

## **Committee for Risk Assessment RAC**

Annex 1  
**Background document**  
to the Opinion proposing harmonised classification  
and labelling at EU level of

### **Benzophenone**

**EC Number: 204-337-6**

**CAS Number: 119-61-9**

**CLH-O-0000006808-62-01/F**

The background document is a compilation of information considered relevant by the dossier submitter or by RAC for the proposed classification. It includes the proposal of the dossier submitter and the conclusion of RAC. It is based on the official CLH report submitted to public consultation. RAC has not changed the text of this CLH report but inserted text which is specifically marked as 'RAC evaluation'. Only the RAC text reflects the view of RAC.

**Adopted**  
**11 June 2020**



## **CLH report**

### **Proposal for Harmonised Classification and Labelling**

**Based on Regulation (EC) No 1272/2008 (CLP Regulation),  
Annex VI, Part 2**

#### **International Chemical Identification:**

#### **Benzophenone**

**EC Number: 204-337-6**

**CAS Number: 119-61-9**

**Index Number: -**

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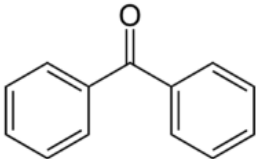
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## 1 IDENTITY OF THE SUBSTANCE

### 1.1 Name and other identifiers of the substance

Table 1: Substance identity and information related to molecular and structural formula of the substance

<b>Name(s) in the IUPAC nomenclature or other international chemical name(s)</b>	Benzophenone, di(phenyl)methanone, diphenyl ketone, diphenyl methanone, diphenylmethanone, methanone, diphenyl-
<b>Other names (usual name, trade name, abbreviation)</b>	Diphenyl ketone Diphenylmethanone
<b>EC number (if available and appropriate)</b>	204-337-6
<b>EC name (if available and appropriate)</b>	Benzophenone
<b>CAS number (if available)</b>	119-61-9
<b>Molecular formula</b>	C <sub>13</sub> H <sub>10</sub> O
<b>Structural formula</b>	
<b>SMILES notation (if available)</b>	C1=CC=C(C=C1)C(=O)C2=CC=CC=C2
<b>Molecular weight or molecular weight range</b>	182
<b>Information on optical activity and typical ratio of (stereo) isomers (if applicable and appropriate)</b>	Not applicable
<b>Description of the manufacturing process and identity of the source (for UVCB substances only)</b>	Not UVCB substance
<b>Degree of purity (%) (if relevant for the entry in Annex VI)</b>	Not relevant for classification purpose

### 1.2 Composition of the substance

Table 2: Constituents (non-confidential information)

<b>Constituent (Name and numerical identifier)</b>	<b>Concentration range (%) w/w minimum and maximum in multi-constituent substances)</b>	<b>Current Annex VI (CLP)</b>	<b>CLH Table 3.1</b>	<b>Current classification and self-labelling (CLP)</b>
Benzophenone	Monoconstituent substance No information on purity given in the publicly available version of the REACH registration	none		REACH registration: STOT Rep. Exp. 2 (oral) H373: May cause damage to organs (liver, kidneys) through prolonged or repeated exposure.

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Constituent (Name and numerical identifier)	Concentration range (% w/w minimum and maximum in multi- constituent substances)	Current CLH in Annex VI Table 3.1 (CLP)	Current self- classification and labelling (CLP)
			Aquatic Chronic 3, H412: Harmful to aquatic life with long lasting effects  One out of 50 CLP notifications uses a Carc 2 classification.

Table 3: Impurities (non-confidential information) if relevant for the classification of the substance

Impurity (Name and numerical identifier)	Concentration range (% w/w minimum and maximum)	Current CLH in Annex VI Table 3.1 (CLP)	Current self- classification and labelling (CLP)	The impurity contributes to the classification and labelling
Benzophenone	No information on impurities given in the publicly available version of the REACH registration			

Table 4: Additives (non-confidential information) if relevant for the classification of the substance

Additive (Name and numerical identifier)	Function	Concentration range (% w/w minimum and maximum)	Current CLH in Annex VI Table 3.1 (CLP)	Current self- classification and labelling (CLP)	The additive contributes to the classification and labelling
Benzophenone	No information on additives given in the publicly available version of the REACH registration				

Table 5: Test substances (non-confidential information) (this table is optional)

Identification of test substance	Purity	Impurities and additives (identity, %, classification if available)	Other information	The study(ies) in which the test substance is used
Benzophenone	>99%			NTP (2006) studies

## 2 PROPOSED HARMONISED CLASSIFICATION AND LABELLING

### 2.1 Proposed harmonised classification and labelling according to the CLP criteria

Table 6:

	Index No	International Chemical Identification	EC No	CAS No	Classification		Labelling			Specific Conc. Limits, M-factors	Notes
					Hazard Class and Category Code(s)	Hazard statement Code(s)	Pictogram, Signal Word Code(s)	Hazard statement Code(s)	Suppl. Hazard statement Code(s)		
Current Annex VI entry	none	benzophenone	204-337-6	119-61-9	none	none	none	none			
Dossier submitters proposal	TBD	benzophenone	204-337-6	119-61-9	Carc. 2	H351	GHS08	H351			
Resulting Annex VI entry if agreed by RAC and COM	TBD	benzophenone	204-337-6	119-61-9	Carc. 2	H351	GHS08	H351			

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Table 7: Reason for not proposing harmonised classification and status under public consultation

Hazard class	Reason for no classification	Within the scope of public consultation
Explosives	hazard class not assessed in this dossier	No
Flammable gases (including chemically unstable gases)	hazard class not assessed in this dossier	No
Oxidising gases	hazard class not assessed in this dossier	No
Gases under pressure	hazard class not assessed in this dossier	No
Flammable liquids	hazard class not assessed in this dossier	No
Flammable solids	hazard class not assessed in this dossier	No
Self-reactive substances	hazard class not assessed in this dossier	No
Pyrophoric liquids	hazard class not assessed in this dossier	No
Pyrophoric solids	hazard class not assessed in this dossier	No
Self-heating substances	hazard class not assessed in this dossier	No
Substances which in contact with water emit flammable gases	hazard class not assessed in this dossier	No
Oxidising liquids	hazard class not assessed in this dossier	No
Oxidising solids	hazard class not assessed in this dossier	No
Organic peroxides	hazard class not assessed in this dossier	No
Corrosive to metals	hazard class not assessed in this dossier	No
Acute toxicity via oral route	hazard class not assessed in this dossier	No
Acute toxicity via dermal route	hazard class not assessed in this dossier	No
Acute toxicity via inhalation route	hazard class not assessed in this dossier	No
Skin corrosion/irritation	hazard class not assessed in this dossier	No
Serious eye damage/eye irritation	hazard class not assessed in this dossier	No
Respiratory sensitisation	hazard class not assessed in this dossier	No
Skin sensitisation	hazard class not assessed in this dossier	No
Germ cell mutagenicity	hazard class not assessed in this dossier	No
Carcinogenicity	<i>harmonised classification proposed</i>	<i>Yes</i>
Reproductive toxicity	hazard class not assessed in this dossier	No
Specific target organ toxicity-single exposure	hazard class not assessed in this dossier	No
Specific target organ toxicity-repeated exposure	hazard class not assessed in this dossier	No
Aspiration hazard	hazard class not assessed in this dossier	No
Hazardous to the aquatic environment	hazard class not assessed in this dossier	No
Hazardous to the ozone layer	hazard class not assessed in this dossier	No

### 3 HISTORY OF THE PREVIOUS CLASSIFICATION AND LABELLING

Not included in Annex VI to CLP.



#### 4 JUSTIFICATION THAT ACTION IS NEEDED AT COMMUNITY LEVEL

The present proposal for harmonised classification concerns carcinogenicity, thus covered by CLP article 36 1 (b) with no justification needed. Benzophenone has been subject to substance evaluation under REACH and the evaluating member state identified toxicological data considered relevant for harmonised classification for carcinogenicity (Danish EPA 2018).

#### 5 IDENTIFIED USES

According to ECHA's web-site substance information on benzophenone:

<https://echa.europa.eu/substance-information/-/substanceinfo/100.003.943> (retrieved November 2018)

benzophenone is used in the following products:

air care products, polishes and waxes, washing & cleaning products, anti-freeze products, biocides (e.g. as a odoriferous agent in disinfectants, pest control products), inks and toners, perfumes and fragrances, pharmaceuticals and cosmetics and personal care products.

#### 6 DATA SOURCES

The primary documentation used in this dossier is:

- Registration dossier information on benzophenone publicly available from ECHA dissemination page (consulted 2018).
- Danish EPA (2018). SUBSTANCE EVALUATION CONCLUSION as required by REACH Article 48 and EVALUATION REPORT for Benzophenone. 5 April 2018.
- EFSA (2017). Safety of Benzophenone to be used as flavouring. The EFSA Journal 15(11):5013  
<http://onlinelibrary.wiley.com/doi/10.2903/j.efsa.2017.5013/epdf>
- IARC (2013). Benzophenone in: Some Chemicals Present in Industrial and Consumer Products, Food and Drinking-water. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans vol 101.  
<http://monographs.iarc.fr/ENG/Monographs/vol101/mono101-007.pdf>
- NTP (2006). National Toxicology Program (2006) Technical Report on the toxicology and carcinogenesis studies of benzophenone (CAS No. 119-61-9) in F344/N rats and B6C3F1 and B6C3F1 mice (feed studies). February 2006. National Toxicity Program. Toxicity Report 5333. NIH publication No.06-4469.

## 7 PHYSICOCHEMICAL PROPERTIES

Table 8: Summary of physicochemical properties (from Danish EPA 2018)

Property	Value
<b>Physical state at 20°C and 101,3 kPa</b>	Organic solid. White crystals or flakes with a geranium or sweet, rose-like odour.
<b>Melting/freezing point</b>	48.5 °C (HSDB)
<b>Boiling point</b>	299.49 °C (calculated) (Registrant(s) dossier publicly available at ECHA's homepage) 305.4 °C (HSDB)
<b>Vapour pressure</b>	0.00257 hPa at 25 °C
<b>Water solubility</b>	137 mg/L (at 25 °C) (HSDB)
<b>Partition coefficient n-octanol/water</b>	3.18 at 25°C (measured) (HSDB)
<b>Flammability</b>	Not susceptible to ignition on contact with air; however, the flammability range of gaseous Benzophenone is reported to be 0.7 - 5.4 vol%
<b>Explosive properties</b>	Dust can form an explosive mixture with air
<b>Oxidising properties</b>	No oxidising properties
<b>Granulometry</b>	Median diameter D (v, 0.1)=23.18 µm, D (v, 0.5)=228.04µm, D (v, 0.9)=695.93 µm, D (4, 3)=302.12 µm, and D (3, 2)=60.16 µm  The particle size distribution of Benzophenone crystals was analysed by laser diffraction technology.
<b>Stability in organic solvents and identity of relevant degradation products</b>	Stable in organic solvents based on structural aspects
<b>Dissociation constant</b>	No content of functional groups that are susceptible to dissociation.

## 8 EVALUATION OF PHYSICAL HAZARDS

Physical hazards not evaluated.

## 9 TOXICOKINETICS (ABSORPTION, METABOLISM, DISTRIBUTION AND ELIMINATION)

Not further evaluated.

## 10 EVALUATION OF HEALTH HAZARDS

### Acute toxicity

Hazard class not evaluated.

### **10.1 Acute toxicity - oral route**

Hazard class not evaluated.

### **10.2 Acute toxicity - dermal route**

Hazard class not evaluated.

### **10.3 Acute toxicity - inhalation route**

Hazard class not evaluated.

### **10.4 Skin corrosion/irritation**

Hazard class not evaluated.

