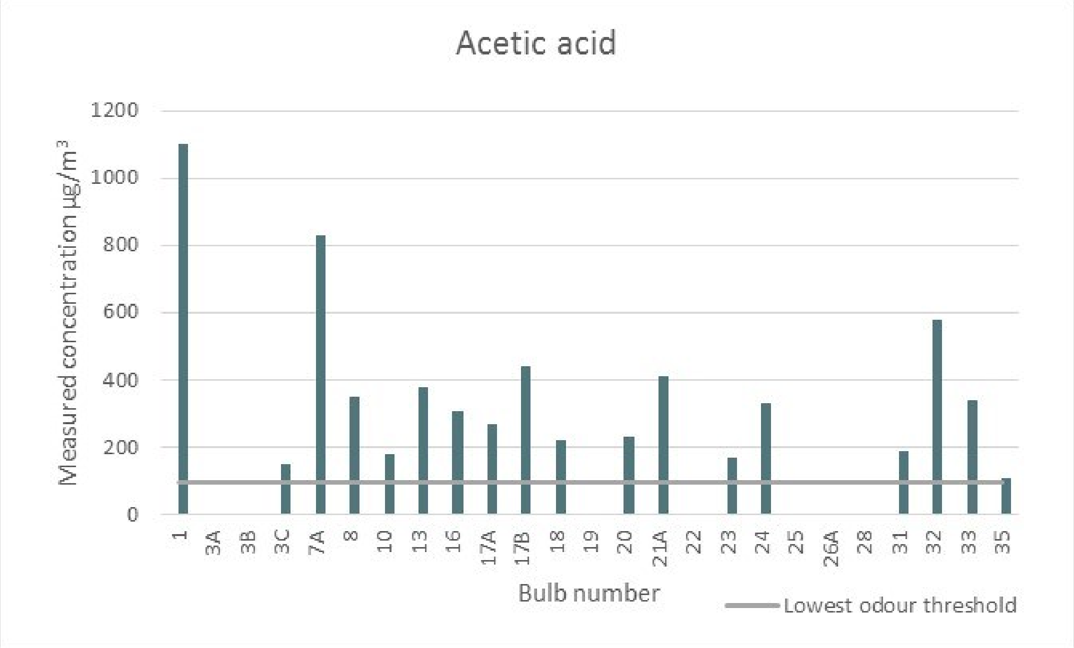
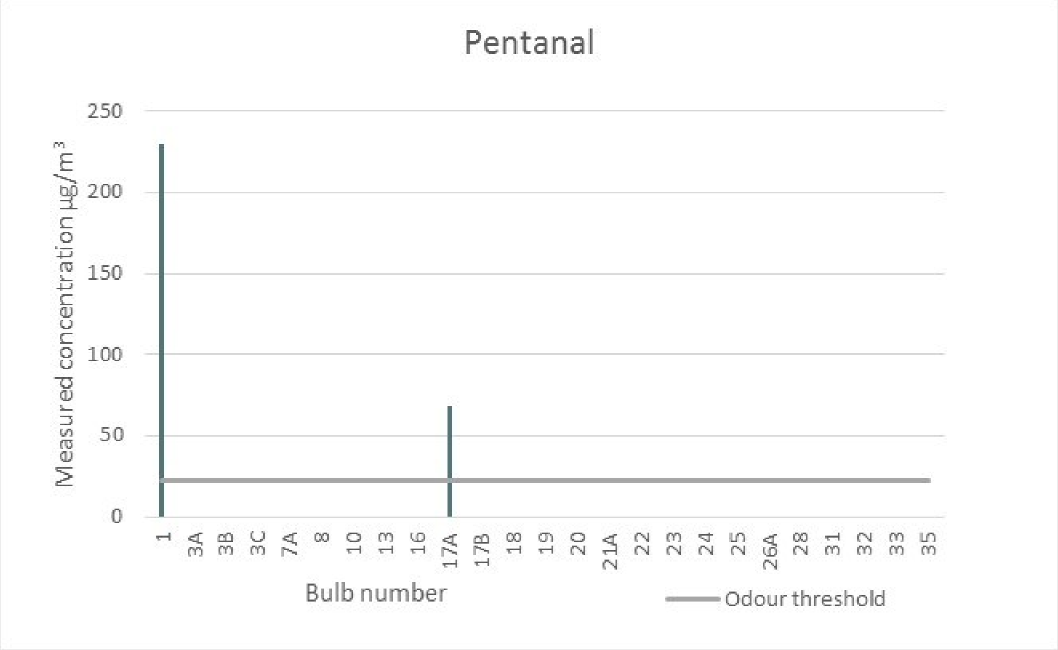


FIGURE 5
EMISSION OF ACETIC ACID FROM ENERGY-SAVING LIGHT BULBS DURING 6 LIGHTING HOURS

Pentanal was emitted from two out of 25 light bulbs and for both light bulbs the concentration exceeded the odour threshold value (Figur 6). Therefore, pentanal may also be the reason why the two light bulbs could be smelled by the consumers.



FIGUR 6
EMISSION OF PENTANAL FROM ENERGY-SAVING LIGHT BULBS DURING 6 LIGHTING HOURS

Toluene degassed from three light bulbs where the concentration from one light bulb is only just on the odour threshold value of toluene (Figure 7). Thus, toluene may be the reason why one consumer experienced odour from his energy-saving light bulb.

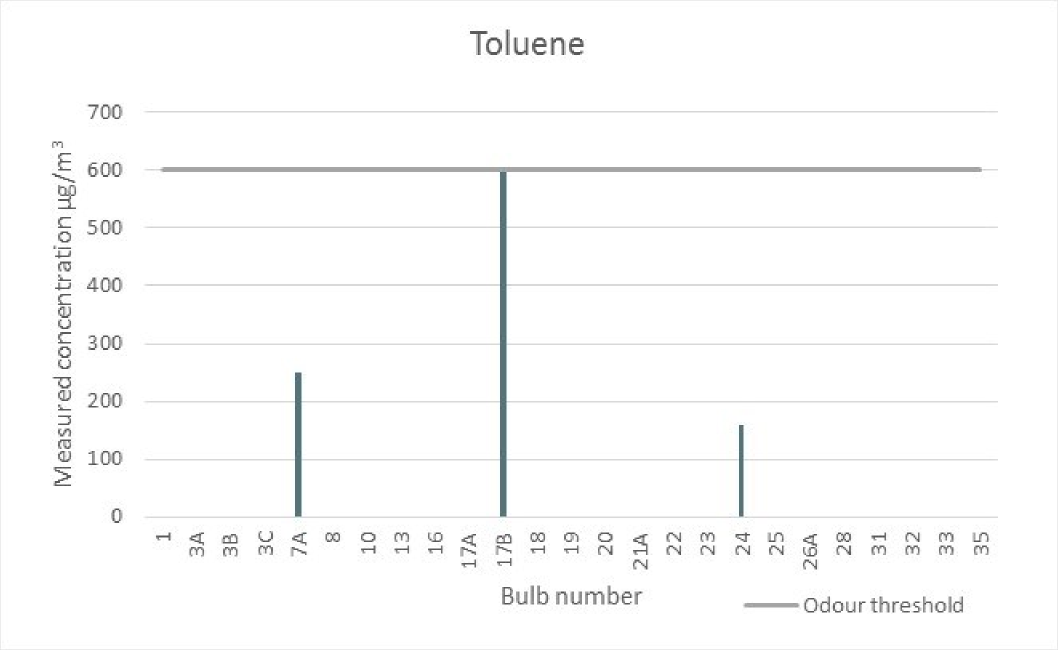


FIGURE 7
EMISSION OF TOLUENE FROM ENERGY-SAVING LIGHT BULBS DURING 6 LIGHTING HOURS

Styrene and phenol were separately measured to degas from two different light bulbs and for both substances the concentration was above the odour threshold value (Figure 8 and Figure 9). The concentration of styrene after 6 lighting hours was 250 µg/m³ for one of the light bulbs while the odour threshold value is 160 µg/m³. The concentration of phenol after 6 lighting hours was 510 µg/m³ for one of the light bulbs while the odour threshold value is 179 µg/m³. Therefore, styrene and phenol may be the reason why two different light bulbs were regarded as smelling.

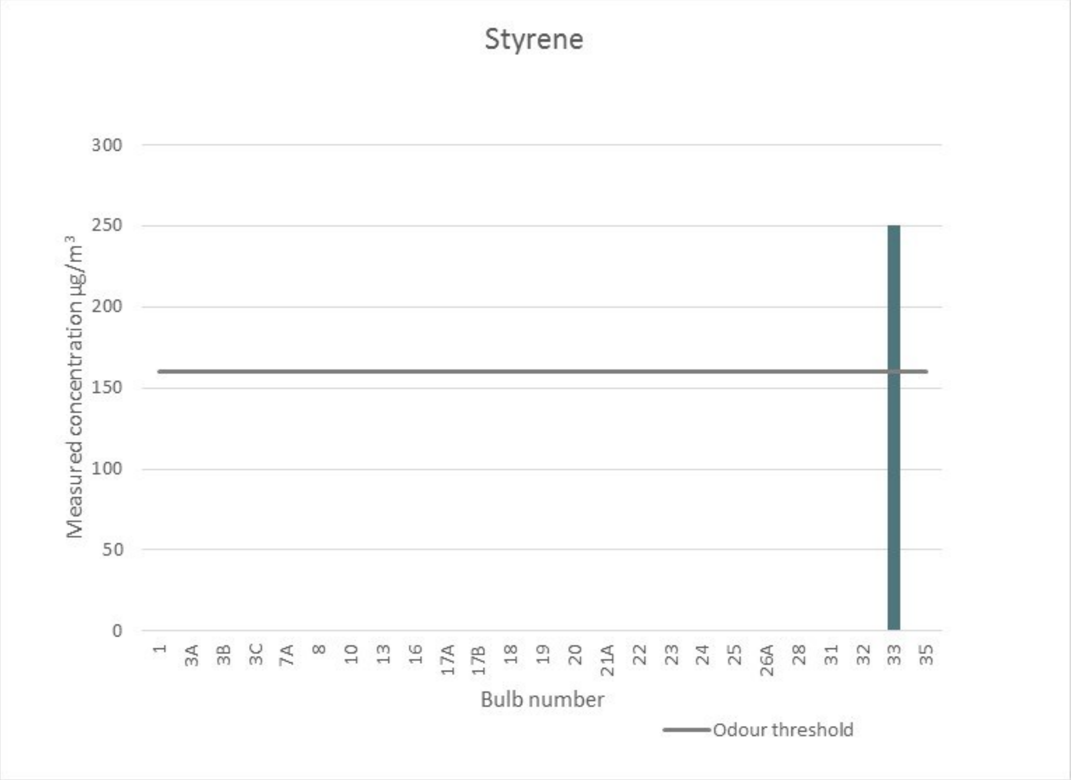


FIGURE 8
EMISSION OF STYRENE FROM ENERGY-SAVING LIGHT BULBS DURING 6 LIGHTING HOURS

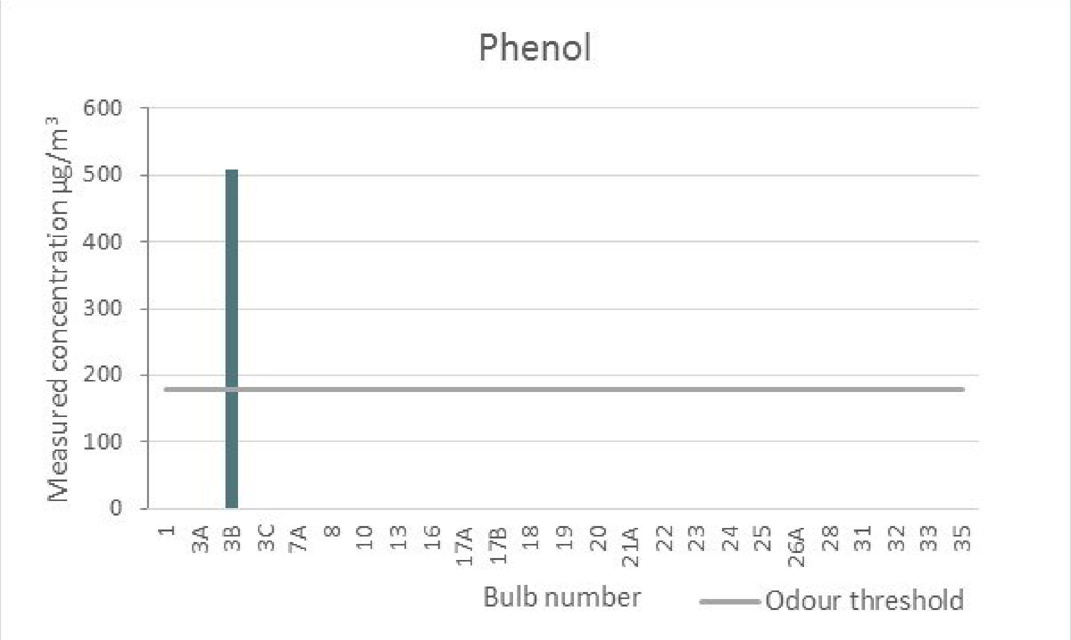


FIGURE 9
EMISSION OF PHENOL FROM ENERGY-SAVING LIGHT BULBS DURING 6 LIGHTING HOURS

3.6.1.1 Conclusion of substances identified above their odour threshold value

When looking at all the 25 energy-saving light bulbs for degassing of smelling substances, it is seen from the graphs that for 24 of the 25 energy-saving light bulbs minimum one and up to four of the nine substances with concentrations above the odour threshold value are identified. Therefore, there is thus, as a minimum, one substance which degasses from 24 of the energy-saving light bulbs in a concentration above the odour threshold value of the substance. This can explain the reason why a consumer experiences that the energy-saving light bulb smells.

For one light bulb (number 28), no degassing of a substance in a concentration above the odour threshold value is identified. This does not necessarily mean that the light bulb does not release smelling gases. The analysis is made by semiquantifying the ten degassed substances with the highest contraction. It is possible that light bulb number 28 as well as the other light bulbs have degassed a substance in a small concentration which has not been quantified but has a low odour threshold value.

3.6.2 Emission profile for two identical energy-saving light bulbs

Of the in total 25 analysed light bulbs, two light bulbs were identical. Figure 10 shows the degassing of substances from the two light bulbs. No connection can be seen between the degassing of substances and the two light bulbs as 10 out of 15 degassed substances, including the substances found in the highest concentration, are not seen for both light bulbs. The five substances which are degassed from both light bulbs are acetic acid, 1-butanol, propylenglycol, benzene and N,N-dimethylformamide. The degassing of acetic acid, propylengylcol and N,N-dimethylformamide is of approximately the same size but the concentration of 1-butanol and benzene from the two light bulbs is very different.

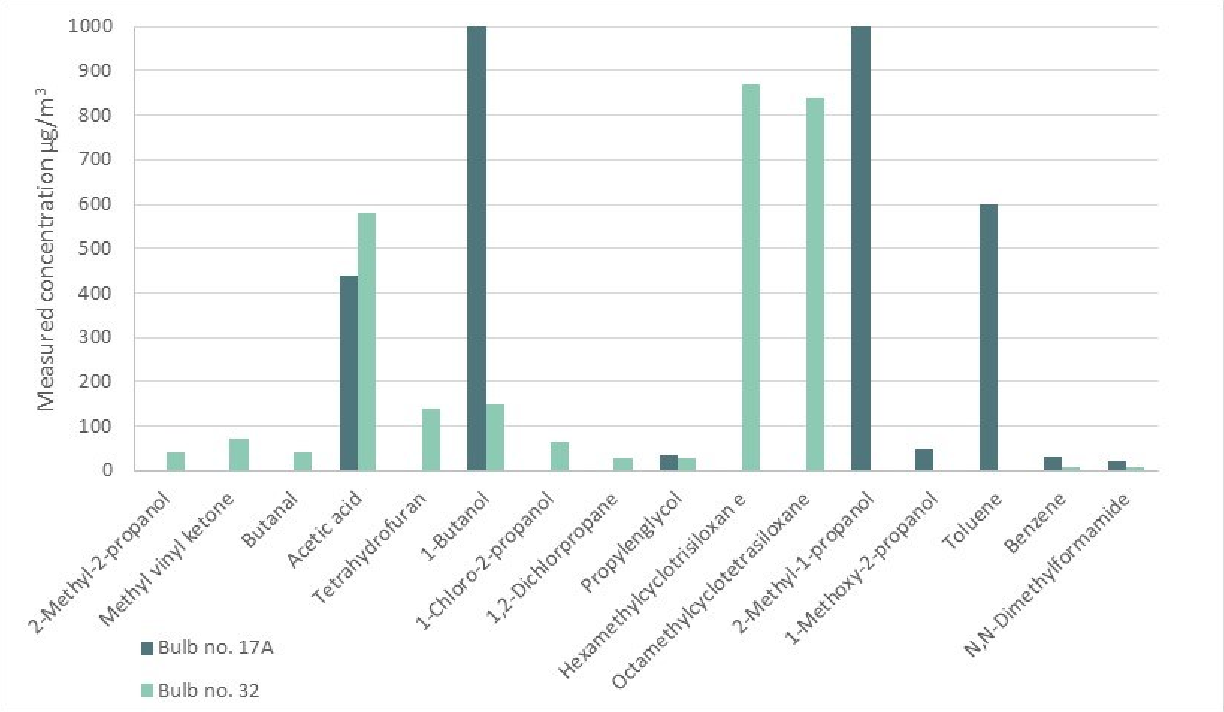


FIGURE 10
DEGASSING OF SUBSTANCES FROM TWO COMPLETELY IDENTICAL ENERGY-SAVING LIGHT BULBS

3.6.3 Emission profile for energy saving light bulbs from the same producer

A part of the analysed light bulbs came from the same producers and in the following graphs the degassed substances from light bulbs from the same producer are presented. Among the analysed energy saving light bulbs, three different producers were represented with two or more light bulbs and these producers are shown below as producer 1, 2 and 3. Other producers were only represented with in total one light bulb and therefore this data is not pointed out here.

For producer number 1, eight energy-saving light bulbs were analysed and the result showed that 23 different substances in total were degassed from the eight light bulbs. The results are shown in Figure 11 (substances degassed in low concentrations) and Figure 12 (substances degassed in high concentrations). Of the 23 substances, 14 substances were only emitted from one of the eight light bulbs while seven substances were degassed from three or more light bulbs. 1-butanol, benzene, acetic acid and tetrahydrofuran were degassed from six of the eight light bulbs from the same producer but for the four substances, there was no clear connection between concentration and light bulb. Consequently, for producer number 1, a connection between degassed substances in the eight light bulbs cannot be identified.

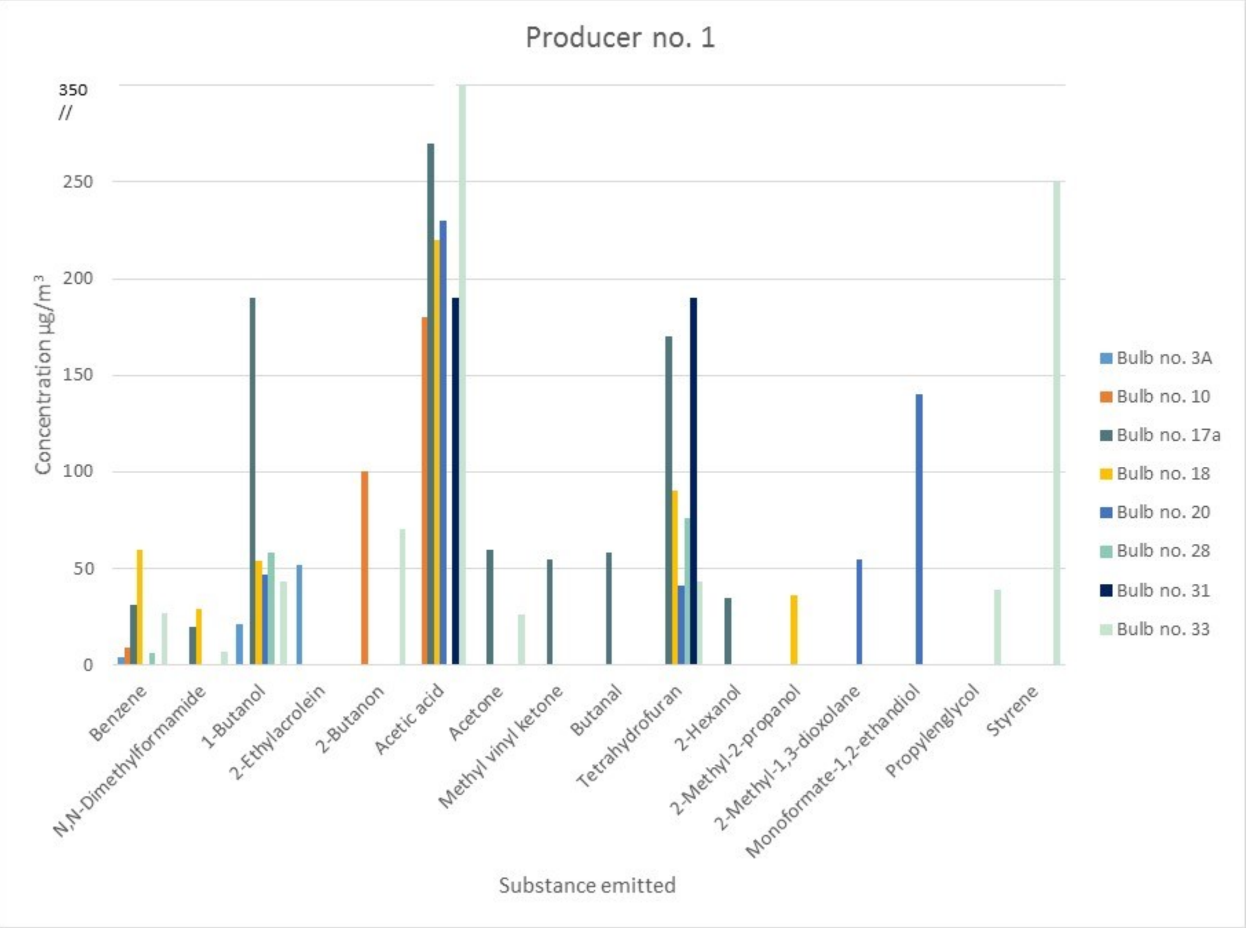


FIGURE 11
DEGASSED SUBSTANCES IN LOW CONCENTRATIONS FROM EIGHT LIGHT BULBS FROM PRODUCER NO. 1

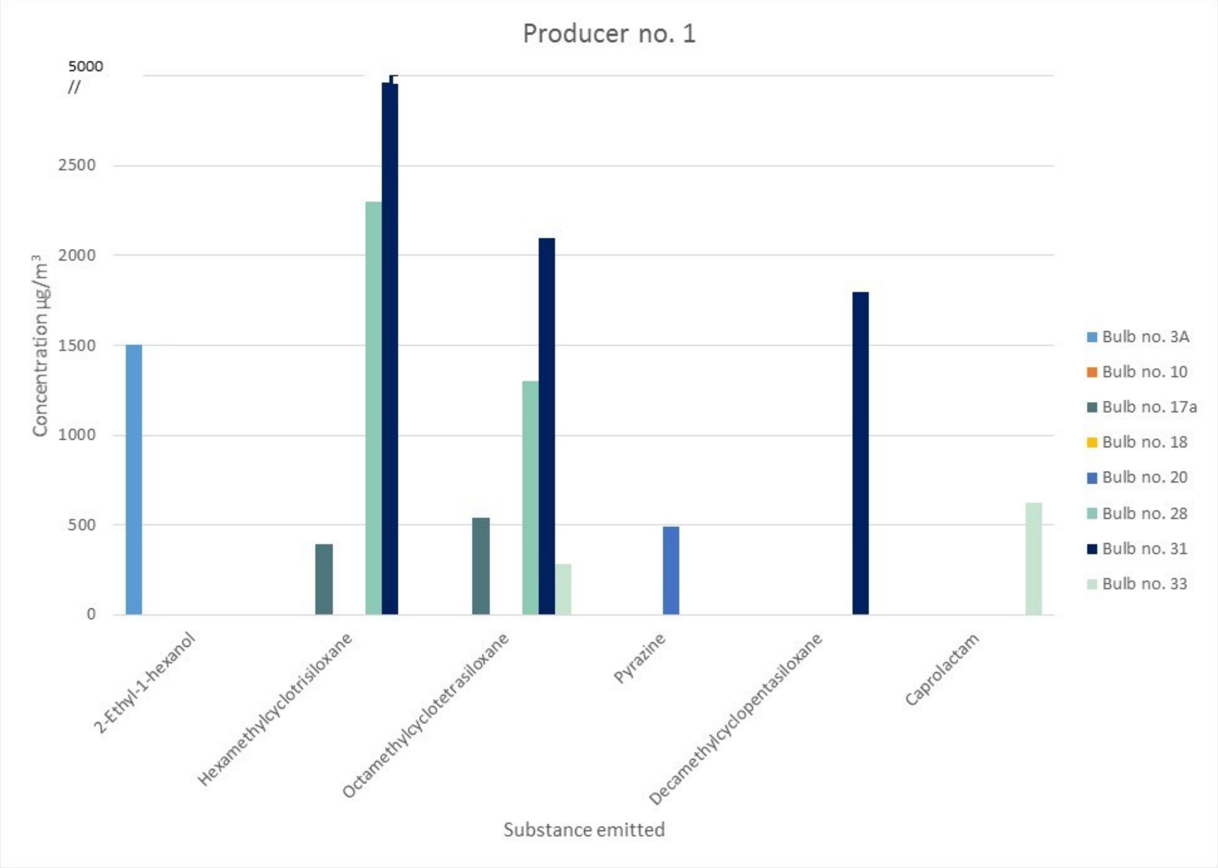


FIGURE 12
DEGASSED SUBSTANCES IN HIGH CONCENTRATIONS FROM EIGHT LIGHT BULBS FROM PRODUCER NO. 1
PLEASE NOTE THAT LIGHT BULB 31 DEGASSED A CONSIDERABLY LARGER AMOUNT OF HEXAMETHYLCYCLOTRISOLOXANE THAN THE OTHER LIGHT BULBS

Three of the analysed energy-saving light bulbs were from the same producer (number 2) and in total they degassed 15 different substances from the light bulbs (Figure 13). Among the 15 substances, 10 were degassed from only one light bulb while two substances (tetrahydrofuran and 1-butanol) degassed from all three light bulbs. Tetrahydrofuran degassed at approximately the same level for all three light bulbs (170-200 µg/m^3). The substance 1-butanol degassed from the three light bulbs in concentration between 62-110 µg/m^3. However, generally there seems to be no connection between degassing of substances and the light bulbs from producer number 2.

