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Chemical Composition and Hazard Classification of Petroleum UVCB Substances with a Case Study in S. Korea

국내 석유계 UVCB 물질의 성분, 유해성 분류 및 국내 사례 연구

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Abstract

Chemical Composition and Hazard Classification of Petroleum UVCB Substances with a Case Study in S. Korea

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Petroleum substances derived from crude oil and naphtha cracking have unknown, variable, or complex composition, due to using multiple refineries and various production methods, and thus, are recognized as Unknown or Variable composition, Complex reaction products, or Biological materials (UVCB). When chemical control regulations and guidance's on petroleum UVCB substances are compared between Korea and EU, Korea is lacking in many details for management of petroleum UVCB's, especially in the hazard classification area.

Korea requires hazard classification for only 10 petroleum UVCB (PUVCB) substances, compared to 698 in EU, and these gaps are assumed to be present because the details about PUVCB manufacturing process and its management procedures in Korean industries are unknown. Therefore, through documentation review and interview with the selected company, the overall naphtha refining process starting from naphtha cracking to basic hydrocarbon distillation was mapped out, and total 32 PUVCB substances present in the process were identified.

The PUVCB hazard classification procedures were also examined and the company had a few best practice cases and few improvements to be made in

the management system – such as establishing standardized internal guidelines for PUVCB management. Also, different classification methods recommended by the EU CLP regulation, CONCAWE guidance and MoE guidance were compared and the overall matching score was 61.8%. The most effective method for hazard classification of the PUVCB substances was found to be using the "containing" method (the highest matching score at 69.1%) for *Section 3. Composition/ Information on Ingredients* and applying the hazard classifications by CONCAWE (the lowest matching score at 52.7%) *on 2. Hazard Identification*.

Keyword: UVCB, petroleum UVCB, naphtha process, chemical composition, SDS, classification

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1. Introduction

1.1 Study Background

1.1.1 UVCB Substance

In global chemical inventories, such as in *EU Registration, Evaluation, Authorisation, and Restriction of CHemicals* (EU REACH), a chemical substance is categorized into three main types – a mono-constituent substance, a multi-constituent substance, or an Unknown or Variable composition, Complex reaction products or of Biological materials (UVCB) substance. The first two have well-defined composition with clear constituents and concentrations each but the UVCB substance consists of many different constituents, some of which are even unknown, and each concentration is inconsistent or unpredictable. (ECHA, 2017)

One example of UVCB substance is *naphtha* which is an intermediate hydrocarbon stream, refined from crude oil at a boiling point range between 30 and 200 ℃ and further cracked to make basic hydrocarbon products such as ethylene and propylene (**Figure 1**). Naphtha cannot be defined as one simple substance because it is a complex mixture of paraffins, naphthenes, olefins, and aromatics in the C_5-C_{12} range and may also contain other compounds of nitrogen or sulfur and metal, depending on the crude oil source and naphtha cracking process (Prestvic et al., 2004).

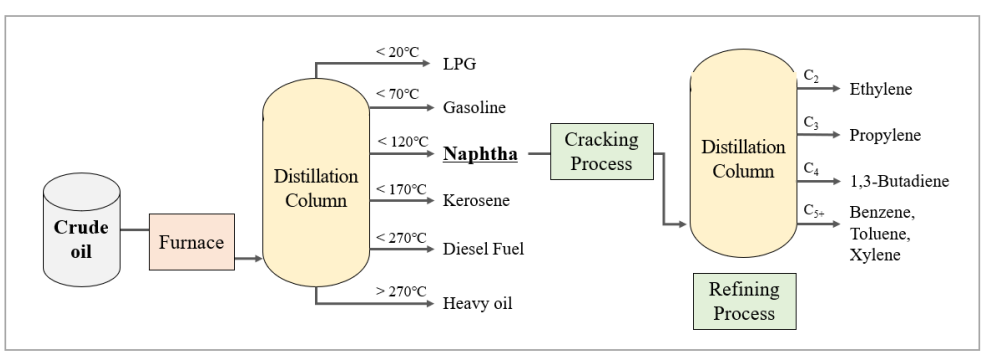

Figure 1. Crude oil distillation & naphtha cracking process (CONCAWE, 2017).

1.1.2 Complex Nature of Naphtha

There exist hundreds of crude oil refineries globally and each has its own process operating conditions and composition specifications. Even if from the same crude oil and the same refinery, the composition can vary by the types of naphtha streams depending on its boiling range, distillation or cracking method, etc. For example, naphtha processed from the heavier oil fractions through catalytic cracking, visbreaking or coking method contains olefins, while the "straight-run" type naphtha, obtained directly from the fractional distillation method, contains none of the olefins. **Table 1** illustrates various composition of different naphtha streams from the same crude oil, and shows a pattern of paraffinicity decrease and aromaticity increase in straight-run naphtha streams with the increase in boiling point. (Prestvic et al., 2004)

Table 1. Typical compositions of naphtha streams from the same origin

Properties / Naphtha stream	Boiling point (°C)	Carbon range	Paraffins (w/w%)	Olefins (w/w%)	Naph-thenes (w/w%)	Aromatics (w/w %)
Light, straight run	30-90	C_5-C_6	55	-	40	5
Medium, straight run	90-150	C_7-C_9	31	-	50	19
Heavy, straight run	150-180	C_{10}-C_{12}	30	-	44	26
Catalytic cracking	30-220	C_5-C_{12}	34	23	11	32
Light, visbreaking	30-90	C_5-C_6	64	10	25	1
Heavy, visbreaking	90-150	C_7-C_{12}	46	30	16	8

It is also known that as carbon number increases, molecular complexity and functionality increase; thus, naphtha can make a few hundred chemical compounds with different isomers and aromatic rings (CONCAWE, 2012). The number of compounds in medium, straight-run naphtha typically ranges up to 300, while full-range[1] naphtha goes up beyond 500 (Prestvic et al., 2004).

[1] Light, medium and heavy naphthas

1.1.3 Hazardous Constituents in Petroleum UVCB Substances

Constituents in naphtha streams vary but generally include *n-hexane, n-heptane, n-octane, methylcyclohexane, ethylbenzene, toluene, xylene, benzene,* and *hydrogen sulfide* (Clark et al., 2013, Prestvic et al., 2004). All of them are classified under *EU regulation of Classification, Labelling and Packaging of substances and mixture* (EU CLP) (ECHA, 2020), and few of them are known to be carcinogenic by International Agency for Research on Cancer (IARC), along with *petroleum* substance itself (See

Table 2). However, these constituents are generally not managed well in the petroleum industry because they are too complex and variable to analyze and define. Thus, it is important that naphtha, its distillate streams from the refining process, and its various constituents – called petroleum UVCB substances (PUVCB) – are carefully scrutinized so that they can be precisely identified and their hazard be managed.

Table 2. Health hazard classification of typical naphtha components

Chemical Name	CAS No.	IARC	EU CLP Classification Category						
			C.	M.	R.	Asp.	SE	RE	AT
Petroleum refining	-	2A	-	-	-	-	-	-	-
***n*-hexane**	110-54-3	-			2	1	3	2	-
***n*-heptane**	142-82-5		-	-	-	1	3	-	-
***n*-octane**	111-65-9	-	-	-	-	1	3	-	-
Methyl cyclohexane	108-87-2	-	-	-	-	1	3	-	-
Ethyl benzene	100-41-1	2B	-	-	-	1	-	2	4
Toluene	108-88-3	-	-	-	2	1	3	2	-
Xylene	1330-20-7	-	-	-	-	-	-	-	4
Benzene	71-43-2	1	1A	1B		1	-	1	-
Hydrogen Sulfide	7783-06-4	-	-	-	-	-	-	-	2

* ***Abbreviations***: EU CLP, EU regulation of Classification, Labelling and Packaging of substances and mixture; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; Asp, Aspiration toxicity; SE, Specific target organ toxicity – Single Exposure; RE, Specific target organ toxicity – Repeated Exposure; AT, Acute Toxicity

* ***Notes***: Classifications for skin and eye irritations are not shown;

IARC carcinogen classifications – Group 1: carcinogenic to humans, Group 2A: probably carcinogenic to humans, Group 2B: possibly carcinogenic to humans (IARC, 2021)

1.1.4 Safety Regulations of Petroleum UVCB Substances

In response to the challenges faced by the petroleum industry with the chemical complexity but high hazard potential of PUVCBs, there has been long and meaningful efforts in regulatory and product stewardship programs by the government and industry trade associations in the EU. For example, EU REACH regulates several PUVCBs as a substance of very high concern (SVHC), authorization substance, or a substance restricted (ECHA, 2020), and EU CLP requires classification for almost seven hundred PUVCBs (ECHA, 2020). In the industry side, CONservation of Clean Air and Water Europe (CONCAWE) was established in 1964 to coordinate activities in hazard characterization of petroleum products (Swick et al., 2014). CONCAWE and other industry stakeholder organizations such as Hydrocarbons Solvents REACH consortium (HCSC) and Lower Olefins and Aromatics (LOA) consortium each manage an inventory with hundreds of PUVCBs and publish many supportive guidelines on their management (ECHA).

In Korea, however, despite the recent developments and major amendments in chemicals regulations, there has been no active movement on PUVCB management. *Act on the Registration, Evaluation, etc. of Chemicals* (K-REACH) has a registration deadline closing by the end of this year (2021) for all existing chemicals manufactured and imported at more than 1,000 tons per year and 364 designated Carcinogenic, Mutagenic, Reprotoxic (CMR) substances manufactured and imported at more than 1 ton per year (MoE, 2020). But the list of designated CMR substances includes none of the PUVCBs (MoE, 2018), despite their high CMR potential and high production tonnage of ethylene at 11,800 tons per year (KPIA). Having only one guidance on UVCB substance registration published by the Ministry of Environment (MoE) in December 2020 (MoE, 2020) also shows that MoE has just started looking into this complex

subject. In addition, *Occupational Safety and Health Act* (KOSHA) requires all safety data sheet (SDS) with classification to be submitted and approved before placing in the market, starting this year (2021) (MoEL, 2020); however, there is not yet a specific guidance on how to address UVCB substances when classifying for hazard, and only ten PUVCBs are currently required for classification (NIER, 2021 and MoEL, 2020). **Table 3** compares EU and Korea on the number of PUVCBs subject to regulation and hazard classification. (**Table A-1**).

Table 3. Comparison between EU and Korea on the number of Petroleum UVCB substances under control with regulation and hazard classification

Regulation / Category	EU		Korea	
	EU REACH	**EU CLP**	**K-REACH, KCCA**	**KOSHA**
Regulation	18	-	3	6
Hazard Classification	-	698	2	8

* ***Abbreviations***: K-REACH, Act on the Registration, Evaluation, etc. of Chemicals; KCCA, Chemical substances Control Act in Korea; KOSHA, Occupational Safety and Health Act in Korea; EU REACH, EU Registration, Evaluation, Authorisation, and Restriction of Chemicals; EU CLP, EU regulation of Classification, Labelling and Packaging of substances and mixture

1.1.5 Hazard Classification of Petroleum UVCB Substances

The major difference between Korea and EU on PUVCB regulation can be found in hazard classification. When the chemical inventory in each country was searched in the following words – *petroleum, naphtha, distillate, oil,* and *hydrocarbons*, 698 PUVCBs were classified under EU CLP (ECHA, 2020) while only 10 for Korea (MoEL, 2020 and NIER, 2021). The two countries are similar in that most of the PUVCBs require carcinogenicity and mutagenicity classifications but most of the substances do not have the hazard classifications matching 100% because each country takes different approaches when classifying the PUVCBs. **Table A-2** shows

an example of difference in hazard classifications between EU and Korea for the 10 PUVCBs classified in Korea.

In CONCAWE's guidance on hazard classification and labelling of petroleum substances, two types of approach are suggested when classifying the PUVCBs; the first is *category approach* to group the petroleum substances according to the processes and basic physical properties, and the second is *precautionary approach* to assign the most severe potential hazard classification appropriate for the category, in order to take account of the variable composition of PUVCBs. As a result, CONCAWE categorizes PUVCBs into 25 groups and recommends classification and labelling for each group with classification endpoint rational and data references. For example, the classification recommendations for Low Boiling Point Naphtha[2] (LBPN) are flammable liquid, skin irritation, aspiration toxicity, reproductive toxicity, mutagenicity, carcinogenicity, specific target organ toxicity – single exposure to central nervous system, and chronic aquatic toxicity. Also, the preferred method for classification is to use data on the PUVCB substance itself, where available. But for certain categories of PUVCBs, classification is driven by the presence of specific hazardous constituents that are classified and these are addressed by the use of "Notes" in EU CLP – for example, *naphtha* (CAS No. 8030-30-6) is classified as carcinogen only when *benzene* is contained for more than 0.1%. For these hazard classification "marker" constituents, *benzene*, *toluene*, *n-hexane*, *dimethyl sulfoxide (DMSO)*, and *1,3-butadiene* are considered, and thus, are also recommended as reference substances when conducting composition analysis (CONCAWE, 2020 and ECHA, 2020). **Table 4** summarizes the difference in hazard classification approach and recommendations made in EU CLP and K-REACH on PUVCBs.