### **10.5 Serious eye damage/eye irritation**

Hazard class not evaluated.

### **10.6 Respiratory sensitisation**

Hazard class not evaluated.

### **10.7 Skin sensitisation**

Hazard class not evaluated.

### **10.8 Germ cell mutagenicity**

This hazard end-point is not subjected to further detailed analysis and discussion as the conclusion on this end-point is based on previous evaluations:

Danish EPA (2018). Member state substance evaluation conclusion document.

EFSA (2017). Safety of Benzophenone to be used as flavouring.

In the substance evaluation conclusion document Danish EPA, 2018 it was concluded:

*“The results of genotoxicity assays with Benzophenone showed no evidence of genotoxicity both in in vitro and in vivo tests. In one assay, the use of human recombinant P450 enzyme preparations, including P450 family 1 enzymes, in a Salmonella typhimurium umu gene expression assay with Benzophenone and two metabolites, benzhydrol and p-benzoylphenol, produced dose-related increases in gene expression (Takemoto et al., 2002). However, this assay is not an OECD guideline assay and moreover Benzophenone was negative in the bacterial in vitro OECD guideline test, Salmonella typhimurium gene mutation assay. Benzophenone was also negative in another bacterial assay, the unscheduled DNA synthesis test, as well as in the OECD guideline test using mammalian cells, the mouse lymphoma assay. Two reported in vivo micronucleus tests of Benzophenone in mice gave negative results.*

*Based on this the evaluating MS has taken the overall conclusion that Benzophenone is not genotoxic.”*

The report from EFSA on benzophenone as a flavouring agent (2017) concluded:

*“Overall, the Panel considered that based on the available data, which covers all relevant genetic endpoints (i.e. gene mutations, structural and numerical chromosomal aberrations) there is no concern with respect to genotoxicity of benzophenone”.*

Overall, the evaluations from Danish EPA (2018) and EFSA (2017) indicate that benzophenone is not genotoxic. In the Danish EPA conclusion document (2018), it is further stated that no further assessment of the genotoxic potential for benzophenone is needed. Thus, a genotoxic mode of action in relation to a carcinogenic potential of benzophenone is considered unlikely by the dossier submitter as well.

## RAC evaluation of germ cell mutagenicity

### Summary of the Dossier Submitter’s proposal

Germ cell mutagenicity was not assessed by the DS. However, a summary of the conclusion document of the member state CA conducting the substance evaluation (Danish EPA (2018), together with the conclusion of an EFSA report (2017) on the safety of benzophenone used as a flavouring agent, was provided. Overall these two evaluations indicate that benzophenone is not genotoxic. On this basis the DS considered that a genotoxic mode of action in relation to the carcinogenic potential of benzophenone is unlikely.

### Comments received during public consultation

This hazard was not open to commenting during the consultation of the CLH report.

### Assessment and comparison with the classification criteria

Germ cell mutagenicity has not therefore been evaluated by RAC.

## 10.9 Carcinogenicity

Data on benzophenone (BP) regarding carcinogenicity pertains to two high-quality oral carcinogenicity studies in mice and rats, respectively, performed and reported by NTP (2006). Further, two relatively old dermal carcinogenicity studies of lower quality are available and reported by Stenbäck & Shubik (1974) using mice and by Stenbäck (1977) using rabbits.

Table 9: Summary table of animal studies on carcinogenicity, oral exposure

Method, guideline, deviations if any, Klimish score, species, strain, sex, no/group	Test substance, dose levels duration of exposure	Results	Reference
Carcinogenicity study, corresponding to OECD TG	Benzophenone (BP) (purity > 99%)	Mortality: Non-significant decreased survival in high dose females (62 % vs 80% in controls). Other groups similar survival to controls (>80%)	NTP (2006)

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Method, guideline, deviations if any, Klimish score, species, strain, sex, no/group	Test substance, dose levels duration of exposure	Results	Reference																																																		
451 and in accordance with GLP principles. Klimish score 1.  B6C3F1 mice  50 males and 50 females in each group	Oral via diet  0, 312, 625, or 1250 ppm BP for 105 weeks. Corresponding to 40, 80, and 160 mg BP/kg bw/day for males and 35, 70, and 150 mg BP/kg bw/day for females	<p>Body weights: No effect on mean body weights of exposed males. In females, body weights were decreased from week 37 in the high dose group (14% decrease at study termination) from week 52 in the mid-dose group (8% decrease at study termination) and from week 92 in the low-dose group (7% decrease at study termination). No effect on feed intake.</p> <p>Clinical signs: No clinical signs in either sex per dose group except in moribund animals).</p> <p><u>Neoplastic findings:</u></p> <table><tr><th colspan="5">Males</th></tr><tr><th>Dose levels, ppm (mg/kg bw/day)</th><th>0 (0)</th><th>312 (40)</th><th>625 (80)</th><th>1250 (160)</th></tr><tr><td>hepatocellular adenoma<sup>a</sup></td><td>11/50 22%</td><td>15/50 30%</td><td>23/50 46%*</td><td>23/50 46%*</td></tr><tr><td>Hepatocellular carcinoma<sup>b</sup></td><td>8/50 16%</td><td>5/50 10%</td><td>6/50 12%</td><td>6/50 12%</td></tr><tr><td>Hepatoblastoma<sup>c</sup></td><td>0/50 0%</td><td>1/50 2%</td><td>1/50 2%</td><td>3/50 6%</td></tr><tr><td>Hepatocellular adenoma, carcinoma or hepatoblastoma<sup>d</sup></td><td>18/50 36%</td><td>20/50 40%</td><td>25/50 50%</td><td>29/50 58%*</td></tr><tr><td>Histiocytic sarcoma<sup>e</sup></td><td>1/50</td><td>0/50</td><td>0/50</td><td>0/50</td></tr></table> <p>*Significantly different (P≤0.05) from the control group</p> <p><sup>a</sup> historical incidences<sup>1</sup>, feed: 9/460, range 12-30%, (mean 20%).</p> <p><sup>b</sup> historical incidences, all routes: 8-46% (mean 22.9%) in 1257 controls.</p> <p><sup>c</sup> historical incidences, feed: 1/460, range 0-2%, (mean 0.2%)</p> <p><sup>d</sup> historical incidences, feed: 145/460 range 20-47%, mean of 32%.</p> <p><sup>e</sup> no information on HCD for histiocytic sarcoma in males available.</p> <table><tr><th colspan="5">Females</th></tr><tr><th>Dose levels, ppm (mg/kg bw/day)</th><th>0 (0)</th><th>312 (35)</th><th>625 (70)</th><th>1250 (150)</th></tr><tr><td>hepatocellular</td><td>5/50</td><td>4/50</td><td>10/50</td><td>8/50</td></tr></table>	Males					Dose levels, ppm (mg/kg bw/day)	0 (0)	312 (40)	625 (80)	1250 (160)	hepatocellular adenoma <sup>a</sup>	11/50 22%	15/50 30%	23/50 46%*	23/50 46%*	Hepatocellular carcinoma <sup>b</sup>	8/50 16%	5/50 10%	6/50 12%	6/50 12%	Hepatoblastoma <sup>c</sup>	0/50 0%	1/50 2%	1/50 2%	3/50 6%	Hepatocellular adenoma, carcinoma or hepatoblastoma <sup>d</sup>	18/50 36%	20/50 40%	25/50 50%	29/50 58%*	Histiocytic sarcoma <sup>e</sup>	1/50	0/50	0/50	0/50	Females					Dose levels, ppm (mg/kg bw/day)	0 (0)	312 (35)	625 (70)	1250 (150)	hepatocellular	5/50	4/50	10/50	8/50	
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<sup>1</sup> Historical control data (HCD): The HCD are reported in the NTP-carcinogenicity study with BP (published in 2006). The data are from 7 NTP-2000 feed studies performed in the period from 1995-2004. For some tumour types, reference to 23 studies from all routes is used. The feed “NTP-2000” was introduced in 1995. The study period of the BP study was from sept 1999 through sept 2001 for mice. and from aug 1999 through aug 2001 for rats. The strains of choice of NTP were the F334/N rats until 2006 and the B6C3F1 mice, and the latter is still the preferred mice strain by NTP. It is therefore presumed that the HCD in the database are for the same strains as used in the carcinogenicity study with BP.

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Method, guideline, deviations if any, Klimish score, species, strain, sex, no/group	Test substance, dose levels duration of exposure	Results					Reference																																																																						
		adenoma <sup>a</sup>	10%	8%	20%	16%																																																																							
		hepatocellular carcinoma	0/50 0%	1/50 2%	0/50 0%	1/50 2%																																																																							
		hepatocellular adenoma or carcinoma <sup>b</sup>	5/50 10%	5/50 10%	10/50 20%	9/50 18%																																																																							
		Hepatoblastoma**	0/50	0/50	0/50	0/50																																																																							
		Histiocytic sarcoma <sup>c</sup> ,	0/50 0%	0/50 0%	5/50 10%*	3/50 6%																																																																							
		* Significantly different (P≤0.05) from the control group ** findings not reported. <sup>a</sup> historical incidences,feed: <sup>1</sup> :40/457, range 6-12% (mean 9.6%) <sup>b</sup> historical incidences,feed 53/457,range 8-16% (mean 11.8%) <sup>c</sup> historical incidences,feed : 2/459 0-2% (mean o.3%).  <u>Non-neoplastic findings:</u> <table><tr><th colspan="5">Males</th></tr><tr><th>Dose levels, ppm (mg/kg bw/day)</th><th>0 (0)</th><th>312 (40)</th><th>625 (80)</th><th>1250 (160)</th></tr><tr><td>Liver</td><td></td><td></td><td></td><td></td></tr><tr><td>Hypertrophy hepatocytes</td><td>0/50</td><td>44/50**</td><td>50/50**</td><td>48/50**</td></tr><tr><td>Micronucleated hepatocytes</td><td>0/50</td><td>41/50**</td><td>47/50**</td><td>48/50**</td></tr><tr><td>Active chronic inflammation</td><td>33/50</td><td>47/50**</td><td>44/50**</td><td>42/50*</td></tr><tr><td>Hepatocyte degeneration</td><td>0/50</td><td>0/50</td><td>5/50*</td><td>30/50**</td></tr><tr><td>Kidney</td><td></td><td></td><td></td><td></td></tr><tr><td>Nephropathy</td><td>49/50</td><td>48/50</td><td>50/50</td><td>50/50</td></tr><tr><td>Severity grade average</td><td>1.2</td><td>1.4</td><td>1.7</td><td>3.0</td></tr><tr><td>Spleen</td><td></td><td></td><td></td><td></td></tr><tr><td>Hyperplasia of lymphoid follicles</td><td>17/50</td><td>31/50**</td><td>34/50*</td><td>32/50**</td></tr><tr><td>Testes</td><td></td><td></td><td></td><td></td></tr><tr><td>Mineralisation in testes</td><td>0/50</td><td>1/50</td><td>4/50</td><td>12/50**</td></tr></table> * Significantly different (P≤0.05) from the control group ** P≤0.01					Males					Dose levels, ppm (mg/kg bw/day)	0 (0)	312 (40)	625 (80)	1250 (160)	Liver					Hypertrophy hepatocytes	0/50	44/50**	50/50**	48/50**	Micronucleated hepatocytes	0/50	41/50**	47/50**	48/50**	Active chronic inflammation	33/50	47/50**	44/50**	42/50*	Hepatocyte degeneration	0/50	0/50	5/50*	30/50**	Kidney					Nephropathy	49/50	48/50	50/50	50/50	Severity grade average	1.2	1.4	1.7	3.0	Spleen					Hyperplasia of lymphoid follicles	17/50	31/50**	34/50*	32/50**	Testes					Mineralisation in testes	0/50	1/50	4/50	12/50**	
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Method, guideline, deviations if any, Klimish score, species, strain, sex, no/group	Test substance, dose levels duration of exposure	Results					Reference
		Females					
		Dose levels, ppm (mg/kg bw/day)	0 (0)	312 (35)	625 (70)	1250 (150)	
		Liver Hypertrophy hepatocytes	0/50	29/50**	44/50**	37/50**	
		Kidney Nephropathy	21/50	33/50**	31/50*	30/50*	
		Mineralisation	15/50	31/50**	36/50**	49/50**	
		Severity grade average	1.2	1.1	1.5	1.7	
		Spleen Hyperplasia of lymphoid follicles	24/50	36/50**	37/50**	22/50	
		Hematopoietic cell proliferation	16/50	35/50**	32/50**	27/50*	
		* Significantly different (P≤0.05) from the control group					
		** P≤0.01					
Further, metaplasia of the olfactory epithelium was significantly increased in the high-dose group of males and females.							
Carcinogenicity study, corresponding to OECD TG 451 and in accordance with GLP principles. Klimish score 1.	Benzophenone (BP) (purity > 99%)	Mortality: Severely decreased survival seen in high dose males (4% vs 44% in controls). Low and mid-dose male groups and all female groups have similar or higher survival compared to controls (≥54%).					NTP (2006)
F344/N rats	Oral via diet	Body weights: In males, body weights were decreased from week 62 in the high dose group (36% decrease at study termination), from week 86 in the mid-dose group (11% decrease at study termination). In females, body weights were decreased from week 10 in the high dose group (14% decrease at study termination), and mid-dose group (9% decrease at study termination). Feed consumption was reduced in high dose males from week 70 and in high dose females throughout the study.					
50 males and 50 females in each group	0, 312, 625, or 1250 ppm BP for 105 weeks. Corresponding to 15, 30, and 60 mg BP/kg bw/day for males and 15, 30, and 65 mg BP/kg bw/day for females	Clinical signs: No clinical signs were reported in either sex per dose group except in relation to morbidity.					
Neoplastic findings:							
Males							
Dose levels, ppm (mg/kg bw/day)	0 (0)	312 (15)	625 (30)	1250 (60)			
Mononuclear cell leukemia <sup>a</sup>	27/50 54%	41/50* 82%	39/50* 78%	24/50 48%			
Histiocytic sarcoma	0/50	0/50	0/50	0/50			
Renal tubule adenoma <sup>b</sup>	2/50	2/50	7/50	8/50			