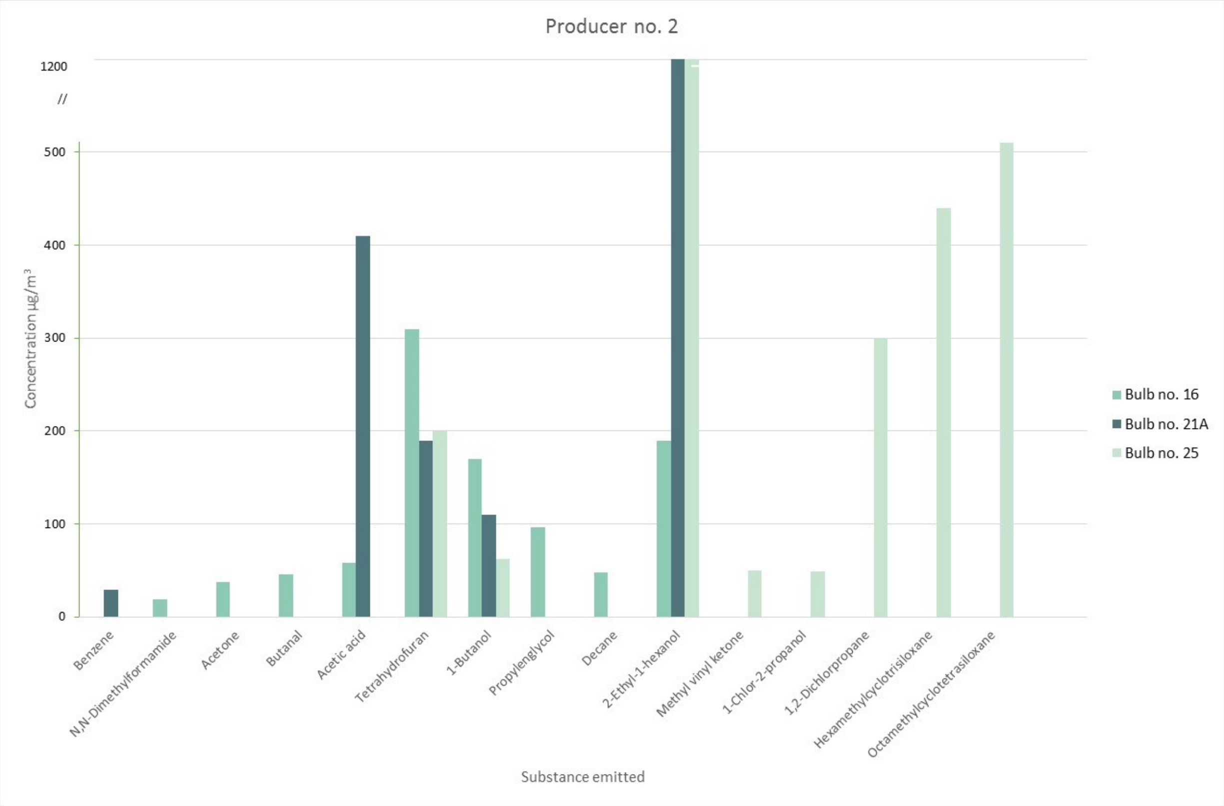


FIGURE 13
DEGASSED SUBSTANCES FROM THREE LIGHT BULBS FROM PRODUCER NO. 2

Three light bulbs are represented by producer number 3 (Figure 14) where two of the light bulbs are completely identical (see Figure 10). 17 different substances were degassed from the three light bulbs from producer number 3, and four of the 17 substances were only degassed from one light bulb while seven substances were degassed from all three light bulbs but in concentrations without a connection between the light bulbs. Benzene, N,N-dimethylformamide, methylvinylketone, butanal, acetic acid, tetrahydrofuran and 1-butanol were among the seven substances. Benzene and butanal were in the most comparable concentrations. Benzene was measured to be degassed in concentrations between 10 and 50 µg/m^3 and butanal between 41 and 100 µg/m^3. Generally, there seems to be no connection between degassed substances and light bulbs from producer number 3.

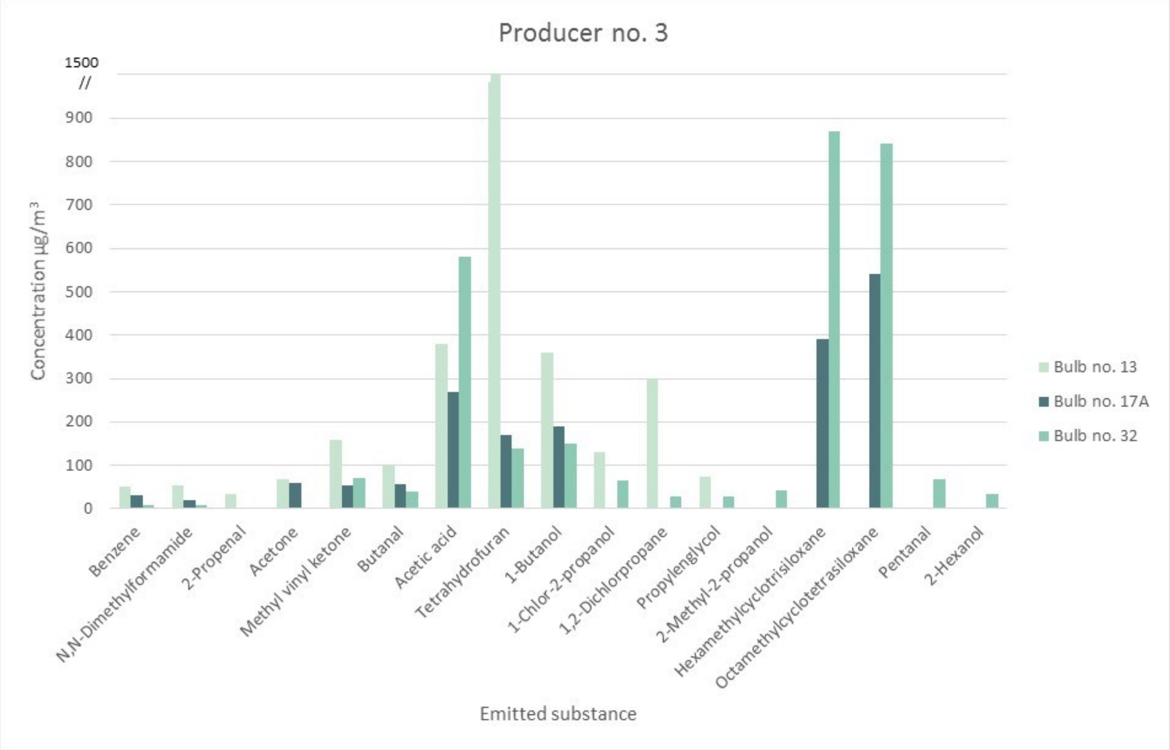


FIGURE 14
DEGASSED SUBSTANCES FROM THREE LIGHT BULBS FROM PRODUCER NO. 3

3.6.3.1 Conclusion of substances degassed from energy-saving light bulbs from the same producer

As Figure 11 to Figure 14 illustrate, no overall connection between the degassed substances from energy-saving light bulbs from the same producer has been identified.

4. Health and risk assessment

In this section, first the substances which are selected for the health and risk assessment are described (see section 4.1). The method of calculation of the risk for exposure for the selected degassed substances is described in section 4.2. Exposure calculations are described in section 4.3 and the health assessment of the five selected degassed substances is described in section 4.4. The risk assessment is described in section **Fejl! Henvisningskilde ikke fundet.**.

4.1 Selection of substances

Selection of the analysed substances for risk assessment is made on the basis of the hazardous properties of the substance, the measured concentrations, and partly whether the substance is degassed in concentrations above the odour threshold value. The following five substances are selected for a risk assessment:

1. **Benzene**. The substance is emitted from 19 different light bulbs and has a harmonised classification as carcinogenic. The highest emitted concentration was measured to 76 µg/m^3. The odour threshold value of benzene is 4,500 µg/m^3.
2. **N,N-Dimethylformamide**. The substance emitted from 10 different light bulbs and has a harmonised classification as toxic to reproduction. The highest emitted concentration was measured to 670 µg/m^3. The odour threshold value of N,N-dimethylformamide is 300 µg/m^3.
3. **Octamethylcyclotetrasiloxane**. The substance emitted from 13 different light bulbs and has a harmonised classification as toxic to reproduction. The highest emitted concentration was measured to 2,100 µg/m^3. The odour threshold value of octamethylcyclotetrasiloxane is not identified.
4. **Tetrahydrofuran**. The substance emitted from 16 different light bulbs and has a harmonised classification as carcinogenic. The highest emitted concentration was measured to 1,400 µg/m^3. The odour threshold value of tetrahydrofurane is 7,375 µg/m^3.
5. **Phenol**. The substance has a harmonised classification as mutagenic and is harmful at repeated exposure. In this project, phenol was identified in one of the analysed light bulbs. The highest emitted concentration was measured to 510 µg/m^3. The odour threshold value of phenol is 179 µg/m^3.

It has to be noted that a connection between odour and health effects does not always exist. The threshold of when a substance smells and when a substance is hazardous is two different matters which vary from substance to substance.

The concentration of the selected five substances in the 25 analysed light bulbs is shown in the following graphs. It is seen from the graphs that apart from phenol the substances are identified in several of the analysed energy-saving light bulbs in varying concentrations.

Benzene which is classified as carcinogenic was degassed from 19 of the analysed energy-saving light bulbs in concentrations between 3.8 to 76 µg/m^3 (Figure 15).

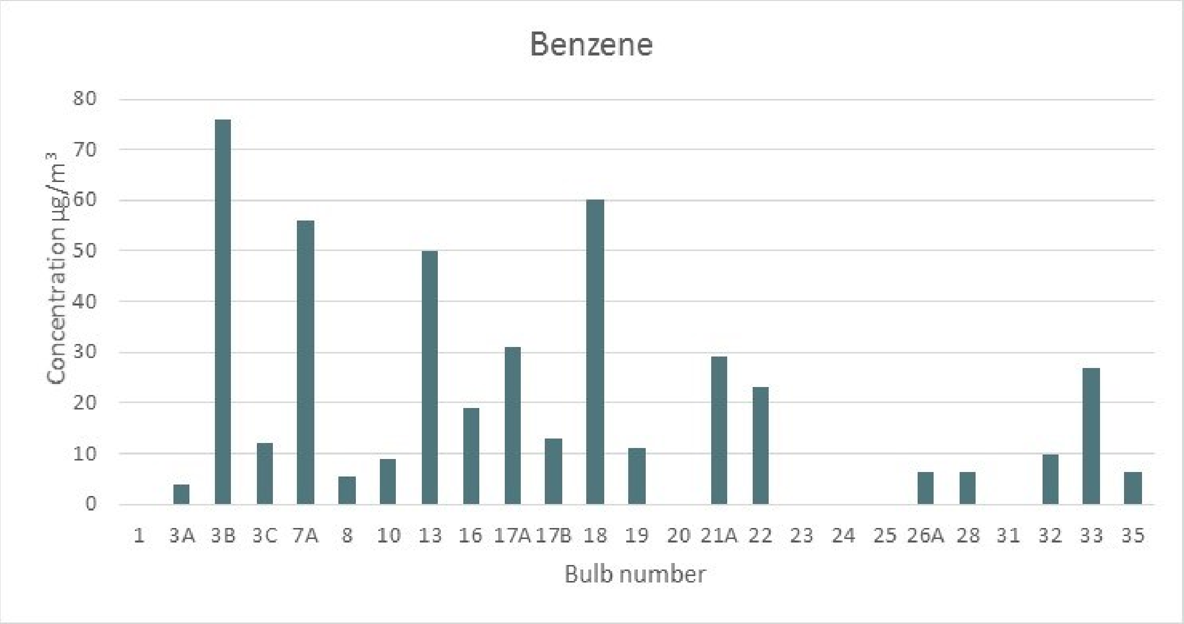


FIGURE 15
DEGASSING OF BENZENE FROM 25 ANALYSED ENERGY-SAVING LIGHT BULBS. THE ODOUR THRESHOLD VALUE OF BENZENE OF 4,500 µG/M3 IS NOT SHOWN IN THE GRAPH AS THE VALUE IS FAR ABOVE THE IDENTIFIED CONCENTRATIONS.

N,N-dimethylformamide which is considered to be toxic to reproduction was degassed from 10 of the analysed energy-saving light bulbs in concentrations between 5.8 to 670 µg/m³ (Figure 16).

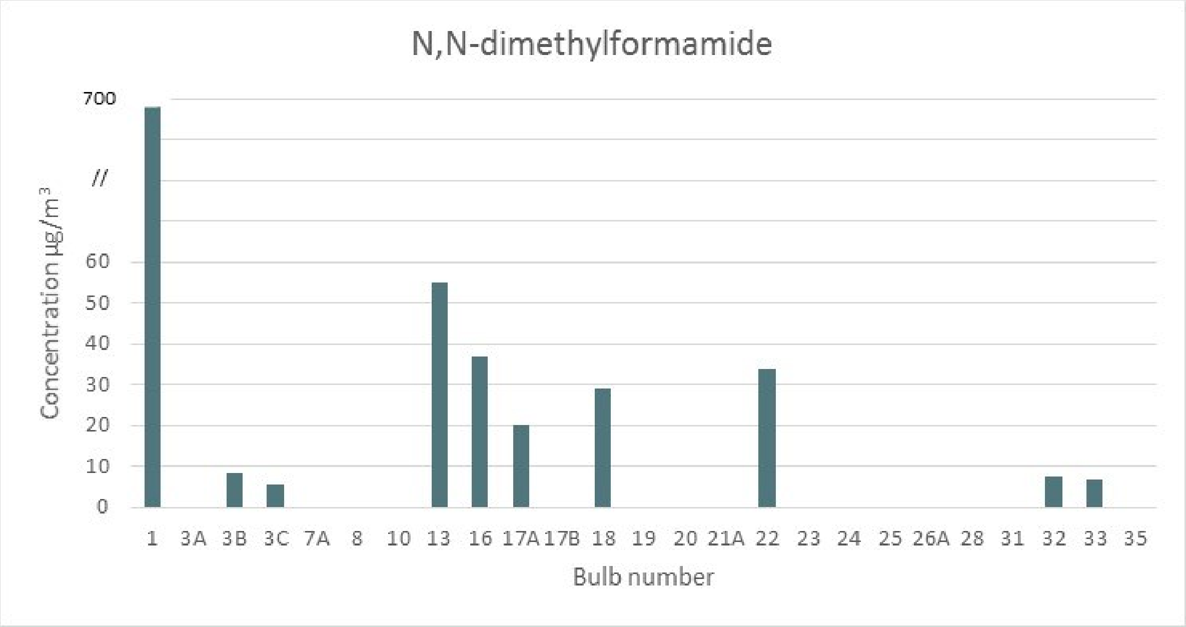


FIGURE 16
DEGASSING OF N,N-DIMETHYLFORMAMIDE FROM 25 ANALYSED ENERGY-SAVING LIGHT BULBS. THE ODOUR THRESHOLD VALUE OF N,N-DIMETHYLFORMAMIDE OF 300 MG/M3 IS NOT SHOWN IN THE GRAPH AS THE VALUE IS FAR ABOVE MOST OF THE IDENTIFIED CONCENTRATIONS.
NOTE THAT LIGHT BULB 1 DEGASSED CONSIDERABLY LARGER AMOUNTS THAN THE OTHER LIGHT BULBS AND THAT THIS LIGHT BULB AS THE ONLY ONE DEGASSED CONCENTRATIONS ABOVE THE ODOUR THRESHOLD VALUE.

Octamethylcyclotetrasiloxane which is considered to be toxic to reproduction was degassed from 13 of the analysed energy-saving light bulbs in concentrations between 250 to 2,100 µg/m³ (Figure 17).

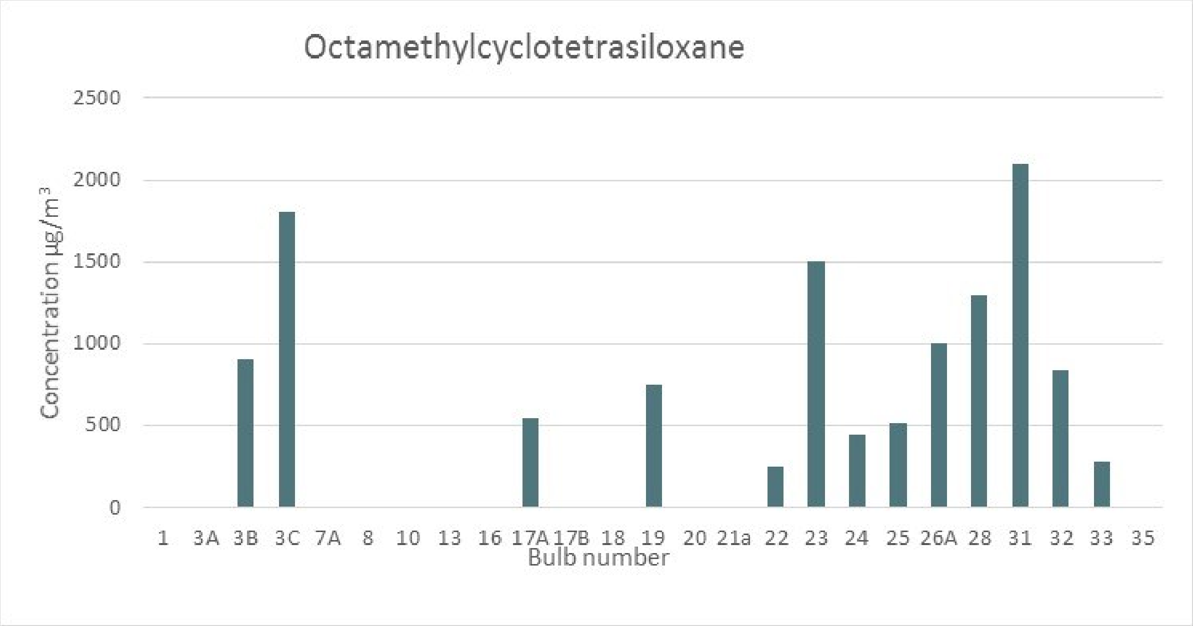


FIGURE 17
DEGASSING OF OCTAMETHYLCYCLOTETRASILOXANE FROM 25 ANALYSED LIGHT BULBS. THE ODOUR THRESHOLD VALUE OF OCTAMETHYLCYCLOTETRASILOXANE IS NOT SHOWN IN THE GRAPH AS THE ODOUR THRESHOLD VALUE IS UNKNOWN.

Tetrahydrofuran which is classified as carcinogenic was degassed from 19 of the analysed energy-saving light bulbs in concentrations between 41 to 1,400 µg/m³ (Figure 18).

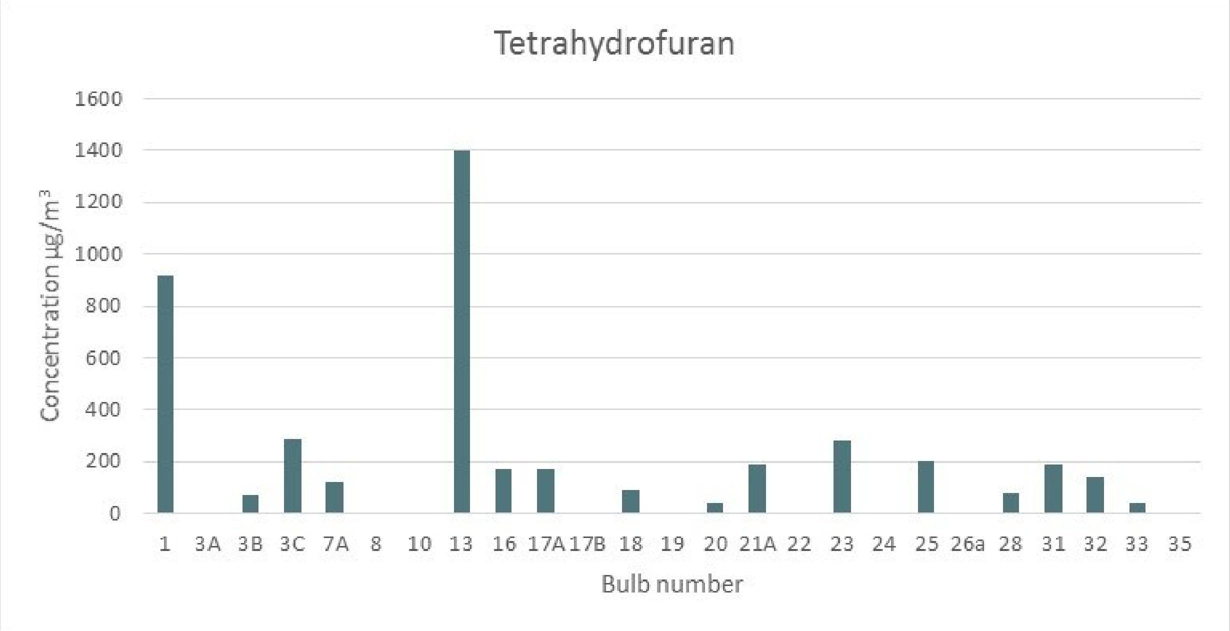


FIGURE 18
DEGASSING OF TETRAHYDROFURAN FROM 25 ANALYSED LIGHT BULBS. THE ODOUR THRESHOLD VALUE OF TETRAHYDROFURAN OF 7,375 µG/M3 IS NOT SHOWN IN THE GRAPH AS THE VALUE IS ABOVE THE IDENTIFIED CONCENTRATIONS.

