

산안법 관리대상물질의 변이원성 검색을 통한 GLP 유전독성 시험대상 후보물질의 선정

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Selection of Target Materials for GLP Genotoxic Tests by Searching the Mutagenicity Information of Chemicals by Occupational Safety and Health Act

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ABSTRACT

Objectives: There is a requirement to select target materials for mutagenicity(Genotoxicity) testing, so we determined to set the test priorities of them by searching the related database.

Methods and Results: We searched a number of databases to find information on mutagenicity tests with chemicals under the Occupational Safety and Health Act(OSH Act), such as KOSHANET, National Toxicology Program(NTP), European Chemicals Agency(ECHA), US National Library of Medicine(NLM), and Genetic Toxicology Data Bank(GENE-TOX), as well as ChemIDplus webpage, and presented the information. Also we anticipated their hazards with ACToR sites to confirm the 58 mutagenicity(Genotoxicity) tests we will perform.

Conclusions: We presented target materials for mutagenicity testing with specific GLP tests consisting of reverse mutation(Ames), chromosomal aberration and micronucleus test.

Key words: Candidate materials, genotoxic, GLP, mutagenicity, Occupational Safety and Health Act

I. 서 론

화학공업과 기술의 발달로 수많은 화학물질이 제성 또는 효능 증진을 목적으로 개발·생산되며 날로 그 종류와 양이 증대되어 현재 전 세계적으로 약 10만 여종의 화학물질이 상업적으로 유통되고 매일 새로운 화학물질들이 소개되고 있다. 화학물질의 국제적 교역의 증가, 다양한 수요자의 욕구 충족을 위한 시장의 빠른 움직임은 화학물질의 종류와 양을 증가시키고 있으며, 이러한 추세는 앞으로도 지속될

것으로 예상된다. 이에 따라 화학물질 사용량 및 종류가 폭발적으로 증가하고 있으며, 새로운 화학물질이 수입 또는 개발되어, 이들 물질의 혼합 제품은 수십만 종에 달하고 있는 상황이다. 한편 화학물질은 현대 인간생활을 영위함에 있어 없어서는 안 될 중요한 요소이며, 경제활동에서 차지하는 역할 또한 중요하다. 그러나 그 제조·수입·사용·취급·폐기 등의 전 단계에서 환경이나 사람에게 노출되어 돌이킬 수 없는 위해성을 가지는 원인물질이기도 하다. 독성이 높은 유해화학물질의 수요는 급증하고 있으며 유

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해성이 검증도 되기 전에 생산 공정에서 사용되고 있는 실정으로, 대부분의 화학물질은 유해성 자료가 없는 상태로 유통되고 있어 취급 근로자에게 직업병, 폭발·화재, 맹독성 물질에 대한 질식 등의 사고가 빈발하고 있다(Rim et al., 2007). 모든 화학물질은 잠재적으로 유해하다는 관점에서 볼 때 화학물질을 그 유해성·위험성별로 분류하여 적절하게 관리하고, 사고를 사전 예방하는 것이 무엇보다 중요한 과제이며, 이를 위해서는 사업주, 근로자 및 관리감독자 등이 그 화학물질의 유해성·위험성을 충분히 숙지하고 있어야만 한다. 특히 화학물질로 인한 사고가 빈번하게 발생하고 있어, 안전한 작업환경을 조성하기 위한 국가주도의 종합적이고 체계적인 관리방안이 절실히 필요하였고, 고용노동부와 안전보건공단을 중심으로 이를 선도하고 있다.

우리나라는 산업안전보건법 제정 이후 규제수준별 화학물질은 개별로 시행령, 시행규칙 및 고시 개정을 통하여 삭제되거나 추가되어 왔다. 그러나 보다 체계적인 규제수준별 구분을 위하여 동법 제39조(유해인자의 관리 등) 및 제39조의2(유해인자 허용기준의 준

수)에 의한 유해성·위험성평가 후 그 해당 물질을 제조 등의 금지, 제조 등의 허가, 허용기준 대상물질, 작업환경측정 대상물질 및 노출기준 설정 대상물질로 분류하기 위한 기준의 필요성이 제기되었으며(Phee et al., 2011), 신규화학물질에 대한 유해성·위험성조사 제도(법 제40조)를 도입함으로써 신규화학물질의 유해·위험성 관리를 제도화하였다(MoEL, 2014a; 2014b).