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Method, guideline, deviations if any, Klimish score, species, strain, sex, no/group	Test substance, dose levels duration of exposure	Results					Reference																																			
			4% <sup>b</sup>	4%	14%	16%																																				
		<p>* Significantly different (P≤0.05) from the control</p> <p>** no findings reported, and no HCD available for histiocytic sarcomas in males.</p> <p><sup>a</sup> historical incidences,feed<sup>2</sup>:: 231/460, 30 mean 49.1%)</p> <p><sup>b</sup> historical incidences,feed:: 0- 2% in 1152 control animals, all routes.</p>																																								
		<table><tr><th colspan="5">Females</th></tr><tr><th>Dose levels, ppm (mg/kg bw/day)</th><th>0 (0)</th><th>312 (15)</th><th>625 (30)</th><th>1250 (65)</th></tr><tr><td>Mononuclear cell leukemia<sup>a</sup></td><td>19/50 38%</td><td>25/50 50%</td><td>30/50* 60%</td><td>29/50 58%</td></tr><tr><td>Histiocytic sarcoma<sup>b</sup></td><td>0/50 0%</td><td>0/50 0%</td><td>1/50 2%</td><td>2/50 4%</td></tr></table> <p>* Significantly different (P≤0.05) from the control group</p> <p><sup>a</sup> historical incidences,feed<sup>3</sup>: 112/460, range 12-38% (mean 24.6%)</p> <p><sup>b</sup>historical incidences,feed: 0/460. HCD all routes 0-2 % (mean 0.1%) 1/1209</p> <p><i>Non-neoplastic findings:</i></p> <table><tr><th colspan="5">Males</th></tr><tr><th>Dose levels, ppm (mg/kg bw/day)</th><th>0 (0)</th><th>312 (15)</th><th>625 (30)</th><th>1250 (60)</th></tr><tr><td>Liver  Hepatocytes, centrilobular Hypertrophy</td><td>0/50</td><td>17/50**</td><td>31/50**</td><td>19/50**</td></tr></table>					Females					Dose levels, ppm (mg/kg bw/day)	0 (0)	312 (15)	625 (30)	1250 (65)	Mononuclear cell leukemia <sup>a</sup>	19/50 38%	25/50 50%	30/50* 60%	29/50 58%	Histiocytic sarcoma <sup>b</sup>	0/50 0%	0/50 0%	1/50 2%	2/50 4%	Males					Dose levels, ppm (mg/kg bw/day)	0 (0)	312 (15)	625 (30)	1250 (60)	Liver  Hepatocytes, centrilobular Hypertrophy	0/50	17/50**	31/50**	19/50**	
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<sup>2</sup> Historical control data (HCD): The HCD are reported in the NTP-carcinogenicity study with BP (published in 2006). The data are from 7 NTP-2000 feed studies performed in the period from 1995-2004. For some tumour types, reference to 23 studies from all routes is used. The feed “NTP-2000” was introduced in 1995. The study period of the BP study was from sept 1999 through sept 2001 for mice. and from aug 1999 through aug 2001 for rats. The strains of choice of NTP were the F334/N rats until 2006 and the B6C3F1 mice, and the latter is still the preferred mice strain by NTP. It is therefore presumed that the HCD in the database are for the same strains as used in the carcinogenicity study with BP.

<sup>3</sup> Historical control data (HCD): The HCD are reported in the NTP-carcinogenicity study with BP (published in 2006). The data are from 7 NTP-2000 feed studies performed in the period from 1995-2004. For some tumour types, reference to 23 studies from all routes is used. The feed “NTP-2000” was introduced in 1995. The study period of the BP study was from sept 1999 through sept 2001 for mice. and from aug 1999 through aug 2001 for rats. The strains of choice of NTP were the F334/N rats until 2006 and the B6C3F1 mice, and the latter is still the preferred mice strain by NTP. It is therefore presumed that the HCD in the database are for the same strains as used in the carcinogenicity study with BP.



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Method, guideline, deviations if any, Klimish score, species, strain, sex, no/group	Test substance, dose levels duration of exposure	Results				Reference
		Degeneration, cystic	8/50	11/50	20/50*	15/50*
		Inflammation chronic active	22/5	21/50	35/50*	33/50*
		<i>Kidney</i>				
		Renal tubule hyperplasia	3/50	11/50*	30/50*	40/50*
		Severity grade of nephropathy	1.3	2.4	3.3	3.8
		* Significantly different ( $P \leq 0.05$ ) from the control group				
		** $P \leq 0.01$				
		<b>Females</b>				
		<b>Dose levels, ppm (mg/kg bw/day)</b>	<b>0 (0)</b>	<b>312 (15)</b>	<b>625 (30)</b>	<b>1250 (65)</b>
		<i>Liver</i>				
		Hepatocytes, centrilobular hypertrophy	0/50	27/50*	30/50*	33/50*
		Bile duct hyperplasia	10/50	35/50*	39/50*	40/50*
		Inflammation chronic active	46/50	38/50*	29/50*	30/50*
		<i>Kidney</i>				
		renal tubule hyperplasia	1/50	8/50*	10/50*	7/50*
		severty nephropathy	1.1	1.4	1.7	2.0
		* Significantly different ( $P \leq 0.05$ ) from the control				

Table 10: Summary table of animals studies of carcinogenicity, dermal exposure

Method, guideline, deviations if any, species, strain, sex, no/group	Test substance, dose levels duration of exposure	Results	Reference
Non-guideline Dermal carcinogenicity lifetime study in Swiss mice: Klimish score	Benzophenone (BP) 0.2 ml of 5, 25 and 50% BP in acetone. Twice weekly in	No significant effects on survival or body weight gain were noted.	Stenbäck & Shubik 1974

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Method, guideline, deviations if any, species, strain, sex, no/group	Test substance, dose levels duration of exposure	Results						Reference
2(-3). 50 female mice/group	110 weeks	Group	Control (untreated/ acetone)	5% BP	25% BP	50% BP	Positive control DMBA	
		Number						
		Tumour bearing mice	64/22	26	16	14	39	
		Lymphomas	26/12	15	11	6	6	
		Lung adenomas	17/9	3	3	6	4	
		Liver hemangiomas	4/2	1	1	2	1	
		Thymomas	6/0	1	1	0	0	
		Skin tumours	3/2	2	1	0	75	
		Other tumours	16/6	16	5	4	0	
Non-guideline dermal lifetime study in New Zealand rabbits. Klimish score 2/(3). 5 females and 5 males /group	BP 0.2 ml of 5, 25 and 50% BP (Acetone or methanol) Twice weekly up to 160 weeks	<p>No effects on clinical signs, survival and body weight gain were noted.</p> <p>Autopsy was performed on all animals. Skin samples, grossly observed tumours and other lesions of the lung, liver, kidney etc. from all animals were studied histologically. No abnormalities were detected, as well as no skin tumours or other tumours in animals treated with BP. A nephroblastoma was observed in an untreated animal. In the positive control group 12 tumours were recorded including 7 papillomas, 2 keratoacanthomas and 3 squamous cell carcinomas.</p>						Stenbäck 1977

## 10.9.1 Short summary and overall relevance of the provided information on carcinogenicity

The carcinogenic potential of benzophenone (BP) has been investigated in different species. Two-year oral carcinogenicity studies were performed in rats and mice, in accordance with OECD guidelines and GLP (see table above). Further, two carcinogenicity studies with dermal application were performed in mice and rabbits, respectively. These studies were non-guideline studies, and limited information on the studies are available from the publications.

The major findings relevant for the end-point of carcinogenicity in the four studies are described below.

### 10.9.1.1 Carcinogenicity studies, oral exposure

#### *Mice*

B6C3F1 mice orally were exposed via the diet to 0, 312, 625, or 1250 ppm BP, corresponding to 0, 35, 70, and 150 mg BP/kg bw/day for females and 0, 40, 80, and 160 mg BP/kg bw/day for males. Mortality was increased in the high dose females but not in males. Body weights were affected in females from all dose groups with 14% and 7% and 8% reduction at study termination in high, mid and low dose, respectively, compared to controls, whilst male body weights were only slightly affected. No significant clinical signs were reported except in moribund animals. Tumours were reported in the liver and in the haematopoietic system of females and in the liver of male mice. Non-neoplastic changes in the liver, kidney and spleen were also reported as well as in the testes in the males.

#### *Hepatocellular adenoma, mice*

The incidences of hepatocellular adenoma after exposure to BP showed a positive trend in males with 11/50 (22%), 15/50 (30%), 23/50 (46%) and 23/50 (46%) in the groups receiving 0, 312, 625 and 1250 ppm, respectively, with clear dose-response relationship and significant differences from controls in the two highest dose groups. The incidences exceeded historical control range (12-30%, mean 20%) NTP-2000 feed studies in the mid and high dose groups. In females, incidences of hepatocellular adenomas were 5/50 (10%) in controls, 4/50 (8%) in the low, 10/50 (20%) in the middle and 8/50 (16%) in the high-dose groups. The incidences in treated females were not statistically significantly different from the concurrent controls, but exceeded the NTP feed historical controls for the period (1995-2004) (range 6-12%, mean 9.6%). Also, when correction for weight decrease was performed the incidences in the two highest dose groups expected numbers.