Phenol which is classified as being mutagenic was degassed from one analysed energy-saving light bulb in a concentration of 510 µg/m^3 (Figure 19) which is above the odour threshold value of 179 µg/m^3.

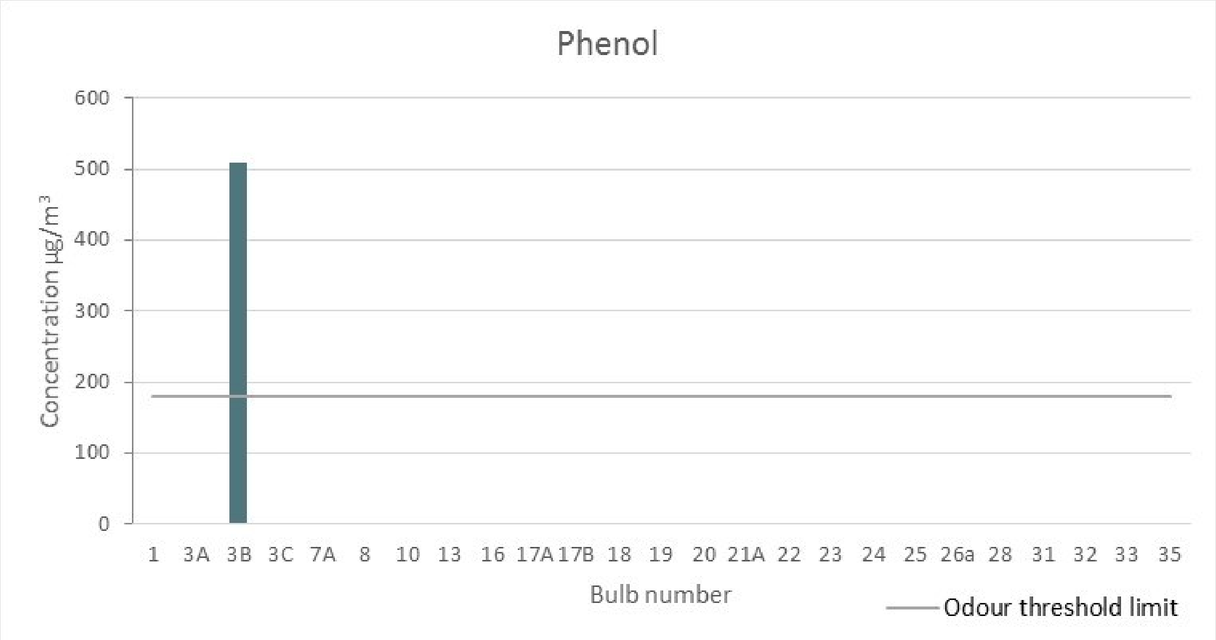


FIGURE 19
DEGASSING OF PHENOL FROM 25 ANALYSED LIGHT BULBS AS WELL AS THE ODOUR THRESHOLD VALUE OF PHENOL.

4.2 Metod of calculation of risk

Consumers who have used the analysed energy-saving light bulbs may have been exposed to the same substance via different routes of exposure (dermally, orally and when inhaled). According to the REACH guidelines (ECHA, 2012a), the exposure from the different routes of exposure is added to find the total exposure. In this project, the exposure is solely calculated via inhalation as it is assumed that the dermal exposure, i.e. in the form of evaporated substances which penetrate the skin, will be insignificant in relation to the exposure via inhalation. Likewise, the oral exposure is assumed to be irrelevant in this situation.

According to the REACH guidelines on risk assessment (ECHA, 2012b), it is assessed in each case whether the exposure situation constitutes a health risk based on the following formula. The risk is calculated by use of Risk Characterisation Ratio (RCR) and by used of Derived No Effect Level (DNEL):

$$RCR = \frac{Exposure\ (D_{total})}{DNEL}$$

If RCR > 1 (i.e. the exposure is larger than the DNEL value), there is a risk. If RCR < 1, the exposure is not considered to constitute any risk.

DNEL is calculated as described in ECHA's REACH Guidance Chapter R.8 (ECHA, 2012c) based on the NO(A)EL value (No Observed (Adverse) Effect Level) for the substance. DNEL is the NOAEL value corrected for differences between the experimental and the expected human exposure conditions. DNEL is calculated as the NOAEL value divided by different relevant safety factors (named assessment factors).

$$DNEL = \frac{NOAEL}{AF_1 \times AF_2 \times AF_3 \times AF_4 \times AF_5}$$

Five types of assessment factors (abbreviated as AF) can be used as stated in Table 4 below. The calculated DNEL values are shown in section 4.4. The assessment factors are determined according to the principles in the REACH guidelines (ECHA, 2012c) as stated in Table 4.

Parameter	Description	Used AF value
Interspecies differences	Allometric scaling Correction for differences in metabolic rate per kg of body weight	4 for rats
Interspecies differences	Remaining differences between species	2.5
Intraspecies differences	Differences between individuals	10
Duration of exposure	Sub-chronic to chronic If a sub-chronic study has been used instead of a chronic study (which typically gives the lowest NOAEL)	2
Dose response	LOAEL to NOAEL LOAEL is used because NOAEL is not determined	3

TABLE 4
ASSESSMENT FACTORS (AF) FOR CALCULATION OF DNEL

4.3 Exposure calculations

In sector 4.3.1, it is described how the exposure is calculated. After this, the exposures of the selected substances are stated in section 4.3.2.

4.3.1 Exposure scenario

Calculation of the exposure scenarios is based on the formula arranged by ECHA (2012) in the *"Guidance on information requirements and chemical safety assessment. Chapter R.15: Consumer exposure estimation"*. In this calculation, the analysed values of air concentration of the substances as well as absorption fraction, respiratory rate and body weight are used.

A person's inhalation dose of a substance can thus be calculated on the basis of the following formula as stated in formula R.15-2 in ECHA (2012a).

$$D_{inh} = \frac{\text{Fresp} \times \text{Csubstance} \times \text{IHair} \times T_{contact} \times n}{\text{bw}}$$

Where D_{inh} is the inhalation dose of a substance, per kilogram bodyweight, F_{resp} is the possible absorption fraction of the inhaled substance, $C_{substance}$ is the air concentration of the substance, IH_{air} is the ventilation rate of a person (amount of air which is inhaled per day), $T_{contact}$ is the duration of the exposure, n is the number of incidents per day, and bw is the bodyweight.

The exposure scenario (worst case) which is calculated in this project is that a person sits close at the energy-saving light bulb, i.e. in the immediate near zone of 1 m^3 around the light bulb for six hours. According to ECHA's Guidance document (ECHA, 2012a), the ventilation rate (IH_{air}) for an adult is 26 m^3/day at light activity and for a child 5.8 m^3/day at light activity. This means that during the six hours, both adults and children will inhale more than 1 m^3 (hhv. 6.5 and 1.4 m^3). As worst case it is therefore assumed that the person will inhale the total amount of substance which by analysis is measured to be degassed from the light bulb during the six hours. The above equation can thus be simplified when full intake is assumed and the total amount of the substance from the analyses ($M_{substance}$) is used as the total degassed concentration during the six hours. The formula is as follows:

$$D_{inh} = \frac{\mathrm{Msubstance} \times n}{bw}$$

The analysis results in Table 3, Appendix 3: and Appendix 4: from the analysis institute are stated in the unit µg/m^3. However, the experiments with the light bulbs are, as described in section 3.2, made in 10 litres (i.e. 0.01 m^3) tedlar bags. To be able to use the actual amount of degassed substance in the exposure calculations, the measured concentration has to be multiplied by 0.01 m^3. When for instance a concentration of 76 µg/m^3 is stated for benzene, it means that the actual amount of benzene degassed in the 10 litres tedlar bag is 0.76 µg which is the value that is used in the calculations below.

The inhaled dose is calculated for both an adult person in an average population of 60 kg and for a child of 10 kg (bw) (ECHA 2012a).

4.3.2 Exposure to the degassed substances

In this section, calculations of the exposure from the energy-saving light bulbs are made:

1. Benzene
2. N,N-Dimethylformamide
3. Octamethylcyclotetrasiloxane
4. Tetrahydrofuran
5. Phenol

The calculation of the exposure for the emitted substances is calculated as shown in the example below:

$$D_{inh,\ \mathrm{light\ bulb\ 3B\ (benzene),\ adult}} = \frac{0{,}76\ \mu g\ \times 1\ \mathrm{incident\ per\ day}}{60\ kg} = 0.013\ \mu g/kg\ bw/day$$

The values used for the exposure calculations and the results are stated in Table 5 below. It has to be noted that the exposure is only calculated for the light bulb with the highest emitted concentration of the substance in order to calculate a *worst-case* scenario. In case the risk assessment based on the *worst-case* scenario shows that there is or may be a risk, a risk assessment based on less extreme or more realistic scaenarios is carried out.

Name of substance	Person	Highest degassed amount (µg)	Bw (kg)	n (day^{-1})	D_{inh} (µg/kg bw/day)
Benzene (light bulb 3B)	Adult	0.76	60	1	0.013
	Child	0.76	10	1	0.076
N,N-dimethyl-formamide	Adult	6.7	60	1	0.112

Name of substance	Person	Highest degassed amount (µg)	Bw (kg)	n (day^{-1})	D_{inh} (µg/kg bw/day)
(light bulb 1)	Child	6.7	10	1	0.670
Octamethylcyclotetrasiloxane (light bulb 31)	Adult	21	60	1	0.350
	Child	21	10	1	2.1
Tetrahydrofuran (light bulb 13)	Adult	14	60	1	0.233
	Child	14	10	1	1.4
Phenol (light bulb 3B)	Adult	5.1	60	1	0.085
	Child	5.1	10	1	0.510

TABLE 5
EXPOSURE VIA INHALATION FOR THE FIVE SELECTED SUBSTANCES

4.4 Health assessment of chosen emitted compounds

4.4.1 Benzene

To assess the health effects of exposure to benzene, the EU risk assessment report from 2008 (ECB, 2008) is used as background information as well as the ECHA database on Registered Substances (ECHA RSD, 2014), as benzene is registered under REACH.

Benzene is restricted under REACH Annex XVII which concerns the manufacture, placing on the market and the use of certain hazardous compounds. Benzene is restricted in toys and as a compound in itself, or as a compound in chemical mixtures. Benzene has a harmonised classification according to the CLP Regulation as (ECHA C&L, 2014):

- Flam. Liq. 2, H225 – Highly flammable liquid and vapour
- Asp. Tox. 1, H304 – May be fatal if swallowed and enters airways
- Skin Irrit. 2, H315 – Causes skin irritation
- Eye Irrit. 2, H319 – Causes serious eye irritation
- Muta. 1B, H340 – May cause genetic defects
- Carc. 1A, H350 – May cause cancer
- STOT RE 1, H372 – Causes damage to organs through prolonged or repeated exposure

The occupational threshold limit value of benzene is 0.5 ppm or 1.6 mg/m^3. Benzene has the annotations E, H and K on the Danish list of occupational threshold limit values (Danish Working Environment Authority, 2007). The annotations mean that benzene has an EU threshold limit value (E), that benzene can be absorbed through skin (H), and that the compound is carcinogenic (K).

4.4.1.1 Identification of physical chemical parameters of benzene

The physical chemical parameters of benzene are given in Table 6.

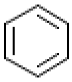
Chemical name (IUPAC)	Benzene
Synonyms	Petroleum benzene
CAS no. / EC no.	71-43-2 / 200-753-7
Molecular structure	
Molecule formula	C_6H_6
SMILES code	C1=CC=CC=C1
Physical state	Liquid at 20° C and 1 atm
Molecular mass	78.11 g/mol
Melting point	5.49° C at 1 atm
Boiling point	80.1° C t 1 atm
Density	0.88 g/cm^3
Vapour pressure	10 kPa at 20˚C
Octanol-water partition (log Kow)	2.13
Water solubility	Soluble (1000-10000 mg/L) 1.78 g/L at 25° C

TABLE 6
PHYSICAL CHEMICAL PROPERTIES OF BENZENE (ECHA RSD, 2014)

4.4.1.2 Absorption and distribution

In a study where mice were *intra peritoneal* exposed to a single dose of benzene in doses between 5 ng/kg bw to 500 mg/kg bw (Turtletaub and Mani (2003) in ECHA RSD (2014)), the following metabolites were identified in urine: unidentified > phenyl sulphate > muconic acid > phenyl glucuronide > hydroquinone sulphate. The amount of metabolites in the urine was dose dependant. Muconic acid, cathechol and hydroquinone were formed in the liver and were also dose dependant. Phenol was formed independently of the dose. None of the mentioned metabolites was observed in plasma or bone marrow.

Inhalation of C^{13}-labelled benzene by mice resulted in excretion of the metabolites phenol, catechol, and t,t-muconic acid. The largest amount of labelled metabolites was excreted 4 hours after exposure (Weisel et al. (2003) in ECHA RSD (2014)).

In the EU risk assessment of benzene, the compound was assessed to be quickly absorbed by both dermal and oral exposure and by inhalation (ECB, 2008). Animal studies have shown an absorption rate of between 10 and 50% after inhalation. Human data shows similar absorption rate. An absorption rate of benzene of 50% in humans is applied in the risk assessment by ECB (2008).

4.4.1.3 Irritation and allergy

Rabbits were dermally exposed (on shaved skin) to 0.5 mL benzene for four hours by means of an exposure chamber of 6 m^2 (Jacobs (1991) in BAUA (2008)). Erythema and oedema were both observed one hour after exposure while only erythemia were observed 24 to 144 hours after exposure. It was concluded that benzene is skin irritating to rabbits and should be classified under the CLP Regulation.

One study describes the presence of erythema, oedema and superficial necrosis in rabbits after they were exposed to benzene in an unknown dose on shaved ears or abdomen (Wolf et al., 1956 in ECB, 2008). Furthermore, exfoliation of large patches of skin was observed at the exposed areas.

In humans, benzene is reported to be irritating to mucus cells in eyes, nose and respiratory tract (Gerarde (1960) in BAUA (2008)). During a work accident people were dermally and respiratory exposed to benzene (Avis and Hutton (1989) in BAUA (2008)). Observed effects were second degree chemical burns to the face, trunk and limbs, haemorrhagic airless lungs with confluent alveolar haemorrhage and oedema.

Data on the sensitation properties of benzene is limited. One study in ECHA RSD (2014) states that benzene is not skin sensitising (Gad et al. (1986) in ECHA RSD(2014)).

4.4.1.4 Acute and chronic effects

Several studies in ECHA RSD state the acute toxicity of benzene. Generally, acute effects of benzene occur at high doses:

- LD50, oral rat: > 2000 mg/kg bw (Kimura et al. (1971) in ECHA RSD (2014))
- LD50, oral rat: > 5000 mg/kg bw (Withey and Hall (1975) in ECHA RSD (2014))
- LC50, inhalation rat: 43.7 mg/L (Drew and Fouts (1974) in ECHA RSD (2014))
- LD50, dermal guinea pig: > 9.4 mL/kg bw (Roudabush et al. (1965) in ECHA RSD (2014))

Effects on haematopoiesis

A group of researchers studied the effects of benzene in both mice and rats and for 17 or 103 weeks (NTP (1986) in BAUA (2008)). Animals of both genders were orally exposed to benzene in doses of 0, 25, 50, 100, 200, 400, or 600 mg/kg bw for five days per week. Among the studied effects, lower final body weight was identified as well as leucopoenia and lymphocytopenia, lymphoid depletion of B-cells in the spleen, and increased extramedullary haematopoiesis. Generally, the effects occurred at lower doses for mice than for rats. Therefore, mice were more sensitive than rats. NOAEL could not be determined in the study on mice exposed for 103 weeks while LOAEL was found to be 50 and 25 mg/kg bw/day for male and female mice respectively.

Case-control studies have shown that lymphopenia is the most sensitive effects in humans after chronic exposure (Rothman et al. (1996a) and (1996b), Docimeci et al. (1997) in BAUA (2008)). In the studies, people were exposed to benzene at their workplace (rubber industry, manufacturing of adhesive tapes and paint and varnish factories). The exposed people were compared to a cohort of non-exposed individuals who did not have a history of exposure to benzene, other marrow-toxic chemicals or ionizing radiation. The workers were exposed to benzene in concentrations between 1.6 and 30 ppm for at least six months. In the workers, lymphocytes, platelet and red blood cell counts were significantly reduced compared to the non-exposed cohort. As an overall conclusion of epidemiological studies on effects on lymphocytes, LOAEL was suggested to be 10 ppm (32 mg/m^3) while NOAEL of 1 ppm (3.2 mg/m^3) was derived for depression of lymphocytes by benzene (Rothman et al.(1996a) og (1996b) i BAUA (2008)).

Effects on the immune system

Benzene has shown effects on the immune system in mice. By inhalation of doses from 10 ppm for six hours per day for six days (Rozen et al. (1984) i BAUA (2008)) and from 40 mg/kg bw/day for four weeks (Hsieh et al. (1988) in BAUA (2008)), the results showed depression effects on the cellular and humural immune system (reduced red blood cell count and reduced number of B-lymphocytes and T-lymphocytes). Furthermore, a response from the immune system at doses as low as 8 mg/kg bw/day was observed (Hsieh et al. (1988) in BAUA (2008)).

Neurological effects

Benzene has shown neurological effects in mice. Increased amount of the hormone catecholamine in the brain as well as increased blood concentration of the hormones adrenocorticotropine and corticosterone was observed in mice exposed to doses from 8 mg/kg bw/day after four weeks orally exposure (Hsieh et al., 1991 in BAUA, 2008). The effects were suggested to be caused indirectly by effects on the immune system.

Mutagenic effects

The mutagenic effects of benzene are investigated in both *in vitro* and *in vivo* studies (BAUA, 2008). *In vitro* studies showed mainly negative results in bacterial tests while tests in human cell cultures showed mixed results. *In vivo* studies showed mainly positive results for mutagenic effects on somatic cells from rats and mice and by different routes of exposure (oral, *intra peritoneal* and by inhalation). Among the positive tests, chromosomal abberation, micronucleus test, comet assay, gene mutation and sister chromatid exchange are found. The positive results are found in cells in bone marrow, lymphocytes and liver cells. In stem cells the results are mixed (BAUA, 2008). Benzene is therefore classified as Muta. 1B, H340 (”May cause genetic defects”).

Carcinogenic effects

The risk assessment conducted on EU level (BAUA, 2008) concludes benzene to be carcinogenic to humans based on epidemiological studies and supported by animal studies.

Studies in mice have shown a development of leukaemia by impact on haematopoiesis or the lymphatic system which is the target organ in mice, after oral exposure or inhalation of benzene. Furthermore, studies in mice have shown carcinogenic effects in epithelial, tumours in lymph nodes, in other glands, in the liver, ovaries and lungs.

Unlike mice, studies in rats have not resulted in any association between exposure to benzene and formation of tumours in lymph nodes. Other studies in rats have shown an association between benzene exposure and development of leukaemia. Furthermore, different studies have revealed carcinogenic effects of benzene on skin, oral cavity and forestomach (rats have forestomach).

Many epidemiological studies are reported by BAUA (2008). Common to these studies is that many of the studies result in an association between leukaemia and occupational exposure to benzene. In some of the studies, the associations are very convincing. Furthermore, many of the epidemiological studies do not have complete information on i.e. potential confounders, measured benzene concentrations in the working environment, a short follow up period or a cohort too small. BAUA (2008) concludes benzene to be carcinogenic to humans, despite these deficiencies in the studies. This is most likely reasoned by the overwhelmingly amount of data (despite the quality) and because animal studies also have shown benzene to be carcinogenic.

It is stated by BAUA (2008) that it is not possible to list a threshold limit value for the causal relation between leukaemia and benzene exposure. Furthermore, BAUA states that leukaemia can be developed after exposure to low doses of benzene. Therefore, it is not possible to obtain a NOAEL or LOAEL value or hence to calculate a DNEL value for carcinogenic effects.

Reproductive effects
The reproductive effects of benzene on fertility are not reported for men, while studies in women exposed via the working environment are of a quality not sufficient to prove a causal relationship. Among the suspected effects of exposure to benzene are menstrual disorders, spontaneous abortions and absence of births despite no use of contraceptives. In animal studies, mice have shown to be more sensitive than rats to reproductive effects. BAUA (2008) suggests the application of a study of Ward et al. (1985 in BAUA, 2008) in a risk assessment of the reproductive effects of benzene. The study showed that both male and female mice had affected weights of organs (i.e. testis) and histopathological changes in reproductive organs. The mice were exposed to benzene in concentrations of 0, 3.3, 32.5, 97.4 or 974 mg/m^3 for 13 weeks. NOAEL was assessed to be 97.4 mg/m^3.

Animal studies have furthermore shown benzene to affect the development of foetuses by growth retardation of weight and length and affection of skeletal ossification. It is suggested that the growth retardation is caused by a lack of weight gain in the pregnant animal. BAUA (2008) recommends to apply the results by Kuni and Kapp (1981 in BAUA, 2008) in a risk assessment. In this study, inseminated rats were exposed to 0, 32.5, 162 or 1,624 mg/m^3 benzene by inhalation for 10 days (gestation day 6 to 15). NOAEC was found to be 32.5 mg/m^3 for growth retardation of the foetus (decreased birth weight and decreased head-tail-length).

4.4.1.5 Critical effect and calculation of DNEL

The critical effect of benzene is found to be its carcinogenic effects, which is shown in several epidemiological studies. It is not possible to calculate either a DNEL or DMEL for threshold or non-threshold effects because the epidemiological studies, which are the background material on the relationship between benzene exposure and cancer, do not provide sufficient information. The studies show i.e. that the risk of cancer was higher among workers at a production site than for the general population, although no measurements of the benzene concentration, which the workers were exposed to, were available.

Instead, a DNEL is calculated for the effects on the lymphocyte count in the blood of humans in a case control study (Rothman et al. (1996a) and (1996b), Docimeci et al. (1997) in BAUA (2008)). The workers in this study were exposed to benzene for at least six months and they had a significant lower number of lymphocytes compared to an unexposed cohort. The studies are also used by BAUA (2008) in the risk assessment of benzene. NOAEC was found to be 1 ppm (3.2 mg/m^3). This NOAEC value is converted to a value representing a safe exposure level for the general population, and not only workers. This is done by taking into account the number of exposed hours per day (8 hours for workers against 6 hours for the general population), number of exposure days per week (5 days against 7 days per week for the general population) and that persons at work have a higher activity level compared to persons in the home. The following values given by ECHA (2012c) are applied in the calculation of NOAEC:

- Body weight of workers is 70 kg
- Inhalation volume for humans with light activity (workers) is m^3/8 h

$$Adjusted\ NOAEC = 3.2\ mg/m^3 \times \frac{5\ days\ per\ week}{7\ days\ per\ week} \times \frac{10\ m^3/8\ h\ \times 6\ h}{70\ kg}$$

$$= 0.245\ \text{mg/kg bw/day} = 245\ \mu\text{g/kg bw/day}$$

In the calculation of the DNEL value of benzene, the adjusted NOAEC value is divided by an assessment factor of 10 to adjust for differences in humans. Thus, the DNEL value is 24.5 µg/kg bw/day.