또한 화학물질 취급 근로자에게 그 유해성·위험성 등에 대한 알권리의 확보와 화학물질에 의한 산업재해의 근원적인 예방을 위하여 산업안전보건법 제41조에 물질안전보건자료(Material Safety Data Sheets, MSDS)의 제도를 시행하고, 안전보건공단에서는 KOSHANET을 통해 MSDS를 제공하고 있으며, 화학물질 분류 및 경고표지의 통일화 방안인 GHS (Globally Harmonized System of Classification and Labelling of Chemicals) 기준이 확립됨에 따라 모든 화학물질의 유해성·위험성을 재분류하고 이에 따른 전 세계적으로 통일된 형태의 화학물질 정보자료를 작성하여 체계적인 형태의 자료로 개선되었다. 이러

Table 1. Toxicity test items in OSHRI, KOSHA according to GLP guidelines

Test items	Capabilities of GLP test in OSHRI, KOSHA	Test guidelines	Nos. of chemicals with no toxicity information in KOSHA MSDS
Acute Toxicity - Oral	Yes	TG 401/TG 420/TG 423/TG 425	170
Acute Toxicity - Skin	Yes	TG 402	326
Acute Toxicity - Inhalation	Yes	TG 403/TG 436	326
Skin Corrosion/Skin Irritation			
Serious Eye Damage/Eye Irritation			
Respiratory Sensitizer			
Skin Sensitizer			
Carcinogenicity			
Germ Cell Mutagenicity	Yes	1) Reverse mutation test: TG471 2) Chromosomal aberration test: TG473 3) Micronucleus test: TG474	352
Reproductive Toxicity			
Specific Target Organ Toxicity - Single Exposure	Yes	1) Acute-Oral: TG401/TG420/TG423/TG425 2) Acute-Skin: TG402 3) Acute-Inhalation: TG403/TG436	-
Specific Target Organ Toxicity - Repeated Exposure	Yes	1) Oral: TG407(28 days), TG408(90 days) 2) Skin: TG410(21/28 days), TG411(90 days) 3) Inhalation: TG412(28 days), TG413(90 days)	232
Aspiration Toxicity			

한 GHS 분류기준에 맞는 화학물질 유해성·위험성에 대한 정확한 시험과 평가를 통한 최신의 시험자료 획득이 필수적이며, 특히 화학물질의 (생식세포) 변이원성 정보는 그 화학물질의 초기 발암성에 대한 사전 스크리닝 차원의 의미일 뿐만 아니라 기타 유전적 질병의 예방 차원에서도 상당히 중요한 정보임에 틀림없다.

안전보건공단 산업안전보건연구원(화학물질센터)에서는 국내에서 사용되는 화학물질 중 국내외적으로 독성정보가 없거나 부족한 화학물질 중 그 사용량과 취급 근로자수가 많으면서 독성이 강하게 예측되는 유해물질에 대해 GLP(Good Laboratory Practice) 흡입독성시험을 중심으로 하여, 유전독성시험(복귀돌연변이시험, 염색체이상시험, 소핵시험)을 수행하여 왔으며(Table 1), 이를 통해 많은 화학물질 유해성시험 정보를 생산하여 KOSHANET MSDS를 통해 사업장에 제공하여 왔다. 우선적으로는 산업안전보건법 상의 노출기준설정, 특수건강검진대상, 작업환경측정대상 등의 관리대상물질들에 대한 GLP 유전독성(변이원성) 시험을 수행하여 왔으며(MoEL, 2013a; 2013b; 2014a; 2014b), 그 시험결과를 KOSHANET MSDS에 반영하여 왔다. 또한 시험결과 양성으로 판정되는 경우는 급성 및 아만성 흡입독성시험을 수행하여 만성·발암성의 규명을 할 수 있는 기초자료의 생성에 노력하여 왔다(Rim et al., 2014).