According to two articles describe B6C3F1 mice carry hepatocellular tumour susceptibility loci that results in a high susceptibility to chemically induced cellular hepatocarcinogenesis and therefore a risk of overestimation of the carcinogenic potential in the liver exists (Gariboldi *et al.*, 1993; Manenti *et al.*, 1994). Based on this, the relevance to human risk assessments of hepatic tumours in mice, when induced by non-genotoxic compounds, is disputed (Gold & Slone, 1993; Carmichael *et al.*, 1997; Boobis *et al.*, 2006; Holsapple *et al.*, 2006; Billington *et al.*, 2010).

Overall, the dossier submitter evaluates the findings of hepatoadenomas in mice to be supportive evidence for the carcinogenicity of BP, taking into account the benignity of the tumour form and the increased susceptibility of the mouse strain used. The dossier submitter also notes that the increases in hepatocellular adenoma at the two highest doses occur at higher incidences than spontaneous incidence levels in both male and female mice and thus may be attributed to the BP treatment.

#### *Hepatoblastomas and hepatocellular carcinomas, mice*

Malignant hepatic tumours recorded in the mice in the present study include hepatoblastomas and hepatocellular carcinomas in male mice, and hepatocellular carcinomas in female mice.

With regard to the incidence of *hepatoblastomas* that only occurred in male mice, a positive trend in the incidence of this tumour implies a relation to the treatment (0/50, 1/50, 1/50 and 3/50 in control and low, medium and high dose, respectively). The incidences of this rare tumour were not statistically significant different from that in the controls, but they exceed the NTP-2000-feed historical control incidence range of 0-2% (mean 0.2%). Hepatoblastoma is an uncommon tumour in B6C3F1 mice with shifting incidences in the control B6C3F1 mice in NTP studies (i.e. 0.3 % between 1986 and 1992, and 1.6 % between 1993 and 1999) (Turusov *et al.*, 2002).

The *hepatocellular carcinomas* in the treated males occurred at non-significant levels incidences of 5/50 (10%), 6/50 (12%) and 6/50 (12%) in the low, mid and high dose, respectively, whilst control males incidences were 8/50 (17%) and with no dose-response was demonstrated. For hepatocellular carcinomas, historical controls data in the male B6C3F1 mice were available for an earlier time span (a range of 6-29 %, Maronpot, 1999) No information from the NTP-2000 feed database were reported for hepatocarcinomas alone, only for combined adenoma, carcinoma and hepatoblastoma in male B6C3F1 mice (NTP, 2006) In females, the single incidence of hepatocellular carcinoma in the low and high dose group could be an

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incidental, non treatment related finding considering that the incidence of spontaneous hepatocarcinoma in female B6C3F1 mice is highly variable as indicated by the range 0-20 % (Maronpot, 1999). The NTP report on BP only included historical control data from the NTP-2000 feed studies for combined adenoma and carcinomas in female mice, and not for hepatocarcinomas alone (NTP, 2006).

Thus, the low non-significant incidences of hepatoblastomas and hepatocellular carcinomas in mice lead to uncertainty as to concluding on their relation to BP. However, some concern remains to the occurrence of hepatoblastomas as this is a rare and severe tumour form and even a small increase in such type of tumours should be considered in the context of classification.

Concerning liver tumours in mice as a whole, the NTP concluded that there was “*some evidence of carcinogenic activity*” of BP in males, based on the increased incidences of hepatocellular neoplasms, primarily adenomas and that the incidences of hepatoadenoma in females may have been related to BP exposure,.

### *Histiocytic sarcomas, mice*

In relation to carcinogenicity in the haematopoietic system, the occurrence of histiocytic sarcomas is noted in female B6C3F1 mice treated with BP. The incidence reported in the study is statistically significant in the mid-dose, but not at the high dose, (0/50, 0/50, 5/50 (10%), 3/50 (6%) in the control, low-, middle- and high-dose groups, respectively). Histiocytic sarcoma is a rare tumor form. The incidences in the mid- and high dose groups treated with BP exceed the historical incidence reported by the authors of the study: Mean of 0.3%; range 0-2 % from NTP-2000 feed studies, and mean 1.5%; range 0-8 % based on all routes from historical controls from NTP-studies (1995-2004), and in earlier historical feed studies from the literature (mean 1.4 %, range 0-4 % from Maronpot, 1999; ). Also, a positive trend in the incidences of this tumour in female mice was reported, and indicates a relation to treatment even if a clear dose response is not apparent. The concern for a carcinogenic effect to the hematopoietic system is supported by the statistically significant increase in incidence of the hematopoietic cell proliferation in the spleen in all dosed female groups (16/50, 35/50, 32/50, 27/50).

Based on the finding of increased occurrence of the rare tumour histiocytic sarcoma, the NTP concludes that BP shows “*some evidence of carcinogenic activity*” in female mice. The dossier submitter considers this effect to the hematopoietic system of relevance to the classification for carcinogenicity of BP.

### **Rats**

F334/Nrats were exposed orally via the diet to 0, 312, 625, or 1250 ppm BP which led to mean intakes of 0, 15, 30, and 65 mg BP/kg bw/day for females and 0, 15, 30, and 60 mg BP/kg bw/day for males. The doses were selected based on results from a 14 day-study in which body weights were significantly decreased in all female groups from 1250 ppm to 20,000 ppm and in males from 2500 ppm. Significant non-neoplastic effects were reported from the 14 day study in the liver and kidney from 1250 ppm and in the females from 2500 and 5000 ppm, respectively.

In the carcinogenicity study, mortality was significantly increased in the high dose group males, but not in females at any dose. Body weights in males were decreased in the high dose group (36% decrease at study termination), and in the mid-dose group (11% decrease at study termination). In females, body weights were decreased in the high dose group (14% decrease at study termination), and mid-dose group (9% decrease at study termination). Feed consumption was reduced in high dose animals of both sexes. No clinical signs in either sex per dose group except in relation to morbidity.

Tumours were reported in the liver, the kidney and haematopoietic system of male rats and in the liver and haematopoietic system of females. Non-neoplastic changes in the liver and kidney in both sexes were also reported.

### *Renal tubule adenoma and hyperplasia, rats*

A positive trend in the incidences of renal tubule adenoma was found in the treated males, with a statistically significant increase in the high-dose group.

Spontaneous renal neoplasms in the rat are uncommon (Chandra *et al.*, 1993). Background incidences of renal cell adenomas as low as 0.38 % and 0.19 % were reported for male and female F344 rats, respectively (Chandra *et al.*, 1993). The association between BP treatment and renal tubule adenoma is supported by the fact that the incidences in the treated male groups exceeded the historical incidence for 2-year control feed studies given NTP-2000 diet (range 0-2 % as reported in NTP, 2006).

Statistically significant increase in incidences of renal tubule hyperplasia was seen in all BP treated groups of males and females. Chronic progressive nephropathy (CPN) is a common, spontaneous disease of the rat kidney (Travlos *et al.* 2011). An association between treatment related chronic progressive nephropathy in 90-day studies and increased incidence of renal tubule tumours at 2 years has been found for 7 chemicals studied by NTP (Travlos *et al.*, 2011). It was concluded that CPN leads to renal tubular tumours in male rats and should be considered of no relevance for humans risk assessment as CPN has no counterpart in humans (Travlos *et al.*, 2011; Hard *et al.*, 2009). However, the possible aetiology and mode of action leading to the development of renal tubular tumours are disputed, based i.a. on an analysis of 60 NTP carcinogenicity studies in rats (Melnick *et al.*, 2012). Based on the morphological hyperplastic changes in the kidney in both the 14-week and the 2-year study of BP, it is clear that BP exacerbates CPN (NTP, 2000; 2006). In the discussion of the results of the NTP carcinogenicity study with BP (NTP 2006) the involvement of chronic nephropathy in development of the renal tubule tumours is assessed to be possible. However, NTP further stresses that the pathogenesis of chemically induced renal tubular tumours has not been determined, but appears to be complex and not solely due to CPN. The NTP concluded that the increased incidence of renal tubule adenomas in male F344/N rats were “*some evidence of carcinogenic activity*” (NTP, 2006).

As the mode of action leading to the increased renal tubule tumour incidence in male rats is not fully elucidated, a residual concern for these tumours remains and the finding should be taken in consideration in the evaluation of Weight of evidence (WoE) to the classification of BP for carcinogenicity.

#### *Mononuclear cell leukemia (MNCL), rats*

A statistically significant increase in the incidences of MNCL in the low- and middle-dose groups of males, and in the middle-dose group of females was found in rats. The incidence of MNCL in the male high-dose (48%) group was comparable to that in the control group (54%). Both low (82%) and middle group incidences (78%) were outside the historical range from the NTP control database using NTP-2000 feed between 1995 and 2004 (30-68%) reported by the authors of the study. The lack of dose response for incidences of MNCL in the male rats treated with BP, may be due to reduced survival (deaths) in the high-dose group (the tumour from is generally a late developing neoplasm, and half of the animals died before week 90).

In treated females, the increased incidence of MNCL reached statistical significance only was recorded only in the middle dose (60%) group compared to concurrent controls (38%), which was at the upper end of the historical control data.. All treated females had increased incidences of MNCL compared to historical incidence in controls from 2-year feed studies by NTP (controls given the NTP-2000 diet between 1995 and 2004) was in a range of 12-38 % in females (NTP, 2006).

The human relevance of increased incidences of MNCL in F344 rats is debated. Caldwell (1999) found that MNCL occur in untreated, aged F-344 rats at a high and variable rate, that it is uncommon in most other rat strains, and that its background incidence has increased significantly over time. In relation to MNCL in F-344 rats of both sexes, Caldweel (1999) noted that hemolymphoreticular neoplasm is unique to the rat and is only common in this strain. MNCL has not been found in other mammalian species (e.g. mice and hamsters) and no histologically comparable tumour is found in humans. Thus, Caldwell (1999) concluded MNCL in F344 rats to be of little or no relevance to humans. A similar view is given by Scheepmaker *et al.* (2005) in a report for RIVM. The authors noted that the mechanism for the induction of MNCL in F344 is unknown, and that several substances increasing MNCL in chronic studies also have a growth stimulating effect on MNCL cells which indicates that increases in MNCL are at least partly caused by stimulation of proliferation of existing MNCL. Overall, Scheepmaker *et al.* (2005) concluded that substance-induced increases in MNCL in F344 rats should not be considered of human relevance, whereas increases of MNCL in other rat strains and other species should be considered as relevant for humans.

However, Thomas et al. (2007) found that a rare form of human lymphocyte leukemia (natural killer cell large granular lymphocyte leukemia; NK-LGLL) is similar to MNCL observed in F344 rats. They further noted that little is known about the cellular/molecular pathways of leukemogenesis in the F344 rats and found that more mechanistic information is needed for arriving a scientifically sound conclusions as to the relevance in human cancer risk assessment. Pointing towards elements such as levels of significance, nature of dose-response curve, reduction in latency time, genotoxicity, cytotoxicity a.o., the authors called for a more precautionary approach and using a weight-of evidence approach when assessing the human relevance of increased MNCL in F344 rats.

Thus, for the increase in MNCL, human relevance cannot completely be ruled out. The NTP concluded that the MNCL in male as well as female F344/N rats contributed to “some evidence of carcinogenic activity”, whilst the marginally increased incidences of MNCL in female rats were indication of “*equivocal evidence of carcinogenic activity*” (NTP, 2006).