4.4.2 N,N-dimethylformamide

To assess the health effects of N,N-dimethylformamide, information given in an Annex XV dossier written by the Swedish Chemicals Agency (unknown year), a supporting document for the identification of N,N-dimethylformamide as a candidate as ”*substances of very high concern*” (SVHC) (ECHA, 2012d) as well as the OECD SIDS report from 2004 are used.

N,N-dimethylformamide is on the Candidate list of substances of very high concernand has a harmonised classification in the CLP Regulation as (ECHA C&L, 2014):

- Acute Tox. 4, H312 – Harmful in contact with skin
- Eye Irrit. 2, H319 – Causes serious eye irritation
- Acute Tox. 4, H332 – Harmful if inhaled
- Repr. 1B, H360D – May damage the unborn child

The occupational threshold limit of N,N-dimethylformamide is 10 ppm or 30 mg/m^3. N,N-dimethylformamide is annotated with an H on the Danish list of occupational threshold limit values. This means that the compound can be absorbed through the skin (Danish Working Environment Authority, 2007).

4.4.2.1 Identification of physical chemical parameters

The physical and chemical parameters of N,N-dimethylformamide are given in Table 7.

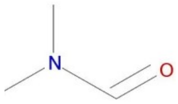
Chemical name (IUPAC)	**N,N-dimethylformamide**
Synonyms	-
CAS no. / EC no.	68-12-2 / 200-679-5
Molecular structure	
Molecular formula	C_3H_7NO
SMILES code	CN(C)C=O
Physical state	Liquid (at 20 °C and 1 atm)
Molar mass	73.09 g/mol
Melting point	-61 °C
Boiling point	153 °C
Density	0.94 g/cm^3 at 25 °C
Vapour pressure	3.08 to 3.77 hPa at 20 °C
Octanol-water partition (log Kow)	-0.85 to -0.89 (measured value)
Water solubility	Miscible (1000 g/L)

TABLE 7
PHYSICAL CHEMICAL PARAMETERS FOR N,N-DIMETHYLFORMAMIDE (ECHA RSD, 2014)

4.4.2.2 Absorption and distribution

In a study, rats were exposed by inhalation to 1.71 or 6.82 mg/L for four hours inhalation (Lundberg et al. (1983) in ECHA RSD (2014)). Blood and different tissues were afterwards examined for a content of N,N-dimethylformamide and monomethylformamide 0, 3, 6, 20 and 48 hours after exposure. Both compounds were identified in the blood and in different tissues, especially kidney tissue.

Two rats were exposed to either 1.71 mg/L or 6.82 mg/L C^{14}-labelled N,N-dimethylformamide by inhalation (a study from 1971 in ECHA RSD (2014)). 85% of the C^{14} was collected during three days and the major amount of the labelled carbon was identified to be monomethylformamide.

In a study, rats were subcutaneously exposed to N,N-dimethylformamide (a study from 1966 in ECHA RSD (2014)). The rats were exposed to two doses of 300 mg with an interval of two days. Afterwards, urine was collected from day 0 to day 5. The study showed that N,N-dimethylformamide was mainly metabolised to monomethylformamide which was measured in the blood one hour after exposure, but not after 48 hours. Monomethylformamide was also measured in the urine and approximately 75% of the administrated dose was excreted via urine as N,N-dimethylformamide and monomethylformamide.

Several studies in OECD SIDS (2004) state that N,N-dimetehylformamide is rapidly absorbed through the skin and lung tissue. An actual absorption fraction is not reported, therefore, as a worst case scenario, it is assumed that humans absorb 100% N,N-dimetehylformamide by inhalation.

4.4.2.3 Irritation and allergy

In a study four rabbits were exposed to 0.5 mL N,N-dimethylformamide for 20 hours by application of a patch soaked in the test substance (OECD SIDS (2004) in ECHA RSD (2014)). The patch was applied on shaved skin of the back. One rabbit showed faint redness at the exposure site after one day. Two days after exposure, no effects were observed in any of the exposed rabbits.

Four rats were exposed to N,N-dimethylformamide on shaved skin in a concentration of 3,160 mg/kg bw (a study from 1978 in ECHA RSD (2014)). N,N-dimethylformamide was applied on skin for 24 hours and the animals were observed for 14 days. No animals showed any reactions such as erythema and oedema. N,N-dimethylformamide is therefore not regarded as skin irritant.

Several studies in EHCA RSD (2014) state N,N-dimethylformamide as an eye irritant.

In study on skin sensitation, the ears of mice were exposed to 25 µL N,N-dimethylformamide or control vehicle three times during three days (Ulrich et al. (2001) in ECHA RSD (2014)). 24 hours after the last application, the animals were sacrificed and the weight of the ears and lymph nodes were investigated. The result showed a small increase in activation of lymph nodes shown as increased weight and number of cells. As the results were not replicated in a new study, it was concluded that N,N-dimethylformamide was not skin sensitising.

4.4.2.4 Acute and chronic effects

Several studies state the acute toxicity of N,N-dimethylformamide. These are given below:

- LD50, oral rat: 2800 mg/kg bw (Druckey et al. (1967) in ECHA RSD (2014))
- LD50, oral mice: 2755 mg/kg bw (BASF (1975) in ECHA RSD (2014))
- LD50, oral rat: 7600 mg/kg bw (BASF (1976) in ECHA RSD (2014))
- LD50, oral rat: 3895 mg/kg bw (BASF (1952) in ECHA RSD (2014))
- LD50, oral mice: >5000 mg/kg bw (Exxon Chem Co (1978) in ECHA RSD (2014))
- LC50, inhalation mice: >5,85 mg/L (OECD (2004) in ECHA RSD (2014))
- LD50, dermal rabbit: 1500 mg/kg bw (IPCS (1991) in ECHA RSD (2014))

- LD50, dermal mice: >5000 mg/kg bw (BUA-Stoffdossier (1991) in ECHA RSD (2014))
- LD50, dermal rabbit: 4720 mg/kg bw (Amer IND. (1969) in ECHA RSD (2014))
- LD50, subcutaneous rat: 2280 mg/kg bw (BASF (1952) in ECHA RSD (2014))
- LD50, *intraperitoneal* mice: 5035 mg/kg bw (BASF (1972) in ECHA RSD (2014))
- LD50, *intraperitoneal* rat: 1425 mg/kg bw (BASF (1972) in ECHA RSD (2014))
- LD50, *intraperitoneal* rat: 4095 mg/kg bw (BASF (1972) in ECHA RSD (2014))

Effects on the liver
In short term and chronic studies, N,N-dimethylformamide showed mainly to have hazardous effects on the liver (OECD SIDS 2004). Selected studies on these effects are described in the following text.

Mice and rats were exposed to N,N-dimethylformamide by inhalation in doses of 0, 25, 100 and 400 ppm for up to 18 or 24 months (Malley et al. (1994) in OECD SIDS (2004) and in ECHA RSD (2014)). For male rats and male mice, a decrease in weight gain was observed in animals exposed to 100 and 400 ppm, and for female mice at exposure dose 400 ppm. Furthermore, an increase in enzyme activity, increased weight of liver and some histopathological changes in liver for animals exposed to 400 ppm were observed. Similar effects were observed in mice exposed to 100 ppm; however, the findings were not significantly different from the control group. In all three exposure groups morphological changes in the liver of mice were observed. However, in the lowest exposure group the findings were not significantly different than for the control group. The authors concluded that LOAEC was 25 ppm for mice despite this. NOAEC was concluded to be 25 ppm for rats.

In an inhalation study, both mice and rats were exposed to N,N-dimethylformamide either in doses of 0, 100, 200, 400, 800 or 1600 ppm for 2 weeks, or 0, 50, 100, 200, 400 or 800 ppm for 13 weeks (a study from 2003 in ECHA RSD (2014)). In the group of rats exposed to 1600 ppm 10 animals died during the study. No mice exposed to the same dose died during the study. Significant necrosis of liver cells was an observed effect in mice and rats in all exposure groups. Animals exposed in 13 weeks showed effects as increased liver weight, increased incidence of the centrilobular hepatocellular hypertrophy and an increased amount of the enzymes alanine transaminase, aspartate aminotransferase and lactate dehydrogenase, cholesterol and phospholipids in the blood. BMDL10 (benchmark dose level of 10%) was concluded to be 1 ppm for increased weight of liver in both mice and rats exposed for 13 weeks and 17 ppm for hepatocellular hypertrophy in male rats.

Increased weight of liver was observed in a study on rats exposed for 90 days via feed for 0, 200, 1000 or 5000 ppm N,N-dimethylformamide (TSCATS: OTS 0520880 (1960), TSCATS: OTS 0571664 (1960), TSCATS: OTS 0572893 (1960) in OECD SIDS (2004)). In the group of rats exposed to 1000 ppm, the relative liver weight was slightly increased while the concentration of phospholipids in the blood of female rats was elevated. Furthermore, leucocytosis was observed as well as a decrease in the count of red blood cells. In the animals exposed to 5000 ppm, an observation of decreased weight gain and feed intake, slight anaemia, leucocytosis, increased cholesterol and concentration of phospholipids was seen. The NOAEL value was concluded to be 1000 ppm and LOAEL to be 5000 ppm.

Mutagenic effects
N,N-dimethylformamide is used as a negative control in studies of mutagenicity and genotoxicity. N,N-dimethylformamide is therefore regarded not to have mutagenic or genotoxic effects. OECD SIDS (2004) makes the conclusion that N,N-dimethylformamide is not mutagenic based on several *in vivo* and *in vitro* studies on chromosome aberration or gene mutations (Ames-Test, Micronucleus assays, sister-chromatide exchange).

Carcinogenic effects
Mice and rats were exposed to N,N-dimethylformamide by inhalation in doses of 0, 25, 100 and 400 ppm for up to either 18 and 24 months (Malley et al. (1994) in OECD SIDS (2004)). Tumours were identified in both animal species. However, it was concluded that there was no dose-response relation between the incidence of tumours and exposure to N,N-dimethylformamide. Benign tumours were mainly observed in liver cells of male rats. Malign tumours were observed to a less extent. Furthermore, benign and malign tumours were identified on the skin. Generally, the male rats were more sensitive to N,N-dimethylformamide in the development of tumours compared to the female rats. In mice benign hepatocellular tumours were observed and for male mice a few malign tumours. The incidence of tumours in mice was significant lower than for rats. Testicular adenomas and adenomas in the mammary tissue were also observed. Despite the observed tumours, it was not possible to identify a significant difference between the exposed animals and the control group. However, a significant difference for benign tumours generally in female mice was found in the group of animals exposed to 400 ppm. These animals had a significant lower incidence of benign tumours compared to the control group and the other exposure groups. Both studies concluded that N,N-dimethylformamide is not carcinogenic in studies on animals. LOAEL was determined to be more than 400 ppm.

Reprotoxic effect
In the investigation of potential effects for the reproduction, a one generation study was performed on rats (a study from 1973 in ECHA RSD (2014)). The rats were exposed to 0, 500, 1000 or 2000 mg/kg bw/day by an unknown route of administration. The animals were divided into three different groups which were exposed to N,N-dimethylformamide in a different number of days. Group 1 was exposed before mating. Group 2 during mating and until labour of first generation. Group 3 was exposed in the entire study period; that is before and during mating, during lactation of first generation, during second mating period and until section. Apart from decreased weight gain in group 2 and 3, death among animals in group 3 exposed 1000 and 2000 mg/kg bw/day was also an effect. In all three groups, fewer viable pups were born in the second generation when exposed to 2000 mg/kg bw/day. The lower number was caused by a lower number of corpora lutea and implantation sites. No NOAEL values are given in the study.

Another study has also investigated the effects of N,N-dimethylformamide in mice which were exposed to 0, 1000, 4000 or 7000 ppm via the drinking water (Fail et al. (1998) in OECD SIDS (2004)). The study was a two generation study, where the firstly exposed mice showed lower body weight and lower fertility when exposed to 7000 ppm. The firstborn cubs showed effects such as lower body weight and increased liver weight and hepatocellular hypertrophy when exposed to 4000 and 7000 ppm. Furthermore, the oestrous cycle was prolonged in the 7000 ppm group. Lower weight of prostate was observed in all exposure doses, while only the highest exposed group showed a lower sperm cell count as well as a lower number of matings. The exposed animals in the second generation also showed lower body weight compared to the control group. Cubs in both the first and second generation were born with cranial malformations and malformations in the sternum if exposed to 4000 or 7000 ppm. It was concluded that NOAEL for effects on the fertility was 219 mg/kg bw/day while the first generation of offspring showed a NOAEL of 219 mg/kg bw/day for effects on the development. The second generation of mice resulted in a LOAEL of 1000 ppm, as the lowest tested dose resulted in effects.

In a study of Saillenfait et al., 1997 (in OECD SIDS (2004)), rats were exposed to 0, 50, 200 or 300 mg/kg bw/day for 14 days during gestation. The born animals were examined for decreased body weight and for skeletal alterations. There was a significant difference between the control group and the group of animals exposed to 200 and 300 mg/kg bw/day. Skeletal alterations were also observed in the group of animals exposed to 50 mg/kg bw/day; however, the differences were not significantly different from the control group. Despite this, a LOAEL of 50 mg/kg bw/day is given for embryo and fetal toxicity. The exposed pregnant animals also showed signs of toxicity at this dose.

In a study by Keller and Lewis (1989), rats were exposed by inhalation of N,N-dimethylformamide in doses of 0, 30 or 300 ppm in the gestation period from day 6 to 15 (6 hours per day). In the highest exposed group lower birth weight and skeletal malformations and malformations in soft tissue were observed. NOAEL was therefore determined to be 30 ppm.

From animal studies, rabbits have shown to be the most sensitive species in relation to effects on the reproductive system (OECD SIDS, 2004). In a study by BASF (1975e in OECD SIDS (2004)), rabbits were orally exposed to 0, 44.1, 65 or 190 mg N,N-dimethylformamide/kg bw/day for 13 days, with the first exposure 6 days after insemination. In the highest exposure group, the pregnant rabbits showed decreased food consumption and weight gain, and three out of 11 rabbits miscarried. Furthermore, an increase in malformations in the offspring was observed. In the middle exposure group, two pups showed effects of hydrocephalus internus while this was the case for one animal in the lowest exposure group. The result of the lowest exposure group was not significantly different than for the control group. NOAEL for malformations was concluded to be 44.1 mg/kg bw/day and 65 mg/kg bw/day for embryo and fetal toxicity.

Thus, the conclusion on the given studies is that N,N-dimethylformamide is toxic to the reproduction in animal studies and is classified according to CLP as Repr. 1B, H360D ”May damage the unborn child”.

Human data
Only limited information on the effects of N,N-dimethylformamide on humans exists and several studies report inconclusively on redness of skin after exposure in the working environment and increased intolerance of alcohol (ECHA RSD (2014)). A study by Cai et al. (1992 in ECHA RSD (2014)) investigated the effects of N,N-dimethylformamide on 318 workers exposed at a production site of plastic. The observed effects in the workers were compared to unexposed controls. Most exposed workers were exposed to N,N-dimethylformamide in a concentration of 7 ppm, while others were exposed to 2.1 ppm N,N-dimethylformamide and 4.2 ppm toluene. Both blood samples and samples of serum were comparable among the three groups. However, subjective symptoms, such as stomach ache and nausea, resulted in a dose-response correlation between the groups. Men exposed to N,N-dimethylformamide reported on increased intolerance of alcohol.

4.4.2.5 Critical effect and calculation of DNEL

The critical effect of N,N-dimethylformamide is toxic effects on the liver. The lowest observed NOAEC value is 25 ppm for rats (Malley et al. (1994) in ECHA RSD (2014) and OECD SIDS (2004)). The study by Keller and Lewis (1989) resulted in a NOAEC value of 30 ppm also for rats, but for fetal effects. Thus, two studies have observed a NOAEC value at the same level. The lowest observed NOAEL value of 25 ppm corresponds to 80.5 mg N,N-dimethylformamide/m^3.

To calculate the DNEL value for N,N-dimethylformamide based on the NOAEC value, it is necessary to take into account the animals presumed respiration volume, body weight and the duration of the exposure in order to be able to compare the NOAEC value in humans. In the study by Malley et al. (1994) rats were exposed for six hours per day, five days per week, for 24 months. The respiration volume is stated to be 0.0002 m^3/min and the weight to be 0.25 kg (ECHA, 2012c). The adjusted NOAEC is calculated from the equation:

$$\text{Adjusted NOAEC} = \frac{NOAEC \cdot number\ of\ exposure\ days\ per\ week \cdot Resp \cdot Exposre\ time}{Body\ weight}$$

It is calculated to be:

$$\text{Adjusted NOAEC} = \frac{80.5\ \text{mg/m3} \cdot \frac{5}{7} \cdot 0.0002\ \text{m3/min} \cdot 6\ \text{hours} \cdot 60\ \text{min/hour}}{0.25\ \text{kg}} = 16.6\ \text{mg/kg bw/day}$$

To transfer the adjusted NOAEC value from rats to humans, assessment factors are applied. An assessment factor of 4 is applied to adjust from rats to humans, 2.5 for the rest of differences between species and a factor of 10 for differences among humans. Thus, a total assessment factor of 100 is applied. DNEL for toxic effects on the liver is hence 166 µg/kg bw/day.

In a REACH Annex XV dossier on N,N-dimethylformamide, DNEL for inhalation is given to be 15 mg/m^3 for the working part of the population (both local and systemic effects). The DNEL value is gathered from the ECHA registration database and is based on allowed threshold limits in the working environment (OEL, *occupational exposure level*). This value is approximately 19 times higher than the calculated DNEL value. One explanation can be that an occupational exposure level is set to protect workers and not the general population.

4.4.3 Octamethylcyclotetrasiloxane

Octamethylcyclotetrasiloxane is REACH registered. Therefore information from registration dossiers is available in the ECHA database on registered substances (ECHA RSD, 2014). An opinion of the substance has been submitted by the Scientific Committee on Consumer Safety (SCCS, 2010), and the opinion is used in this health assessment together with an assessment by Environment Canada (2008).

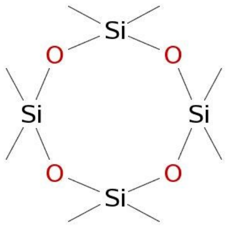
Octamethylcyclotetrasiloxane (D4) has a harmonised classification as (ECHA C&L, 2014):

- Repr. 2, H361f – Suspected of damaging fertility
- Aquatic Chronic 4, H413 – May cause long-lasting harmful effects to the aquatic life

No occupational threshold limit is given for D4 (Danish Working Environment Authority, 2007).

4.4.3.1 Identification and physical chemical parameters

The physical chemical parameters of D4 are given in Table 8.

Chemical name (IUPAC)	**2,2,4,4,6,6,8,8-octamethyl-1,3,5,7,2,4,6,8-tetroxatetrasilocane**
Synonyms	Octamethylcyclotetrasiloxane D4 ; Cyclomethicone; cyclotetrasiloxane; 2,2,4,4,6,6,8,8-octamethyl-cyclotetrasiloxane (Source: OARS, 2014; SCCS, 2010; Toxnet, 2014)
CAS no. / EC no.	556-67-2 / 209-136-7
Molecular structure	
Molecular formula	$C_8H_{24}O_4Si_4$

SMILES code	C[Si]1(O[Si](O[Si](O[Si](O1)(C)C)(C)C)(C)C)C
Physical state	Colourless liquid
Molecular weight	296.2 g/mol (SCCS, 2010)
Melting point	17.5 /17.7 °C
Boiling point	175 °C
Density	0.95 g/cm^3 at 25 °C 0.96 g/cm^3 at 20 °C
Vapour pressure	132/160 Pa at 25 °C Approximately 110 Pa at 20 °C
Octanol-water partition (log K_{OW})	6.488 at 25.1 °C 6.98 at 21.7 °C 4.22 at 24 °C
Water solubility	Insoluble 0.0562 mg/L at 23 °C 0.033/0.07 mg/L at 25 °C

TABLE 8
IDENTIFICATION AND PHYSICAL CHEMICAL PARAMETERS OF OCTAMETHYLCYCLOTETRASILOXANE (ECHA RSD (2014) IF NOT OTHERWISE STATED)

4.4.3.2 Uptake and distribution

Studies using radio labelled D4 show the compound to be rapidly absorbed after oral exposure using corn oil as vehicle. The level of D4 in tissue corresponded to the level in plasma over time. The study indicates that the oral absorption of D4 depends on the choice of vehicle. D4 administered with corn oil resulted in the largest absorption (SCCS (2010), a study from 1998 in ECHA RSD (2014)).

Several studies on absorption after inhalation by rats exist in ECHA RSD (2014). An absorption rate of 5% after inhalation is stated by these studies (varies from approx. 4-6.5%). In humans, approximately 12% of D4 is absorbed when inhaled (SCCS, 2010). Thus, an absorption rate of 12% for humans after inhalation is applied. The major levels of D4 are observed in lung tissue and adipose tissue compared to other tissues. This is expected as D4 is lipophilic and thus has a tendency to accumulate in lipophilic tissues. Research indicates that D4 accumulates in adipose tissue, but the toxicological relevance of this is unknown (SCCS, 2010).

Several *in vivo* and percutaneous absorption studies are performed in order to investigate the dermal absorption of D4; however, there are variations in the results. In *in vitro* studies a mean dermal absorption rate of 0.5% is identified if the compound is applied in pure form or as a 62% solution on human cadaver skin. Maximum value was 0.94%. An *in vitro* study on skin of pigs and an *in vivo* study on rats show the major amount (> 90%) of D4 vaporises before absorption through skin which seems to explain the low dermal absorption. SCCS applies a dermal absorption rate of 0.5% in their risk assessment of D4 (SCCS, 2010).

An oral study on rats shows that 79 and 75% of the administered dose was absorbed by male and female rats respectively. Radio labelled D4 was observed in blood, tissue, oesophagus, fat, liver, lungs, spleen, ovaries, testicles and uterus. D4 is metabolised in the body and is excreted mainly via urine and exhaled air. 59 and 58% of D4 was excreted 24 hours after administration for female and male rats respectively (a study from 2012 in ECHA RSD, 2014).

Modelling and toxicokinetics have shown that 80% of the systemic available D4 in the body is excreted via exhaled air (SCCS, 2010).

A study on both Fischer 344 and Sprague-Dawley rats showed differences in the urine as a result of differences in especially the metabolism of D4. Multiple metabolites and increased amount of metabolized D4 were observed in Fischer 344 rats compared to Sprague-Dawley rats. This indicates that Ficsher 344 rats are better in metabolising D4. The primary metabolite of both rat species was dimethylsilanediol [Me2Si(OH)2] (studies from 2000 and 2002 in ECHA RSD, 2014). Another important metabolite is methylsilanetriol [MeSi(OH)3] (Varaprath et al., 1999 in ECHA RSD, 2014).

4.4.3.3 Irritation and allergy

Only few studies aer reported in the ECHA database on registered substances. These studies state that there is no irritation of skin or eyes after exposure to D4 (ECHA RSD, 2014).

According to the single study reported in ECHA RSD (2014), D4 is not recognised as as a skin sensitisor. No data on sensitising through inhalation is available.