[2] derived from crude oil, refined by cracking, hydrotreatment, etc. with boiling point range from -88 ℃ to 260 ℃ and in C_4 to C_{12} (CONCAWE, 2020)

Table 4. Comparison between EU and Korea on the hazard classification recommendations on petroleum UVCB substances

Regulation / Category	Korea	EU
Grouping/Category approach	4 groups : crude oil, petroleum gases, naphtha/gasolines and kerosene	25 groups : crude oil, petroleum gases, other petroleum gases, low boiling point naphtha, kerosene, diesel fuel, straight-run gas oils, cracked gas oils, etc.
Data use method	UVCB substance itself or constituents, whichever has the more severe hazard classification	UVCB substance itself with classification marker constituents
Classification and labelling recommendations for naphtha category	Carcinogenicity, Mutagenicity, Specific target organ toxicity *(*no specific category per hazard class provided)*	Carcinogenicity 1B, Mutagenicity 1B, Specific target organ toxicity (single exposure) 3, Flammable liquid 1, Skin irritation 2 Aspiration toxicity 1, Reproductive toxicity 2, Aquatic chronic 2
Classification marker constituents	benzene, toluene, n-hexane, naphthalene	benzene, toluene, n-hexane, DMSO, 1,3-butadiene, benzo[a]-pyrene

* ***Abbreviations***: DMSO, Dimethyl sulfoxide

* ***Notes***: Benzene (CAS No. 71-43-2), Toluene (CAS No. 108-88-3), *n*-hexane (CAS No. 110-54-3), naphthalene (CAS No. 91-20-3), DMSO (CAS No. 67-68-5), 1,3-butadiene (CAS No. 106-99-0), benzo[a]-pyrene (CAS No. 50-32-8)

Compared to EU, the chemical regulations and guidance in Korea lack details in regulatory management of PUVCBs, especially in the hazard classification area. The hazard classification is based on the substance identity and its constituents but there are limitations in identifying the PUVCBs because the details about their manufacturing process and actual management procedures in Korean industries are unknown, compared to the PUVCB-specific inventories and supportive guidelines available and systemically managed by CONCAWE and other consortiums in the EU. A recent, collaborated study done by MoE on CMR criteria for PUVCBs, also raises concern about the PUVCB substance identification. As a result of the study, a list of PUVCBs was compiled and their manufacturing process

diagram was drawn but only up to naphtha cracking process, and several criteria for CMR determination were examined but how to actually apply the composition information into the SDS for hazard classification was not suggested (Kwon et al., 2020). Therefore, it is necessary to map out the overall naphtha refining process – starting from naphtha cracking to basic hydrocarbon distillation, and to list what PUVCBs and hazardous constituents may be commonly present in the distillate streams. Since there is not yet a specific guideline on hazard classification and labelling of PUVCBs in Korea, it is important to first examine the current PUVCB hazard classification procedures in the Korean petroleum companies, and then to compare the different classification methods recommended by the EU CLP regulation, CONCAWE guidance and MoE guidance, in order to find what may be the most effective way to adequately classify the PUVCBs and important considerations or caution to take.

1.2 Purpose of Research

The objectives of this study are:

1) to identify the PUVCBs and their constituents present in the naphtha refining process of a representative company in Korea;
2) to draw the PUVCB hazard classification process in the company; and
3) to analyze and compare the PUVCB hazard classification method in the company, with matching score to the methods recommended by the EU and Korean regulations and guidelines.

2. Materials & Methods

2.1 Selection of a Representative Company

There are currently three big petrochemical industry complexes in Korea - in Daesan, Ulsan, and Yeosu cities. Among them, one representative company with the highest ethylene production capacity was selected (KPIA). It is one of the big three naphtha cracking centers in Korea, and there are sufficient data to analyze due to having two naphtha cracking center sites.

2.2 Documentations from the Selected Company

Available records and data on management of PUVCBs from the selected company were obtained under approval. Documents on naphtha cracking process and its distillate streams, and naphtha's purchased from January 2015 to December 2020 were accessible and these include:

1) Analysis laboratory records and Certification of Analysis documents, dated from January 2020 to December 2020.
2) Internal standard procedure documents on product specification and analysis method, dated from 2012 to 2021.
3) Most updated safety data sheets, dated as oldest as 2016 and the newest as 2021.

2.3 Identification of Petroleum UVCBs & Constituents

The overall process of naphtha cracking to refining was investigated through documentary review and interview with the relevant teams such as naphtha global sourcing team, naphtha trading team and production team. The process was drawn in a flow chart form, starting from purchasing of the naphtha source to manufacturing the basic hydrocarbons. The purchased

naphtha sourced into the process, and the PUVCBs and basic hydrocarbons present as intermediates or final products were marked in the chart and organized into a list with categorization into the groups according to CONCAWE and MoE guidances. The constituents written in the SDS files of the identified PUVCBs were investigated and the most common components were analyzed.

2.4 Hazard Classification Process

The selected company's current practice of hazard classification of PUVCBs was examined through documentary review and interview with the relevant teams. For the purchased naphtha, the process was drawn out from ordering the purchase to revising the original, foreign SDS to KOSHA version. For the process streams, the process of determining a CAS number for the PUVCB substance and the final composition, and creating SDS was examined by interview and documentary review of a relevant guidance from Environment, Health and Safety (EHS) team, and drawn into a flow chart.

2.5 Hazard Classification Method

The total 41 SDS documents of the identified naphtha process streams and purchased naphtha were first analyzed on how the substance identity and composition information were applied on *Section 3. Composition/ Information on Ingredients* and what the most common classifications were. Then, the hazard classifications on *Section 2. Hazard Identification* of the SDS were compared with re-classifications using the five methods recommended in the EU CLP regulation, CONCAWE guidance and MoE guidance:

- Classification according to EU CLP Annex VI table based on 1) UVCB substance only, 2) constituent only, and 3) both by

summing the classifications from 1) and 2) methods (ECHA, 2020);

- 4) Classification recommendation for the LBPN or other applicable categories by CONCAWE (CONCAWE, 2020); and
- 5) Classification recommendation for the naphtha/gasoline or other applicable groups by MoE (MoE, 2020).

The numbers of matching classifications and total classifications per each method were counted, and the matching classification was divided from the total to calculate the matching score by percentage. The methodological outline is shown in **Figure 2**. The matching score was compared in various ways to suggest what may be the most effective way. The most matching and the least matching classifications were identified.

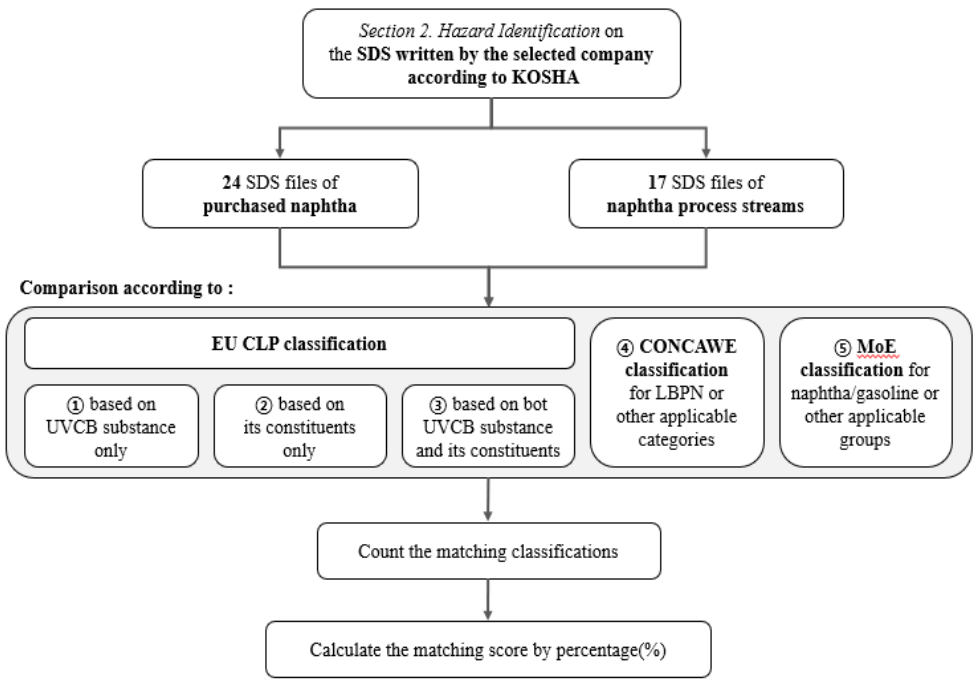

Figure 2. The outline of the hazard classification evaluation and comparison.

* ***Abbreviations:*** CONCAWE, CONservation of Clean Air and Water Europe; MoE, Ministry of Environment in Korea

3. Results & Discussion

3.1 Identification of Petroleum UVCBs & Constituents

3.1.1 Purchased Naphtha

In the selected company in Korea, naphtha is sourced off-shore in two ways – cost and freight ("CFR") and free on board ("FOB"). The CFR contract is made with trading agency so it may be difficult to know the actual crude oil source or naphtha refinery. The trading agency blends naphtha from various refineries so the composition information can differ every time traded, and multiple number of SDS can exist for one purchase of naphtha. However, the FOB contract is signed directly with the naphtha producer so the composition and SDS information is consistent. Total 11 purchase on naphtha were made from January 1st, 2015 to December 31st, 2020, and among them, nine were imported, one-third of which were traded with CFR method. Up to ten naphtha origins were identified for one of the CFR-traded naphtha's and thus, total 24 SDS files of naphtha substance were obtained. After removing the same CAS number substances, total 15 different types of purchased naphtha were identified and are shown in **Table 5.** All of them were confirmed to fall under LBPN category according to CONCAWE (CONCAWE, 2021). One of them were not listed in the CONCAWE inventory but assumed of the LBPN category based on the category description (CONCAWE, 2020). For grouping under MoE's guidance, there is no inventory or detailed description for each category; thus, all of them were assumed to fall under Naphtha/Gasoline group based on the CONCAWE's category. The most common type of naphtha present was *naphtha(petroleum), full-range straight run* (CAS No. 64741-42-0).

Table 5. A list of purchased naphtha and its chemical description

No.	CAS No.	Chemical Name and EC Description
1	8030-30-6	*Naphtha*; Refined, partly refined, or unrefined petroleum products produced by the distillation of natural gas. It consists of hydrocarbons having carbon numbers predominantly in the range of C5 through C6 and boiling in the range of approximately 100°C to 200°C.
2	64741-42-0	*Naphtha (petroleum), full-range straight-run*; A complex combination of hydrocarbons produced by distillation of crude oil. It consists of hydrocarbons having carbon numbers predominantly in the range of C4 through C11 and boiling in the range of approximately minus 20°C to 220°C.
3	64741-55-5	*Naphtha (petroleum), light catalytic cracked*; A complex combination of hydrocarbons produced by the distillation of products from a catalytic cracking process. It consists of hydrocarbons having carbon numbers predominantly in the range of C4 through C11 and boiling in the range of approximately minus 20°C to 190°C. It contains a relatively large proportion of unsaturated hydrocarbons.
4	64741-87-3	*Naphtha (petroleum), sweetened*; A complex combination of hydrocarbons obtained by subjecting a petroleum naphtha to a sweetening process to convert mercaptans or to remove acidic impurities. It consists of hydrocarbons having carbon numbers predominantly in the range of C4 through C12 and boiling in the range of approximately minus 10°C to 230°C.
5	64742-73-0	*Naphtha (petroleum), hydrodesulfurized light*; A complex combination of hydrocarbons obtained from a catalytic hydrodesulfurization process. It consists of hydrocarbons having carbon numbers predominantly in the range of C4 through C11 and boiling in the range of approximately minus 20°C to 190°C.
6	64741-46-4	*Naphtha (petroleum), light straight-run*; A complex combination of hydrocarbons produced by distillation of crude oil. It consists predominantly of aliphatic hydrocarbons having carbon numbers predominantly in the range of C4 through C10 and boiling in the range of approximately minus 20°C to 180°C.
7	64741-63-5	*Naphtha (petroleum), light catalytic reformed*; A complex combination of hydrocarbons produced from the distillation of products from a catalytic reforming process. It consists of hydrocarbons having carbon numbers predominantly in the range of C5 through C11 and boiling in the range of approximately 35°C to 190°C. It contains a relatively large proportion of aromatic and branched chain hydrocarbons. This stream may contain 10 vol. % or more benzene.
8	64741-84-0	*Naphtha (petroleum), solvent-refined light*; A complex combination of hydrocarbons obtained as the raffinate from a solvent extraction process. It consists predominantly of aliphatic hydrocarbons having carbon numbers predominantly in the range of C5 through C11 and boiling in the range of approximately 35°C to 190°C.
9	64741-41-9	*Naphtha (petroleum), heavy straight-run*; A complex combination of hydrocarbons produced by distillation of crude oil. It consists of hydrocarbons having carbon numbers predominantly in the range of C6 through C12 and boiling in the range of approximately 65°C to 230°C.

Table 5. A list of purchased naphtha and its chemical description (continued)

No.	CAS No.	Chemical Name and EC Description
10	64741-69-1	*Naphtha (petroleum), light hydrocracked*; A complex combination of hydrocarbons from distillation of the products from a hydrocracking process. It consists predominantly of saturated hydrocarbons having carbon numbers predominantly in the range of C4 through C10, and boiling in the range of approximately minus 20°C to 180°C.
11	64741-78-2	*Naphtha (petroleum), heavy hydrocracked*; A complex combination of hydrocarbons from distillation of the products from a hydrocracking process. It consists predominantly of saturated hydrocarbons having carbon numbers predominantly in the range of C6 through C12, and boiling in the range of approximately 65°C to 230°C.
12	92045-60-8	*Naphtha (petroleum), light, C5-rich, sweetened*; A complex combination of hydrocarbons obtained by subjecting a petroleum naphtha to a sweetening process to convert mercaptans or to remove acidic impurities. It consists of hydrocarbons having carbon numbers predominantly in the range of C4 through C5, predominantly C5, and boiling in the range of approximately minus 10°C to 35°C.
13	93165-19-6	*Distillates (petroleum), C6-rich*; A complex combination of hydrocarbons obtained from the distillation of a petroleum feedstock. It consists predominantly of hydrocarbons having carbon numbers of C5 through C7, rich in C6, and boiling in the range of approximately 60°C to 70°C.
14	64741-47-5	*Natural gas condensates (petroleum)*; A complex combination of hydrocarbons separated as a liquid from natural gas in a surface separator by retrograde condensation. It consists mainly of hydrocarbons having carbon numbers predominantly in the range of C2 to C20. It is a liquid at atmospheric temperature and pressure.
15	848301-65-5	*C4-C10 branched and linear hydrocarbons (light) – Naphtha* [a)]

* ***Abbreviations***: EC, EU Commission

**** Notes**: **a)** This substance was not found in CONCAWE Inventory of Petroleum Substances so the chemical name was referenced from ECHA Inventory (ECHA, 2021).*

Based on the final composition information provided by each naphtha supplier, the top 3 common components were *benzene, n-hexane, toluene* and *pentane*, which are summarized in **Table 6**. Their lowest and highest concentration inside the naphtha were examined to be 0 to 9.9%, and the most common hazard classifications according to EU CLP were aspiration toxicity and flammable liquid (ECHA, 2020).