### *Histiocytic sarcomas, rats*

Histiocytic sarcomas did not occur in male rats treated with BP but occurred in one female rat in the middle dose group (1%), and 2 female rats in the high dose group (2/50) whilst no histiocytic sarcoma was detected in the controls or in the low-dose group of either sex. Histiocytic sarcoma of haematopoietic system found in the study with BP in female F-344 rats is a rare tumour as indicated by the historical incidence. This malignant neoplasm was not observed in the historical feed control studies between 1995 and 2004 of F344 rats given NTP-2000 diet and its incidence for all routes in 2-year rat studies was in a range of 0-2 % (NTP, 2006). The NTP considered the histiocytic sarcoma in females rats to be “*equivocal evidence of carcinogenic activity*” (NTP, 2006)

Although very few incidences are reported, the relation to treatment and histiocytic sarcoma in female rats in the middle- and high-dose groups is supported by the fact that this tumour is very rare, and this finding is therefore evaluated by the dossier submitter to be of relevance to the classification of BP. Furthermore, the findings are supported by the observations of histiocytic sarcomas in female mice (see above).

### **10.9.1.2 Dermal carcinogenicity studies**

A non-guideline dermal carcinogenicity lifetime study was performed in Swiss mice with 50 females per group. BP was by open dermal application exposed to 0.2 ml of 5, 25 and 50% BP in acetone on the dorsal skin of the animals twice weekly in 110 weeks.

In BP treated groups the highest number of animals bearing tumours was in the low-dose group and it was not statistically significantly higher than in the positive control group (26/50 versus 39/50;  $p > 0.05$ , Fisher's exact test performed by the evaluators). There was no dose response in total number of tumours, lymphomas, thymomas, skin tumours and other tumours. The numbers of liver adenomas and haemangiomas were low and not higher than in the vehicle control group. No increased mortality or body weight changes occurred in the dosed group (other types of effects including organ weight and macroscopic and microscopic changes in organs were reported). Overall, the authors concluded that there was no indication of a carcinogenic potential of BP in mice following a topical administration under conditions of this bioassay. It should be noted that open dermal application was used which may limit the dermal absorption of the substance in this study. Under more optimal conditions for dermal absorption a dermal absorption rate of about 70% was found for BP in rhesus monkeys under occlusive conditions according to Bronaugh et al. (1990), as reported in the REACH registration of the substance.

Further, a non-guideline dermal carcinogenicity lifetime study was also performed in New Zealand rabbits with 5 rabbits (both sexes) per group. BP was exposed by open dermal application to 0.2 ml of 5, 25 and 50% BP in solvent to the interior left ear of the animals twice weekly in up to 116 weeks.

No treatment related effect was found on mortality. The survival at week 160 was 1, 3 and 2 rabbits in the low, middle, and high-dose BP groups, and 3 in the untreated control group, respectively, with an initial number of animals of 5. In another control group (4 rabbits in the start) no survivals were present in week 120.

Complete autopsies were performed on all animals. Skin samples, grossly observed tumours and other lesions of the lungs livers, kidneys etc. from all animals were studied histologically. No abnormalities were detected, as well as no skin tumours or other tumours in animals treated with BP. A nephroblastoma was observed in an untreated animal. In the positive control group 12 tumours were recorded including seven papillomas, two keratoacanthomas and three squamous cell carcinomas.

**In summary, no indication of carcinogenic effects of BP was found after dermal application in mice or rabbits. The study in mice was published in 1974, and as such was not performed according to Good Laboratory Practice (GLP) and OECD guidelines. As open dermal application of the test substance was used in both studies the studies are considered most relevant for the assessment of the potential to induce local skin tumours as it is very uncertain to which degree dermal absorption had occurred in the studies. Thus, the studies are considered of limited relevance for assessing the carcinogenic potential of BP in connection with systemic exposure.**

### 10.9.1.3 Mechanistic considerations

As indicated in the evaluation of the oral carcinogenicity studies in mice and rats increases in various tumours have been found and explanations/ mechanisms and relevance for humans have been discussed. Table 11 below provides an overview of the tumour forms and possible mechanistic considerations and indicate a qualitative score for use in a WoE assessment for the tumour form as such (i.e. no dose-response considerations are included):

Table 11. Overview of tumour types and qualitative interpretation with regard to the WoE assessment. The relevance was scored as follows: - Not to be considered; + considered as weak evidence; ++ considered as important evidence.

Species, sex Type of tumours	Explanations/ mechanistic considerations	Relevance to humans	Emphasis for WoE assessment
B6C3F1 mice, female <i>-Hepatocellular adenoma/carcinoma</i>  <i>-Histiocytic sarcoma</i>	B6C3F1 mice carry a hepatocellular tumour susceptibility loci. High spontaneous rate, but below incidences when treated with BP.  Rare tumour form. Mechanism not clarified.	Reduced susceptibility in humans  Relevant	+ / -  ++
B6C3F1 mice, male <i>-Hepatocellular adenoma/carcinoma</i>  <i>-Hepatoblastoma</i>	B6C3F1 mice carry a hepatocellular tumour susceptibility loci. High spontaneous rate, but below incidences when treated with BP.  Rare tumour form. Mechanism not clarified.	Reduced susceptibility in humans  Relevant	+ / -  ++
F344/N rats, female <i>-Mononuclear cell leukemia</i>  <i>- Histiocytic sarcoma</i>	High spontaneous rate. Mechanism not clarified  Rare tumour.	Relevance debated but cannot be excluded  Relevant	+  ++

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	Mechanism not clarified		
F344/N rats, male <i>-Mononuclear cell leukemia</i>	High spontaneous rate. Mechanism not clarified	Relevance debated but cannot be excluded	+
<i>-Renal tubule adenoma</i>	Uncommon tumour form. Mechanism of tumour formation not clarified, albeit in male rats appears related to progression from chemically induced severe nephropathy, which has no counterpart in humans	Relevance debated but cannot be excluded	-

As indicated in table 11 above very little is known regarding mechanisms of the different types of tumour.

This is in line with evaluation of BP by IARC (2013) who found that mechanistic explanations for the tumours occurring in the NTP (2006) studies currently are not understood in detail. The involvement of generation of reactive oxygen species and/or endocrine disruption through multiple receptors were hypothesized. Overall, it was concluded that data for mechanistic explanations were too limited and weak to rule out the human relevance of the tumour response found in the experimental animals (IARC 2013).

In the Substance evaluation conclusion document by the Danish EPA (2018) potential endocrine mechanisms for BP were discussed including thyroid peroxidase (TPO) inhibition and estrogenic and anti-androgenic activity. However, no firm conclusion could be drawn from the available data

### 10.9.1.4 Overall summary

In summary, BP exhibits carcinogenic effects in several organs in two species of rodents as reported in a GLP and OECD guideline study from 2006.

The dose setting for the mouse carcinogenicity was based on the results of a 14-day mouse study conducted by the NTP in 2000 in which doses of 2500 ppm led to dramatic increases in liver weights in males (55%) and females (56%).

The study doses for rats were chosen based on minimal toxicity response at 1250 ppm in a 14-day study conducted by the NTP in 2000, in which 2500 ppm led to body weight gains reductions of 7% and 12% in male and female rats, respectively, liver weight increased of 43 and 28%, respectively, and incidences of kidney lesions were increased.

In the carcinogenicity study, there was a high level of mortality in the high dose male rats. Body weight decreases of 9-36% were reported in mid- and high-dose groups. In the mice, survival was non-significantly affected only in the high dose females, and body weight decrease over 10% in that group, whilst males and mid-group females did not exhibit signs of general toxicity.

It cannot be excluded that higher doses could have been tolerated in the carcinogenicity study by especially male mice and female rats. As some general toxicity is reported at the highest dose group in both the mouse and the rat, the doses administered in the carcinogenicity study by NTP in mice and rats are relevant and the study is considered valid. However, it is possible that higher doses might have enhanced the tumorigenic response and/or led to more clear dose-responses.

The tumour findings for mice following oral exposure to BP show significantly increased dose-related incidences of hepatocellular adenomas in exposed male mice and increased incidence outside the historical control range in female mice. However, no increases in hepatocellular carcinoma were noted neither in



female nor male mice. In male mice a small non-significant number of the rare tumour heptablastoma was noted in the treated groups.

In rats, significantly increased incidences of mononuclear cell leukemia (MNCL) and of renal tubule tumours were observed in males treated with BP for 2 years. The NTP concluded that the MNCL in male as well as female F344/N rats contributed to “some evidence of carcinogenic activity”, whilst the marginally increased incidences of MNCL in female rats were indication of “*equivocal evidence of carcinogenic activity*” (NTP, 2006). Thus, the dossier submitter evaluates that the human relevance of the increase in MNCL cannot completely be ruled out.

Further, increases of the rare tumour histiocytic sarcoma were observed in both female mice and female rats. Although not significant the increases exceeded the historical control values in both species.

No increased carcinogenic response was found following dermal exposure of mice and rabbits to BP in pre GLP and pre OECD guideline studies. However, these two studies were not conducted according to today's standard. As open dermal application of the test substance was used in both studies only lack of carcinogenic potential towards local skin tumours can be concluded from these studies.

### 10.9.2 Comparison with the CLP criteria

As no relevant human data on the carcinogenicity of benzophenone is available, a classification in Category 1A is not appropriate.

Classification as carcinogenic in Category 1B: “*presumed to have carcinogenic potential for humans, classification is largely based on animal evidence*” should be considered, if there are animal experiments available “*for which there are sufficient evidence to demonstrate animal carcinogenicity (presumed human carcinogen)*” (CLP criteria section 3.6.2.1). The criteria for carcinogenicity Category 1B further stipulate that “*a causal relationship should be established between the agent and an increased incidence of malignant neoplasms or of an appropriate combination of benign and malignant neoplasms in two or more species of animals*” (CLP criteria section 3.6.2.2.3.).

Arguments for a Category 1B classification for benzophenone are:

- Increase of multiple, tumour forms in two species
- Occurrence of increased incidences of the rare tumour forms, histiocytic sarcoma in female mice and female rats, and of hepatoblastomas in male mice
- Supporting evidence from significantly increased findings of hepatocellular adenoma in female mice and male mice, of renal tubular tumours in male rats and of significantly increased findings of mononuclear cell leukemia (MNCL) in female and male rats

However, the dossier submitter does not consider the criteria for classification in Category 1B to be fulfilled for benzophenone for the following reasons:

- For tumours with a high spontaneous incidences as liver tumours in B6C3F1 mice and MNCL in F344 rats the increases in the tumour incidences in exposed animals, seen with BP treatment although beyond background levels, may not provide sufficient certainty of treatment related carcinogenicity.
- The relevance to humans of renal tubular tumours is debated, as these tumours have been suggested to develop from chronic progressive neuropathy, with no counterpart in humans.
- BP is not a genotoxic substance

Classification as carcinogen, category 2 “*Suspected human carcinogen*”s criteria reads: “*The placing of a substance in Category 2 is done on the basis of evidence obtained from human and/or animal studies, but which is not sufficiently convincing to place the substance in Category 1A or 1B, based on strength of evidence together with additional considerations (see section 3.6.2.2). Such evidence may be derived either*

*from limited ( 1 ) evidence of carcinogenicity in human studies or from limited evidence of carcinogenicity in animal studies.”*

The dossier submitter concludes that a classification of benzophenone in Category 2, H351 is warranted based on the available data.

This classification is based on increased incidences of the rare tumour form *histiocytic sarcoma* in one sex from two species: female mice and female rats and the likewise rare *hepatoblastoma* in male mice above historical background levels.

The increased incidences of *hepatocellular adenoma* in male and female mice above high spontaneous incidences as well as the increased incidences of *mononuclear cell leukaemia* and of *renal tubular tumours* in male rats, with the uncertainty expressed above, further support this classification.

The increased incidences of hepatocellular adenoma in female and male mice and increased incidences of mononuclear cell leukaemia and renal tubular tumours in male rats further support this classification. The relevance to humans of these tumour forms is discussed. However, the evidence on modes of action for the tumours is insufficient to completely dismiss their relevance to humans. Thus, a concern for the multiple organ carcinogenicity of BP remains.