4.4.3.4 Acute and chronic effects

Several data on animals report the acute toxicity of D4, and these are given below:

- LD$_{50}$ oral, rat: > 4800 mg/kg bw (a study from 1979 in ECHA RSD (2014))
- LD$_{50}$ oral, rat: > 61.440 mg/kg bw (Carpenter et al. (1979) in ECHA RSD (2014))
- LD$_{50}$ oral, mouse: 1700 mg/kg bw (a study from 1971 in ECHA RSD (2014))
- LC$_{50}$ inh., rat (4t): 36 mg/L (a study from 1994 in ECHA RSD (2014))
- LC$_{50}$ inh., rat (4t): > 12 mg/L (a study from 1984 in SCCS (2010))
- LD$_{50}$ dermal, rat: > 2400 mg/kg bw (a study from 1985 in ECHA RSD (2014))
- LD$_{50}$ dermal, rat: > 2000 mg/kg bw (a study from 1982 in ECHA RSD (2014))

Studies on repeated exposure show onset of effects after relatively high doses of D4 after inhalation or oral exposure and show that D4 results in a few systemic effects. An observed effect was enlargement of the liver (hypertrophy). However, this effect was reversible (SCCS, 2010). The most important studies which lead to determination of NOAEL or NOAEC value are described below. Several studies are described in ECHA RSD (2014), which all result in higher NOAEC values.

An inhalation study exposed four groups of rats to D4 in concentrations of 10, 30, 150 or 700 ppm D4 for 6 hours/day in 5 days/week for 6, 12 or 24 months. The rats exposed to 700 ppm D4 for 24 months showed the effects mentioned below. Based on the study, a NOAEC for carcinogenic effects was determined to be 150 ppm for female rats, and ≥ 700 ppm for male rats. NOAEC for general toxicity was determined to be 150 ppm based on nephropathy (a study from 2004 in ECHA RSD (2014)).

- Reduced survival after two years of study period and reduced body weight
- Increased weight of liver, kidney, and uterus
- Lymphocytic leukocytosis (abnormal increasing in number of white blood cells)
- Minimal to mild hyperplasia in nasal mucous membrane when exposed for 12 or 24 months
- Increased incidence of adenomas in mucous membrane of the uterus when exposed for 24 months
- Increased extension of chronic nephropathy when exposed for 24 months

In a sub-chronic 13 weeks study, rats were exposed to 5, 10 or 300 ppm 5 days/week. Observed effects were increased levels of sodium, potassium and glucoses; however, after 4 weeks of restitution the levels were normal. Observed weight increases of organs were assumed to be in relation with biological variation. NOAEC was determined to be ≥ 300 ppm (a study from 1991 in ECHA RSD (2014)).

In a sub-chronic 90 days inhalation study, rats were exposed via the nose only, for concentrations of 34, 120, 480 or 883 ppm. An observation of a reversible increase of liver weight was made for rats exposed to 480 or 883 ppm. Rats exposed to 883 ppm also showed a reversible changes in ovaries and vaginas. Signs of mild irritation in the nasal cavity were observed as increased cell formation in the rats exposed to maximum doses and signs of chronic inflammation in the lungs in all exposed animals. After the period of restitution of 28 days, signs of recovery were observed. A NOAEC of 480 ppm was determined based on the effects on ovaries and vaginas. NOAEC for local effects on the lungs was determined to be 34 ppm (Mast et al. (1996) in ECHA RSD (2014).

A single dermal study is described in ECHA RSD (2014), but this study did not result in any effects and a NOAEL value was not determined (> 1 mL/kg bw/day).

Immuno toxicity
According to several *in vivo* and *in vitro* studies on immune toxicity, D4 is assessed not to have an effect on the immune system. Oral doses up to 300 mg/kg bw/day do not result in effects in rats (ECHA RSD, 2014; OARS, 2014). Human data shows that a daily intake of 12 mg/day for two weeks does not result in immune toxic effects (a study from 1998 in ECHA RSD (2014)).

Genotoxicity
D4 is tested negative for genotoxic effects in several studies both *in vitro* and *in vivo* (SCCS (2010), ECHA RSD (2014)). One study reports on clastogenic effects; however, only in concentrations which are clearly toxic (Isquith et al. (1988) in ECHA RSD (2014)). Therefore, D4 is not assessed to be mutagenic.

Carcinogenic effects
The 24 months inhalation study previously mentioned observed adenomas in the mucous membrane of uterus when exposed to maximum dose of 700 ppm. As D4 does not show any genotoxic effects, SCCS (2010) assesses the formation of tumours to be a result of effects at threshold limits. In a study on F344 rats, an increased incidence of mononuclear cell leukaemia was observed in male rats. However, as this type of tumours is unique in rats, the relevance in human is questionable. SCCS (2010) has assessed this type of tumours to be irrelevant in the assessment of D4.

Toxic effects for the reproduction
Several studies exist on the toxic effects of D4 on the reproduction system. Overall, there is no clear evidence of D4 to cause developmental toxicity in rats or rabbits. Furthermore, D4 should not cause severe effects of the fertility of male rats. However, the following effects have been observed in the fertility of female rats (SCCS, 2010):

- Effect on the fertility which shows at ovulation and results in a reduced number of eggs at ovulation.
- Reduction in the number of corpora lutea, in the number of born pubs and in the mean size of the born pubs was observed in a one generation study when exposed to large concentrations. Two studies resulted in determination of a NOAEL value of 300 ppm for reproductive effects.

SCCS (2010) states that the signs of reproductive toxicity of females are caused by delayed ovulation.

4.4.3.5 The critical effect and calculation of DNEL

The lowest identified NOAEC value of D4 is 150 ppm where the effect was nephropathy. This value corresponds to a NOAEC of 1817 mg/m^3. Thus, the critical effect is nephropathy.

The NOAEC value of 150 ppm is based on exposure of female rats for 6 hours/day in 5 days/week. In this report, a risk assessment of the identified substances is performed based on a worst case exposure of 6 hours per day. The NOAEC value is converted to a value in mg/kg bw/day. It is adjusted using the following calculation where the following standard values are applied (Table R.8-2 in ECHA (2012c)):

- Weight of a rat is 250 g
- The inhalation volume of a rat is 0.2 L/minute

$$Adjusted\ NOAEC = 1817\ mg/m^3 \times \frac{5\ days\ per\ week}{7\ days\ per\ week} \times \frac{0.0002\ m^3/min\ \times 6\ h/day\ \times 60\ min/h}{0.250\ kg}$$

= 374 mg/kg bw/day

The NOAEC value of 150 ppm is based on a chronic study on rats. Therefore, an assessment factor of 4 is applied for rats and a default assessment factor of 10 to adjust for intraspecies differences. For D4 there is information on the toxicokinetic differences between rats and humans and the result of observed differences must be applied. The differences are (as mentioned in 4.4.3.2) that rats absorb 5% of D4 when inhaled and humans 12%. Thus, there is a factor of 12/5 = 2.4. Thus, instead of a default assessment factor of 2.5 a factor of 2.4 is applied for the rest of the interspecies differences (ECHA, 2012c). A total assessment factor of 96 in total is applied which results in a DNEL value of D4 of 3.9 mg/kg bw/day.

4.4.4 Tetrahydrofuran

Tetrahydrofuran (THF) is registered so information from registrations dossiers is available in the database of registered substances of ECHA (ECHA RSD, 2014). However, the database only contains a limited amount of information. Therefore, an ECHA Annex VI report concerning a proposal for a harmonised classification of tetrahydrofuran is used in this health assessment (ECHA, 2009).

Tetrahydrofuran has a harmonised classification as (ECHA C&L, 2014):
- Flam. Liq. 2, H225 – Highly flammable liquid and vapour
- Eye Irrit. 2, H319 – Causes serious eye irritation
- STOT SE 3, H335 – May cause respiratory irritation
- Carc. 2, H351 – Suspected of causing cancer

The occupational threshold limit of tetrahydrofuran is 50 ppm or 148 mg/m^3. Tetrahydrofuran is marked as E and H on the Danish list of occupational threshold limit values, which means that the compound has an EU threshold limit and that the substance can be absorbed through skin (Danish Working Environment Authority, 2007).

4.4.4.1 Identification and physical chemical parameters

The physical and chemical parameters of tetrahydrofuran are given in Table 9.

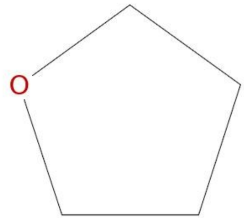
Chemical name (IUPAC)	**Tetrahydrofuran**
Synonyms	1,4-epoxybutane, butylene oxide, diethylene oxide, THF, cyclotetramethylene oxide (ECHA, 2009)
CAS no. / EC no.	109-99-9 / 203-726-8
Molecular structure	
Molecular formula	C_4H_8O
SMILES code	C1CCOC1
Physical state	Colourless liquid with ether-like odour
Mole weight	72.11 g/mol
Melting point	-108.5 °C
Boiling point	65-66 °C
Density	0.883 g/cm^3 at 25 °C 0.8892 g/cm^3 at 20 °C
Vapour pressure	17 kPa at 20 °C
Octanol-water partition (log Kow)	0.45 – 0.46 at 25 °C
Water solubility	Miscible

TABLE 9
IDENTIFICATION AND PHYSICAL CHEMICAL PARAMETERS OF TETRAHYDROFURAN
(ECHA RSD (2014) IF NOTHING ELSE STATES)

4.4.4.2 Absorption and distribution

Only limited data on absorption and distribution of THF is available. According to ECHA (2009), the absorption of THF is rapid via all exposure routes, but especially via the lungs, the gastrointestinal tract and the skin. This is confirmed by a new study from 2005 where the dermal absorption of THF was examined on skin samples of dead people (ECHA, 2009). It was concluded that THF was very rapidly absorbed through the skin of humans. Limited data on the absorption of THF via the respiratory tract exists. ECHA (2009) mentions data of older date where humans were exposed to THF for 20 minutes and still had 60% of the inhaled dose of THF in the body. In this health assessment, an exposure period of 6 hours is applied, but no studies state the absorption rate of this amount of time. Therefore, an inhalation absorption rate of 100% is applied in this health assessment as a worst case scenario.

THF is widely distributed in the body. Studies on rats have showed THF to be measured in the blood, the adipose tissue and kidneys after orally exposure. In humans, the exhalation air seems to be the primarily excretion path of THF. The halftime of excretion of THF is 30 minutes for rats in inhalation studies and 5 to 7.5 hours after orally exposure of THF (ECHA, 2009). Thus, THF is excreted relatively rapidly from the body after inhalation and oral exposure. The metabolism of THF is not well studied and is solely based on hypothesis. One hypothesis is that THF is metabolised to butanal (ECHA, 2009)

4.4.4.3 Irritation and allergy

The few studies reported in ECHAs database on registered substances state that THF is not skin irritating (ECHA RSD, 2014). ECHA (2009) states that THF shows irritating effects on the skin of humans after only a short exposure period. This irritation is stated to be caused by formation of peroxides when THF is exposed to oxygen. Therefore, THF is not classified as skin irritating. Exposure of eyes results in varying results from strongly irritating to corrosive. THF has a harmonised classification as eye irritating.

According to the few studies reported in ECHA RSD (2014), THF is not regarded as skin sensitising. No data on sensitising of the respiratory tract is available.

4.4.4.4 Acute and chronic effects

Limited data of animal studies states the acute toxicity of THF. Below, these studies are stated. The acute toxicity is regarded as being low.

- LD_{50} oral, rat: 1650 mg/kg bw (a study from 1978 in ECHA RSD (2014)
- LD_{50} oral, rat: 2.3 – 3.6 ml/kg bw (a study from 1971 in ECHA RSD (2014)
- LC_{50} inhalation, rat: > 14.7 mg/l (Malley et al. (2001) in ECHA RSD (2014))
- LC_{50} inhalation, rat: ca. 375 mg/l (a study from 1979 in ECHA RSD (2014)
- LD_{50} dermal, rat: > 2000 mg/kg bw (a study from 2009 in ECHA RSD (2014)

One incidence is reported where an unknown dose of THF is reported to have caused fatal poison of a human. In the beginning, the patient showed symptoms such as stomach pain, nausea, vomiting followed by coma. The patient developed jaundice, oliguria (decreased excretion of urine) and high fever. The patient died six days after the incidence (ECHA, 2009).

The study by Malley et al. (2001 in ECHA RSD, 2014) reports a NOEC (No Observed Effect Concentration) of 500 ppm after an exposure of rats for 6 hours. The observed effect of inhalation of the high doses of 2500 and 5000 ppm was temporarily sedation. The effect appeared to be concentration dependant. The observed neurotoxic effects were completely absent a few hours after termination of exposure for the animals exposed to 2500 ppm and after 19 hours for the animals exposed to 5000 ppm. Based on this study, a classification as STOT SE 3 is applied for THF based on the effects on the central nervous system.

Rats were exposed to THF in doses of 0, 1, 10, 100 or 1000 mg/L via the drinking water in a sub acute study of 4 weeks. No observation of significant changes of biochemical or haematological effects was seen for any of the animals. Minimal to mild changes in the liver, kidney and thyroid gland were observed. NOAEL was identified to be 1000 mg/L which corresponds to 111.3 mg/kg bw/day (Komsta et al. (1988) in ECHA RSD (2014)).

By repeated long term exposure of THF, the respiratory tract, kidneys and central nervous system were identified as target organs in rats and mice (ECHA, 2009).

In a sub-chronic study on rats, the animals were exposed to 0, 0.3, 0.6, 3 or 15 mg/L THF by the inhalation air for 4 hours/day and 5 days/weeks for 12 weeks. The study was only performed on male rats. In the highest exposure group, the following observations were seen: decreased weight gain, significant changes in the relative organ weight, significant local symptoms of irritation, morphological damages in the mucous membrane in the respiratory tract, and significant changes in the number of leukocyte, blood sugar and liver values. At both 3 and 15 mg/L the effects on the central nervous system were observed as well as effects on the function of the liver (i.e. increased blood sugar). At the dose 0.6 mg/L, lesions and effects on cells of the nasal mucous membrane were observed. At the dose 0.3 mg/L, no significant effects were observed apart from slight local irritation of the mucous membrane. NOAEC in this study was observed to 0.3 mg/L, corresponding to 100 ppm (Katahira et al. (1982) in ECHA (2009)).

In a sub-chronic 14 weeks inhalation study, both mice and rats were exposed to 0, 66, 200, 600, 1800 or 5000 ppm THF for 6 hours/day and 5 days/weeks. Two male mice exposed to 5000 ppm died in week 2-8 but all female mice and all rats survived the study period. Male mice exposed to 5000 ppm had similar body weight as the control group after the 14 weeks, while female mice had a significant increased body weight. All mice exposed to 1800 or 5000 ppm were at some point in a state of narcosis during the study periods. The mice exposed to 1800 ppm were fully awake and alert immediately after the daily exposure; however, the mice exposed to 5000 ppm needed up to two hours of recovery after the daily exposure. The rats exposed to 5000 ppm showed ataxia (lack of voluntary coordination of muscle movements). The absolute and relative weights of liver were significantly greater for mice exposed to 600 ppm or greater (for male mice), 1800 ppm or greater (for female mice), and 5000 ppm for female rats. The weight of the thymus was significantly reduced for male mice exposed to 600 ppm or higher. Effects on the spleen were observed in mice exposed to 5000 ppm THF. Minimal to mild hyperplasia of the forestomach was observed for rats exposed to 5000 ppm. NOAEC was determined to be 200 ppm for mice and 1800 ppm for rats (a study from 1990 in ECHA RSD (2014)).

In a sub-chronic inhalation study on rats, the animals were exposed to 0.00002, 0.002 and 0.02 mg/L THF for 24 hours/day and 7 days per week for 3 months. Only scarce information on the study exists and inclusion of a control group is uncertain (the information originates from an IUCLID data set without stated test method) (ECHA, 2009). At the highest exposure dose, lesions on the liver were observed as well as significant reduced muscular chronaxy (latency between electric stimulation and contraction of muscel), and other effects of the central nervous system. At dose 0.002 mg/L, reduced muscular chronaxy and damages on the liver were observed. No effects were observed at the lowest exposure dose. NOAEL was determined to be 0.00002 mg/L which corresponds to 0.07 ppm.

Human data
Only limited data on human exists for exposure to THF. In ECHA (2009), an example of a 55-year old man is described, who had been exposed to THF and 2-butanon for two years without sufficient protection. His nerves were damaged (neuropathy), but he recovered 3 months after the exposure stopped. TFH was assessed to be the likely cause of the effects (Viader et al. (1973) in ECHA (2009)).

Furthermore, an example exists of scientists who have tested the pharmacological effects of THF. They were exposed to an unknown dose of THF and developed serious headache in the back of the head (Gosselin et al. (1984) in ECHA (2009)). Other humans showed a significant decrease in the count of white blood cells after exposure to an unknown dose of THF. The persons performed spin tests of synthetics fibres where THF was used as solvent. The symptoms were found to be caused by THF exposure. The persons recovered after two years of treatment (Gosselin et al. (1984) in ECHA (2009)).

THF is stated to affect the central nervous system in humans and based on the effects observed in test animals, THF is also expected to cause irritation of mucous membrane and the upper parts of the respiratory tract and to cause damages on liver and kidneys. Chronic effects on humans are not reported (Hathaway et al. (1991) in ECHA (2009)).

Genotoxicity
In ECHA RSD (2014) several tests on *in vitro* gene mutation (performed on cells in mammals or bacteria (Ames test)) are reported, but these are negative. *In vivo* gene mutation tests are also negative. However, structural changes in the DNA of thymus in hamster foetus cells are reported in mutation tests (ECHA, 2009), but generally THF is not regarded to be mutagenic.

Toxicity to reproduction
Two studies from the nineties are reported in ECHA RSD (2014) and they investigated the effects on the reproduction system in rats. None of the two studies resulted in reprotoxic effects of THF.

In a study, pregnant rats were exposed to 0, 600, 1800 or 5000 ppm THF vapours for 6 hours/day for 7 days/week from gestation day 6 to 17. NOAEL for toxicity of dams and toxicity for the development was determined to be 600 ppm. The effects were seen in the central nervous system as severe sedation, malformations such as oedema and cryptochidism. None of the malformations was statistically significantly different from the control group (a study from 1992 in ECHA RSD (2014)). In a similar study on rats exposed to similar doses, NOAEL was determined to be 1800 ppm (a study from 1992 i ECHA RSD (2014)).

Carcinogenic effects
In a chronic inhalation study on mice and rats, the animals were exposed to 0, 200, 600 or 1800 ppm THF for 6 hours/day 5 days/week for 105 weeks. Male mice exposed to the highest dose were in a state of narcosis during and up to one hour after end of exposure. Several male mice did not survive 36 weeks (significantly more than in the control group). Survival rate and mean body weight for female mice and for male and female rats exposed to THF were similar to the control group. In female mice exposed to 1800 ppm, the incidence and the multiplicity of tumours in liver cells (hepatocellular neoplasm) were significantly greater than for the control group. The incidence of nephropathy in male mice exposed to 200 ppm was significantly higher than for the control group. For male rats exposed to 600 or 1800 ppm, adenoma and carcinoma were observed in the kidneys. Similar effects were not observed in female rats. Based on the observed hepatocelluar neoplasm in female mice, it was concluded that there was clear evidence for carcinogenic effects in female mice exposed to THF while no evidence for carcinogenic effects in male mice exists. Based on the observed tumours in the kidneys of the male rats, it was concluded that THF indicates carcinogenic effects in male rats, but not in female rats. Later it was concluded by a working group that this type of tumours is not expected in humans. NOAEC was determined to be 600 ppm for mice and 1800 ppm for rats (a study from 1998 in ECHA RSD (2014)).

Generally, this study demonstrates that THF has a potential to cause carcinogenic effects in male rats and female mice. However, the formation of tumour in male rats is not regarded as relevant for humans. The tumour formation in female mice results in a classification of THF as Carc. 2, H351 ”Suspected of causing cancer” (ECHA, 2009).

4.4.4.5 The critical effect and calculation of DNEL

The lowest identified NOAEC value for inhalation is 0.00002 mg/L (which corresponds to 0.07 ppm) found in a sub-chronic inhalation study on rats (ECHA, 2009). The effects were reduced muscular chronaxy and damages on the liver. This value is notably lower than the second lowest values identified in a different sub-chronic study on rats where NOAEC was determined to be 100 ppm. In this study the observed effects were seen on the central nervous system and on the function of the liver such as increased blood sugar (Katahira et al. (1982) in ECHA (2009)). The first mentioned study which resulted in the lowest identified NOAEC value of 0.007 ppm is poorly described and apparently does not use a control group. Furthermore, information on application of acceptable guidelines does not exist. It should be noted that the NOAEC value of 0.07 ppm is approximately 700 times less than the occupational threshold limit of 50 ppm or 148 mg/m^3. Because of the uncertainties of the validity of the mentioned study, the NOAEC value of 100 ppm from Katahira et al. (1982) in ECHA (2009) is applied in this health assessment.

This NOAEC value is adjusted for exposure and is converted to a value in mg/kg bw/day using the following formula applying standard values from ECHA (2012c) (Table R.8-2):

- Body weight of rats 0.250 kg
- Inhalation volume of rats 0.2 L/min

$$\begin{aligned}
&Adjusted\ NOAEC \\
&\quad = 100\ ppm\ \times 3.18\ mg/m^3/ppm\ \times \frac{5\ days\ per\ weeks}{7\ days\ per\ weeke} \times\ 0.0002\ m^3/min \\
&\quad \times \frac{4\ h/day\ x\ 60\ min/h}{0.250\ kg} \\
&\quad = 43.61\ \text{mg/kg bw/day}
\end{aligned}$$

The NOAEC value of 100 ppm is based on a sub-chronic study on rats. Therefore, an assessment factor of 4 is applied for rats, a factor of 2.5 for the rest of the differences between species, a standard assessment factor of 10 for differences between humans and a default assessment factor of 2 due to the use of a sub-chronic study. Thus, a total assessment factor of 200 is applied and the DNEL value of THF is 218 µg/kg bw/day.

4.4.5 Phenol

Phenol is registered hence information from registration dossiers is available via ECHAs database of registered substances (ECHA RSD, 2014). This data and the EU risk assessment of phenol (ECB, 2006) are the primary information sources used in the health assessment of phenol. Other sources are a toxicological profile of phenol by ATSDR (2008) and the LOUS report on phenol published by the Danish EPA (Møller et al., 2014).

Phenol is harmonised classified as (ECHA C&L, 2014):
- Acute Tox. 3, H301 – Toxic if swallowed
- Acute Tox. 3, H311 – Toxic in contact with skin
- Skin Corr. 1B, H314 – Causes severe skin burns and eye damage
- Acute Tox. 3, H331 – Toxic if inhaled
- Muta 2, H341 – Suspected of causing genetic defects
- STOT RE 2, H373 – May cause damage to organs through prolonged or repeated exposure

The occupational threshold limit of phenol is set to be 1 ppm or 4 mg/m^3. Phenol is marked with E and H on the Danish list of occupational threshold limit values. This means that the substance has an EU threshold limit and the substance can be absorbed through the skin (Danish Working Environment Authority, 2007).

4.4.5.1 Identification and physical and chemical parameters

The physical and chemical parameters of phenol are given in Table 10.