이러한 GLP 유전독성(변이원성)시험의 대상물질을 선정하는 데는 위에 언급한 바와 같이 산업안전보건법상 관리대상물질 중 MSDS DB에 그 시험결과 자료가 “자료없음”으로 되어 있는 물질을 우선적으로 선별하여 국내외 화학물질 유해성 관련 인터넷 정보 사이트에서 해당물질의 CAS 번호 및 화학물질명을 키워드로 하여 검색함으로써 시험자료의 유무를 다시 한 번 확인하고, 시험자료가 확실히 존재하지 않는 경우 그 화학물질의 유통량, 취급근로자수 등의 시험의 필요성을 확인하여 시험대상물질로 편입하여 왔다.

본 연구에서는 위와 같은 목적으로 진행되는 산업안전보건연구원의 사업에 도움이 되고자, 산업안전보건법 상 관리대상물질의 유전독성(변이원성) 시험정보를 얻는 과정에 대한 고찰을 통해 GLP 유전독성(변이원성) 시험이 필요한 시험대상 후보물질 목록

및 우선필요 시험을 함께 제안하고자 노력한 사례를 보고하였다.

II. 연구 방법

본 사례보고에서는 산업안전보건법상 관리대상물질 중 공단에서 제공하고 있는 KOSHANET MSDS에 그 유전독성(변이원성) 시험결과 자료가 “자료없음”으로 되어 있는 물질을 우선적으로 선별하였으며(Table 2), 국내·외 화학물질 유해성 관련 각종 인터넷 정보 사이트에서 해당물질의 CAS 번호 및 화학물질명을 키워드로 하여 검색함으로써 시험자료의 유무를 다시 한 번 확인하고, 시험자료가 확실히 존재하지 않는 경우 각 GLP 유전독성(변이원성)시험별 대상물질로 제안하고자 하였다.

본 GLP 변이원성시험 자료의 검색 및 시험대상 후보물질 선정과 각 필요시험의 선정은 아래의 방법으로 수행하였다.

1. 모집단의 설정

본 사례보고서에서 변이원성 시험자료의 검색을 위한 1차 모집단은 산업안전보건법상 관리대상물질을 포함한 기존화학물질 700종으로 하였으며, 안전보건공단에서 KOSHANET을 통해 서비스하는 물질 안전보건자료의 내용 중에 변이원성시험자료가 없는 (“자료없음”으로 표기되어 있는) 물질 352종을 모집단 데이터베이스(DB)로 하였다.

2. GLP변이원성(유전독성) 시험결과 정보 검색

위 모집단 화학물질들을 아래의 인터넷 정보 사이트를 참고하여 그 GLP변이원성(유전독성) 시험결과 정보들을 검색하였다.

1) 미국 국가독성관리체계(National Toxicology Program, NTP) 홈페이지의 데이터베이스(<http://ntpsearch.niehs.nih.gov/texis/search/>)에서 각 물질에 대한 변이원성(유전독성)시험 결과정보들을 검색하였다.

2) 위 NTP 사이트에서 시험결과 정보가 검색되지 않은 물질들에 대해 유럽 화학물질청(European Chemicals Agency, ECHA) 홈페이지에 등록된 화학물질 데이터베이스(<http://echa.europa.eu/information-on-chemicals/registered-substances>)에서 변이원성(유전독성)

성)시험 결과정보들을 추가검색 하였다.

3) 위 ECHA 사이트에서도 시험결과 정보가 검색되지 않은 물질들에 대해 미국 국립의학도서관(US National Library of Medicine, NLM)에서 제공하는 유전독성 자료은행(Genetic Toxicology Data Bank)인 GENE-TOX 홈페이지 (<http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?GENETOX>)에서 변이원성(유전독성) 시험 결과정보들을 추가검색 하였다.

4) 위 GENE-TOX 사이트에서도 시험결과 정보가 검색되지 않은 물질들에 대해서는 역시 미국 국립의학도서관(NLM)에서 제공하는 화학물질정보 포털 서비스 사이트인 ChemIDplus(<http://chem.sis.nlm.nih.gov/chemidplus/>) 홈페이지에서 경구, 경피, 흡입독성 등의 일반독성시험 정보 및 수용해도 등의 물리화학적 특성에 대한 정보를 추가검색 하였다.