“No classification” of benzophenone for carcinogenicity is not relevant: The available data from animal studies in both rats and mice at relatively low doses demonstrate increased incidences of various tumour forms and also include rare tumour types in both species. Even though some of the tumours may have low relevance to humans the data show that benzophenone has a carcinogenic potential. Therefore, BP should be classified for carcinogenicity.

## 10.9.3 Conclusion on classification and labelling for carcinogenicity

Based on the available data and considering the CLP classification criteria and guidance established in connection with these, it is concluded appropriate to classify BP as:

*Carcinogenic in Category 2, H351*

### RAC evaluation of carcinogenicity

#### Summary of the Dossier Submitter’s proposal

The DS included two high-quality oral carcinogenicity studies in mice and rats, respectively, performed and reported by NTP (2006). Furthermore, two relatively old dermal carcinogenicity studies of lower quality by Stenbäck & Shubik (1974) using mice and by Stenbäck (1977) using rabbits were summarised in the CLH report.

Based on the available data the DS concluded that a classification of benzophenone in Category 2, H351 is warranted based on increased incidences of the rare tumour histiocytic sarcoma in female mice and female rats (single sex, two species) and the likewise rare hepatoblastoma in male mice at above historical background levels.

In addition, an increased incidence of hepatocellular adenoma in male and female mice above high spontaneous incidences as well as increased incidences of mononuclear cell leukaemia and of renal tubular tumours in male rats were used as supporting evidence.

The DS considered the evidence on the mode of action for the above-mentioned tumours insufficient to dismiss their relevance to humans.

## Comments received during public consultation

Comments were provided by 3 MSCA. Two MSCA supported the proposed classification as Carc. 2, however one MSCA indicated that Carc. 1B should be considered based on induction of rare malignant tumours relevant for humans in two species, namely the histiocytic sarcoma in female mice and rats and hepatoblastoma in male mice.

## Assessment and comparison with the classification criteria

The DS included four studies for the evaluation of carcinogenicity. This included two oral carcinogenicity studies in mice and rats and two dermal carcinogenicity studies in mice and rabbits. The studies are summarised in the table below.

*Table: Summary of animal carcinogenicity studies, oral exposure to Benzophenone (BP)*

Method, guideline, test substance, deviations, Klimisch score, species, strain, sex, no/group, dose levels duration of exposure	Results	Ref.																								
Carcinogenicity study, corresponding to OECD TG 451  BP (purity > 99%)  Oral via diet  GLP  Klimisch score 1  B6C3F1 mice  50 m/f per group  0, 312, 625, or 1250 ppm for 105 weeks. Corresponding to 40, 80, and 160 mg BP/kg bw/day for males and 35, 70, and 150 mg BP/kg bw/day for females	<p>Mortality: Non-significant decreased survival in high dose females (62 % vs 80% in controls). Other groups similar survival to controls (&gt;80%)</p> <p>Body weights: No effect on mean body weights of exposed males. In females, body weights were decreased from week 37 in the high dose group (14% decrease at study termination) from week 52 in the mid-dose group (8% decrease at study termination) and from week 92 in the low-dose group (7% decrease at study termination). No effect on feed intake.</p> <p>Clinical signs: No clinical signs in either sex per dose group except in moribund animals).</p> <p><u>Neoplastic findings:</u></p> <table><tr><th colspan="6">Males /females (50/50)</th></tr><tr><th>Dose levels, ppm (mg/kg bw/d</th><td>0 (0/0)</td><td>312 (40/35)</td><td>625 (80/70)</td><td>1250 (160/150)</td><td>HCD</td></tr><tr><td>Hepato-cellular adenoma</td><td>11/5 22%/10%</td><td>15/4 30%/8%</td><td>23*/10* 46%/20 %</td><td>23*/8* 46%/16%</td><td>Males (feed): 9/460, range 12-30%, mean 20%, Females: 40/457, range 6-12%, mean 9.6%</td></tr><tr><td>Hepato-cellular carcinoma</td><td>8/0</td><td>5/1 10%/2%</td><td>6/0 12%/0%</td><td>6/1 12%/2%</td><td>Males (all routes): 8-46%,</td></tr></table>	Males /females (50/50)						Dose levels, ppm (mg/kg bw/d	0 (0/0)	312 (40/35)	625 (80/70)	1250 (160/150)	HCD	Hepato-cellular adenoma	11/5 22%/10%	15/4 30%/8%	23*/10* 46%/20 %	23*/8* 46%/16%	Males (feed): 9/460, range 12-30%, mean 20%, Females: 40/457, range 6-12%, mean 9.6%	Hepato-cellular carcinoma	8/0	5/1 10%/2%	6/0 12%/0%	6/1 12%/2%	Males (all routes): 8-46%,	NTP (2006)
Males /females (50/50)																										
Dose levels, ppm (mg/kg bw/d	0 (0/0)	312 (40/35)	625 (80/70)	1250 (160/150)	HCD																					
Hepato-cellular adenoma	11/5 22%/10%	15/4 30%/8%	23*/10* 46%/20 %	23*/8* 46%/16%	Males (feed): 9/460, range 12-30%, mean 20%, Females: 40/457, range 6-12%, mean 9.6%																					
Hepato-cellular carcinoma	8/0	5/1 10%/2%	6/0 12%/0%	6/1 12%/2%	Males (all routes): 8-46%,																					

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		16%/0%				mean 22.9%, 1257 controls.
	Hepato-blastoma	0/- 0%/-	1/- 2%/-	1/- 2%/-	3/- 6%/-	Males (feed): 1/460, range 0-2%, mean 0.2%. Females: not reported.
	Hepato-cellular adenoma, carcinoma or hepato-blastoma (males)	18/- 36%/-	20/- 40%/-	25/- 50%/-	29*/- 58%/-	Males (feed): 145/460, range 20-47%, mean 32%.
	Hepato-cellular adenoma or carcinoma (females)	-/5 - /10%	-/5 -/10%	-/10 -/20%	-/9* -/18%	Females: 53/457, range 8-16%, mean 11.8%
	Histiocytic sarcoma	1/0 0%/0%	0/0 0%/0%	0/5* 0%/10%	0/3 0%/6%	Males; not available. Females: 2/459, range 0-2%, mean 0.3%
*: Significantly different ( $P \leq 0.05$ ) from the control group -: not reported						
<i>Non-neoplastic findings:</i>						
<b>Males/females (50/50):</b>						
	Dose levels, ppm (mg/kg bw/d)	0 (0/0)	312 (40/35)	625 (80/70)	1250 (160/150)	
	<i>Liver</i>					
	Hypertrophy hepatocytes	0/0	44**/29**	50**/44**	48**/37**	
	Micronucleated hepatocytes	0/-	41**/-	47**/-	48**/-	
	Active chronic inflammation	33/-	47**/-	44**/-	42**/-	
	Hepatocyte degeneration	0/-	0/-	5/-	30**/-	
	<i>Kidney</i>					
	Nephropathy	49/21	48/33**	50/31*	50/30*	
	Mineralisation	-/15	-/31**	-/36**	-/49**	
	Severity grade	1.2/1.2	1.4/1.1	1.7/1.5	3.0/1.7	

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	<table><tr><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td><i>Spleen</i> Hyperplasia of lymphoid follicles Hematopoietic cell proliferation</td><td>17/24  -/16</td><td>31**/36**  -/35**</td><td>34*/37**  -/32**</td><td>32**/22  -/27*</td></tr><tr><td><i>Testes</i> Mineralisation</td><td>0/-</td><td>1/-</td><td>4/-</td><td>12**/-</td></tr></table> <p>Significantly different from the control group: * (P≤0.05), ** P≤0.01 -: not reported</p> <p>Further, metaplasia of the olfactory epithelium was significantly increased in the high-dose group of males and females.</p>							<i>Spleen</i> Hyperplasia of lymphoid follicles Hematopoietic cell proliferation	17/24  -/16	31**/36**  -/35**	34*/37**  -/32**	32**/22  -/27*	<i>Testes</i> Mineralisation	0/-	1/-	4/-	12**/-									
<i>Spleen</i> Hyperplasia of lymphoid follicles Hematopoietic cell proliferation	17/24  -/16	31**/36**  -/35**	34*/37**  -/32**	32**/22  -/27*																						
<i>Testes</i> Mineralisation	0/-	1/-	4/-	12**/-																						
Carcinogenicity study, corresponding to OECD TG 451  BP (purity > 99%)  Oral via diet  GLP  Klimisch score 1  F344/N rats  50 m/f per group  0, 312, 625, or 1250 ppm BP for 105 weeks. Corresponding to 15, 30, and 60 mg BP/kg bw/day for males and 15, 30, and 65 mg BP/kg bw/day for females	<p>Severely decreased survival seen in high dose males (4% vs 44% in controls). Low and mid-dose male groups and all female groups have similar or higher survival compared to controls (≥54%).</p> <p>Body weights: In males, body weights were decreased from week 62 in the high dose group (36% decrease at study termination), from week 86 in the mid-dose group (11% decrease at study termination). In females, body weights were decreased from week 10 in the high dose group (14% decrease at study termination), and mid-dose group (9% decrease at study termination). Feed consumption was reduced in high dose males from week 70 and in high dose females throughout the study.</p> <p>Clinical signs: No clinical signs were reported in either sex per dose group except in relation to morbidity.</p> <p><u>Neoplastic findings:</u></p> <table><tr><th colspan="6">Males/females (50/50)</th></tr><tr><td>Dose levels, ppm (mg/kg bw/d)</td><td>0/0 (0/0)</td><td>312/312 (15/15)</td><td>625/625 (30/30)</td><td>1250/1250 (60/65)</td><td>HCD</td></tr><tr><td>Mononuclear cell leukemia</td><td>27/19 54%/38%</td><td>41*/25 82%/50%</td><td>39*/30* 78%/60%</td><td>24/29 48%/58%</td><td>(feed), Males: 231/460, range 30-68% (mean 49.1%), Females: 112/460, range 12-38%, mean 24.6%)</td></tr><tr><td>Histiocytic sarcoma</td><td>-/0 -/0%</td><td>-/0 -/0%</td><td>-/1 -/2%</td><td>-/2 -/4%</td><td>Males: not available. Females (feed): 0/460. All routes range 0-2%, mean 0.1%, 1/1209</td></tr></table>	Males/females (50/50)						Dose levels, ppm (mg/kg bw/d)	0/0 (0/0)	312/312 (15/15)	625/625 (30/30)	1250/1250 (60/65)	HCD	Mononuclear cell leukemia	27/19 54%/38%	41*/25 82%/50%	39*/30* 78%/60%	24/29 48%/58%	(feed), Males: 231/460, range 30-68% (mean 49.1%), Females: 112/460, range 12-38%, mean 24.6%)	Histiocytic sarcoma	-/0 -/0%	-/0 -/0%	-/1 -/2%	-/2 -/4%	Males: not available. Females (feed): 0/460. All routes range 0-2%, mean 0.1%, 1/1209	NTP (2006)
Males/females (50/50)																										
Dose levels, ppm (mg/kg bw/d)	0/0 (0/0)	312/312 (15/15)	625/625 (30/30)	1250/1250 (60/65)	HCD																					
Mononuclear cell leukemia	27/19 54%/38%	41*/25 82%/50%	39*/30* 78%/60%	24/29 48%/58%	(feed), Males: 231/460, range 30-68% (mean 49.1%), Females: 112/460, range 12-38%, mean 24.6%)																					
Histiocytic sarcoma	-/0 -/0%	-/0 -/0%	-/1 -/2%	-/2 -/4%	Males: not available. Females (feed): 0/460. All routes range 0-2%, mean 0.1%, 1/1209																					