Table 6. Top 3 components present in the purchased naphtha with their concentration range and hazard classification

Order	Chemical Name	CAS No.	Conc. range (%)	EU CLP classification									
				C.	M.	R.	Asp.	FL	SE	RE	SI	EI	AC
1	Benzene	71-43-2	0.1~5	1A	1B		1	2		1	2	2	
2	*n*-hexane	110-54-3	0.005~9.9			2	1	2	3	2	2		2
3	Toluene	108-88-3	0~4.75			2	1	2	3	2	2		
3	Pentane	109-66-0	0~0.06				1	2	3				2
Counts				1	1	2	**4**	**4**	3	3	3	1	2

* ***Abbreviations***: Conc., Concentration(w/w%); EU CLP, EU regulation of Classification, Labelling and Packaging of substances and mixture; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; Asp, Aspiration toxicity; FL, Flammable Liquid; SE, Specific target organ toxicity – Single Exposure; RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; AC, Aquatic toxicity – Chronic

3.1.2 Naphtha Process Streams

The overall process from naphtha cracking to basic hydrocarbon distillation is illustrated in **Figure 3**. Naphtha is sourced off-shore and is sometimes replaced with low-cost C_3 or C_4 LPG. In the thermal cracking process, naphtha and recycled ethane is cracked inside the furnace at high temperature of 800~850 ℃ and produce low-hydrocarbon gas. Then, the high-temperature cracked gas is quenched up to 27 ℃ at the outlet in order to prevent polymer reaction. The gas is first quenched in cooling oil to separate the heaviest component – pyrolysis fuel oil, and then in cooling water. The quenched cracked gas at approximately 0.5kg is then compressed under high pressure up to 40kg for economic separation. The compressed and dried cracked gas is cooled under -170 ℃ first to separate hydrogen and

methane gas, and then is distilled to produce ethylene, propylene, mixed C_4, and raw pyrolysis gasoline.

The PUVCBs present as intermediates in the naphtha refining process are marked in purple color in the process diagram (**Figure 3**). 17 major process streams used to produce basic hydrocarbons or sold in market were identifiable, and more detailed description are shown in **Table 7** with category from CONCAWE and MoE. Although 11 of them were not listed in the CONCAWE inventory, they were assumed of the category group based on the category description and similar substances listed. 10 of the 17 process streams (58.8%) met with the CONCAWE's definition of LBPN and MoE's Naphtha/Gasoline group. The others are summarized in **Table 8**.

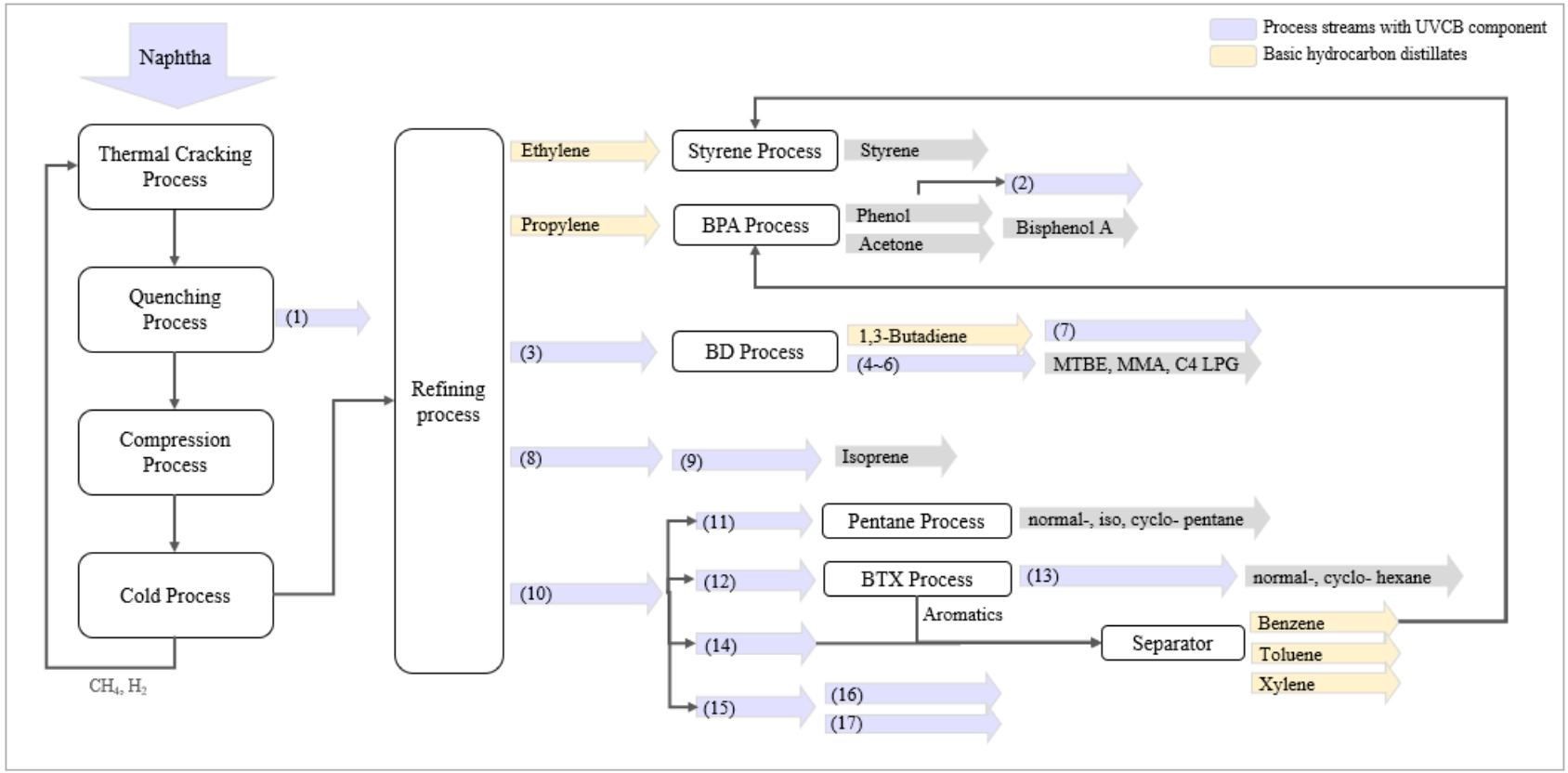

Figure 3. Naphtha refining process diagram: from naphtha cracking to basic hydrocarbon distillation

* ***Abbreviations***: BD, Butadiene; BPA, Bisphenol A; MTBE, *Tert*-Butyl Methyl Ether; MMA, MethylMethAcrylate; LPG, Liquified Petroleum Gas; BTX, Benzene, Toluene, Xylene

Table 7. A list of petroleum UVCB substance in the naphtha refining process with chemical description and categories by CONCAWE and MoE

Process Stream	CAS No.	Chemical Name and EC description	CONCAWE Category	MoE Category
(1)	64742-90-1	*Residues (petroleum), steam-cracked*: A complex combination of hydrocarbons obtained as the residual fraction from the distillation of the products of a steam cracking process (including steam cracking to produce ethylene). It consists predominantly of unsaturated hydrocarbons having carbon numbers predominantly greater than C14 and boiling above approximately 260°C (500°F). This stream is likely to contain 5 wt. % or more of 4- to 6-membered condensed ring aromatic hydrocarbons.	HFO (assumed)	Petroleum gases (assumed)
(2)	68603-08-7	*Naphtha (petroleum), arom*	LBPN	Naphtha /Gasolines (assumed)
(3)	68476-52-8	*Hydrocarbons, C4, ethylene-manuf.-by-product*	Other petroleum gases [a)] (assumed)	Petroleum gases (assumed)
(4)	92045-23-3	*Hydrocarbons, C4, steam-cracker distillate*: A complex combination of hydrocarbons produced by the distillation of the products of a steam cracking process. It consists predominantly of hydrocarbons having a carbon number of C4, predominantly 1-butene and 2-butene, containing also butane and isobutene and boiling in the range of approximately minus 12 °C to 5 °C (10.4 °F to 41 °F)		
(5)	68956-54-7	*Hydrocarbons, C4-unsatd.*		
(6)	-	*Unable to identify*		
(7)	64741-96-4	*Distillates (petroleum), solvent-refined heavy naphthenic*: A complex combination of hydrocarbons obtained as the raffinate from a solvent extraction process. It consists of hydrocarbons having carbon numbers predominantly in the range of C20 through C50 and produces a finished oil with a viscosity of at least 100 SUS at 100 °F (19cSt a 40 °C). It contains relatively few normal paraffins.	LBO	
(8)	68606-10-0	*Gasoline, pyrolysis, debutanizer bottoms*: A complex combination of hydrocarbons obtained from the fractionation of depropanizer bottoms. It consists of hydrocarbons having carbon numbers predominantly greater than C5	LBPN	Naphtha /Gasolines (assumed)
(9)	102110-14-5	*Hydrocarbons, C3-6, C5-rich, steam-cracked naphtha*: A complex combination of hydrocarbons obtained by distillation of steam-cracked naphtha. It consists predominantly of hydrocarbons having carbon numbers in the range of C3 through C6, predominantly C5.	LBPN (assumed)	

Table 7. A list of petroleum UVCB substance in the naphtha refining process with chemical description and categories by CONCAWE and MoE (continued)

Process Stream	CAS No.	Chemical Name and EC description	CONCAWE Category	MoE Category
(10)	68477-39-4	*Distillates (petroleum), cracked stripped steam-cracked petroleum distillates, C8-10 fraction*: A complex combination of hydrocarbons obtained by distilling cracked stripped steam-cracked distillates. It consists of hydrocarbons having carbon numbers in the range of C8 through C10 and boiling in the range of approximately 129°C to 194°C (264°F to 382°F).	LBPN (assumed)	Naphtha /Gasolines (assumed)
(11)	68956-55-8	*Hydrocarbons, C5-unsatd.*		
(12)	94114-03-1	*Gasoline, pyrolysis, hydrogenated*: A distillation fraction from the hydrogenation of pyrolysis gasoline boiling in the range of approximately 20°C to 200°C (68°F to 392°F).	LBPN	
(13)	92128-65-9	*Hydrocarbons, C5-8*	LBPN (assumed)	
(14)	90989-41-6	*Aromatic hydrocarbons, C6-10, C8-rich*		
(15)	94733-07-0	*Distillates (petroleum), cracked, ethylene manuf. by-product, C9-10 fraction*		
(16)	68512-78-7	*Solvent naphtha (petroleum), light arom., hydrotreated*: A complex combination of hydrocarbons obtained by treating a petroleum fraction with hydrogen in the presence of a catalyst. It consists predominantly of aromatic hydrocarbons having carbon numbers predominantly in the range of C8 through C10 and boiling in the range of approximately 135°C to 210°C(275°F to 410°F).	LBPN	
(17)	64742-94-5	*Solvent naphtha (petroleum), heavy arom.*: A complex combination of hydrocarbons obtained from distillation of aromatic streams. It consists predominantly of aromatic hydrocarbons having carbon numbers predominantly in the range of C9 through C16 and boiling in the range of approximately 165°C to 290°C (330°F to 554°F).	Kerosene [b)]	Kerosene

* ***Abbreviations***: HFO, Heavy Fuel Oil (streams obtained as either distillates or residues from distillation and cracking processes and containing saturated, aromatic and olefinic hydrocarbons >C8 and boiling point range of 150~750 ℃); LBPN, Low Boiling Point Naphtha (derived from crude petroleum or separated as a liquid from natural gas through various refinery processes, and containing saturated, aromatic, olefinic hydrocarbons C4-C12 and boiling point range of -88~260 ℃); LBO, Lubricant Base Oils (derived from crude petroleum, refined by atmospheric and vacuum distillation, and containing aromatics, paraffins and naphthenics in C12-C20 and boiling point range of 200-800 ℃) (CONCAWE, 2020).

* ***Notes***: **a)** Other petroleum gases cover hydrocarbon streams in predominantly C1-C5 range and may contain 1,3-butadiene, benzene, and carbon monoxide. **b)** Kerosene derived from crude petroleum through various refining processes, and containing cycloparaffins, alkylbenzenes, and alkylnaphthalenes, in C6-C17, and boiling point range of 90-320 ℃ (CONCAWE, 2020).

Table 8. Naphtha process streams categorized into groups under the guidance's by CONCAWE and Ministry of Environment

Group by CONCAWE	Definition	Corresponding group by MoE	Percentage of naphtha process streams
Low boiling point naphtha (LBPN)	derived from crude petroleum or separated as a liquid from natural gas through various refinery processes, and containing saturated, aromatic, olefinic hydrocarbons C4-C12 and boiling point range of -88~260 ℃	Naphtha /Gasoline	58.8% (10/17)
Other petroleum gases	hydrocarbon streams in predominantly C1-C5 range and may contain 1,3-butadiene, benzene, and carbon monoxide	Petroleum gases	23.5% (4/17)
Heavy fuel oil (HFO)	obtained as either distillates or residues from distillation and cracking processes and containing saturated, aromatic and olefinic hydrocarbons >C8 and boiling point range of 150~750 ℃		5.9% (1/17)
Lubricant base oil (LBO)	derived from crude petroleum, refined by atmospheric and vacuum distillation, and containing aromatics, paraffins and naphthenics in C12-C20 and boiling point range of 200-800 ℃		5.9% (1/17)
Kerosene	derived from crude petroleum through various refining processes, and containing cycloparaffins, alkylbenzenes, and alkylnaphthalenes, in C6-C17, and boiling point range of 90-320 ℃	Kerosene	5.9% (1/17)

* ***Abbreviation***: MoE, Ministry of Environment

According to the composition information provided by the production team and quality assurance (QA) team, there were total 58 different chemicals contained in the 17 process streams, and the most common constituents were *1,3-butadiene, n-butane,* and *ethylbenzene,* which are summarized in **Table 9**. Their lowest and highest concentration inside the process streams were determined to be 0.13 to 43%, and the most common hazard classifications according to EU CLP were flammable gas and pressurized gas (ECHA, 2020).

Table 9. Top 8 components present in the naphtha process streams with their concentration range and hazard classification

Order	Chemical Name	CAS No.	Concentration range (%)	EU CLP classification										
				C.	M.	R.	Asp.	FG	FL	PG	RE.	AT	SI	EI
1	1,3-butadiene	106-99-0	0.3~43	1A	1B			1		v				
1	n-butane	106-97-8	0.13~37.1	(1A)[a)]	(1B)[a)]			1		v				
1	Ethylbenzene	100-41-4	0.14~25				1		2		2	4		
2	But-1-ene	590-18-1	4.2~18.3					1		v				
2	Isobutane	75-28-5	2.7~7	(1A)[a)]	(1B)[a)]			1		v				
2	(E)-but-2-ene	624-64-6	7~30.7					1		v				
2	Styrene	100-42-5	0.38~20			2			3		1	4	2	2
2	Xylene	1330-20-7	2.39~15						3			4	2	
Counts				1	1	1	1	**5**	3	**5**	2	3	2	1

* ***Abbreviations***: C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; Asp, Aspiration toxicity; FG, Flammable Gas; FL, Flammable Liquid; PG, Pressurized gas; RE, Specific target organ toxicity – Repeated Exposure; AT, Acute Toxicity; SI, Skin Irritant; EI, Eye Irritant

* ***Notes***: **a)** When containing 1,3-butadiene at 0.1% or greater, additional classification of Carcinogenicity 1A and Mutagenicity 1B applies but they are not applicable for the individual substances.