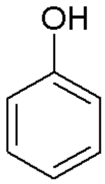
Chemical name (IUPAC)	Phenol
Synonyms	Phenol Carbolic acid, oxybenzene, monohydroxybenzol, phenylic alcohol, phenylhydroxide, hydroxybenzene, phenylic acid
CAS no. / EC no.	108-95-2 / 203-632-7
Molecular structure	
Molecular formula	C_6H_6O
SMILES code	C1(CCCCC1)O
Physical state	Solid substance, crystals, colourless to yellow or pink
Molecular weight	94.11 g/mol
Melting point	40.9 °C
Boiling point	181.8 °C
Density	1.07 g/cm^3 at 20 °C 1.13 g/cm^3 at 25 °C
Vapour pressure	0.2 hPa at 20 °C
Octanol water partition (log Kow)	1.47 at 30 °C 1.5 at 25 °C
Water solubility	Very soluble (> 10,000 mg/L) 84 g/L at 20 °C

TABLE 10
IDENTIFICATION AND PHYSICAL CHEMICAL PARAMETERS OF PHENOL (ECHA RSD (2014))

4.4.5.2 Uptake and distribution

Multiple studies show that oral and dermal exposure and inhalation results in rapid absorption in both animals and humans (ECHA RSD (2014) and ECB (2006)). High absorption rates are measured in animals after oral exposure. Oral absorption rates of 90, 85 and 84% 8 hours after exposure of 25 mg/kg for rats, sheep and pigs respectively, are measured (ECB, 2006). Experiences in rats show a dermal absorption rate of 80% (Hughes & Hall (1995) in ECHA RSD (2014)). Humans voluntarily exposed to phenol in concentration of 6-20 mg/m^3 via inhalation absorbed 60-88% of the substance (ECB, 2006). In the risk assessment, ECB (2006) uses an oral absorption rate and absorption via inhalation of 100%, and a dermal absorption rate of 80%. Similar values are used in this report, thus an inhalation rate of 100% after inhalation is applied.

Animal studies on rats on inhalation or oral exposure show that phenol quickly absorbs and metabolises by conjugation with sulphate and glucuronic acid. More than 75-90% is excreted via the urine during 24 hours after exposure and small amounts are excreted by faeces. Small amounts can also be identified in tissues 24 hours after exposure (a study from 1994 in ECHA RSD (2014) and ECB, 2006).

A study has investigated the metabolism of phenol in multiple animal species including humans. The study showed that the differences are great in absorption and metabolism of phenol, but also that similar metabolic mechanism exists for human and rats and similar amounts of phenol in urine after exposure. The highest absorption rates were identified in humans and rats after oral exposure. Therefore, it was concluded that rats are suitable models for the human metabolism of phenol (Capel et al. (1992) in ECHA RSD (2014)).

4.4.5.3 Irritation and allergy

Phenol is corrosive to both skin and eyes. Phenol has shown severe corrosive effects on skin of rats (in concentrations of 1 mL/kg bw for 1 minute) and rabbits (0.5 g for 24 hours) (ECHA RSD, 2014). A solution of 1% phenol is strongly corrosive to the skin (ECB, 2006) and a 5% phenol solution is assessed as irritating to the eyes of rabbits. Phenol has therefore a harmonised classification as corrosive: Skin Corr. 1B, H314 ”Causes severe skin burns and eye damage”.

Phenol is not regarded as skin sensitising. Both animal studies and studies in humans show that phenol does not elicitate contact dermatitis (ECHA RSD, 2014; ECB, 2006). No data on the sensitising effects of phenol after inhalation exists in animal studies, but phenol is not regarded as being sensitising when inhaled because allergenic effects are not observed in the working environment where phenol is used (ECB, 2006).

4.4.5.4 Acute and chronic effects

Several data exists from animal studies which states the acute toxicity of phenol. The data is given below and shows that phenol has a high acute toxicity for all exposure routes. However, LC_{50} values on inhalation are not available.

- LD_{50} oral rat: 650 mg/kg bw (Flickinger (1976) in ECHA RSD (2014))
- LD_{50} oral rat: 350-540 mg/kg bw (Deichmann et al. (1944) in ECHA RSD (2014))
- LD_{50} oral rabbit: 620 mg/kg bw (Deichmann et al. (1944) in ECHA RSD (2014))
- LD_{50} oral mouse: 300 mg/kg bw (Oetingen et al. (1946) in ECHA RSD (2014))
- LD_{50} oral mouse: 282 mg/kg bw (Horikawa et al. (1975) in ECHA RSD (2014))
- LC_0 inhalation rat[8]: 900 mg/m^3 (Flickinger (1976) in ECHA RSD (2014))
- LD_{50} dermal rat: 660 mg/kg bw (Conning et al. (1970) in ECHA RSD (2014))
- LD_{50} dermal rat: 525 mg/kg bw (Brown et al. (1975) in ECHA RSD (2014))
- LD_{50} dermal rabbit: 850 mg/kg bw (Flickinger (1976) in ECHA RSD (2014))
- LD_{50} dermal rabbit: 1400 mg/kg bw (Vernot et al. (1977) in ECHA RSD (2014))

The symptoms of acute toxicity of exposure to phenol are similar despite the exposure route and can be present minutes after exposure. The symptoms can be uneasiness, irritation or corrosive burns on skin, mucous membrane and eyes depending on the concentration. Exposure to vapours of phenol in a concentration of 47 ppm (180.9 mg/m^3) has shown to cause difficulties in breathing, irritation of skin, mucous membrane and eyes (Jensen, 2003). Furthermore, electrocardiographical alterations reported after acute oral and dermal exposure to phenol as well as vomiting and lethargy

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[8] LC_0 is the concentration where no animals died during the study

(ATSDR, 2008). Mortal doses for humans are reported to be at low doses as 140-290 mg/kg bw (ECB, 2006).

In an oral sub-acute study on mice, the animals were exposed to phenol in concentrations of 4.7, 19.5 and 95.2 mg/L in the drinking water. This caused anaemia at 19.5 mg/L (6.2 mg/kg bw/day). Furthermore, effects on the immune system as changes in T-cells were observed at the same dose. At the lowest exposure dose of 4.7 mg/L (1.8 mg/kg bw/day), a clear dose response reduction in the number of red blood cells was observed. Therefore, LOAEL was determined to be 1.8 mg/kg bw/day. Rats exposed to phenol via the drinking water did not show similar effects on T-cells in doses up to 301 mg/kg bw/day (ECB, 2006).

Rabbits were dermally exposed for 18 days (sub acute) for a 1.18 to 7.12% phenol solution on a skin area of 10-15 cm^2 for 5 hours per day (corresponding to 130-780 mg/kg bw/day). Systemic effects such as tremor at 260 mg/kg bw/day were observed. Mild skin irritation was observed at a solution of 3.56%. Mortal dose was 780 mg/kg bw/day. NOAEL was determined to be 130 mg/kg bw/day. NOAEC for local effects on skin was a 3.56% solution (Deichmann et al. (1950) in ECHA RSD (2014)).

Prolonged repeated exposure to phenol has shown effects on the nervous system and liver (in humans and animals) and for the hemopoietic system, immune system, kidneys and skin (on animals) (ECB, 2006). Repeated exposure has caused tremor of muscles and deficient coordination. Exposure to maximum concentrations (no exact concentration is stated) of phenol in the air for several weeks caused paralysis and severe damages on heart, liver, kidney and lungs, and in few cases death (Møller et al., 2014).

In an oral 14 days study on rats, these were exposed to 0, 4, 12, 40 or 120 mg/kg bw/day respectively. All rats exposed to the maximum concentration died during the 14 days of the study. Weight loss was observed among the animals in the group exposed to 120 mg/kg bw/day and effect such as vacuolar degeneration of liver cells and necrosis or atrophy of spleen or thymus at 40 mg/kg bw/day. One female rat had necrosis of the spleen at 12 mg/kg bw/day; therefore, NOAEL was determined to be 4 mg/kg bw/day in this study (Berman et al. (1995) in ECHA RSD (2014)).

In a chronic 103 weeks study, rats and mice were exposed to 0, 2500 or 5000 ppm (0, 200 or 450 mg/kg bw/day for rats and 0, 280 or 370 mg/kg bw/day for mice) daily in the drinking water. In both exposed groups, the water intake decreased in the period compared to the controls and for the groups exposed to the maximum dose, the body weight was reduced. No clinical signs of toxicity were observed. NOAEL was determined to be 5000 ppm or 450 mg/kg bw/day and 370 mg/kg bw/day for rats and mice respectively (NIH (1980) in ECHA RSD (2014)).

In a sub-chronic 13 week study on rats, these were exposed to 0, 200, 1000 or 5000 ppm (0, 18, 83, 308 mg/kg bw/day for male rats) daily in the drinking water. In concentrations of 5000 ppm, lower body weight was observed as well as reduced water and feed intake, abnormal clinical effects such as dehydration. Dehydration resulted in sacrifice of one female rat due to poor condition. At 1000 ppm reduced water intake was observed and in some cases dehydration. No effects were observed in animals exposed to 200 ppm. In all exposure doses, no neurological effects were observed. Based on this study, a NOAEL value of 5000 ppm (308 mg/kg bw/day) was found for neurotoxic effects and a NOEL for general effects of 200 ppm (18 mg/kg bw/day) (a study from 1998 in ECHA RSD (2014)). ECB (2006) describes that other studies report on effects of the nervous system such as tremor, loss of coordination, reduced body temperature and convulsion and states NOAEL for neurotoxic effects to be 200 ppm (18 mg/kg bw/day).

Rats were exposed (only close to the nose) for 14 days for phenol concentrations of 0, 0.5, 5 or 25 ppm (0, 1.9, 19 or 96 mg/m^3) for 6 hours/day for 5 days/week. NOAEC of 25 ppm (96 mg/m^3) was determined as signs of toxicological effects, changes in feed intake and body weight were not observed (Hofmann et al. (2001) in ECHA RSD (2014)).

In a 90 days sub-chronic inhalation study on monkeys, rats and mice, the animals were exposed for 8 hours/day, 5 days/week for air concentrations of 5 ppm (19.6 mg/m^3). No systemic effects at this dose were observed in any of the animals (a study from 1961 in ECHA RSD (2014)).

Limited data is available for chronic effects on phenol in humans. ECB (2006) describes workers exposed to phenol for 13.5 years in average showed signs of liver toxicity. Here the time-weighted mean concentration was 21 mg/m^3. This value is regarded as LOAEL for systemic effects. In comparison, the threshold limit of phenol in the working environment is 4 mg/m^3.

Genotoxicity
Phenol does not induce gene mutations according to the major part of the available bacteria tests (ECB, 2006). In *in vitro* tests in mammals (ovarian cells from Chinese hamsters) is meanwhile observed as positive such as chromosomal changes and gene mutations. Positive reactions are furthermore observed in several indicator tests. *In vivo* tests have mainly resulted in negative reactions, but also minor positive reactions (ECB, 2006). Due to this, phenol is classified as Muta 2, H341 (”Suspected of causing genetic defects”).

Carcinogenic effects
In the 103 week study on rats and mice described above, no evidence of increased tumour formation was seen (NIH (1980) in ECHA RSD (2014)). Phenol is therefore not regarded as carcinogenic.

Reproductive effects
Available data on toxic effects for the reproductive system does not exist for humans. In an oral sub-chronic two generation study, rats were exposed for 13 weeks to 0, 200, 1000 or 5000 ppm (0, 15/20, 71/93 or 300/320 mg/kg bw/day for male rats or female rats respectively) daily in the drinking water. Among the observed effects were reduced body weight, reduced water and feed intake, and increased weight of organs at the maximum dose. No observation of clinical, haematological or immunological effects was made in male rats after the 13 weeks study period. Furthermore, reduced survival and delayed sexual maturation were observed in the group of animals exposed to maximum dose. The effects were assumed to be caused by the reduced water consumption due to flavour aversion to the drinking water. NOAEL for phenol in the drinking water was determined to be 1000 ppm (71 mg/kg bw/day) (Ryan et al. (2001) in ECHA RSD (2014)). On developmental toxicity, a NOAEL was determined to be 93 mg/kg bw/day based on the behaviour of the pubs. ECB (2006) concluded no evidence of hazardous effects on the reproductive system of phenol.

4.4.5.5 The critical effects and calculation of DNEL

The lowest identified value of inhalation is the value given from the working environment where humans have been exposed for several years to phenol in a mean concentration of 21 mg/m^3. The critical effect here is liver toxicity. This value is regarded as a LOAEC value based on a 5 days work week. For the general population, the exposure will be 7 days per week in the home. Similar, the exposure during work is 8 hours per day while in this report the exposure is based on 6 hours exposure to phenol emitted from an energy-saving bulb. The LOAEC value is adjusted for exposure and is converted to a value with a unit of mg/kg bw/day using the following calculation where standard values from ECHA (2012c)) are applied:

- Body weight of a working human is 70 kg
- Inhalation volume of humans for light activity (workers) is 10 m^3/8 h

$$Adjusted\ LOAEC = 21\ mg/m^3 \times \frac{5\ days\ per\ week}{7\ days\ per\ week} \times \frac{10\ m^3/8\ h\ \times 6\ h}{70\ kg}$$

= 1.6 mg/kg bw/day

The LOAEC value of 21 mg/m³ is based on chronic observations in humans. Therefore, an assessment factor of 1 is applied for humans and a default assessment factor of 3 is applied due to the use of a LOAEC value instead of a NOAEC value. Thus, a total assessment factor of 30 is applied which results in a DNEL value of phenol of 54 µg/kg bw/day. It should be noted that this calculated DNEL value of phenol is a factor of 10 lower than the TDI value (Tolerable Daily Intake) of 0.5 mg/kg bw/day which is given by EFSA on food (Møller et al., 2014). It is approximately 7 times lower than the DNEL value of 0.4 mg/kg bw/day on oral exposure given in ECHA RSD (2014). This means that the DNEL value calculated here for the risk assessment in this report is a conservative value.

4.5 Risk assessment

In the risk assessment, the calculated exposure (the calculated inhaled amount of substance based on the analysis result) is set in relation to the DNEL value which is stated for each of the five substances in section 4.4 above.

The calculated RCR values for these five substances are stated in Table 11 below and are calculated by means of the following formula:

$$RCR_{\text{light bulb 3B (benzene),adult}} = \frac{D_{inh}}{DNEL} = \frac{0.013\ \mu g/kg\ bw/day}{24.5\ \mu g/kg\ bw/day} = 0.00052$$

Name of substance	Person	D_{inh} (µg/kg bw/day)	DNEL (µg/kg bw/day)	RCR (-)
Benzene (light bulb 3B)	Adult	0.013	24.5	0.00052
	Child	0.076	24.5	0.00310
N,N-dimethyl-formamide (light bulb 1)	Adult	0.112	166	0.00067
	Child	0.670	166	0.00404
Octamethylcyclo-tetrasiloxane (light bulb 31)	Adult	0.350	3900	0.00009
	Child	2.100	3900	0.00054
Tetrahydrofuran (light bulb 13)	Adult	0.233	218	0.00107
	Child	1.4	218	0.00642
Phenol (light bulb 3B)	Adult	0.085	54	0.00157
	Child	0.510	54	0.00944

TABLE 11
RCR VALUES FOR THE FIVE SELECTED SUBSTANCES DEGASSED FROM ENERGY-SAVING LIGHT BULBS. THE VALUES ARE BASED ON THE HIGHEST MEASURED DEGASSED AMOUNT AND THAT THE PERSONS ARE EXPOSED FOR 6 HOURS IN A VOLUME OF 1 M³ AROUND THE ENERGY-SAVING LIGHT BULB.

It is seen from Table 11 that none of the RCR values exceeds 1. On the contrary, the values are far below 1 which means that none of the five emitted and selected substances one by one constitutes a health problem despite the fact that worst-case scenarios are used in the calculation of RCR. The w*orst-case* scenarios in this project are based on calculations where the maximum degassed concentrations for each substance are used and where the persons inhale the total amount of substance which degasses from the light bulbs, i.e. possible ventilation/air exchange is not taken into account.

As the survey and the analysis results show, an energy-saving light bulb can degas many different chemical substances. The total exposure of these substances can be added if the substances have the same effect on the same target organ. However, the low RCR values mean that degassing of many different chemical substances at the same time is not expected to constitute a health problem as the amounts of the individual degassed substances are so low that the total RCR will not exceed 1. As an example, light bulb number 1 degassed in total 16 different substances during the 6 lighting hours.

The above calculations of RCR values only apply for health effects where a threshold value can be defined. A threshold value cannot be stated for the carcinogenic properties of benzene (section 4.4.1). Thus, as in this case, even a small exposure to benzene is undesirable.

The average air concentration of benzene at the west coast of Sweden (i.e. relevant for Danish conditions) was measured about 20 years ago to 2 µg/m³ (EU Position Paper, 1998). If comparison of data for benzene concentrations in the air from the USA which is halved in the period 1994-2009[9] is made, the air concentration around Denmark today would probably also be the half, i.e. approx. 1 µg/m³. In OECD SIDS (2005), it is stated that consumers can be short-term exposed to benzene when filling up petrol in a concentration of 1300 µg/m³ and when painting in a concentration of 17 µg/m³ (prolonged exposure). By way of comparison, the measured concentrations of benzene from energy-saving light bulbs are thus at level with the benzene concentration in the outdoor air and the benzene concentration when painting but far below the benzene concentrations when filling up petrol.

Finally it can be mentioned that the number of lighting hours for the light bulbs before the analysis for the analysed light bulbs is unknown. The opinion is that both new and old light bulbs were sent from consumers to the project team. The age of the light bulb may have an influence on the degassing. A theory is that the degassing is due to glue residues from the energy-saving light bulb which volatilise at heating. In this case, it is assumed that the degassing will be highest at the beginning of the life of the energy-saving light bulb and will decrease over time.

The K-Tipp study (K-Tipp, 2011, section 2.1.2.12) is the study which until now has made the most comprehensive test of degassed substances from energy-saving light bulbs. Unlike the present study, the K-Tipp study has not had an aim to examine whether there is a connection between odour and release of chemical substances which can constitute a risk for the consumers. Instead the K-Tipp study has examined newly purchased energy-saving light bulbs for degassing of substances, intensity of light, colour reproduction and many other parameters. Table 12 shows the highest and lowest concentrations of 8 substances for both the K-Tipp study and this study. In the K-Tipp study, the results are based on a total concentration after 7 days of lighting hours while for this study, it is based on 6 lighting hours. Furthermore, degassing from the light bulbs in the K-Tipp test was examined in climate chambers where air exchange took place (see section 2.1.2.12).

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[9] http://cfpub.epa.gov/eroe/index.cfm?fuseaction=detail.viewInd&lv=list.listByAlpha&r=231333&subtop=341&part=meta

Name of substance	The K-Tipp study (K-Tipp, 2011)			This study		
	Number of light bulbs with identified substance	Lowest measured conc. (µg/m³)	Highest measured conc. (µg/m³)	Number of light bulbs with identified substance	Lowest measured conc. (µg/m³)	Highest measured conc. (µg/m³)
1-Butanol	100%	8	449	84%	21	2300
Benzene	86%	1	20	76%	3.8	76
Acetic acid	0%	-	-	72%	1100	110
Tetrahydrofuran	100%	25	355	64%	41	1400
Octamethylcyclotetrasiloxane	64%	1	65	52%	250	2100
Hexamethylcyclotrisiloxane	100%	1	65	52%	220	4800
N,N-dimethylformamide	100%	2	108	40%	5.8	670
Phenol	100%	52.8	730	4%	510	510

TABLE 12
NUMBER OF LIGHT BULBS WITH IDENTIFIED SUBSTANCE AS WELL AS THE LOWEST AND HIGHEST IDENTIFIED CONCENTRATION.
NOTE THAT THE CONCENTRATIONS FOR THE K-TIPP STUDY IS THE TOTAL CONCENTRATION AFTER 7 DAYS OF LIGHTING HOURS WHILE FOR THE PRESENT STUDY IT IS THE TOTAL CONCENTRATION AFTER 6 LIGHTING HOURS.

According to Table 12, the measured lowest and highest concentrations of benzene, N,N-dimethylformamide, octamethylcyclotetrasiloxane and tetrahydrofuran are higher in this study compared to the K-Tipp study. Phenol was found in one light bulb in this study which is at the level with the result in the K-Tipp study where on the other hand, phenol was identified in all analysed light bulbs. Acetic acid was identified in 18 light bulbs out of 25 in this study while acetic acid was not degassed from any light bulb in the K-Tipp study.

Possible explanations of the higher measured concentrations in this study despite a shorter period of lighting hours compared with the K-Tipp study are that the air is not exchanged during the tests in this study as it is in the climatic chambers used in the K-Tipp study. When exchanging the air the concentration of the substances is diluted. Furthermore, it is possible that the life of the light bulbs has an importance of which substances and in which concentrations these are degassed from the energy-saving light bulbs. It is known that the 14 analysed light bulbs in the K-Tipp study were quite newly purchased light bulbs which had never been turned on. On the other hand, the age as well as the number of lighting hours is not known for the light bulbs which were analysed in this study. However, it is for certain known that the light bulbs have been turned on in the consumer's home as this has been necessary for the consumer in order to register the odour of the light bulb. It is a possibility that older light bulbs degas breakdown products from other substances which might explain why acetic acid is identified in 18 out of 25 analysed light bulbs in this project but is not seen in the K-Tipp study. However, this is solely a theory which cannot be confirmed on basis of the results in this project. Another possible explanation might be that the substances are degraded or react with each other when they are kept in the tedlar bag.

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Appendix 1: Test results from ALAB of 14 tested CFLs for K-Tipp, 2011

The test results of the 126 identified released gases from the K-Tipp study are shown in this appendix. For each of the identified substances in this test, the classification of the substances as well as the notified self-classification has been listed unless a harmonised classification of the substance is available. It must be emphasised that this self-classification has not been evaluated, and that differences of opinion exist between different notifiers when it comes to the self-classification. The full classification is not noted but exclusively whether the substance has one of the below classifications as these classifications are considered as the most relevant in relation to the assessment whether the substances might constitute a health risk.

- Carc. 1A, 1B and 2,
- Muta. 1A, 1B and 2,
- Repr. 1A, 1B and 2,
- Resp. Sens. 1, 2 abd 3, as well as
- STOT RE 1, 2 and 3.

Furthermore, the lowest odour threshold value of the substances is stated if it could be found in the literature. References to the specific odour threshold values are marked with footnotes in the table. It has to be noted that odour threshold values are subjective and will depend on the individual person when the odour is experienced. However, it is the lowest odour threshold value which is reported in the references that is stated in the table. Finally for all the identified substances, it is stated in how many light bulbs (out of the 14 tested light bulbs) the substance is identified as degassed from.

In the table, the following markings are used to indicate substances which are particularly interesting in this test from K-Tipp:

- Light green background colour: The substance is relevant because it occurs in a concentration where it might be smelled, i.e. the concentration is higher than the odour threshold limit.
- **Bold type**: The substance is relevant because it has one of the above classifications.
- *Italic and underlined text*: The substance is relevant because it occurs in high concentrations (> 50µg/m^3).