# ANNEX 1 – BACKGROUND DOCUMENT TO RAC OPINION ON BENZOPHENONE

	<table><tr><td>Renal tubule adenoma</td><td>2/- 4%</td><td>2/- 4%</td><td>7/- 14%</td><td>8/- 16%*</td><td>0-2% in 1152 controls</td></tr></table> <p>* Significantly different (P≤0.05) from the control -: not reported</p> <p><i>Non-neoplastic findings:</i></p> <table><tr><th colspan="6">Males/females (50/50)</th></tr><tr><td>Dose levels, ppm (mg/kg bw/d)</td><td>0/0 (0/0)</td><td>312/312 (15/15)</td><td>625/625 (30/30)</td><td>1250/1250 (60/65)</td><td></td></tr><tr><td>Liver Hepatocytes, centrilobular hypertrophy</td><td>0/0</td><td>17**/27*</td><td>31**/30*</td><td>19**/30*</td><td></td></tr><tr><td>Degeneration, cystic</td><td>8/-</td><td>11/-</td><td>20*/-</td><td>15*/-</td><td></td></tr><tr><td>Inflammation chronic active</td><td>22/46</td><td>21/38*</td><td>35*/29*</td><td>33*/30*</td><td></td></tr><tr><td>Bile duct hyperplasia</td><td>-/10</td><td>-/35*</td><td>-/39*</td><td>-/40*</td><td></td></tr><tr><td>Kidney Renal tubule hyperplasia</td><td>3/1</td><td>11*/8*</td><td>30*/10*</td><td>40*/7*</td><td></td></tr><tr><td>Severity grade of nephropathy<sup>a</sup></td><td>1.3/1.1</td><td>2.4/1.4</td><td>3.3/1.7</td><td>3.8/2.0</td><td></td></tr></table> <p>* Significantly different (P≤0.05) from the control group ** P≤0.01 -: not reported <sup>a</sup>Severity grade: 1=minimal, 2=mild, 3=moderate, 4=marked</p>	Renal tubule adenoma	2/- 4%	2/- 4%	7/- 14%	8/- 16%*	0-2% in 1152 controls	Males/females (50/50)						Dose levels, ppm (mg/kg bw/d)	0/0 (0/0)	312/312 (15/15)	625/625 (30/30)	1250/1250 (60/65)		Liver Hepatocytes, centrilobular hypertrophy	0/0	17**/27*	31**/30*	19**/30*		Degeneration, cystic	8/-	11/-	20*/-	15*/-		Inflammation chronic active	22/46	21/38*	35*/29*	33*/30*		Bile duct hyperplasia	-/10	-/35*	-/39*	-/40*		Kidney Renal tubule hyperplasia	3/1	11*/8*	30*/10*	40*/7*		Severity grade of nephropathy <sup>a</sup>	1.3/1.1	2.4/1.4	3.3/1.7	3.8/2.0		
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Dermal carcinogenicity lifetime study in Swiss mice  Non-guideline  Klimisch score 2(-3).  50 female mice/group  0.2 mL of 5, 25 and 50% BP in acetone  Twice weekly in 110 weeks	No significant effects on survival or body weight gain were noted.  <table><tr><td></td><td>Control (untreated/acetone)</td><td>5% BP</td><td>25% BP</td><td>50% BP</td><td>Positive control DMBA</td></tr><tr><td>Tumour bearing mice</td><td>64/22</td><td>26</td><td>16</td><td>14</td><td>39</td></tr><tr><td>Lymphomas</td><td>26/12</td><td>15</td><td>11</td><td>6</td><td>6</td></tr><tr><td>Lung adenomas</td><td>17/9</td><td>3</td><td>2</td><td>6</td><td>4</td></tr><tr><td>Liver heman-giomas</td><td>4/2</td><td>1</td><td>1</td><td>2</td><td>1</td></tr><tr><td>Thymomas</td><td>6/0</td><td>1</td><td>1</td><td>0</td><td>0</td></tr></table>		Control (untreated/acetone)	5% BP	25% BP	50% BP	Positive control DMBA	Tumour bearing mice	64/22	26	16	14	39	Lymphomas	26/12	15	11	6	6	Lung adenomas	17/9	3	2	6	4	Liver heman-giomas	4/2	1	1	2	1	Thymomas	6/0	1	1	0	0	Stenbäck & Shubik, 1974																		
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	Skin tumours	3/2	2	1	0	75		
	Other tumours	16/6	16	5	4	0		
Dermal lifetime study in New Zealand rabbits.  Non-guideline  Klimisch score 2/(3)  5 m/f per group  0.2 mL of 5, 25 and 50% BP (Acetone or methanol)  Twice weekly up to 160 weeks	No effects on clinical signs, survival and body weight gain were noted.  Autopsy was performed on all animals. Skin samples, grossly observed tumours and other lesions of the lung, liver, kidney etc. from all animals were studied histologically.  No abnormalities were detected, as well as no skin tumours or other tumours in animals treated with BP. A nephroblastoma was observed in an untreated animal. In the positive control group 12 tumours were recorded including 7 papillomas, 2 keratoacanthomas and 3 squamous cell carcinomas.							Stenbäck, 1977

**The historical control data (HCD)** reported in the carcinogenicity study with BP (NTP, 2006) are from 7 NTP feed studies performed from 1995-2004. For some tumour types, reference to 23 studies for all routes is used. The study period for the BP study was from September 1999 through September 2001 for mice and from August 1999 through August 2001 for rats.

### **Oral studies**

#### Mice

The DS included one carcinogenicity study (corresponding to OECD TG 451, GLP) with B6C3F1 mice (50/sex/dose group) orally exposed to 0, 312, 625, or 1250 ppm Benzophenone (diet), corresponding to 0/0, 40/35, 80/70, and 160/150 mg Benzophenone /kg bw/day for males/females (NTP, 2006). Increased mortality was observed for females in the high dose group. Body weights were reduced in exposed females by 8%, 7% and 14% for low-, mid-, and high dose group respectively, compared to controls. In males, body weights were only slightly affected. No significant clinical signs were reported except in moribund animals. Tumours were reported in the liver and in the haematopoietic system of females and in the liver of male mice. Non-neoplastic changes in the liver, kidney and spleen were also reported as well as in the testes in the males.

#### Liver

The incidences of hepatocellular adenoma after exposure to Benzophenone showed a positive trend in males with 11 (22%), 15 (30%), 23 (46%) and 23 (46%) in the control, low, mid and high dose groups, respectively. The incidences in the mid and high dose groups were significantly different from the control group and in addition exceeded the HCD (range 12-30%, mean 20%). In females, the incidences of hepatocellular adenomas were 5 (10%), 4 (8%), 10 (20%) and 8 (16%) in the control, low, mid and high dose groups, respectively, however without statistical significance. The HCD (range 6-12%, mean 9.6%) was exceeded for the mid and high dose groups.

The hepatocellular carcinomas in the treated males occurred at non-significant incidences of 8 (17%), 5 (10%), 6 (12%) and 6 (12%) in control, low, mid and high dose groups, respectively. The reported HCD (all routes) for males were 8-46% (mean 22.9%). In females, only single incidences of hepatocellular carcinoma were reported in the low and

high dose group which could be considered incidental. No HCD was reported for hepatocellular carcinomas.

Hepatoblastomas were only observed in male mice, with an incidence of 0, 1 (2%), 1 (2%) and 3 (6%) in control and low, medium and high dose, respectively. The findings were not statistically significant, however they exceeded the HCD incidence (range 0-2%, mean 0.2%).

The combined incidence of hepatoadenomas, hepatocarcinomas and hepatoblastomas in male mice reached statistical significance in the high dose group, with an incidence of 18 (36%), 20 (40%), 25 (50%) and 29 (58%) in control, low, mid and high dose groups, respectively. The HCD from seven NTP studies (1995-2004) showed a combined incidence of hepatoadenomas, hepatocarcinomas and hepatoblastomas in male mice of 20 (47%; mean 32%). For female mice the combined incidence of hepatoadenomas and hepatocarcinomas were 5 (10%), 5 (10%), 10 (20%) and 9 (18%) in control, low, mid and high dose groups, respectively. The HCD from these seven NTP studies showed a combined incidence of hepatoadenomas and hepatocarcinomas in female mice of 8-16% (mean 11.8%). Hepatoblastomas were not observed in female mice.

A statistically significant increase in incidences of hypertrophy of hepatocytes was seen in all treated groups and both sexes (0/0, 44/29, 50/44, 48/37 for control, low, mid and high dose for males/females, respectively). Further, active chronic inflammation was reported in males (33, 47, 44, 42 for control, low, mid and high dose for males, respectively) but not in females.

#### *Haematopoietic system*

Histiocytic sarcomas were observed in females with an incidence of 0, 0, 5 (10%) and 3 (6%) in the control, low-, middle- and high-dose groups, respectively. The findings were statistically significant at the mid-dose only. The HCD (mean of 0.3%; range 0-2 %) was exceeded in the mid- and high dose groups. The concern for carcinogenicity in the hematopoietic system is supported by a statistically significant increase in hematopoietic cell proliferation in the spleen in female mice (incidences 16, 35, 32 and 27 for control, low, mid and high dose groups, respectively). In the high dose group of female mice, the histiocytic sarcomas were highly invasive. Multiple organs throughout the body had neoplastic histiocytic lesions.

#### Rats

The DS included one carcinogenicity study in rats (F334/N) exposed orally (diet) to 0, 312, 625, or 1250 ppm Benzophenone corresponding to 0/0, 15/15, 30/30, and 60/65 mg Benzophenone /kg bw/day for males/females (NTP, 2006). Mortality was significantly increased for males in the high dose group (% survival at end of study: 44%, 54%, 62% and 4% in the control, low, mid and high dose males, respectively). Body weights in males/females were decreased by 11%/9% in the mid-dose group and 36%/14% in the high dose group. Feed consumption was reduced in high dose animals of both sexes. No clinical signs were reported. Tumours were reported in the kidney and haematopoietic system of male rats and in the haematopoietic system of females. Non-neoplastic changes in the liver and kidney in both sexes were also reported.



*Kidneys*

The incidences of renal tubule adenoma in male rats increased with increasing doses and reached statistical significance at the high dose level (2 (4%), 2 (4%), 7 (14%) and 8 (16%) for control, low, mid and high dose, respectively). No renal tubule adenomas were observed in female rats. The HCD (range 0-2 %) was exceeded in the in all treated groups, however it was noted that also the incidence in the concurrent control exceeded the HCD range presented.

A statistically significant increase in incidences of renal tubule hyperplasia was seen in all treated groups and both sexes (3/1, 11/8, 30/10, 40/7 for control, low, mid and high dose for males/females, respectively). It should be noted that the severity grade increased with increasing dose, especially in male rats.

*Haematopoietic system*

The incidences of mononuclear cell leukaemia (MNCL) were 27/19, 41/25, 39/30, 24/29 for males/females in the control, low, mid and high dose groups, respectively. The finding was statistically significantly increased and outside the reported HCD in the low and mid dose groups of males, and in the mid dose group of females. It should be noted that there was a decreased survival in the high dose males (4 % vs 44% in controls).

Histiocytic sarcomas were observed in one female rat in the mid dose group (1%) and 2 female rats in the high dose group (4%). Histiocytic sarcoma was not observed in the HCD for feed studies (1995-2004), however the HCD for all routes of exposure in the 2-year rat studies ranged from 0-2 % (NTP, 2006).

**Dermal studies**

The DS included one non-guideline dermal carcinogenicity lifetime study with Swiss mice (50 females/group) exposed to Benzophenone by open dermal application of 0.2 mL of 5, 25 and 50% Benzophenone in acetone applied on the dorsal skin of the animals twice weekly for 110 weeks (Stenbäck and Shubik, 1974). A vehicle control group and a positive control group (treated with dimethylbenzanthracene (DMBA)) were included and in addition an untreated control group (150 animals). No increased mortality or body weight changes were observed in the dosed groups and there was no dose response relationship in the total number of tumours observed.