3.2 Hazard Classification Process

3.2.1 Purchased Naphtha

Due to complexity in sourcing naphtha and obtaining the correct composition data, all naphtha purchases must be pre-discussed between the QA, EHS, and product stewardship (PS) teams. The PS team operates an IT system for chemical management, and suppliers of any purchased materials are required to submit the basic information on the chemical composition and their safety. The purchasing order is approved only after this information is obtained and carefully reviewed by the responsible teams. First in the composition information review step, both QA and EHS teams review whether the submitted information matches with what is written on SDS and other verification documents. Next in the regulatory review step, the two teams check whether the purchased material contains hazardous components according to the corporate PS standard, KOSHA and Korea Chemical substances Control Act (KCCA). For the PS standard, the teams check whether the purchase material contains *Level 1, 2 or 3 substances* (See **Table 10**); however, PUVCBs are not included in the list and *benzene* is included. For KOSHA and KCCA, the teams check whether the purchased material contains any of the regulated or classified substances and whether the information is well applied in *Section 2. Hazard Information* and *Section 15. Regulatory Information* of the SDS. Lastly, EHS team reviews whether the SDS is appropriately written and has sufficient amount of safety information. **Figure 4** summarizes the process.

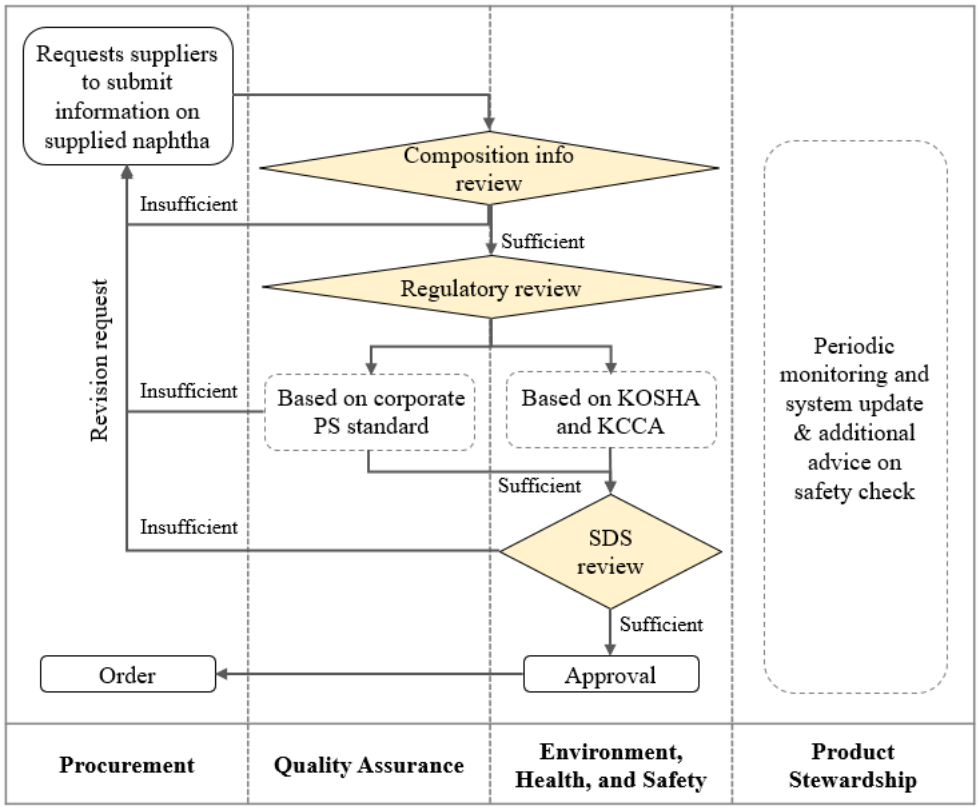

Figure 4. Chemical safety information management process on the purchasing materials.

* ***Abbreviations***: PS, Product Stewardship; KCCA, Chemical substance Control Act in Korea; KOSHA, Occupational Safety and Health Act in Korea; SDS, Safety Data Sheet

Table 10. Level 1,2,3 substances according to corporate product stewardship standard

Types	Meaning	Global standard referenced	Example substances
Level 1, Level 2	Substances prohibited to use above the maximum allowable concentration	▪ EU REACH ▪ EU RoHS Directive ▪ Dodd-Frank Act	Lead, mercury, phthalates, perfluorinated compounds, asbestos, conflict minerals, etc.
Level 3	Substances being monitored to be prohibited in sooner future	▪ EU SVHC	Benzene, volatile organic compounds, etc.

In order to prevent any important composition information from missing and to facilitate the data management, the information provided by all naphtha suppliers are carefully scrutinized and revised before finalization. For CFR-traded naphtha's with multiple SDS files from various refineries,

all composition information with average concentration must be submitted in a method illustrated in **Table 11**. Generally, the suppliers feel bothersome and hesitant to disclose information on composition, especially due to the complex nature of naphtha. However, the QA team makes the best effort to verify the composition information as much as possible and to make the SDS in the most conservative way.

Table 11. Example 1 of composition information submitted by the supplier vs. how it was revised as for management purpose

Composition info submitted as		To be revised as
Naphtha refinery	**Composition per refinery**	
A	▪ CAS 1 : 90% ▪ CAS 2 : 3% ▪ CAS 3 : 4% ▪ CAS 4 : 3%	▪ CAS 1 : 48% ▪ CAS 2 : 1% ▪ CAS 3 : 1% ▪ CAS 4 : 1% ▪ CAS 5 : 49%
B	▪ CAS 1 : 99% ▪ CAS 2 : 1%	
C	▪ CAS 5 : 100%	

In one case, a supplier provided the SDS with naphtha containing hydrogen sulfide and benzene, which are hazardous chemical substances under KCCA but refused to disclose the concentration information or provide additional verification documents required by KCCA; thus, the QA team separately had to take analysis measurement and make a new SDS in Korean with the measured concentrations applied. In another case where supplier also refused to provide detailed data on concentration as in **Table 12**, the QA team took the most conservative way of management by creating total five SDS in Korean – one per each CAS number with the highest concentration of 99%, since the actual concentration per component is unknown.

Table 12. Example 2 of composition information submitted by the supplier vs. how it was revised as for management purpose

Composition info submitted as	To be revised as
▪ CAS 1,2,3,4,5 : 0~99%	▪ CAS 1 : 99% ▪ CAS 2 : 99% ▪ CAS 3 : 99% ▪ CAS 4 : 99% ▪ CAS 5 : 99% ▪ Unknown impurity : 1%

3.2.2 Naphtha Process Streams

For the naphtha process streams, they go through sampling analysis to identify its composition according to the standardized internal procedure. The internal procedures are clearly written in the standardized format and include composition analysis method, accuracy and precision management, and required product specification. The sampling analysis is conducted one or two times a week, and the result is averaged to be applied on the Certificate of Analysis, a document sent to customers on product specification, and SDS. The test method used for composition analysis is Gas Chromatography for Paraffins, Iso-paraffins, Olefins, Naphthenes, and Aromatics (PIONA-GC). Other components such as sulfur, carbonyl substances, and water are also analyzed through standardized methods from American Society for Testing Materials (ASTM). The test items are a bit different for each process stream due to different number of carbons. The internal procedure documents include the retention time and the matching chemical substance, and also the typical composition and maximum allowed concentration for non-major components, such as sulfur, nitrogen and solvents.

Once the composition analysis is complete and finalized, the UVCB substance is identified with a chemical name and CAS number based on the analysis result. The most similar and representative CAS number. is searched through lists of 542 PUVCBs in the CONCAWE and LOA

Consortium inventories (CONCAWE, 2020) with few keywords. If no similar one is found, then keywords are searched in the chemical inventory of Korea through National Chemical Information System (NCIS), and the most closely defined CAS number is selected. The next step is registering the CAS number under the company's own product composition management IT system. However, the system is interfaced with the classification database to automatically draft SDS based on the product composition information, and the problem is that there is only ten PUVCB substances classified in Korea. Thus, the UVCB substances are managed in a special way – to register the constituent information instead of the known CAS number for UVCB substance itself – so that the SDS can be drafted with sufficient amount of hazard classification based on the constituent information.

The SDS documents are generated in the company's own chemical management IT system and are reviewed by EHS team for its adequacy before finalization. The SDS is made with the composition information interfaced with the hazard and regulatory information database per each country. In order for the SDS file to be downloaded, the EHS team must first review the followings: 1) *Section 3. Composition/Information on ingredients*: whether the composition sums up to 100% and no hazardous chemical substances are marked as confidential or concentrations hidden, 2) *Sections 9. Physical and chemical properties, Section 11. Toxicological information, Section 12. Ecological information*: whether sufficient amount of physical properties and health and ecotoxicity information are written, and 3) *Section 15. Regulatory information*: whether any regulated substances are missing.

The UVCB substances are managed in special way because the hazard and regulatory information in Korea is not sufficient and thus, the SDS based on the UVCB substance's CAS number only will generate no or inadequate classification. Therefore, the company's PS team advises to

register the UVCB product's composition information with the constituents instead so that sufficient amount of hazard and regulatory information and classification per each constituent are interfaced into making SDS, like a mixture. And then, the composition information should be revised on the downloaded SDS file so that the CAS number of UVCB substance itself can be added to *Section 3. Composition/Information on ingredients* and be referred to the constituents with the word "containing," as shown in **Table 13**. The PS team also advises to add the hazard information on the UVCB substance itself in other sections by searching through CONCAWE and EU CLP classification. This way, sufficient information on hazard and regulatory status can be obtained from both the UVCB substance itself and the constituents. The overall process from composition analysis to substance identification to SDS generation is shown in **Figure 5.** The SDS for the purchased naphtha comes in original, foreign language format; thus, when naphtha sourcing team revises the SDS into the KOSHA version, the same SDS generation and approval process is performed.

Table 13. Example of how *Section 3. Composition/Information on ingredients* should be written for UVCB substances on SDS (The "containing" method)

CAS No.	Chemical Name	Concentration range (%)
8030-30-6	Naphtha	100
Containing:		
71-43-2	Benzene	3~8%
110-54-3	n-Hexane	10~20%
108-88-3	Toluene	5~12%

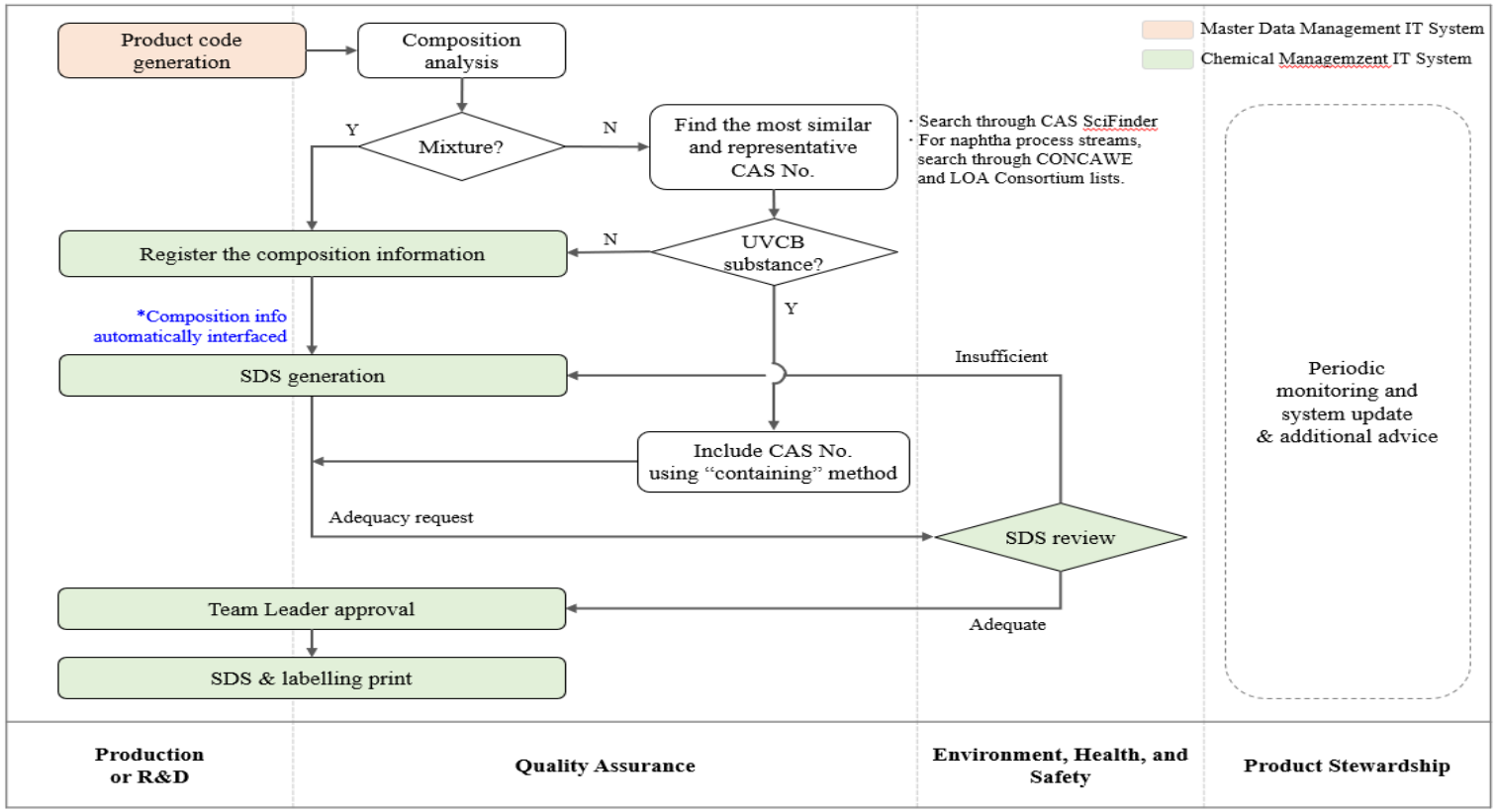

Figure 5. SDS generation and approval process diagram.

3.3 Hazard Classification Method

3.3.1 Composition Information

The 24 SDS files of purchased naphtha's and 17 files for naphtha process streams were reviewed on how the composition information is written on *Section 3. Composition/Information on ingredients*. All of the purchased naphtha's were identified with a UVCB CAS number, as provided by the suppliers (**Table 5**) but only 7 of them used the "containing" method in the SDS. For the naphtha process streams, 16 out of 17 were identified with a UVCB CAS number (**Table 7**) but only 3 SDS files had it written on *Section 3* and only 1 of them used the "containing" method. The result is summarized in **Table 14**.