No.	Substance name	CAS no.	Lowest odour threshold value (µg/m^3)*	Lowest measured value (µg/m^3)	Highest measured value (µg/m^3)	Identified in no. of light bulbs	Harmonised classification	Relevant notified self-classification**
1	**n-nexane**	**110-54-3**		7	7	**1**	**Repr. 2** **STOT RE 2**	-
2	n-heptane	142-82-5	41,000[1]	1	5	2	None	None
3	n-octane	111-65-9	28[1]	1	5	2	None	None
4	n-nonane	111-84-2		3	3	1	None	None
5	n-decane	124-18-5	3,087[2]	1	2	2	None	None
6	n-undecane	1120-21-4	7,800[1]	1	1	1	None	None
7	n-dodecane	112-40-3	14,500[1]	1	1	1	None	None
8	n-tridecane	629-50-5	17,000[1]	1	1	2	None	None
9	n-tetradecane	629-59-4		1	3	9	None	None
10	n-pentadecane	629-62-9		1	10	14	None	None
11	n-hexadecane	554-76-3		1	31	14	None	None
12	*n-heptadecane*	*629-78-7*		*1*	*56*	*14*	*None*	*None relevant*
13	n-octadecane	593-45-3		1	34	12	None	None relevant
14	n-nonadecane	629-29-5		25	25	1	None	None

No.	Substance name	CAS no.	Lowest odour threshold value (µg/m^3)*	Lowest measured value (µg/m^3)	Highest measured value (µg/m^3)	Identified in no. of light bulbs	Harmonised classification	Relevant notified self-classification**
15	n-icosane	112-95-8		1	2	4	None	None relevant
16	2,2,4,6,6-pentamethylheptane	13475-82-6		1	3	3	None	None relevant
17	1-heptene	592-76-7		1	4	3	None	None relevant
18	**1-dodecene**	**112-41-4**		**3**	**5**	**2**	**None**	**Carc. 1B**
19	1-tridecene	2437-56-1		2	2	1	None	None relevant
20	**Benzene**	**71-43-2**	**4,500**[3]	**1**	**20**	**12**	**Carc. 1A** **Muta. 1B** **STOT RE 1**	-
21	***Toluene***	***108-88-3***	***600***[2]	***8***	***237***	***14***	***Repr. 2*** ***STOT RE 2***	-
22	***Ethylbenzene***	***100-41-4***	***2,000***[1]	***1***	***113***	***8***	***None relevant***	***Carc. 2*** ***STOT RE 2***
23	***m-/p-xylene***	***1330-20-7***	***78***[2]	***1***	***118***	***10***	***None relevant***	***STOT RE 2***
24	o-xylol	95-47-6	-	2	24	7	None relevant	None relevant
25	***Styrene***	***100-42-5***	***160***[1]	***1***	***209***	***13***	***None relevant***	***Carc. 2*** ***STOT RE 1***

No.	Substance name	CAS no.	Lowest odour threshold value (µg/m3)*	Lowest measured value (µg/m3)	Highest measured value (µg/m3)	Identified in no. of light bulbs	Harmonised classification	Relevant notified self-classification**
26	1,3,5-trimethylbenzene	108-67-8		1	8	2	None relevant	None relevant
27	1,2,4-trimethylbenzene	95-63-6		2	14	2	None relevant	None relevant
28	1,2,3-trimethylbenzene	526-73-8		1	1	1	None	None relevant
29	Cumene	98-82-8	120 [1]	1	1	2	None relevant	None relevant
30	n-propylbenzene	103-65-1		3	9	2	None relevant	None relevant
31	3-/4-ethyltoluene	620-14-4 /622-96-8		1	49	6	None	None relevant
32	2-ethyltoluene	611-14-3		2	12	2	None	None relevant
33	**p-cymene**	**99-87-6**		**1**	**1**	**1**	**None**	**STOT SE 3**
34	Indane	496-11-7		2	8	2	None	None relevant
35	1-ethyl-3,5-dimethylbenzene	934-74-7		1	1	1	None	None relevant
36	1,2,3,5-tetramethylbenzene	95-93-2		7	7	1	None	None relevant
37	**1,2,3,4-tetrahydro-naphthalene**	**119-64-2**		**0.1**	**0.1**	**4**	**None relevant**	**Carc. 2**
38	**Naphthalene**	**91-20-3**	**80 [1]**	**0.1**	**18.8**	**12**	**Carc. 2**	**-**
39	2-methylnaphthalene	91-57-6	58 [3]	0.1	3.9	13	None	None relevant

No.	Substance name	CAS no.	Lowest odour threshold value (µg/m3)*	Lowest measured value (µg/m3)	Highest measured value (µg/m3)	Identified in no. of light bulbs	Harmonised classification	Relevant notified self-classification**
40	1-methylnaphthalene	90-12-0		0.1	1.3	10	None	None relevant
41	2,7-dimethylnaphthalene	582-16-1	43 [3]	0.1	0.8	11	None	None relevant
42	1,3-dimethylnapthalene	575-41-7	43 [3]	0.1	0.8	12	None	None relevant
43	1,4-dimethylnaphthalene	571-58-4	43 [3]	0.1	0.4	6	None	None
44	1,2-dimethylnaphthalene	573-98-8	43 [3]	0.1	0.1	2	None	None relevant
45	**Chloroform**	**67-66-3**		**1**	**1**	**1**	**Carc. 2** **Repr. 2** **STOT RE 1**	-
46	**1,2-dichlorethane**	**107-06-2**	**445,500 [3]**	**1**	**7**	**3**	**Carc. 1B**	-
47	**Chlorobenzene**	**108-90-7**	**980 [3]**	**1**	**5**	**5**	**None**	**Carc. 1A** **Muta. 1B** **Repr. 2** **Resp. sens. 1** **STOT RE**
48	Pin-2(3)-ene	80-56-8	100 [2]	1	1	1	None	None relevant
49	Limonene	138-86-3	211 [2]	1	1	1	None relevant	None relevant

No.	Substance name	CAS no.	Lowest odour threshold value (µg/m^3)*	Lowest measured value (µg/m^3)	Highest measured value (µg/m^3)	Identified in no. of light bulbs	Harmonised classification	Relevant notified self-classification**
50	Eucalyptol	470-822-6		2	2	1	None	None
51	Longifolene	475-20-7		1	5	3	None	None relevant
52	*Hexamethyl-cyclotrisiloxane (D3)*	*541-05-9*		*3*	*159*	*14*	*None*	*None relevant*
53	***Octamethylcyclo-tetrasiloxane (D4)***	***556-67-2***		***1***	***65***	***9***	***Repr. 2***	***-***
54	Decamethylcyclo-pentasiloxane (D5)	541-02-6		1	24	6	None	None relevant
55	*Isobutanol*	*78-83-1*	*3,300* [1]	*10*	*272*	*7*	*None relevant*	*None relevant*
56	*1-butanol*	*71-36-3*	*90* [1]	*8*	*449*	*14*	*None relevant*	*None relevant*
57	*2-ethyl-1-hexanol*	*104-76-7*	*500* [1]	*5*	*112*	*14*	*None*	*None relevant*
58	1-dodecanol	112-53-8	15 [3]	1	10	9	None	None relevant
59	Methylacetate	79-20-9	610,000	1	2	8	None	None relevant
60	**Vinylacetate**	**108-05-4**	**360** [3]	**2**	**5**	**2**	**Carc. 2**	-
61	Ethylacetate	141-78-6	2,410 [1]	1	1	1	None relevant	None relevant
62	Methylmethacrylate	80-62-6	205 [3]	1	2	3	None relevant	None relevant

No.	Substance name	CAS no.	Lowest odour threshold value ($\mu g/m^3$)*	Lowest measured value ($\mu g/m^3$)	Highest measured value ($\mu g/m^3$)	Identified in no. of light bulbs	Harmonised classification	Relevant notified self-classification**
63	Butylformiate	592-84-7	70,890 [3]	1	17	11	None relevant	None relevant
64	n-butylacetate	123-86-4	33,133 [3]	1	2	6	None relevant	None relevant
65	Methylbenzoate	93-58-3		1	3	4	None	None relevant
66	Bornylacetate	76-49-3		1	1	1	None	None relevant
67	Butanone	78-93-3	737 [3]	1	14	13	None relevant	None relevant
68	Methylisobutylketone	108-10-1	410 [3]	1	19	4	None relevant	None relevant
69	Cyclohexanone	108-94-1	83 [1]	1	7	10	None relevant	None relevant
70	3-heptanone	106-35-4		1	6	6	None relevant	None relevant
71	Acetophenone	98-86-2	834 [3]	1	73	14	None relevant	None relevant
72	**Benzophenone**	**119-61-9**		**12**	**12**	**1**	**None**	**STOT RE 2**
73	2-methylfuran	534-22-5	90,450 [3]	0.08	0.62	13	None	None relevant
74	***Tetrahydrofuran***	***109-99-9***	***7,375 [3]***	***25***	***355***	***14***	***Carc. 2***	***-***
75	**1-methoxy-2-propanol**	**107-98-2**	**360,000 [3]**	**1**	**1**	**4**	**None relevant**	**Repr. 1B**

No.	Substance name	CAS no.	Lowest odour threshold value (µg/m^3)*	Lowest measured value (µg/m^3)	Highest measured value (µg/m^3)	Identified in no. of light bulbs	Harmonised classification	Relevant notified self-classification**
76	***Ethylenglycol***	***107-21-1***	***62,500***[3]	***6***	***71***	***6***	***None relevant***	***Muta. 1B*** ***Repr. 1B*** ***STOT RE 1 og 2***
77	1,2-Propylenglycol	57-55-6		2	8	4	None	None relevant
78	**1,2-diethoxyethane**	**629-14-1**		**1**	**1**	**1**	**Repr. 1A**	**-**
79	**2-butoxyethanol**	**111-76-2**		**1**	**5**	**9**	**None relevant**	**Repr. 2** **STOT RE 2**
80	***2-(-2-metoxyetoxy)ethanol***	***111-77-3***		***6***	***178***	***2***	***Repr. 2***	***-***
81	Dipropylenglycol-monomethylether (DPGMM)	34590-94-8		1	1	3	None	None relevant
82	**Diethylenglycol-monoethylether (DEGME)**	**111-90-0**		**2**	**3**	**2**	**None**	**Repr. 1B og 2** **STOT RE 1 og 2**
83	Diethylenglycol-monobutylether (DEGMB)	112-34-5		8	17	2	None relevant	None relevant
84	**Ethylenglycol-monophenylether (EGMP)**	**122-99-6**		**1**	**1**	**1**	**None relevant**	**Carc. 2** **Muta. 2**

No.	Substance name	CAS no.	Lowest odour threshold value (µg/m^3)*	Lowest measured value (µg/m^3)	Highest measured value (µg/m^3)	Identified in no. of light bulbs	Harmonised classification	Relevant notified self-classification**
85	Tripropylenglycol-monobutylether (TPGMB)	55934-93-5		1	1	1	None	None relevant
86	Propylenglycol-monomethyletheracetate (PGMMA)	108-65-6		30	30	1	None relevant	None relevant
87	**2-butoxyethyl acetate**	**112-07-2**		**1**	**1**	**1**	**None relevant**	**STOT SE 3**
88	Texanol	25265-77-4		1	1	2	None	None relevant
89	***TXIB***	***6846-50-0***		***1***	***83***	***9***	***None***	***STOT RE 2***
90	*n-butanal*	*123-72-8*	*28* [1]	*2*	*165*	*14*	*None relevant*	*None relevant*
91	*n-pentanal*	*110-62-3*	*22* [1]	*1*	*88*	*14*	*None*	*None relevant*
92	*n-hexanal*	*66-25-1*	*58* [1]	*1*	*90*	*14*	*None*	*None relevant*
93	*n-heptanal*	*111-71-7*	*23* [1]	*1*	*53*	*13*	*None*	*None relevant*
94	n-octanal	124-13-0	7 [1]	1	48	14	None	None relevant
95	n-nonanal	124-19-6	14 [1]	2	45	14	None	None relevant
96	n-decanal	112-31-2		2	17	5	None	None relevant
97	Benzaldehyde	100-52-7	0.8 – 183 [3]	1	27	14	None relevant	None relevant

No.	Substance name	CAS no.	Lowest odour threshold value (µg/m^3)*	Lowest measured value (µg/m^3)	Highest measured value (µg/m^3)	Identified in no. of light bulbs	Harmonised classification	Relevant notified self-classification**
98	**1,4-dioxane**	**123-91-1**	**11** [3]	**1**	**6**	**5**	**Carc. 2**	**-**
99	*Butyrolactone*	*96-48-0*		*5*	*251*	*13*	*None*	*None relevant*
100	**Diethylphthalate**	**84-66-2**		**0.5**	**0.9**	**2**	**None**	**Repr. 2** **STOR RE 2**
101	***Diisobutylphthalate***	***84-69-5***		***1***	***139***	***9***	***Repr. 1B***	***-***
102	Di(n-butyl)phthalate	84-72-2		1	13	6	None	None
103	***Phenol***	***108-95-2***	***179*** [3]	***52.8***	***730***	***14***	***Muta. 2*** ***STOT RE 2***	***-***
104	**o-cresol**	**95-48-7**	**1** [3]	**0.2**	**7.1**	**14**	**None relevant**	**Repr. 2**
105	**m/p-cresol**	**108-39-4 /106-44-5**	**1** [3]	**1.5**	**20.0**	**14**	**None relevant**	**Repr. 2/None relevant**
106	**2,6-xylenol**	**576-26-1**	**4** [1]	**0.1**	**0.3**	**9**	**None relevant**	**STOT RE 1**
107	**2,4-Dimethylphenol**	**105-67-9**	**4** [1]	**0.1**	**1.7**	**6**	**None relevant**	**STOT RE 2**
108	2,3-Dimethylphenol	526-75-0	4 [1]	0.1	1.5	9	None relevant	None relevant
109	3,5-Dimethylphenol	108-68-9	4 [1]	0.1	0.4	7	None relevant	None relevant
110	3,4-Dimethylphenol	95-65-8	4 [1]	0.1	0.4	7	None relevant	None relevant

No.	Substance name	CAS no.	Lowest odour threshold value (µg/m^3)*	Lowest measured value (µg/m^3)	Highest measured value (µg/m^3)	Identified in no. of light bulbs	Harmonised classification	Relevant notified self-classification**
111	2,3,5-Trimethylphenol	697-82-5		0.2	0.2	1	None	None relevant
112	2-Ethylphenol	90-00-6		0.1	0.3	4	None	None relevant
113	4-Ethylphenol	123-07-9		0.2	0.6	6	None	None relevant
114	2-Isopropylphenol	88-69-7		2.8	4.8	3	None	None relevant
115	4-Isopropylphenol	99-89-8		0.1	4.9	10	None	None relevant
116	**2,4-Di-tert-butylphenol**	**96-76-4**		**0.5**	**7.7**	**14**	**None**	**STOT RE 2**
117	2,6-Di-tert-butyl-4-methylphenol (BHT)	128-37-7		0.1	4.0	8	None	None
118	2-Phenylphenol	90-43-7		0.1	0.1	1	None relevant	None relevant
119	2-Chlorophenol	95-57-8	19[3]	0.1	0.5	10	None relevant	None relevant
120	3-Chlorophenol	108-43-0	19[3]	0.2	0.2	2	None relevant	None relevant
121	4-Chloro-2-Methylphenol	1570-64-5		0.1	0.1	1	None relevant	None relevant
122	2-Bromphenol	95-56-7		0.3	18.7	14	None	None relevant
123	4-Bromphenol	106-41-2		0.1	3.6	14	None	STOT SE 3
124	**2,4,6-Tribromphenol**	**118-79-6**		**0.1**	**2.0**	**11**	**None**	**Repr. 2** **STOT RE 2**

No.	Substance name	CAS no.	Lowest odour threshold value (µg/m3)*	Lowest measured value (µg/m3)	Highest measured value (µg/m3)	Identified in no. of light bulbs	Harmonised classification	Relevant notified self-classification**
125	**Acrylnitrile**	**107-13-1**	**8,100** [3]	**2**	**7**	**2**	**Carc. 1B**	
126	***N,N-Dimethylformamide***	***68-12-2***	***300,000*** [3]	***2***	***108***	***14***	***Repr. 1B***	

TABLE 13
TEST RESULTS (K-TIPP, 2011) – TEST OF 14 ENERGY-SAVING LIGHT BULBS AND IDENTIFICATION OF CHEMICALS EMITTED FROM THE LIGHT BULBTS. THE CLASSIFICATION OF THE SUBSTANCES FROM ECHAS C&L INVENTORY DATABASE IS LISTED AS WELL AS THE ODOUR THRESHOLD VALUE FOR SELECTED SUBSTANCES.

* IT SHOULD BE NOTED THAT AN ODOUR THRESHOLD VALUE HAS NOT BEEN LISTED FOR ALL SUBSTANCES – ODOUR THRESHOLD VALUES HAVE NOT BEEN IDENTIFIED FOR ALL SUBSTANCES, AND A SEARCH FOR ODOUR THRESHOLD VALUES HAS NOT BEEN PERFORMED FOR THE SUBSTANCES THAT ONLY WERE IDENTIFIED TO BE EMITTED FROM A FEW OF THE LIGHT BULBS.
** THE LISTED SELF-CLASSIFICATION HAS NOT BEEN EVALUATED. PLEASE NOTICE THAT DIFFERENCES OF OPINION DO EXIST BETWEEN THE DIFFERENT NOTIFIERS OF THE SELF-CLASSIFICATION.
1 – DANISH EPA, 2003
2 – WOLKOFF ET AL., 2006
3 – JON H. RUTH, 1986

Appendix 2: Questionnaire on the website of the Danish EPA

At the beginning of the project period (from mid-May 2014 to mid-July 2014), a short questionnaire was set up on the homepage of the Danish EPA. The questionnaire approached consumers who had experienced that one or more of their energy-savning light bulbs smelled.

The questionnaire and its text on the homepage of the Danish EPA are shown below.

Odour from energy-saving light bulbs

The Danish EPA needs your help if you have experienced energy-saving light bulbs which smell when they are turned on.

Occasionally, the Danish EPA is contacted by consumers who experience unpleasant odour from energy-saving light bulbs when they are turned on. Typically, the inquiries are about the cause of the odour from the energy-saving light bulbs and whether it is hazardous to health.

Therefore, the Danish EPA wants to examine which gases the smelling energy-saving light bulbs release and whether the odour constitutes a health risk for the consumer. Some of the central challenges are that it is far from all light bulbs which smell and there is no knowledge stating why some light bulbs smell.

Therefore, the Danish EPA looks for information from consumers who have experienced odour from an energy-saving light bulb. The Danish EPA hopes that the consumers who have experienced odour from an energy-saving light bulb and perhaps are still in possession of the smelling energy-saving light bulb want to write to the Danish EPA via the form below. In this way the consumers get the possibility of having exactly their smelling energy-saving light bulb examined in details.

The following questions were inserted as a formula with reply possibilities (fixed answers in some cases):
If you have experienced odour from an energy-saving light bulb and you might want to have your smelling energy-saving light bulb examined in details we ask you kindly to answer the questions in the below formula:

1. Have you experienced an energy-saving light bulb which smells (yes/no)?
2. How can the odour shortly be described? (for instance, chemical, poisonous, burnt, sweet, “like in a hospital”, “like a hair-drier”, “fishlike”)
3. How bad do you experience the odour? (on a scale from 1 – 5 where 1 is weak and 5 is strong)
4. When does the odour arise? (approx. number of minutes/hours after the light bulb is turned on)
5. Do you still have the energy-saving light bulb which smells? (yes/no)
6. If yes, are you interested in havng the energy-saving light bulb examined? (yes/no)

(If you answer yes to the last two questions, we ask you kindly to fill in contact data and thereafter you will be contacted by the Danish EPA’s consultant in this project (FORCE Technology). Please note, that you get a compensation for your expenses in connection with forwarding of the energy-saving light bulb.

Contact data: Please fill in the below
Name:
Address:
Telephone no.

E-mail:
Click: Send

Return message: Thank you very much for your inquiry. You will be contacted by an employee from FORCE Technology as soon as possible.

Appendix 3: Analysis results

Light bulb no. 1

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Acetic acid	64-19-7	1,100
Tetrahydrofuran	109-99-9	920
1-Butanol	71-36-3	680
Methylvinylketone	78-94-4	290
Butanal	123-72-8	230
Pentanal	110-62-3	230
Acetone	67-64-1	170
2-Methyl-2-propanol	75-65-0	120
Methacrolein	78-85-3	83
Methylisobutylketone (MIBK)	108-10-1	69
2,5-Dihydrofuran	1708-29-8	67
2-Pentanone	107-87-9	59
1-Brombutane	109-65-9	40
2-Propenal	107-02-8	39
3-Buten-1-ol	627-27-0	27

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
N,N-Dimethylformamide	68-12-2	670
Benzene	71-43-2	< 1
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.
THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 3A

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
2-Ethyl-1-hexanol	104-76-7	1,500
2-Ethylacrolein	922-63-4	52
1-Butanol	71-36-3	21

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	3.8
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 3B

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Octamethylcyclotetrasiloxane	556-67-2	910
Hexamethylcyclotrisiloxane	541-05-9	870
Phenol	108-95-2	510
1-Butanol	71-36-3	490
Decamethylcyclopentasiloxane	541-02-6	300
2,5-Dihydroxybenzaldehyde, 2TMS derivate	56114-69-3	270
Phosphonoacetic Acid, 3TMS derivate	53044-27-2	160
2-Butanone	78-93-3	80
Acetone	67-64-1	76
Tetrahydrofuran	109-99-9	75
2-Pentanol	6032-29-7	50
[(methylsulfinyl)methyl]-benzene	824-86-2	38

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	76
N,N-Dimethylformamide	68-12-2	8.5
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 3C

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Hexamethylcyclotrisiloxane	541-05-9	2,100
Octamethylcyclotetrasiloxane	556-67-2	1,800
Decamethylcyclopentasiloxane	541-02-6	610
Tetrahydrofuran	109-99-9	290
1,2-Dichlorpropane	78-87-5	240
Acetic acid	64-19-7	150
1-Chlor-2-propanol	127-00-4	63
Acetone	67-64-1	44

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	12
N,N-Dimethylformamide	68-12-2	5.8
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 7A

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Acetic acid	64-19-7	830
1,2-Dichlorpropane	78-87-5	410
Toluene	108-88-3	250
Tetrahydrofuran	109-99-9	120
1-Chloro-2-propanol	127-00-4	93
Acetone	67-64-1	73
Methylvinylketone	78-94-4	71
Propylenglycol	57-55-6	51
2-Butanone	78-93-3	39
1-Butanol	71-36-3	19

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	56
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 8

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Hexamethylcyclotrisiloxane	541-05-9	1,200
Acetic acid	64-19-7	350

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	5.5
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 10

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Acetic acid	64-19-7	180
2-Butanone	78-93-3	100

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	8.9
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 13

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Tetrahydrofuran	109-99-9	1,400
Acetic acid	64-19-7	380
1-Butanol	71-36-3	360
1,2-Dichlorpropane	78-87-5	300
Methylvinylketone	78-94-4	160
1-Chlor-2-propanol	127-00-4	130
Butanal	123-72-8	100
Propylenglycol	57-55-6	73
Acetone	67-64-1	69
2-Propenal	107-02-8	35

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
N,N-Dimethylformamide	68-12-2	55
Benzene	71-43-2	50
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 16

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Acetic acid	64-19-7	310
Decane	124-18-5	190
Tetrahydrofuran	109-99-9	170
1-Butanol	71-36-3	96
Butanal	123-72-8	58
Propylenglycol	57-55-6	48
Acetone	67-64-1	46

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
N,N-Dimethylformamide	68-12-2	37
Benzene	71-43-2	19
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 17A

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Octamethylcyclotetrasiloxane	556-67-2	540
Hexamethylcyclotrisiloxane	541-05-9	390
Acetic acid	64-19-7	270
1-Butanol	71-36-3	190
Tetrahydrofuran	109-99-9	170
Pentanal	110-62-3	68
Acetone	67-64-1	60
Butanal	123-72-8	58
Methylvinylketone	78-94-4	55
2-Hexanol	626-93-7	35

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	31
N,N-Dimethylformamide	68-12-2	20
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 17B

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
2-Methyl-1-propanol	78-83-1	6,500
1-Butanol	71-36-3	2,300
Toluene	108-88-3	600
Acetic acid	64-19-7	440
1-Methoxy-2-propanol	107-98-2	47
Propylenglycol	57-55-6	35

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	13
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 18

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Acetic acid	64-19-7	220
Tetrahydrofuran	109-99-9	90
1-Butanol	71-36-3	54
2-Methyl-2-propanol	75-65-0	36

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	60
N,N-Dimethylformamide	68-12-2	29
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 19

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Hexamethylcyclotrisiloxane	541-05-9	1,400
Octamethylcyclotetrasiloxane	556-67-2	750
Decamethylcyclopentasiloxane	541-02-6	290
1-Butanol	71-36-3	67

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	11
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 20

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Pyrazine	290-37-9	490
Acetic acid	64-19-7	230
Monoformate-1,2-ethandiol	628-35-3	140
2-Methyl-1,3-dioxolane	497-26-7	55
1-Butanol	71-36-3	47
Tetrahydrofuran	109-99-9	41

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	< 1
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 21A

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
2-Ethyl-1-hexanol	104-76-7	1,100
Acetic acid	64-19-7	410
Tetrahydrofuran	109-99-9	190
1-Butanol	71-36-3	110

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	29
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 22

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
2-Ethyl-1-hexanol	104-76-7	1,400
Octamethylcyclotetrasiloxane	556-67-	250
Hexamethylcyclotrisiloxane	541-05-9	220
1-Butanol	71-36-3	110

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
N,N-Dimethylformamide	68-12-2	34
Benzene	71-43-2	23
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 23

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Octamethylcyclotetrasiloxane	556-67-2	1,500
Decamethylcyclopentasiloxane	541-02-6	1,500
1,2-Dichloropropane	78-87-5	660
2,5-bis[(trimethylsilyl)oxy]-benzaldehyde	56114-69-3	490
Dodecamethylcyclohexasiloxane	540-97-6	350
Tetrahydrofuran	109-99-9	280
Hexamethyldisiloxane	107-46-0	210
Acetic acid	64-19-7	170
1-Chloro-2-propanol	127-00-4	140
1-Butanol	71-36-3	110
Methoxytrimethylsilane	1825-61-2	98
Trimethylsilanol	1066-40-6	62
Butanal	123-72-8	43
Propylenglycol	57-55-6	38

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	< 1
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 24

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
2-Ethyl-1-hexanol	104-76-7	1,100
Hexamethylcyclotrisiloxane	541-05-9	620
Octamethylcyclotetrasiloxane	556-67-2	450
Acetic acid	64-19-7	330
Toluene	108-88-3	160
Decamethylcyclopentasiloxane	541-02-6	140
2,5-bis[(trimethylsilyl)oxy]-benzaldehyde	56114-69-3	130
1-Butanol	71-36-3	66

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	< 1
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 25

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
2-Ethyl-1-hexanol	104-76-7	950
Octamethylcyclotetrasiloxane	556-67-2	510
Hexamethylcyclotrisiloxane	541-05-9	440
1,2-Dichlorpropane	78-87-5	300
Tetrahydrofuran	109-99-9	200
1-Butanol	71-36-3	62
Methylvinylketone	78-94-4	50
1-Chlor-2-propanol	127-00-4	49

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	< 1
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 26A

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
2-Ethyl-1-hexanol	104-76-7	2,100
Octamethylcyclotetrasiloxane	556-67-2	1,000
Hexamethylcyclotrisiloxane	541-05-9	820
Decamethylcyclopentasiloxane	541-02-6	380
2-Methyl-1-propanol	78-83-1	130
1-Butanol	71-36-3	85
Propylenglycol	57-55-6	33

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	6.5
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 28

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Octamethylcyclotetrasiloxane	556-67-2	1,300
Tetrahydrofuran	109-99-9	76
1-Butanol	71-36-3	58
Hexamethylcyclotrisiloxane	541-05-9	2,300

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	6.5
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 29

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Volatile and semi-volatile substances	-	< 30

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	< 1
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Comment
Light bulb no. 29 only gave light for 2.5 hours after which it stopped working. The results for light bulb no. 29 are therefore the concentration in the tedlar bag after only 2.5 lighting hours.