Furthermore, a dermal carcinogenicity lifetime study (non-guideline) in New Zealand White rabbits with 5 rabbits/group (both sexes) was assessed by the DS (Stenbäck, 1977). In this study, the rabbits were exposed by open dermal application of 0.2 mL of 5, 25 and 50% Benzophenone in solvent to the interior left ear twice weekly up to 160 weeks (until animals died spontaneously). No treatment related effect on mortality was observed and the survival at week 160 was 1, 3 and 2 rabbits in the low, mid, and high dose groups, respectively. Two untreated control groups with 5 and 4 animals respectively was included. Survival in these were 3/5 and 0/4 respectively. In addition, a positive control group (15 animals) treated with DMBA was included. The positive control group was terminated at week 50. No tumours were recorded in the treated groups. One nephroblastoma was observed in the untreated control groups, while twelve tumours were recorded in the positive control group, including seven papillomas, two keratoacanthomas and three squamous cell carcinomas.

**Human data**

No human data are available.

**Weight of evidence assessment**Tumour type and background incidence

*Histiocytic sarcoma:* An increased incidence in this rare tumour type was observed in female rats and female mice reaching statistical significance in the mid dose female mice and were shown to be more invasive in the high dose female mice compared to the mid-dose group. It is also noted that the findings exceeded the HCD from feeding studies reported in the mid and high dose females (rats and mice). The concern for a carcinogenic effect on the haematopoietic system is further supported by the increased incidence of hematopoietic cell proliferation in the spleen of all dosed groups of female mice.

*Hepatocellular adenoma, carcinoma and hepatoblastoma:* The incidences of hepatocellular adenoma in male mice showed a clear dose-response relationship, with statistically significant differences from controls in the two highest dose groups which exceeded the HCD. In female mice, the incidences observed were not statistically significantly different from the concurrent controls but exceeded the HCD. The malignant hepatic tumours recorded in the mice included hepatoblastomas and hepatocellular carcinomas in male mice, and hepatocellular carcinomas in female mice. The hepatoblastomas in male mice, showed a positive trend in relation to the treatment. This finding was not statistically significantly different from the concurrent control but exceeded the HCD. The hepatocellular carcinomas in the treated males occurred at non-statistically significant levels and showed no dose-response relationship. In females, the single incidence of hepatocellular carcinoma in the low and high dose groups could be an incidental, non-treatment related finding considering that the incidence of spontaneous hepatocarcinoma in female B6C3F1 mice is highly variable. It should be noted that a statistically significant increase in incidences of hypertrophy of hepatocytes was seen in all treated groups for male as well as female mice and that active chronic inflammation was reported in male mice.

According to Gariboldi *et al.* (1993) and Manenti *et al.* (1994) B6C3F1, mice are susceptible to chemically induced cellular hepatocarcinogenesis. Further, the human relevance of hepatic tumours in mice, when induced by non-genotoxic compounds, is disputed (Gold & Slone, 1993; Carmichael *et al.*, 1997; Boobis *et al.*, 2006; Holsaple *et al.*, 2006; Billington *et al.*, 2010).

Overall, the occurrence of hepatoadenoma in mice can be considered as supportive evidence for the carcinogenicity of Benzophenone, taking into account that the tumours which were formed were benign and the increased susceptibility of the mouse strain used. The low non-significant incidences of hepatoblastomas and hepatocellular carcinomas in mice lead to uncertainty for concluding on their relationship to Benzophenone exposure. However, some concerns are raised from the occurrence of the hepatoblastomas, which are rare tumours and even a small increase in hepatoblastoma could be considered relevant for classification.

*Renal tubular tumours:* A positive trend in the incidences of renal tubule adenoma was found in the treated male rats, with a statistically significant increase in the high-dose

group. Further, statistically significant increases in incidences of renal tubule hyperplasia were seen in all Benzophenone treated groups of male and female rats.

Chronic progressive nephropathy (CPN) is considered to be a common spontaneous effect in the rat kidney, and an association between treatment-related CPN from 90-day studies and kidney tumours from 2-year studies has been found (Travlos *et al.*, 2011). Therefore, their relevance to humans may be questioned. However, no clear pathogenesis of chemically induced renal tubular tumours has been determined and seems to be complex, with genotoxic and non-genotoxic modes of action (Barret and Huff, 1991; Short, 1993; Hard, 1998). The induction of renal tubule adenomas is considered to indicate limited evidence of carcinogenic activity.

*Mononuclear cell leukaemia (MNCL)*: A statistically significant increase in the incidences of MNCL in the low- and middle-dose groups of males, and in the middle-dose group of females was found in rats, however, the human relevance of increased incidences of MNCL in F344 rats has been debated. According to Caldwell (1999) MNCL occur in untreated, aged F344 rats at a high and variable rate. Further, MNCL is uncommon in most other rat strains. The background incidence of MNCL has increased significantly over time. MNCL has not been found in other mammalian species (e.g. mice and hamsters) and no histologically comparable tumour is found in humans. Scheepmaker *et al.* (2005) also noted that the mechanism for the induction of MNCL in F344 is unknown and that several substances have shown increased incidences of MNCL in chronic studies. They concluded that substance-induced increases in MNCL in F344 rats should not be considered to be of human relevance, but they also noted that increases of MNCL in other rat strains and other species should be considered as relevant for humans. However, Thomas *et al.* (2007) indicated that a rare form of human lymphocyte leukaemia (natural killer cell large granular lymphocyte leukaemia; NK-LGLL) is similar to MNCL observed in F344 rats and noted that little is known about the cellular/molecular pathways of leukaemogenesis in the F344 rats. They indicate that more mechanistic information is needed as regards their relevance for humans. Overall, the occurrence of MNCL in rats is considered to be of limited concern for humans.

#### Multi-site responses

An increased incidence was reported for the rare tumour form histiocytic sarcoma in one sex from two species: female mice and female rats. Likewise, the rare tumour hepatoblastoma were reported in male mice above historical background levels.

In addition, an increased incidence of hepatocellular adenoma in male and female mice above high spontaneous incidences, as well as increased incidence of mononuclear cell leukaemia and renal tubular tumours in male rats was reported. However, the increased incidence of mononuclear cell leukaemia and renal tubular tumours in male rats are considered to be of limited concern for humans. *Progression of lesions to malignancy;*

The histiocytic sarcoma observed in female rats and mice and the hepatoblastoma observed in male mice are considered as malignant tumours.

Regarding the hepatocellular adenomas, limited evidence of progression to malignancy were observed. The hepatocellular carcinomas observed showed no dose-response relationship and were not statistically significantly different from the control groups. As already noted, hepatoblastoma is a rare tumour in mice. According to the NTP (2006) study hepatoblastomas are malignant neoplasms that are presumed to be a primitive form of hepatocellular carcinoma, well demarcated neoplastic masses independent of other hepatocellular tumors. The study by Turusov *et al.* (2002) suggests that the

hepatoblastomas observed in mice in NTP-studies arise within hepatocellular adenomas or carcinomas.

#### Reduced tumour latency

No information is available on tumour latency

#### Whether responses are in single or both sexes

Histiocytic sarcoma was observed in female mice and female rats. Further, hepatoblastoma were only observed in male mice. Hepatocellular adenoma was observed in male and female mice, while mononuclear cell leukaemia and renal tubular tumours were observed in male rats.

#### Whether responses are in a single species or several species

Histiocytic sarcoma was observed in rats and mice.

Hepatoblastoma was observed in male mice, in addition mice showed increased incidence of hepatocellular adenoma.

Mononuclear cell leukaemia and renal tubular tumours were only observed in rats.

#### Structural similarity to a substance(s) for which there is good evidence of carcinogenicity

No information available

#### Routes of exposure

Routes of exposure of relevance for humans are used in the animal studies (oral exposure)

#### Comparison of absorption, distribution, metabolism and excretion between test animals and humans

No information available

#### The possibility of a confounding effect of excessive toxicity at test doses

There was a high level of mortality in the high dose males in the carcinogenicity study with rats (survival 4% at the high dose vs 44% in controls). Low and mid-dose male groups and all female groups showed similar or higher survival compared to controls ( $\geq 54\%$ ). Lower body weights than in controls by 9-36% were reported in mid- and high-dose groups. In the carcinogenicity study with mice, survival was non-significantly affected only in the high dose females, and body weights were lower than in controls by over 10% in that group, whilst males and mid-group females did not exhibit signs of general toxicity.

#### Mode of action and its relevance for humans, such as cytotoxicity with growth stimulation, mitogenesis, immunosuppression, mutagenicity

Benzophenone is considered not genotoxic by the Danish EPA (2018) and EFSA (2017). The Danish EPA (2018) further discussed a potential endocrine mechanism including thyroid peroxidase inhibition and estrogenic and anti-androgenic activity. However, no firm conclusion could be drawn from the available data. IARC (2013) hypothesised the involvement of generation of reactive oxygen species and/or endocrine disruption through multiple receptors, however they concluded that ultimately the mechanism is not known.

***In summary***

No human data are available for benzophenone and a classification in category 1A is not justified.

As regards classification in category 1B vs category 2, RAC considers that the available data show evidence of carcinogenicity in two animal species, including increased incidence of the rare tumour histiocytic sarcoma in female mice and female rats. This tumour type is considered to be related to the exposure to benzophenone and to be of biological significance. The low incidences of this tumour is noted. However, due to histiocytic sarcoma being a rare tumour, a low incidence is expected.

Supporting evidence of carcinogenicity included the finding of the rare tumour hepatoblastoma in male mice, and a statistically significantly increased incidence of hepatocellular adenoma in male mice and female mice. In addition renal tubular tumours in male rats and a statistically significantly increased incidence of mononuclear cell leukaemia (MNCL) in male and female rats was observed. However, the high spontaneous incidence of liver tumours in B6C3F1 mice and MNCL in F344 rats as well as the uncertain relevance to humans for MNCL and renal tubular tumour are noted.

Overall, RAC considers that a classification for benzophenone as Carc. 1B is warranted based on sufficient evidence of carcinogenicity in different tissues observed in two species at dose levels which were not excessive.

In conclusion RAC is of the opinion that according to the CLP criteria, **classification as category 1B for carcinogenicity is justified.**

**10.10 Reproductive toxicity**

Hazard class not evaluated.

**10.11 Specific target organ toxicity-single exposure**

Hazard class not evaluated.

**10.12 Specific target organ toxicity-repeated exposure**

Hazard class not evaluated.

**10.13 Aspiration hazard**

Hazard class not evaluated.

**11 EVALUATION OF ENVIRONMENTAL HAZARDS**

**11.1 Rapid degradability of organic substances**

Hazard class not evaluated

**11.2 Environmental transformation of metals or inorganic metals compounds**

Hazard class not evaluated

### **11.3 Environmental fate and other relevant information**

Hazard class not evaluated

### **11.4 Bioaccumulation**

Hazard class not evaluated

### **11.5 Acute aquatic hazard**

Hazard class not evaluated

### **11.6 Long-term aquatic hazard**

Hazard class not evaluated

### **11.7 Comparison with the CLP criteria**

Not evaluated.

### **11.8 CONCLUSION ON CLASSIFICATION AND LABELLING FOR ENVIRONMENTAL HAZARDS**

Not evaluated

## **12 EVALUATION OF ADDITIONAL HAZARDS**

Hazards not evaluated

## **13 ADDITIONAL LABELLING**

No additional labelling needed.

## 14 REFERENCES

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## ANNEX 1 – BACKGROUND DOCUMENT TO RAC OPINION ON BENZOPHENONE

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## 15 ANNEXES

*Annex 1, dated xxx, to the CLH report for benzophenone.*