Table 14. Percentage of the composition information method used

Method / Category	UVCB substance only	Constituents only	Containing method
Purchased naphtha	17/24 (70.8%)	0/24 (0%)	**7/24 (29.2%)**
Naphtha process streams	2/17 (11.8%)	12/17 (70.6%)	**1/17 (5.9%)**

3.3.2 Comparison to Recommended Classifications

First, the hazard classifications on the company's original KOSHA SDS were examined and are summarized in **Table 15** (**Table A-3** through **Table A-4).** For 17 process streams, the average hazard classification number was 8, and the most common classifications present were carcinogenicity, specific target organ toxicity – single exposure, and eye irritations. For 24 purchased naphtha SDS, average 7 hazard classifications were shown and carcinogenicity, flammable liquid, and aspiration toxicity were the most common classifications. Overall, the most common classifications were carcinogenicity, flammable liquid and specific target organ toxicity – single exposure.

Table 15. Summary of hazard classification on the company's KOSHA SDS of the purchased naphtha and naphtha process streams

Type	Hazard classification on the current KOSHA SDS														
	C.	**M.**	**R.**	**FG**	**FL**	**PG**	**SI**	**EI**	**SS**	**AT**	**SE**	**RE**	**Asp.**	**AC**	**AA**
Purchased naphthas	**23**	15	8	1	**23**	0	15	11	0	11	14	5	**17**	16	0
Naphtha Process streams	**15**	10	5	3	7	3	13	**14**	4	10	**16**	9	7	11	1
Total	**38**	25	13	4	**30**	3	28	25	4	21	**30**	14	24	27	1

Abbreviations: KOSHA, Occupational Safety and Health Act in Korea; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; FG, Flammable Gas; FL, Flammable Liquid; PG, Pressurized Gas; SI, Skin Irritant; EI, Eye Irritant; SS, Skin Sensitizer; AT, Acute Toxicity; SE, Specific target organ toxicity – Single Exposure; RE, Specific target organ toxicity – Repeated Exposure; Asp, Aspiration toxicity; AC, Aquatic toxicity – Chronic, AA, Aquatic toxicity – Acute

The comparison result to the five classification recommendation methods are summarized in **Table 16** below. For re-classification according to EU CLP and CONCAWE guidance, the special "notes" were considered and the non-applicable carcinogenicity or mutagenicity classifications were removed from the counts of the matching classification. These removed classifications were still marked with parenthesis in **Table A-7** to **Table A-47**. For MoE's guidance, it recommends the hazard class only, not the specific category; thus, it was considered "matching" if the applicable hazard class were written on the company's SDS regardless of the category. For specific target organ toxicity, MoE does not specify whether single-exposure or repeated-exposure, so if any of them are available on the SDS, it was considered "matching." Also, if the company's SDS takes more severe classification than the five recommended methods, then it was considered "matching." For re-classification according to the third method of summing classifications based on both the UVCB substance and its constituents, if the classifications with gas and liquid coexist – such as flammable gas and flammable liquid, then only one of them was left based

on whether the PUVCB substance is categorized as LBPN (liquid) or petroleum gas (gas).

On average, the overall matching percentage with EU CLP, CONCAWE and MoE guidelines was 61.8%. The highest matching was 72.1% with EU CLP classification based on UVCB substance only, and the lowest matching was 52.7% to the CONCAWE's classification recommendations for each PUVCB category. CONCAWE required the highest number of classifications at average 6, and EU CLP based on the UVCB substance required the lowest number of classifications at average 1. The process streams had higher matching percentage than the purchased naphtha by 0.2%.

Table 16. Summary of comparison result and matching score between the original SDS vs. 5 recommendation classification methods by EU CLP, CONCAWE and MoE

Type	Matching scores					
	EU CLP			#4. CONCAWE	#5. MoE	Average
	#1. UVCB only	#2. Constituent only	#3. Both			
Process Streams	12/16 (75%)	55/83 (66.3%)	34/49 (69.4%)	55/112 (49.1%)	36/50 (86.4%)	**192/310 (61.9%)**
Purchased naphthas	19/27 (70.4%)	30/45 (66.7%)	27/40 (67.5%)	83/150 (55.3%)	47/72 (65.3%)	**206/334 (61.7%)**
Total	**31/43 (72.1%)**	**85/128 (66.4%)**	**61/89 (68.5%)**	**138/262 (52.7%)**	**83/122 (68.0%)**	**398/644 (61.8%)**

As shown in **Table 17**, the original SDS documents that were using the "containing" method in *Section 3* have higher matching percentage than those which did not. The highest matching score among the purchased naphtha SDS files was 100% and that SDS was using the "containing" method; the lowest score was 20% which classified according to the UVCB substance only. For the naphtha streams, highest and lowest scores all came from when classified based on the constituents only.

Table 17. Comparison of matching percentage between those that used the "containing" method and those that did not

Section 3	Applicable process streams and purchased naphtha	Average matching percentage (%)
"Containing" method used	PS (3), N (2, 4, 15, 17~20)	123/178 (69.1%)
Constituents written only like a mixture	PS (2, 4~12, 14~17)	174/274 (63.5%)
UVCB substance written only	PS (1, 13), N (1, 3, 5~14, 16, 21~24)	100/192 (52.1%)

The most common classifications missing from the company's SDS were reproductive toxicity, specific target organ toxicity – repeated exposure, skin irritation, aquatic toxicity – chronic, and aspiration toxicity. In terms of CMR properties, carcinogenicity classification was missing only once out of total 41 SDS. Mutagenicity was only missing 4 times and reproductive toxicity was missing 25 times among the total 41 SDS.

3.4 Discussion

3.4.1 Identification of Petroleum UVCBs & Constituents

The naphtha refining process was drawn in a flow chart, and total 15 different types of purchased naphtha and 17 PUVCBs present in the naphtha refining process were identified in the chart and organized into a list. It is assumed that many more PUVCBs exist as intermediates in the process but only those that are used to produce the final basic hydrocarbons products or sold in the market were identifiable. The most common constituents present in the purchased naphtha and the naphtha process streams were *benzene, n-hexane, toluene, pentane, 1,3-butadiene, n-butane,* and *ethylbenzene*. The 3 substances - *pentane, n-butane* and *ethylbenzene* – are not included in the classification marker constituents recommended by EU and Korea; therefore, it is important that these substances are given special attention to when conducting composition analysis or hazard classification for PUVCBs.

When grouping the total 32 PUVCBs identified, MoE's guidance was not as helpful as CONCAWE's because it did not have an inventory specific for PUVCBs and had no detailed description on the 4 groups. Thus, it would be more effective to use the grouping by CONCAWE so that more appropriate grouping and hazard classification is made on the PUVCB substance.

3.4.2 Hazard Classification Process

General procedures for hazard classification and special measures to take for UVCB substances have been reviewed and drawn into two diagrams: 1) chemical safety information management process on the purchasing materials and 2) SDS generation and approval process. The company seems to be managing the PUVCB substance in a systemic way, and few best practices in the company, such as how the purchasing order is approved only after the basic composition and safety information is obtained and carefully

reviewed by the responsible teams, should be spread to other petroleum companies, too. Also, it seemed like a very efficient process to manage all chemical management from purchasing to product composition and SDS drafting in one interfaced IT system.

However, the company seems to be lacking in few details. At the step of checking whether the purchase material contains *Level 1, 2 or 3 substances* according to the corporate PS standard, it was discovered that no PUVCB substances were included in the list. Among the constituents, *benzene* was included but other common constituents found in the 32 PUVCBs and the few common naphtha sources – for example, *naphtha(petroleum), full-range straight run* (CAS No. 64741-42-0), should be added so that more PUVCB substances purchased can be screened before use in the company. Also, the FOB method is more recommended for the naphtha purchase than the CFR method, since multiple SDS files from various refineries can exist for one CFR-traded naphtha and the composition information can differ every time traded. However, the composition and SDS information is consistent for the FOB-traded naphtha.

Although the company has been making the best effort in verifying the composition information and writing the SDS in the most conservative way, the company does not have a specific guidance or standardized internal procedure on how to identify a substance or to create SDS for PUVCBs. The standardized internal procedures were only available on composition analysis method. When identifying the PUVCBs, it has only been orally communicated by the PS Team to look over the chemical inventories by CONCAWE, LOA Consortium and NCIS and find the most similar CAS number. This is why only 2 of the 17 naphtha process streams had its CAS number written on SDS and other verification documents.

3.4.3 Hazard Classification Method

The most effective method for hazard classification of the PUVCB substances was found to be using the "containing" method for *Section 3. Composition/ Information on Ingredients* and applying the hazard classifications by CONCAWE *on 2. Hazard Identification*.

For the composition information which is a basis for hazard classification, the company was using the "containing" method where the constituents are all first classified and UVCB substance's CAS number is added later so that the hazard and regulatory information on both groups are applied on the SDS. In order to verify the effectiveness of the "containing" method and other, the hazard classifications in the 41 original KOSHA SDS created by the company were compared with five recommended classification methods from EU CLP, CONCAWE and MoE. The "containing" method was proved to be most effective by having the highest matching score of 69.1%, compared to other two methods of writing either the constituents only (63.5%) or the UVCB substance only (52.1%) in *Section 3* of the SDS. This is a good practice that should be considered to be adapted to other companies. However, the review of total 41 SDS files revealed that only 8 of them (19.5%) was using this method; thus, establishing a specific guidance or standardized internal procedure and promoting through employee trainings would be necessary.

The overall matching score with the five recommended classification methods was *moderate* with the average percentage of 61.8%. The highest matching was 72.1% with EU CLP classification based on UVCB substance only, and the lowest matching was 52.7% to the CONCAWE's classification recommendations for each PUVCB category. This may be due to the number of classifications recommended by CONCAWE is the highest at average of 6, and EU CLP based on the UVCB substance is the lowest at average of 1. However, it also implies that the CONCAWE's guideline may

take the most conservative approach and thus, should be the most considered when doing hazard classification for PUVCBs in Korea, in order to mark sufficient amount classification on SDS.

The process streams had higher matching percentage than the purchased naphtha by 0.2%. This is a small difference but suggests that having the constituent information could lead to more “matching” classification. The purchased naphtha SDS were written as either the “containing” method or with UVCB substance only.

One important consideration to take when classifying the PUVCB substance according to the “containing” method is that the classifications with gas and liquid can coexist – such as flammable gas and flammable liquid. In that case, only one of them should be left based on whether the PUVCB substance is categorized as LBPN (liquid) or petroleum gas (gas).

4. Conclusion

Compared to EU chemical regulations and guidelines from CONCAWE, Korea's chemical control regulation is lacking in specific details for the hazard classification of PUVCBs. The selected company's practice in managing the PUVCBs were insufficient due to not having specific guidelines for the substance identification and hazard classification of PUVCBs. The most effective methods for hazard classification of the PUVCBs were found to be using the "containing" method for *Section 3. Composition/ Information on Ingredients* and applying the hazard classifications by CONCAWE *on 2. Hazard Identification*.

The hazard classification guidance's were only compared between EU and Korea and only CONCAWE in EU. But there are more associations with PUVCB inventories in EU such as HCSC and LOA consortiums. Their recommendation methods and those from other countries like US and Japan would be good and will have higher reliability. Also, the UVCB substances, focused on only petroleum types and low boiling point naphtha, were investigated in this research here but there are many more types of UVCB substances such as biological materials and other reaction products. Due to eco-friendly trend in the world, bio-naphtha made of biological origin are popular. Further study would be necessary in those other types of UVCB substances as well.

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Appendix I. Comparison Between EU and Korea Regulations in Petroleum UVCB Substances

Table A-1. A list of petroleum UVCB substances subject to regulation in Korea and EU

Regulation	Regulated as	No.	CAS No.	Chemical Name
K-REACH, KCCA	Toxic substances (NIER, 2021)	1	90640-84-9	Creosote oil, acenaphthene fraction
		2	8001-58-9	Creosote
	Substance subject to intensive control (MoE, 2018)	3	68308-34-9	Shale oil
KOSHA	Harmful materials requiring permission (MoEL, 2021)	1	65996-93-2	Coal tar pitch volatiles
	Dangerous substances (MoEL, 2021)	2	8006-61-9	Gasoline
		3	68334-30-5	Diesel
		4	8008-20-6	Kerosene
	Harmful materials requiring control (MoEL, 2021)	5	8032-32-4	VM&P Naphtha
		6	8052-41-3	Stoddard solvent
EU REACH (ECHA, 2020)	SVHC	1	65996-93-2	Pitch, coal tar, high-temp.
		2	90640-82-7	Anthracene oil (5 different types by anthracene fraction)
		3	91995-17-4	
		4	91995-15-2	
		5	90640-81-6	
		6	90640-80-5	
		7	85335-84-8	Alkanes, C10-13, chloro
	Authorisation substance	8	65996-93-2	Pitch, coal tar, high-temp.
		9	90640-80-5	Anthracene oil
	Substances restricted	10	122384-78-5	Low temperature tar oil, alkaline
		11	8001-58-9	Creosote
		12	8021-39-4	Creosote, wood
		13	84650-04-4	Naphthalene oil
		14	65996-91-0	Heavy anthracene oil
		15	90640-84-9	Creosote oil, acenaphthene
		16	61789-28-4	Creosote oil
		17	65996-85-2	Tar acid, coal, crude
		18	90640-80-5	Anthracene oil

* ***Abbreviations***: K-REACH, Act on the Registration, Evaluation, etc. of Chemicals; KCCA, Chemical substances Control Act in Korea; NIER, National Institute of Environmental Research; MoE, Ministry of Environment; KOSHA, Occupational Safety and Health Act in Korea; MoEL, Ministry of Employment and Labor; EU REACH, EU Registration, Evaluation, Authorisation, and Restriction of Chemicals; SVHC, Substance of Very High Concern

Table A-2. Petroleum UVCB substances classified under Korean regulations, and difference in hazard classification compared to EU CLP

No.	CAS No.	Chemical Name	Hazard Classification		
			MoEL (MoEL, 2020)	NIER (NIER, 2021)	EU CLP (ECHA, 2020)
1	8006-61-9	Gasoline	C. 1B M. 1B	-	C. 1B [a)] M. 1B [a)] **Asp. 1**
2	8030-30-6	Naphtha	C. 1B [a)] M. 1B [a)]	-	C. 1B [a)] M. 1B [a)] **Asp. 1**
3	8032-32-4	VM & P Naphtha	*Same as above*	-	*Same as above*
4	68476-85-7	LPG	C. 1A [b)] M. 1B [b)]	-	C. 1A [b)] M. 1B [b)] **FG 1** **PG**
5	8008-20-6	Kerosene	C. 2 (skin)	-	**Asp. 1**
6	65996-93-2	Coal tar pitch volatiles	C. 1A M. 1B	-	C. 1A M. 1B **R. 1B**
7	8052-41-3	Stoddard solvent	C. 1B [a)] M. 1B [a)]	-	C. 1B [a)] M. 1B [a)] **Asp. 1** **RE. 1**
8	-	Particulate polycylic aromatic hydrocarbons	C. 1A~2	-	C. 1B [c)]
9	90640-84-9	Creosote oil, acenaphthene fraction	-	C. 1B M. 2 AT. 4 SI. 2 EI. 2 AC. 1 AA. 1	C. 1B [d)]
10	8001-58-9	Creosote	-	*Same as above*	C. 1B

* ***Abbreviations***: MoEL, Ministry of Employment and Labor; NIER, National Institute of Environmental Research; MoE, Ministry of Environment; EU CLP, EU regulation of Classification, Labelling and Packaging of substances and mixture; C, Carcinogenicity; M, Mutagenicity; Asp, Aspiration toxicity; FG, Flammable Gas; PG, Pressurized Gas; R, Reproductive toxicity; RE, Specific target organ toxicity – Repeated Exposure; AT, Acute Toxicity (o = oral, d = dermal, i = inhalation); SE, Specific target organ toxicity – Single Exposure; AC, Aquatic toxicity – Chronic, AA, Aquatic toxicity – Acute

* ***Notes***: **a)** Only when benzene is contained for more than 0.1%. **b)** Only when 1,3-butadiene is contained for more than 0.1%. **c)** Classification obtained from aromatic hydrocarbons (CAS No. 101794-74-5, 101794-75-6, 101794-76-7). **d)** Only when benzo[a]-pyrene is contained for more than 0.005%.