Light bulb no. 31

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Hexamethylcyclotrisiloxane	541-05-9	4,800
Octamethylcyclotetrasiloxane	556-67-2	2,100
Decamethylcyclopentasiloxane	541-02-6	1,800
Acetic acid	64-19-7	190
Tetrahydrofuran	109-99-9	190

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	< 1
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 32

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Hexamethylcyclotrisiloxane	541-05-9	870
Octamethylcyclotetrasiloxane	556-67-2	840
Acetic acid	64-19-7	580
1-Butanol	71-36-3	150
Tetrahydrofuran	109-99-9	140
Methylvinylketone	78-94-4	71
1-Chlor-2-propanol	127-00-4	64
2-Methyl-2-propanol	75-65-0	42
Butanal	123-72-8	41
1,2-Dichlorpropane	78-87-5	28
Propylenglycol	57-55-6	28

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	9.7
N,N-Dimethylformamide	68-12-2	7.7
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 33

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Caprolactam	105-60-2	620
Acetic acid	64-19-7	340
Octamethylcyclotetrasiloxane	556-67-2	280
Styrene	100-42-5	250
2-Butanone	78-93-3	70
Tetrahydrofuran	109-99-9	43
1-Butanol	71-36-3	43
Propylenglycol	57-55-6	39
Acetone	67-64-1	26

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	27
N,N-Dimethylformamide	68-12-2	6.8
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Light bulb no. 35

Results – screening analysis by GC/MS

Component	CAS No.	Concentration* µg/m³
Acetic acid	64-19-7	110
2-Butanone	78-93-3	48
1-Butanol	71-36-3	31

Results – specific substances by GC/MS

Component	CAS No.	Concentration* µg/m³
Benzene	71-43-2	6.5
Cresols (ortho, meta and para)	95-48-7/108-39-4/ 106-44-5	< 1
N,N-Dimethylformamide	68-12-2	< 1

Results – ozone

Component	CAS No.	Concentration* mg/m³
Ozone	10028-15-6	< 0.1

<: MEANS LESS THAN THE LISTED DETECTION LIMIT
* CONCENTRATIONEN IN THE TEDLAR BAG AFTER 5.5-6 HOURS LIGHTING HOURS.

THE RESULTS OF THE SCREENING ANALYSES SHOULD BE REGARDED AS SEMI-QUANTITATIVE.

Appendix 4: Overview of the analysis results

This appendix contains an overview of all the 45 substances which are identified from the 26 analysed energy-saving light bulbs. For each substance the following is stated:

- CAS no. for the substance
- From which energy-saving light bulbs the substance is degassed
- In which concentration the substance is degassed for each of the light bulbs
- From how many light bulbs the substance is seen degassed at the analyses
- Highest concentration measured for the substance
- The average concentration measured for the substance
- Harmonised classification (from the ECHA C&L database (2014))
- Notified classification (from the ECHA C&L database (2014) – the classification which most companies have notified is stated). The listed self-classification has not been evaluated. Please notice that differences of opinion exist between the different notificers of the self-classification.
- Relevant notified classification (from the ECHA C&L database (2014) – the classification which is the "worst" notified classification is stated)
- DNEL value according to ECHA's database of registered substance (if it is found and if the substance is registered)
- Odour threshold value for the substance if such a value is identified

Substance name	CAS No.	Bulb no.	Concen-tration ($\mu g/m^3$)	Identi-fied in no. of bulbs	Highest concen-tration identified ($\mu g/m^3$)	Average ($\mu g/m^3$)	Harmonised classification[1]	Relevant notified classification*[1]	DNEL-value (inh.)[2] ($\mu g/m^3$)	Odour threshold value ($\mu g/m^3$)
[(methylsulfinyl)methyl]-benzene	824-86-2	3B	38	1	38	-	Nothing found for this CAS no.	Nothing found for this CAS no.	-	-
1,2-Dichloropropane	78-87-5	3C 7A 13 23 25 32	240 410 300 660 300 28	6	660	323	Flam. Liq. 2 H225 Acute Tox. 4 H302 H332	Carc. 2	14,440	1,165[3]
1-Brombutane	109-65-9	1	40	1	40	-	NONE	STOT SE 3 (resp) Muta. 2	-	-
1-Butanol	71-36-3	1 3A 3B 7A 13 16 17A 17B 18	680 21 490 19 360 96 190 2,300 54	21	2300	245	Flam. Liq. 3 H226 Acute Tox. 4 H302 Skin Irrit. 2 H315 Eye Dam. 1 H318 STOT SE 3 H335 H336	-	55,000	90[4]

Substance name	CAS No.	Bulb no.	Concen-tration (µg/m^3)	Identi-fied in no. of bulbs	Highest concen-tration identified (µg/m^3)	Average (µg/m^3)	Harmonised classification[1]	Relevant notified classification*[1]	DNEL-value (inh.)[2] (µg/m^3)	Odour threshold value (µg/m^3)
		19	67							
		20	47							
		21A	110							
		22	110							
		23	110							
		24	66							
		25	62							
		26A	85							
		28	58							
		32	150							
		33	43							
		35	31							
1-Chloro-2-propanol	127-00-4	3C	63	-	140	90	NONE		Not registered	-
		7A	93							
		13	130							
		23	140							
		25	49							
		32	64							

Substance name	CAS No.	Bulb no.	Concentration (µg/m^3)	Identified in no. of bulbs	Highest concentration identified (µg/m^3)	Average (µg/m^3)	Harmonised classification[1]	Relevant notified classification[*1]	DNEL-value (inh.)[2] (µg/m^3)	Odour threshold value (µg/m^3)
1-Methoxy-2-propanol	107-98-2	17B	47	1	47	-	Flam. Liq. 3 H226 STOT SE 3 H336	Repr. 1B	-	360,000[5]
2,5-Dihydrofuran	1708-29-8	1	67	1	67	-	NONE	STOT SE 3	-	-
2,5-bis[(trimethylsilyl)oxy]-benzaldehyde	56114-69-3	3B 23 24	270 490 130	3	490	297	Nothing found for this CAS no.	Nothing found for this CAS no.	-	-
2-Butanone	78-93-3	3B 7A 10 33 35	80 39 100 70 48	5	100	67	Flam. Liq. 2 H225 Eye Irrit. 2 H319 STOT SE 3 H336	STOT SE 3	-	-
2-Ethyl-1-hexanol	104-76-7	3A 21A 22 24 25	1,500 1,100 1,400 1,100 950	6	2100	1358	NONE	STOT SE 3 (resp)	2,300	500[4]

Substance name	CAS No.	Bulb no.	Concen-tration (µg/m^3)	Identi-fied in no. of bulbs	Highest concen-tration identified (µg/m^3)	Average (µg/m^3)	Harmonised classification[1]	Relevant notified classification*[1]	DNEL-value (inh.)[2] (µg/m^3)	Odour threshold value (µg/m^3)
		26A	2,100							
2-Ethylacrolein	922-63-4	3A	52	1	52	-	NONE	Acute Tox. 2	-	-
2-Hexanol	626-93-7	17A	35	1	35	-	NONE	STOT SE 3 (resp)	-	-
2-Methyl-1,3-dioxolan	497-26-7	20	55	1	55	-	NONE	-	-	-
2-Methyl-1-propanol	78-83-1	17B 26A	6,500 130	2	6500	3315	Flam. Liq. 3 H226 Skin Irrit. 2 H315 Eye Dam. 1 H318 STOT SE 3 H335 H336	Muta. 1B Carc. 1B	-	3,300[4]
2-Methyl-2-propanol	75-65-0	1 18 32	120 36 42	3	120	66	Flam. Liq. 2 H225 Eye Irrit. 2 H319 Acute Tox. 4 H332 STOT SE 3 H336	STOT SE (lungs, resp)	-	31,000[9]
2-Pentanol	6032-29-7	3B	50	1	50	-	NONE	STOT SE 3 (resp)	-	-
2-Pentanone	107-87-9	1	59	1	59	-	NONE	STOT SE 3	-	-
2-Propenal	107-02-8	1 13	39 35	2	39	37	Flam. Liq. 2 H225 Acute Tox. 2 H300 Acute Tox. 3 H311 Skin Corr. 1B H314 Acute Tox. 1 H330	Carc. 2 (inhalation)	200 (for "workers")	370[3]

Substance name	CAS No.	Bulb no.	Concentration (µg/m^3)	Identified in no. of bulbs	Highest concentration identified (µg/m^3)	Average (µg/m^3)	Harmonised classification[1]	Relevant notified classification*[1]	DNEL-value (inh.)[2] (µg/m^3)	Odour threshold value (µg/m^3)
3-Buten-1-ol	627-27-0	1	27	1	27	-	NONE	STOT SE 3	-	-
Acetone	67-64-1	1	170	8	170	71	Flam. Liq. 2 H225 Eye Irrit. 2 H319 STOT SE 3 H336	STOT SE 3	200,000	31,000[3]
		3B	76							
		3C	44							
		7A	73							
		13	69							
		16	46							
		17A	60							
		33	26							
Benzene	71-43-2	3A	3.8	19	76	24	Flam. Liq. 2 H225 Asp. Tox. 1 H304 Skin Irrit. 2 H315 Eye Irrit. 2 H319 Muta. 1B H340 Carc. 1A H350 STOT RE 1 H372	Muta. 1B Carc. 1A STOT RE 1 (resp)	No DNEL value is listed in ECHA RSD	4,500[5]
		3B	76							
		3C	12							
		7C	56							
		8	5.5							
		10	8,9							
		13	50							
		16	19							
		17A	31							

Substance name	CAS No.	Bulb no.	Concen-tration (µg/m^3)	Identi-fied in no. of bulbs	Highest concen-tration identified (µg/m^3)	Average (µg/m^3)	Harmonised classification[1]	Relevant notified classification*[1]	DNEL-value (inh.)[2] (µg/m^3)	Odour threshold value (µg/m^3)
		17B 18 19 21A 22 26A 28 32 33 35	13 60 11 29 23 6.5 6.5 9.7 27 6.5							
Butanal	123-72-8	1 13 16 17A 23 32	230 100 58 58 43 41	6	230	88	Flam. Liq. 2 H225		No DNEL value is listed	28[4]
Caprolactam	105-60-2	33	620	1	620	-	Acute Tox. 4 H302 H332 Skin Irrit. 2 H315	STOT SE 3 (resp) STOT SE 3 (lungs, inalation)	-	-

Substance name	CAS No.	Bulb no.	Concen-tration (µg/m^3)	Identi-fied in no. of bulbs	Highest concen-tration identified (µg/m^3)	Average (µg/m^3)	Harmonised classification[1]	Relevant notified classification*[1]	DNEL-value (inh.)[2] (µg/m^3)	Odour threshold value (µg/m^3)
							Eye Irrit. 2 H319 STOT SE 3 H335			
Cresoles (ortho, meta and para)	95-48-7/108-39-4/106-44-5	-	-	0	-	-	-	-	-	1[5]
Decamethylcyclopentasiloxane	541-02-6	3B 3C 19 23 24 26A 31	300 610 290 1,500 140 380 1,800	7	1,800	717	NONE	STOT SE 3 (airways, inhalation)	17,300	-
Decane	124-18-5	16	190	1	190	-	NONE	STOT SE 3 STOT SE 3 (lungs)		3,087[7]
Dodecamethylcyclohexasiloxane	540-97-6	23	350	1	350	-	NONE	-	-	-
Acetic acid	64-19-7	1 3C 7A	1,100 150 830	18	1,100	347	Flam. Liq. 3 H226 Skin Corr. 1A H314	STOT SE 3 (lungs) STOT RE2 STOT SE 1 (resp)	N/A	98.2-491 µg/m^3 [6]

Substance name	CAS No.	Bulb no.	Concentration (µg/m³)	Identified in no. of bulbs	Highest concentration identified (µg/m³)	Average (µg/m³)	Harmonised classification[1]	Relevant notified classification*[1]	DNEL-value (inh.)[2] (µg/m³)	Odour threshold value (µg/m³)
		8	350							
		10	180							
		13	380							
		16	310							
		17A	270							
		17B	440							
		18	220							
		20	230							
		21A	410							
		23	170							
		24	330							
		31	190							
		32	580							
		33	340							
		35	110							
Volatile and semi volatile substances	-	29	<30	-	-	-	-	-	-	-
Hexamethylcyclotrisiloxane	541-05-9	3B	870	12	4,800	1336	NONE	STOT SE 3 STOT SE 3 (resp)	64,000 (for	-

Substance name	CAS No.	Bulb no.	Concen-tration (μg/m^3)	Identi-fied in no. of bulbs	Highest concen-tration identified (μg/m^3)	Average (μg/m^3)	Harmonised classification[1]	Relevant notified classification*[1]	DNEL-value (inh.)[2] (μg/m^3)	Odour threshold value (μg/m^3)
		3C 8 17A 19 22 24 25 26A 28 31 32	2,100 1,200 390 1,400 220 620 440 820 2,300 4,800 870						”workers”)	
Hexamethyldisiloxane	107-46-0	23	210	1	210	-	NONE	Carc. 2	13,300	-
Methacrolein	78-85-3	1	83	1	83	-	NONE		-	-
Methoxytrimethylsilane	1825-61-2	23	98	1	98	-	NONE	-	-	-
Methylisobutylketone (MIBK)	108-10-1	1	69	1	69	-	Flam. Liq. 2 H225 Eye Irrit. 2 H319 Acute Tox. 4 H332	STOT SE 3 (lunge) STOT SE 3 (resp)	-	2,787[8]

Substance name	CAS No.	Bulb no.	Concentration ($\mu g/m^3$)	Identified in no. of bulbs	Highest concentration identified ($\mu g/m^3$)	Average ($\mu g/m^3$)	Harmonised classification[1]	Relevant notified classification*[1]	DNEL-value (inh.)[2] ($\mu g/m^3$)	Odour threshold value ($\mu g/m^3$)
							STOT SE 3 H335			
Methylvinylketone	78-94-4	1 7A 13 17A 25 32	290 71 160 55 50 71	6	160	116	NONE	STOT SE 1 (resp)	Not registered in ECHA RSD	-
Monoformate-1,2-ethandiol	628-35-3	20	140	1	140	-	NONE		-	-
N,N-Dimethylformamide	68-12-2	1 3B 3C 13 16 17A 18 22 32	670 8.5 5.8 55 37 20 29 34 7.7	10	670	87	Acute Tox. 4 H312 H332 Eye Irrit. 2 H319 Repr. 1B H360D	Repr. 1B Muta. 2 STOT SE 1 STOT RE 1 Repr. 1A	15,000	300,000[5]

Substance name	CAS No.	Bulb no.	Concentration (µg/m^3)	Identified in no. of bulbs	Highest concentration identified (µg/m^3)	Average (µg/m^3)	Harmonised classification[1]	Relevant notified classification*[1]	DNEL-value (inh.)[2] (µg/m^3)	Odour threshold value (µg/m^3)
		33	6.8							
Octamethylcyclotetra siloxane	556-67-2	3B 3C 17A 19 22 23 24 25 26A 28 31 32 33	910 1,800 540 750 250 1,500 450 510 1,000 1,300 2,100 840 280	13	2100	941	Repr. 2 H361f	Repr. 2	13,000	-
Ozone	10028-15-6	0	-	0	-	-	NONE	STOT SE 3 (resp, inhalation) Muta. 2 (inhalation) STOT RE 2 (lungs, bronchus, inhalation)	-	-

Substance name	CAS No.	Bulb no.	Concen-tration (µg/m^3)	Identi-fied in no. of bulbs	Highest concen-tration identified (µg/m^3)	Average (µg/m^3)	Harmonised classification[1]	Relevant notified classification*[1]	DNEL-value (inh.)[2] (µg/m^3)	Odour threshold value (µg/m^3)
Pentanal	110-62-3	1 17A	230 68	2	230	149	NONE	STOT SE 3 (resp)	-	22[4]
Phenol	108-95-2	3B	510	1	510	-	Acute Tox. 3 H301 H311 H331 Skin Corr. 1B H314 Muta. 2 H341 STOT RE 2 H373	Muta. 2 STOT RE 2	1,320	179[5]
Phosphonoacetic Acid, 3TMS derivate	53044-27-2	3B	160	1	160	-	Nothing found for this CAS no.	Nothing found for this CAS no.	-	-
Propylenglycol	57-55-6	7A 13 16 17B 23	51 73 48 35 38	8	73	43	NONE	STOT SE 3 (resp)	50,000	-
Pyrazine	290-37-9	20	490	1	490	-	NONE	STOT SE 3 (resp)	-	-
Styrene	100-42-5	33	250	1	250	-	Flam. Liq. 3 H226 Skin Irrit. 2 H315 Eye Irrit. 2H319 Acute Tox. 4 H332	Carc. 2 STOT RE 1 STOT SE 3 (resp)	-	160[4]
Tetrahydrofuran	109-99-9	1	920	16	1400	275	Flam. Liq. 2 H225 Eye Irrit. 2 H319	STOT SE 3 Carc. 2	62,000	7375[5]

Substance name	CAS No.	Bulb no.	Concentration (µg/m³)	Identified in no. of bulbs	Highest concentration identified (µg/m³)	Average (µg/m³)	Harmonised classification[1]	Relevant notified classification*[1]	DNEL-value (inh.)[2] (µg/m³)	Odour threshold value (µg/m³)
		3B 3C 7A 13 16 17A 18 20 21A 23 25 28 31 32 33	75 290 120 1,400 170 170 90 41 190 280 200 76 190 140 43				STOT SE 3 H335 Carc. 2 H351	STOT SE 3		
Toluene	108-88-3	7A 17B 24	250 600 160	3	600	337	Flam. Liq. 2 H225 Asp. Tox. 1 H304 Skin Irrit. 2 H315 STOT SE 3 H336 Repr. 2 H361d	STOT SE 3 Repr. 2 STOT RE 2	56,500	600[7]

Substance name	CAS No.	Bulb no.	Concen-tration (µg/m³)	Identi-fied in no. of bulbs	Highest concen-tration identified (µg/m³)	Average (µg/m³)	Harmonised classification[1]	Relevant notified classification*[1]	DNEL-value (inh.)[2] (µg/m³)	Odour threshold value (µg/m³)
							STOT RE 2 H373			
Trimethylsilanol	1066-40-6	23	62	1	62	-	NONE		-	-

TABLE 14
SUBSTANCES IDENTIFIED AS WELL AS CONCENTRATION FOR 26 ANALYSED BULBS. DNEL VALUE AND ODOUR THRESHOLDS ARE LISTED FOR 19 SUBSTANCES.

* THE LISTED SELF-CLASSIFICATION HAS NOT BEEN EVALUATED. PLEASE NOTICE THAT DIFFERENCES OF OPINION DO EXIST BETWEEN THE DIFFERENT NOTIFIERS OF THE SELF-CLASSIFICATION.
1 ECHA C&L, 2014.
2 ECHA RSD, 2014.
3 DANISH EPA, 2008.
4 DANISH EPA, 2003.
5 RUTH, 1986.
6 DANISH EMERGENCY MANAGEMENT AGENCY, 2013A.
7 WOLKOFF ET AL., 2006.
8 DANISH EMERGENCY MANAGEMENT AGENCY, 2013B.
9 DANISH EPA, 2006.
- VALUE NOT POSSIBLE TO IDENTIFY
N/A NO THRESHOLD EFFECT AND/OR NO DOSIS RESPONSE INFORMATION AVAILABLE

Odour from energy-saving light bulbs

The study was initiated due to Recent discussions on odour from energy-saving light bulbs. Through notice on homepages and in the press consumers were invited to forward their smelling energy-saving light bulbs. In total, 47 replies were received and 25 light bulbs were analysed for degassing substances. The results in this project confirm that the energy-saving light bulbs which smell also release substances in concentrations above the odour threshold value. Five of the degassed substances were selected for health and risk assessments: N,N-dimethylformamide, octamethylcyclotetrasiloxane (D4), tetrahydrofuran and phenol. The substances were selected due to their harmonised classification as carcinogenic, mutagenic and toxic to reproduction respectively. The risk assessment of the five selected substances was based on a worst-case exposure assessment. Under these conditions, none of the five selected substances constitutes a health problem. Even if energy-saving light bulbs can degas many different chemical substances they are not expected to constitute a health problem.

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