Appendix II. Hazard Classification Analysis & Comparison

Table A-3. Hazard classification on the company's KOSHA SDS of the naphtha process streams

SDS No.	Hazard classification on the current KOSHA SDS															Total number of classifications
	C.	M.	R.	FG	FL	PG	SI	EI	SS	AT	SE	RE	Asp.	AC	AA	
PS (1)	1B	2					2	2				2				**5**
PS (2)	1B	1B	1B				1	1	1	4(o,d),3(i)	3(r)	2		2		**12**
PS (3)	1A	1B		1		∨	2	2			3(r,n)	1		3		**10**
PS (4)	1A	1B		1		∨	2	2			3(n)					**7**
PS (5)	1A	1B					2	2		4(i)	3(n)					**6**
PS (6)	1A			1		∨	2	2			3(n)			4		**7**
PS (7)	2		2		3		2	1								**5**
PS (8)	1A	1B	2		1		2	2			3(r,n)	1	1	2		**11**
PS (9)	1B	2								3(i)	3(r)			3		**5**
PS (10)	1A	1B	2		2		2	2	1	3(i)	3(r)	1	1	3		**12**
PS (11)	1B	1B			1			2		4(o)	3(r,n)		1	2		**9**
PS (12)	1A	1B					2	2				1	1	2		**7**
PS (13)					3		2						1			**3**
PS (14)	2		1B		3		2	2			3(r,n)	1	1	2	1	**11**
PS (15)	2				2		2	2	1	4(o),2(i)	2	2	1	2		**11**
PS (16)	2							2	1	4(o)	1	1		2		**7**
PS (17)																**0**
Subtotal	**15**	**10**	**5**	**3**	**7**	**3**	**13**	**14**	**4**	**10**	**16**	**9**	**7**	**11**	**1**	**(avg=8)**

* ***Abbreviations***: PS, Process Stream; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; FG, Flammable Gas; FL, Flammable Liquid; PG, Pressurized Gas; SI, Skin Irritant; EI, Eye Irritant; SS, Skin Sensitizer; AT, Acute Toxicity (o = oral, d = dermal, i = inhalation); SE, Specific target organ toxicity – Single Exposure; RE, Specific target organ toxicity – Repeated Exposure (r = respiratory tract irritation, n = narcotic effects); Asp, Aspiration toxicity; AC, Aquatic toxicity – Chronic, AA, Aquatic toxicity – Acute

Table A-4. Hazard classification on the company's KOSHA SDS of the purchased naphtha

SDS No.	Hazard classification on the current KOSHA SDS												Total number of classifications
	C.	M.	R.	FG	FL	SI	EI	AT	SE	RE	Asp.	AC	
N (1)	1B		2		1			4(i)	3(n)		1		**6**
N (2)	1A	1B	2		1	2			3(n)		1	2	**8**
N (3)	1B	1B	2		2	2	2		3(r,n)		1	2	**10**
N (4)	1B	1B			2						1		**4**
N (5)	1B				1	2	2		3(r)			2	**6**
N (6)	1B	1B			1	2	2				1	2	**7**
N (7)	1B	1B			1		2	3(i)		2			**6**
N (8)	1B				1						1	2	**4**
N (9)	1B	1B			1	2					1	2	**6**
N (10)	1B	1B			1	2					1	2	**6**
N (11)	1B				1								**2**
N (12)	1B				1			3(i)					**3**
N (13)	1B	1B			1		2	3(i)					**5**
N (14)	1B	1B			1		2				1	3	**6**
N (15)	1B				1		2	3(i)	3(r)			3	**6**
N (16)	1B		2		2	2		4(i)	3(n)		1		**7**
N (17)			2		1	2			3(n)	2	1	3	**7**
N (18)	1A	1B	2	2		2	2	4(o)	3(r)	1	1	2	**11**
N (19)	1B	1B	2		2	2	2	3(i)	3(r,n)	2	1	2	**12**
N (20)	1A	1B	2		4	2	2	4(d),3(i)	3(r,n)	1	1	2	**13**
N (21)	1B	1B			1	2		3(i)			1	2	**7**
N (22)	1B	1B			1	2					1	2	**6**
N (23)	1B	1B			1	2					1	2	**6**
N (24)	1B				2	2	2		3(r)				**5**
Subtotal	**23**	**15**	**8**	**1**	**23**	**15**	**11**	**11**	**14**	**5**	**17**	**16**	**(avg=7)**

* ***Abbreviations***: N, purchased Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; FG, Flammable Gas; FL, Flammable Liquid; PG, Pressurized Gas; SI, Skin Irritant; EI, Eye Irritant; SS, Skin Sensitizer; AT, Acute Toxicity (o = oral, d = dermal, i = inhalation); SE, Specific target organ toxicity – Single Exposure; RE, Specific target organ toxicity – Repeated Exposure (r = respiratory tract irritation, n = narcotic effects); Asp, Aspiration toxicity; AC, Aquatic toxicity – Chronic, AA, Aquatic toxicity – Acute

Table A-5. Summary of the matching scores of the company's KOSHA classification on SDS to the five recommended classification methods on 17 process streams

SDS No.	EU CLP			#4. CONCAWE	#5. MoE	Average
	#1. UVCB only	#2. Constituent only	#3. Both			
PS (1)	1/1 (100%)	N/A	N/A	2/7 (28.6%)	2/3 (66.7%)	**5/11 (45.5%)**
PS (2)	0/1 (0%)	5/8 (62.5%)	5/8 (62.5%)	3/6 (50%)	3/3 (100%)	**16/25 (64%)**
PS (3)	N/A	4/4 (100%)	N/A	5/7 (71.4%)	2/3 (66.7%)	**11/14 (78.6%)**
PS (4)	4/4 (100%)	4/4 (100%)	4/4 (100%)	4/7 (57.1%)	2/3 (66.7%)	**18/22 (81.8%)**
PS (5)	N/A	2/4 (50%)	N/A	2/7 (28.6%)	3/3 (100%)	**7/14 (50.0%)**
PS (6)	N/A	3/4 (75%)	N/A	3/7 (42.9%)	1/3 (33.3%)	**7/14 (50%)**
PS (7)	N/A	0/3 (0%)	N/A	1/4 (25%)	1/3 (33.3%)	**2/10 (20%)**
PS (8)	3/3 (100%)	8/12 (66.7%)	9/11 (81.8%)	8/8 (100%)	3/3 (100%)	**31/37 (83.8%)**
PS (9)	0/1 (0%)	0/2 (0%)	0/2 (0%)	0/6 (0%)	3/3 (100%)	**3/14 (21.4%)**
PS (10)	1/1 (100%)	7/12 (58.3%)	8/11 (72.7%)	5/8 (62.5%)	3/3 (100%)	**24/35 (68.6%)**
PS (11)	N/A	4/4 (100%)	N/A	4/6 (66.7%)	3/3 (100%)	**11/13 (84.6%)**
PS (12)	3/3 (100%)	6/9 (66.7%)	6/7 (85.7%)	5/8 (62.5%)	3/3 (100%)	**23/30 (76.7%)**
PS (13)	N/A	N/A	N/A	2/8 (25%)	0/3 (0%)	**2/11 (18.2%)**
PS (14)	N/A	3/5 (60%)	N/A	5/6 (83.3%)	3/3 (100%)	**11/14 (78.6%)**
PS (15)	N/A	6/7 (85.7%)	N/A	4/6 (66.7%)	2/3 (66.7%)	**12/16 (75%)**
PS (16)	0/1 (0%)	3/4 (75%)	2/4 (50%)	2/6 (33.3%)	2/3 (66.7%)	**9/17 (52.9%)**
PS (17)	0/1 (0%)	0/1 (0%)	0/2 (0%)	0/5 (0%)	0/2 (0%)	**0/11 (0%)**
Sub-Average	**12/16 (75%)**	**55/83 (66.3%)**	**34/49 (69.4%)**	**55/112 (49.1%)**	**36/50 (86.4%)**	**192/310 (61.9%)**

* ***Abbreviations***: PS, Process Stream

* ***Notes***: N/A means that either there was no classification under EU CLP, or no identification information is known for the UVCB substance or the constituent.

Table A-6. Summary of the matching scores of the company's KOSHA classification on SDS to the five recommended classification methods on 24 purchased naphtha

SDS No.	EU CLP			#4. CONCAWE	#5. MoE	Average
	#1. UVCB only	#2. Constituent only	#3. Both			
N (1)	1/1 (100%)	N/A	N/A	4/6 (66.7%)	2/3 (66.7%)	**7/10 (70%)**
N (2)	3/3 (100%)	6/6 (100%)	6/6 (100%)	8/8 (100%)	3/3 (100%)	**26/26 (100%)**
N (3)	1/1 (100%)	N/A	N/A	5/6 (83.3%)	3/3 (100%)	**9/10 (90%)**
N (4)	1/1 (100%)	3/5 (60%)	3/5 (60%)	3/8 (37.5%)	2/3 (66.7%)	**12/22 (54.5%)**
N (5)	0/1 (0%)	N/A	N/A	3/6 (50%)	2/3 (66.7%)	**5/10 (50%)**
N (6)	1/1 (0%)	N/A	N/A	4/6 (66.7%)	2/3 (66.7%)	**7/10 (70%)**
N (7)	0/1 (0%)	N/A	N/A	1/6 (16.7%)	2/3 (66.7%)	**3/10 (30%)**
N (8)	1/1 (100%)	N/A	N/A	3/6 (50%)	1/3 (33.3%)	**5/10 (50%)**
N (9)	1/1 (100%)	N/A	N/A	4/6 (66.7%)	2/3 (66.7%)	**7/10 (70%)**
N (10)	1/1 (100%)	N/A	N/A	4/6 (66.7%)	2/3 (66.7%)	**7/10 (70%)**
N (11)	0/1 (0%)	N/A	N/A	1/6 (16.7%)	1/3 (33.3%)	**2/10 (20%)**
N (12)	0/1 (0%)	N/A	N/A	1/6 (16.7%)	1/3 (33.3%)	**2/10 (20%)**
N (13)	0/1 (0%)	N/A	N/A	1/6 (16.7%)	2/3 (66.7%)	**3/10 (30%)**
N (14)	1/1 (100%)	N/A	N/A	2/6 (33.3%)	2/3 (66.7%)	**5/10 (50%)**
N (15)	1/3 (33.3%)	1/8 (12.5%)	1/8 (12.5%)	2/8 (25%)	1/3 (33.3%)	**6/30 (20%)**
N (16)	1/1 (100%)	N/A	N/A	4/6 (66.7%)	2/3 (66.7%)	**7/10 (70%)**
N (17)	N/A	3/3 (100%)	N/A	5/6 (83.3%)	1/3 (33.3%)	**9/12 (75%)**
N (18)	1/1 (100%)	4/5 (80%)	4/5 (80%)	5/6 (83.3%)	2/3 (66.7%)	**16/20 (80%)**
N (19)	1/1 (100%)	6/8 (75%)	6/8 (75%)	5/6 (83.3%)	3/3 (100%)	**21/26 (80.8%)**
N (20)	1/1 (100%)	7/10 (70%)	7/8 (87.5%)	5/6 (83.3%)	3/3 (100%)	**23/28 (82.1%)**
N (21)	1/1 (100%)	N/A	N/A	4/6 (66.7%)	2/3 (66.7%)	**7/10 (70%)**

Table A-6. Summary of the matching scores of the company's KOSHA classification on SDS to the five recommended classification methods on 24 purchased naphtha (Continued)

SDS No.	EU CLP			#4. CONCAWE	#5. MoE	Average
	#1. UVCB only	#2. Constituent only	#3. Both			
N (22)	1/1 (100%)	N/A	N/A	4/6 (66.7%)	2/3 (66.7%)	**7/10 (70%)**
N (23)	1/1 (100%)	N/A	N/A	4/6 (66.7%)	2/3 (66.7%)	**7/10 (70%)**
N (24)	0/1 (0%)	N/A	N/A	1/6 (16.7%)	2/3 (66.7%)	**3/10 (30%)**
Sub-Average	**19/27 (70.4%)**	**30/45 (66.7%)**	**27/40 (67.5%)**	**83/150 (55.3%)**	**47/72 (65.3%)**	**206/334 (61.7%)**

* ***Abbreviations***: N, purchased Naphtha

* ***Notes***: N/A means that either there was no classification under EU CLP, or no identification information is known for the UVCB substance or the constituent.

Table A-7. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #1 (CAS No. 647427-90-1)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (HFO)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	**1B**			**1B**	V
M.	2					V
R.					2	
RE	2				**2**	
SI	2					
EI	2					
Asp.					1	
AT(i)					4	V
AC					1	
AA					1	
Matching	**-**	**1/1 (100%)**	**N/A**	**N/A**	**2/7 (28.6%)**	**2/3 (66.7%)**

* ***Abbreviation***: HFO, Heavy Fuel Oil; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; AT(i), Acute Toxicity – inhalation; AC, Aquatic toxicity – Chronic, AA, Aquatic toxicity – Acute

* ***Note***: Comparison with #2 and #3 methods not possible due to the constituent information not available on the SDS

Table A-8. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #2 (CAS No. 68603-08-7)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)	(1B)	(1B)	(1B)	V
M.	1B	(1B)	(1B)	(1B)	(1B)	V
R.	1B				**2**	
SE(r)	3					
SE(n)					3	V
RE	2		**2**	**2**		
SI	1		**1**	**1**	**2**	
EI	1		**1**	**1**		
SS	1		**1**	**1**		
Asp.		1	1	1	1	
AT(o)	4		3	3		
AT(d)	4		3	3		
AT(i)	3					
FL					1	
AC	2		**3**	**3**	**2**	
Matching	**-**	**0/1 (0%)**	**5/8 (62.5%)**	**5/8 (62.5%)**	**3/6 (50%)**	**3/3 (100%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(r), Specific target organ toxicity – Single Exposure (respiratory tract irritation); SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; AT(o), Acute Toxicity – oral; AT(d), Acute Toxicity – dermal; AT(i), Acute Toxicity – inhalation; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene.

Table A-9. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #3 (CAS No. 68476-52-8)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (Others)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1A		**1A**		**1A**	∨
M.	1B		**1B**		**1B**	∨
R.					1A	
SE(r)	3					
SE(n)	3					
RE	1				**2**	
SI	2					
EI	2					
AT(i)					3	∨
FG	1		**1**		**1**	
PG	∨		∨		∨	
AC	3					
Matching	-	**N/A**	**4/4 (100%)**	**N/A**	**5/7 (71.4%)**	**2/3 (66.7%)**

* ***Abbreviation***: C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(r), Specific target organ toxicity – Single Exposure (respiratory tract irritation); SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; AT(i), Acute Toxicity – inhalation; FG, Flammable Gas; PG, Pressurized Gas; AC, Aquatic toxicity – Chronic

* ***Note***: Comparison with #1 and #3 methods not possible due to no EU CLP classification required for the UVCB substance

Table A-10. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #4 (CAS No. 92045-23-3)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (Others)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1A	**1A**	**1A**	**1A**	**1A**	∨
M.	1B	**1B**	**1B**	**1B**	**1B**	∨
R.					1A	
SE(n)	3					
RE					2	
SI	2					
EI	2					
AT(i)					3	∨
FG	1	**1**	**1**	**1**	**1**	
PG	∨	∨	∨	∨	∨	
Matching	-	**4/4 (100%)**	**4/4 (100%)**	**4/4 (100%)**	**4/7 (57.1%)**	**2/3 (66.7%)**

* ***Abbreviation***: C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; AT(i), Acute Toxicity – inhalation; FG, Flammable Gas; PG, Pressurized Gas

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are applicable because this UVCB substance contains more than 0.1% 1,3-butadiene

Table A-11. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #5 (CAS No. 68956-54-7)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (Others)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1A		**1A**		**1A**	∨
M.	1B		**1B**		**1B**	∨
R.					1A	
SE(n)	3					
RE					2	
SI	2					
EI	2					
AT(i)	4				3	∨
FG			1		1	
PG			∨		∨	
Matching	**-**	**N/A**	**2/4 (50%)**	**N/A**	**2/7 (28.6%)**	**3/3 (100%)**

* ***Abbreviation***: C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; AT(i), Acute Toxicity – inhalation; FG, Flammable Gas; PG, Pressurized Gas

* ***Note***: Comparison with #1 and #3 methods not possible due to no EU CLP classification required for the UVCB substance

Table A-12. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #6 (CAS No. *Unknown*)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (Others)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1A		**1A**		**1A**	∨
M.			1B		1B	∨
R.					1A	
SE(n)	3					
RE					2	
SI	2					
EI	2					
AT(i)					3	∨
FG	1		**1**		**1**	
PG	∨		∨		∨	
Matching	**-**	**N/A**	**3/4 (75%)**	**N/A**	**3/7 (42.9%)**	**1/3 (33.3%)**

* ***Abbreviation***: C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; AT(i), Acute Toxicity – inhalation; FG, Flammable Gas; PG, Pressurized Gas

* ***Note***: Comparison with #1 and #3 methods not possible due to unknown information on the UVCB substance

Table A-13. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #7 (CAS No. 64741-96-4)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBO)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	2	(1B)	(1B)		1B	V
M.			1B			V
R.	2		1B		**2**	
RE					1	
SI	2					
EI	1					
Asp.					1	
AT(d)			4			V
FL	3					
Matching	**-**	**N/A**	**0/3 (0%)**	**N/A**	**1/4 (25%)**	**1/3 (33.3%)**

* ***Abbreviation***: LBO, Lubricant Base Oils; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; AT(d), Acute Toxicity –dermal; FL, Flammable Liquid

* ***Note***: EU CLP classifications for carcinogenicity are not applicable because this UVCB substance contains less than 3% DMSO. Comparison with #1 and #3 methods not possible due to no EU CLP classification required for the UVCB substance

Table A-14. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #8 (CAS No. 68606-10-0)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1A	**1B**	**1A**	**1A**	**1B**	V
M.	1B	**1B**	**1B**	**1B**	**1B**	V
R.	2		**2**	**2**	**2**	
SE(r)	3		1	1		V
SE(n)	3				**3**	
RE	1		**3**	**3**		
SI	2		**2**	**2**	**2**	
EI	2		**2**	**2**		
Asp.	1	**1**		**1**	**1**	
AT(d)			4	4		
FL	1		**1**	**1**	**1**	
FG			1			
PG			V			
AC	2		**3**	**3**	**2**	
Matching	-	**3/3 (100%)**	**8/12 (66.7%)**	**9/11 (81.8%)**	**8/8 (100%)**	**3/3 (100%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(r), Specific target organ toxicity – Single Exposure (respiratory tract irritation); SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; AT(d), Acute Toxicity –dermal; FL, Flammable Liquid; FG, Flammable Gas; PG, Pressurized Gas; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are applicable because this UVCB substance contains more than 0.1% benzene.

Table A-15. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #9 (CAS No. 102100-14-5)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)	(1B)	(1B)	(1B)	V
M.	2	(1B)	(1B)	(1B)	(1B)	V
R.					2	
SE(r)	3					V
SE(n)					3	
SI					2	
Asp.		1	1	1	1	
AT(i)	3(i)					
FL			1	1	1	
AC	3				2	
Matching	**-**	**0/1 (0%)**	**0/2 (0%)**	**0/2 (0%)**	**0/6 (0%)**	**3/3 (100%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(r), Specific target organ toxicity – Single Exposure (respiratory tract irritation); SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin Irritant; Asp, Aspiration toxicity; AT(i), Acute Toxicity – inhalation; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene.

Table A-16. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #10 (CAS No. 68477-39-4)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1A		**1A**	**1A**	**1B**	V
M.	1B		**1B**	**1B**	**1B**	V
R.	2		**2**	**2**	**2**	
SE(r)	3					
SE(n)					3	V
RE	1		**2**	**2**		
SI	2		**2**	**2**	**2**	
EI	2		**2**	**2**		
SS	1					
Asp.	1	**1**		**1**	**1**	
AT(o)			4	4		
AT(d)			4	4		
AT(i)	3					
FL	2		**2**	**2**	1	
FG			1			
PG			V			
AC	3		2	2	2	
Matching	**-**	**1/1 (100%)**	**7/12 (58.3%)**	**8/11 (72.7%)**	**5/8 (62.5%)**	**3/3 (100%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(r), Specific target organ toxicity – Single Exposure (respiratory tract irritation); SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; SS, Skin Sensitizer; Asp, Aspiration toxicity; AT(o), Acute toxicity – oral; AT(d), Acute Toxicity – dermal; AT(i), Acute Toxicity – inhalation; FL, Flammable Liquid; FG, Flammable Gas; PG, Pressurized Gas; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are applicable because this UVCB substance contains more than 0.1% benzene.

Table A-17. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #11 (CAS No. 68956-55-8)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B		(1B)		(1B)	V
M.	1B		(1B)		(1B)	V
R.					2	
SE(r)	3		**3**			V
SE(n)	3		**3**		**3**	
SI					2	
EI	2					
Asp.	1				**1**	
AT(o)	4					
FL	1		**1**		**1**	
AC	2		**2**		**2**	
Matching	**-**	**N/A**	**4/4 (100%)**	**N/A**	**4/6 (66.7%)**	**3/3 (100%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(r), Specific target organ toxicity – Single Exposure (respiratory tract irritation); SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; AT(o), Acute toxicity – oral; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #1 method not possible due to no EU CLP classification required for the UVCB substance

Table A-18. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #12 (CAS No. 94114-03-1)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1A	**1B**	**1A**	**1A**	**1B**	V
M.	1B	**1B**	**1B**	**1B**	**1B**	V
R.					2	
SE(n)					3	V
RE	1		**1**	**1**		
SI	2		**2**	**2**	**2**	
EI	2		**2**	**2**		
Asp.	1	**1**	**1**	**1**	**1**	
FL			2	2	1	
FG			1			
PG			V			
AC	2				**2**	
Matching	-	**3/3 (100%)**	**6/9 (66.7%)**	**6/7 (85.7%)**	**5/8 (62.5%)**	**3/3 (100%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; FL, Flammable Liquid; FG, Flammable Gas; PG, Pressurized Gas; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are applicable because this UVCB substance contains more than 0.1% benzene.

Table A-19. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #13 (CAS No. 92128-65-9)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.					1B	V
M.					1B	V
R.					2	
SE(n)					3	V
SI	2				**2**	
Asp.	1				**1**	
FL	3				1	
AC					2	
Matching	-	**N/A**	**N/A**	**N/A**	**2/8 (25%)**	**0/3 (0%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin Irritant; Asp, Aspiration toxicity; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are considered applicable because no constituent information is known for this UVCB substance. Comparison with #1~#3 methods is not possible due to no EU CLP classification required for the UVCB substance and no information on constituents.

Table A-20. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #14 (CAS No. 90989-41-6)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	2	(1B)			(1B)	V
M.		(1B)			(1B)	V
R.	1B				**2**	
SE(r)	3					
SE(n)	3				**3**	V
RE	1					
SI	2		**2**		**2**	
EI	2					
Asp.	1		**1**		**1**	
AT(d)			4			
FL	3		2		1	
AC	2		**3**		**2**	
AA	1					
Matching	-	**N/A**	**3/5 (60%)**	**N/A**	**5/6 (83.3%)**	**3/3 (100%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(r), Specific target organ toxicity – Single Exposure (respiratory tract irritation); SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; AT(d), Acute Toxicity – dermal; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic; AA, Aquatic toxicity - Acute

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #1 and #3 methods not possible due to no EU CLP classification required for the UVCB substance.

Table A-21. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #15 (CAS No. 94733-07-0)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	2		**2**		(1B)	V
M.					(1B)	V
R.					2	
SE(n)	2				**3**	V
RE	2					
SI	2		**2**		**2**	
EI	2		**2**			
SS	1					
Asp.	1				**1**	
AT(o)	4		**4**			
AT(d)			4			
AT(i)	2					
FL	2		**2**		1	
AC	2		**2**		**2**	
Matching	-	**N/A**	**6/7 (85.7%)**	**N/A**	**4/6 (66.7%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; SS, Skin Sensitizer; Asp, Aspiration toxicity; AT(o), Acute Toxicity – oral; AT(d), Acute Toxicity – dermal; AT(i), Acute Toxicity – inhalation; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #1 and #3 methods not possible due to no EU CLP classification required for the UVCB substance.

Table A-22. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #16 (CAS No. 68512-78-7)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	2	(1B)	**2**	(1B)	(1B)	V
M.		(1B)		(1B)	(1B)	V
R.					2	
SE(n)	1				**3**	V
RE	1					
SI					2	
EI	2					
SS	1					
Asp.		1		1	1	
AT(o)	4		**4**	**4**		
FL			2	2	1	
AC	2		**2**	**2**	**2**	
Matching	-	**0/1 (0%)**	**3/4 (75%)**	**2/4 (50%)**	**2/6 (33.3%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; SS, Skin Sensitizer; Asp, Aspiration toxicity; AT(o), Acute Toxicity – oral; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene.

Table A-23. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on process stream #17 (CAS No. 64742-94-5)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (Kerosene)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.						V
M.						
R.						V
SE(n)					3	
SI					2	
Asp.		1		1	1	
FL			2	2	3	
AC					2	
Matching	-	**0/1 (0%)**	**0/1 (0%)**	**0/2 (0%)**	**0/5 (0%)**	**0/2 (0%)**

* ***Abbreviation***: C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

Table A-24. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #1 (CAS No. 8030-30-6)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	∨
M.		(1B)			(1B)	∨
R.	2				**2**	
SE(n)	3				**3**	∨
SI					2	
Asp.	1	**1**			**1**	
AT(i)	4					
FL	1				**1**	
AC					2	
Matching	**-**	**1/1 (100%)**	**N/A**	**N/A**	**4/6 (66.7%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin Irritant; Asp, Aspiration toxicity; AT(i), Acute Toxicity – inhalation; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-25. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #2 (CAS No. 64741-42-0)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1A	**1B**	**1A**	**1A**	**1B**	∨
M.	1B	**1B**	**1B**	**1B**	**1B**	∨
R.	2		**2**	**2**	**2**	
SE(n)	3				**3**	∨
SI	2				**2**	
Asp.	1	**1**	**1**	**1**	**1**	
FL	1		**2**	**2**	**1**	
AC	2		**3**	**3**	**2**	
Matching	**-**	**3/3 (100%)**	**6/6 (100%)**	**6/6 (100%)**	**8/8 (100%)**	**3/3 (100%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin Irritant; Asp, Aspiration toxicity; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are applicable because this UVCB substance contains more than 0.1% benzene.

Table A-26. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #3 (CAS No. 64741-55-5)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	V
M.	1B	(1B)			(1B)	V
R.	2				**2**	
SE(r)	3					V
SE(n)	3				**3**	
SI	2				**2**	
EI	2					
Asp.	1	**1**			**1**	
FL	2				1	
AC	2				**2**	
Matching	**-**	**1/1 (100%)**	**N/A**	**N/A**	**5/6 (83.3%)**	**3/3 (100%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(r), Specific target organ toxicity – Single Exposure (respiratory tract irritation); SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin Irritant; EI, Eye Irritation; Asp, Aspiration toxicity; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-27. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #4 (CAS No. 64741-87-3)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	**1B**	1A	1A	**1B**	V
M.	1B	**1B**	**1B**	**1B**	**1B**	V
R.					2	
SE(n)					3	V
RE			2	2		
SI					2	
Asp.	1	**1**	**1**	**1**	**1**	
FL	2		**2**	**2**	1	
AC					2	
Matching	**-**	**1/1 (100%)**	**3/5 (60%)**	**3/5 (60%)**	**3/8 (37.5%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; Asp, Aspiration toxicity; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are applicable because this UVCB substance contains more than 0.1% benzene.

Table A-28. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #5 (CAS No. 64742-73-0)

Classification	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	V
M.		(1B)			(1B)	V
R.					2	
SE(r)	3					V
SE(n)					3	
SI	2				**2**	
EI	2					
Asp.		1			1	
FL	1				**1**	
AC	2				**2**	
Matching	**-**	**0/1 (0%)**	**N/A**	**N/A**	**3/6 (50%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(r), Specific target organ toxicity – Single Exposure (respiratory tract irritation); SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin Irritant; EI, Eye Irritation; Asp, Aspiration toxicity; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-29. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #6 (CAS No. 64741-46-4)

Classification	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	V
M.	1B	(1B)			(1B)	V
R.					2	
SE(n)					3	V
SI	2				**2**	
Asp.	1	**1**			**1**	
FL	1				**1**	
AC	2				**2**	
Matching	**-**	**1/1 (0%)**	**N/A**	**N/A**	**4/6 (66.7%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin Irritant; Asp, Aspiration toxicity; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-30. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #7 (CAS No. 64741-63-5)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	V
M.		(1B)			(1B)	V
R.					2	
SE(n)					3	V
RE	2					
SI					2	
EI	2					
Asp.		1			1	
AT(i)	3					
FL	1				**1**	
AC					2	
Matching	-	**0/1 (0%)**	**N/A**	**N/A**	**1/6 (16.7%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; AT(i), Acute Toxicity – inhalation; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-31. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #8 (CAS No. 64741-84-0)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	V
M.		(1B)			(1B)	V
R.					2	
SE(n)					3	V
SI					2	
Asp.	1	**1**			**1**	
FL	1				**1**	
AC	2				**2**	
Matching	-	**1/1 (100%)**	**N/A**	**N/A**	**3/6 (50%)**	**1/3 (33.3%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effect); SI, Skin Irritant; Asp, Aspiration toxicity; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-32. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #9 (CAS No. 64741-41-9)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	V
M.	1B	(1B)			(1B)	V
R.					2	
SE(n)					3	V
SI	2				**2**	
Asp.	1	**1**			**1**	
FL	1				**1**	
AC	2				**2**	
Matching	-	**1/1 (100%)**	**N/A**	**N/A**	**4/6 (66.7%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effect); SI, Skin Irritant; Asp, Aspiration toxicity; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-33. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #10 (CAS No. 64741-42-0)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	V
M.	1B	(1B)			(1B)	V
R.					2	
SE(n)					3	V
SI	2				**2**	
Asp.	1	**1**			**1**	
FL	1				**1**	
AC	2				**2**	
Matching	-	**1/1 (100%)**	**N/A**	**N/A**	**4/6 (66.7%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effect); SI, Skin Irritant; Asp, Aspiration toxicity; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-34. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #11 (CAS No. 64741-69-1)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	∨
M.		(1B)			(1B)	∨
R.					2	
SE(n)					3	∨
SI					2	
Asp.		1			1	
FL	1				**1**	
AC					2	
Matching	-	**0/1 (0%)**	**N/A**	**N/A**	**1/6 (16.7%)**	**1/3 (33.3%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effect); SI, Skin Irritant; Asp, Aspiration toxicity; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-35. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #12 (CAS No. 64741-78-2)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	∨
M.		(1B)			(1B)	∨
R.					2	
SE(n)					3	∨
SI					2	
Asp.		1			1	
AT(i)	3(i)					
FL	1				**1**	
AC					2	
Matching	-	**0/1 (0%)**	**N/A**	**N/A**	**1/6 (16.7%)**	**1/3 (33.3%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin IrritantAsp, Aspiration toxicity; AT(i), Acute Toxicity – inhalation; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-36. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #13 (CAS No. 92045-60-8)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	V
M.	1B	(1B)			(1B)	V
R.					2	
SE(n)					3	V
SI					2	
EI	2					
Asp.		1			1	
AT(i)	3(i)					
FL	1				**1**	
AC					2	
Matching	**-**	**0/1 (0%)**	**N/A**	**N/A**	**1/6 (16.7%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; AT(i), Acute Toxicity – inhalation; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-37. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #14 (CAS No. 93165-19-6)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	V
M.	1B	(1B)			(1B)	V
R.					2	
SE(n)					3	V
SI					2	
EI	2					
Asp.	1	**1**			**1**	
FL	1				**1**	
AC	3				2	
Matching	**-**	**1/1 (100%)**	**N/A**	**N/A**	**2/6 (33.3%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-38. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #15 (CAS No. 64741-47-5)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	**1B**	1A	1A	**1B**	V
M.		1B	1B	1B	1B	V
R.					2	
SE(r)	3					
SE(n)			3	3	3	V
RE			2	2		
SI					2	
EI	2					
Asp.		1	1	1	1	
AT(d)			4	4		
AT(i)	3					
FL	1		**1**	**1**	**1**	
AC	3		2	2	2	
Matching	-	**1/3 (33.3%)**	**1/8 (12.5%)**	**1/8 (12.5%)**	**2/8 (25%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(r), Specific target organ toxicity – Single Exposure (respiratory tract irritation); SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; AT(d), Acute Toxicity – dermal; AT(i), Acute Toxicity – inhalation; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are applicable because this UVCB substance contains more than 0.1% benzene.

Table A-39. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #16 (CAS No. 8030-30-6)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	V
M.		(1B)			(1B)	V
R.	2				**2**	
SE(n)	3				**3**	V
SI	2				**2**	
Asp.	1	**1**			**1**	
AT(i)	4					
FL	2				1	
AC					2	
Matching	-	**1/1 (100%)**	**N/A**	**N/A**	**4/6 (66.7%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin Irritant; Asp, Aspiration toxicity; AT(i), Acute Toxicity – inhalation; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-40. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha#17(CAS No. 848301-65-5)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.					(1B)	V
M.					(1B)	V
R.	2		**2**		**2**	
SE(n)	3				**3**	V
RE	2					
SI	2				**2**	
Asp.	1				**1**	
FL	1		**2**		**1**	
AC	3		**3**		2	
Matching	-	**N/A**	**3/3 (100%)**	**N/A**	**5/6 (83.3%)**	**1/3 (33.3%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; Asp, Aspiration toxicity; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: Classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #1 and #3 methods not possible due to no EU CLP classification required for the UVCB substance.

Table A-41. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #18 (CAS No. 64742-42-0)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)	(1A)	(1A)	(1B)	∨
M.	1B	(1B)	(1B)	(1B)	(1B)	∨
R.	2		1	1	**2**	
SE(r)	3					∨
SE(n)	3				**3**	
RE	2					
SI	2		**2**	**2**	**2**	
EI	2		**2**	**2**		
Asp.	1	**1**	**1**	**1**	**1**	
AT(i)	3(i)					
FL	2		**2**	**2**	1	
AC	2				**2**	
Matching	**-**	**1/1 (100%)**	**4/5 (80%)**	**4/5 (80%)**	**5/6 (83.3%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(r), Specific target organ toxicity – Single Exposure (respiratory tract irritation); SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; AT(i), Acute Toxicity – inhalation; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene.

Table A-42. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #19 (CAS No. 64741-47-5)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)	(1B)	(1B)	(1B)	V
M.	1B	(1B)	(1B)	(1B)	(1B)	V
R.	2		**2**	**2**	**2**	
SE(r)	3					
SE(n)	3		**3**	**3**	**3**	V
RE	2		**2**	**2**		
SI	2		**2**	**2**	**2**	
EI	2					
Asp.	1	1	**1**	**1**	**1**	
AT(i)	3					
FL	2		**2**	**2**	1	
AA			1	1		
AC	2		1	1	**2**	
Matching	-	**1/1 (100%)**	**6/8 (75%)**	**6/8 (75%)**	**5/6 (83.3%)**	**3/3 (100%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(r), Specific target organ toxicity – Single Exposure (respiratory tract irritation); SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; AT(i), Acute Toxicity – inhalation; FL, Flammable Liquid; AA, Aquatic Toxicity – Acute; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene.

Table A-43. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #20 (CAS No. 64741-47-5)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1A	1B	1A	1A	1B	∨
M.	1B	1B	1B	1B	1B	∨
R.	2		**2**	**2**	**2**	
SE(r)	3					
SE(n)	3		**3**	**3**	**3**	∨
RE	1		**1**	**1**		
SI	2		**2**	**2**	**2**	
EI	2		**2**	**2**		
Asp.	1	**1**	**1**	**1**	**1**	
AT(d)	4					
AT(i)	3					
FL	4		2	2	1	
FG			1			
PG			∨			
AC	2		**3**	**3**	**2**	
Matching	**-**	**1/1 (100%)**	**7/10 (70%)**	**7/8 (87.5%)**	**5/6 (83.3%)**	**3/3 (100%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(r), Specific target organ toxicity – Single Exposure (respiratory tract irritation); SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; AT(d), Acute Toxicity – dermal; AT(i), Acute Toxicity – inhalation; FL, Flammable Liquid; FG, Flammable gas; PG, Pressurized Gas; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are applicable because this UVCB substance contains more than 0.1% benzene.

Table A-44. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #21 (CAS No. 64742-42-0)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	V
M.	1B	(1B)			(1B)	V
R.					2	
SE(n)					3	V
SI	2				**2**	
Asp.	1	**1**			**1**	
AT(i)	3					
FL	1				**1**	
AC	2				**2**	
Matching	**-**	**1/1 (100%)**	**N/A**	**N/A**	**4/6 (66.7%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; AT(i), Acute Toxicity – inhalation; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-45. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #22 (CAS No. 64741-46-4)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	V
M.	1B	(1B)			(1B)	V
R.					2	
SE(n)					3	V
SI	2				**2**	
Asp.	1	**1**			**1**	
FL	1				**1**	
AC	2				**2**	
Matching	**-**	**1/1 (100%)**	**N/A**	**N/A**	**4/6 (66.7%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-46. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #23 (CAS No. 64742-73-0)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	V
M.	1B	(1B)			(1B)	V
R.					2	
SE(n)					3	V
SI	2				**2**	
Asp.	1	**1**			**1**	
FL	1				**1**	
AC	2				**2**	
Matching	**-**	**1/1 (100%)**	**N/A**	**N/A**	**4/6 (66.7%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; FL, Flammable Liquid; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

Table A-47. Matching score of the company's KOSHA classification on SDS to the five recommended classification methods on purchased naphtha #24 (CAS No. 64741-42-0)

Classifi-cation	Company's SDS	EU CLP			#4. CONCAWE (LBPN)	#5. MoE
		#1. UVCB only	#2. Constituent only	#3. Both		
C.	1B	(1B)			(1B)	V
M.		(1B)			(1B)	V
R.					2	
SE(r)	3					V
SE(n)					3	
SI	2				**2**	
EI	2					
Asp.		1			1	
FL	2				1	
AC					2	
Matching	**-**	**0/1 (0%)**	**N/A**	**N/A**	**1/6 (16.7%)**	**2/3 (66.7%)**

* ***Abbreviation***: LBPN, Low Boiling Point Naphtha; C, Carcinogenicity; M, Mutagenicity; R, Reproductive toxicity; SE(r), Specific target organ toxicity – Single Exposure (respiratory tract irritation); SE(n), Specific target organ toxicity – Single Exposure (narcotic effects); RE, Specific target organ toxicity – Repeated Exposure; SI, Skin Irritant; EI, Eye Irritant; Asp, Aspiration toxicity; AT(d), Acute Toxicity – dermal; AT(i), Acute Toxicity – inhalation; FL, Flammable Liquid; FG, Flammable gas; PG, Pressurized Gas; AC, Aquatic toxicity – Chronic

* ***Note***: EU CLP classifications for carcinogenicity and mutagenicity are not applicable because this UVCB substance contains less than 0.1% benzene. Comparison with #2 and #3 methods not possible because the constituents are unknown.

국문초록

국내 석유계 UVCB 물질의 성분, 유해성 분류 및 국내 사례 연구

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원유 및 납사 분해로부터 얻어진 석유화학물질은 여러 정제소를 거치며 업체별 분해 방법이 다양하기 때문에, 조성을 알 수 없거나 가변적이거나 복합적이다. 이러한 물질들은 Unknown or Variable composition, Complex reaction products or Biological materials(UVCB)라고 알려져 있으며, 석유계 UVCB 물질에 대한 한국과 유럽의 화학물질 규제를 비교한 결과 한국은 특히 유해성 분류 부분에서 세부 규제관리 사항이 부족한 것으로 확인되었다. 현재 유럽은 698 종의 석유계 UVCB 물질(PUVCB) 유해성 분류를 의무화하고 있는 반면에, 한국은 10 종에 대해서만 요구하고 있으며, 이는 국내 석유화학 산업에서 취급하는 PUVCB 물질과 이에 대한 제조공정 및 관리절차가 많이 알려지지 않아 있기 때문에 규제 격차가 있는 것으로 예상된다.

따라서 국내 대표 석유화학 업체 인터뷰 및 관련 문서 검토를 통해 납사 분해부터 기초유분 정제까지 전반적인 PUVCB 생산 공정을 도식화했으며, 총 32 종의 PUVCB 물질을 확인했다. 해당 업체의 PUVCB 물질 유해성 분류 방법 및 절차도 조사했으며, 그 결과 모범 사례도 있었지만 내부 지침 표준화 등 몇 가지 개선이 필요한 부분도 발견되었다. 또한 확인된 PUVCB 물질 32 종을 기준으로 유럽 CLP 규정, CONCAWE 가이던스 및 국내 환경부 지침에서 권고하고 있는 PUVCB

유해성 분류 방법을 비교했으나 61.8%만 일치되는 것으로 확인되었으며, PUVCB 물질의 유해성 분류를 가장 효과적으로 표시하는 방법은 물질안전보건자료 '3. 구성성분의 명칭 및 함유량' 항목에서 "containing" 방법을 사용하고(최고 일치율: 69.1%) '2. 유해/위험성' 항목에서 CONCAWE 권고사항을 적용해야(최저 일치율: 52.7%)하는 것으로 조사되었다.

주요어: UVCB, 석유계 UVCB 물질, 납사 분해 공정, 화학물질 조성, 물질안전보건자료, 유해성 분류

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