5) 위 1)에서 4)까지의 변이원성(유전독성)시험 결과정보에 대한 검색 후, 최종적으로 GLP 유전독성(변이원성)시험 결과정보들이 없는 각 물질들에 대해, 그 유해성을 예측하여 추가적인 시험의 필요성을 검증하고자 미국 환경청(US EPA)에서 제공하는 화학물질의 잠재적 위해성에 대한 전산독성정보 모음 사이트인 ACToR(Aggregated Computational Toxicology Resource; <http://actor.epa.gov/actor/faces/ACToRHome.jsp>)에서 각 물질들에 대한 유해성을 예측하였다.

6) 위 5단계의 검색을 통해 최종적으로 GLP 변이원성(유전독성)시험이 필요한 물질 중 각 시험의 현실적인 가능여부를 판단하기 위해 국제적인 화학물질 판매처(예, Sigma-Aldrich 등)의 홈페이지를 통해 구입가능 여부를 추가확인 하였다.

3. 향후 GLP 변이원성(유전독성)시험 반영 물질

추후 산업안전보건연구원의 화학물질 유해성시험 평가 사업 중 GLP 변이원성(유전독성)시험에 반영하여 실시할 물질들을 각 GLP시험별(미생물복귀돌연변이시험, Ames; 염색체이상시험, CA; 및 소핵시험, MN)로 구분하여 제시하였다.

III. 연구 결과 및 고찰

본 사례보고서에서 변이원성 시험자료의 검색을 위한 1차 모집단은 산업안전보건법상 관리대상물질들

포함한 기존화학물질 700종으로 하였으며, 안전보건공단에서 KOSHANET을 통해 서비스하는 물질안전보건자료의 내용 중에 변이원성시험자료가 없는(“자료없음”으로 표기되어 있는, Table 2) 물질인 thioglycolic acid 등 352종을 모집단 데이터베이스(DB)로 하였다. 동 모집단 화학물질들을 위 연구 방법에서 제시한 인터넷 정보 사이트를 참고하여 그 GLP변이원성(유전독성) 시험결과 정보들을 검색한 결과, 미국 국가독성관리체계(National Toxicology Program, NTP) 홈페이지의 데이터베이스에서 thioglycolic acid 등 101종의 화학물질에 대한 살모넬라(Salmonella) 복귀돌연변이시험(Remission mutation assay) 등의 시험관내(*in vitro*) 및 실험동물을 이용한(*in vivo*) 변이원성(유전독성)시험 결과정보들을 찾을 수 있었다.(Table 3) NTP 사이트에서 시험결과 정보가 검색되지 않은 물질들에 대해 ECHA 홈페이지에 등록된 화학물질 데이터베이스에서 변이원성(유전독성)시험 결과정보들을 추가 검색하여 ethanethiol 등 32종에 대한 복귀돌연변이시험(Remission Mutation assay), 자매염색분체교환시험(Sister chromatid exchange assay), 소핵시험(Micronucleus assay) 등의 변이원성(유전독성)시험 결과정보들을 찾을 수 있었으며 (Table 4), 위 ECHA 사이트에서도 시험결과 정보가 검색되지 않은 물질들에 대해서는 NLM에서 제공하는 유전독성 자료은행(Genetic Toxicology Data Bank)인 GENE-TOX 홈페이지에서 heptachlor epoxide 등 추가 15종에 대한 우성치사시험(Dominant lethal test), 성-관련 열성 치사유전자 돌연변이시험(Sex-linked recessive lethal gene mutation test) 등의 변이원성(유전독성)시험 결과정보들을 찾을 수 있었다(Table 5).

위 GENE-TOX 사이트에서도 시험결과 정보가 검색되지 않은 물질들에 대해서는 미국 국립의학도서관(NLM)에서 제공하는 화학물질정보 포털 서비스 사이트인 ChemIDplus 홈페이지에서 1,1,1,2-tetrachloro-2,2-difluoroethane(CAS No. 76-11-9) 등 물질들에 대한 경구(Oral), 경피(Skin), 흡입(Inhalation), 대뇌내(Intracerebral) 및 정맥내(Intravenous) 독성 등의 일반독성시험 정보 및 수용해도(Water solubility) 등의 물리화학적 특성에 대한 정보를 추가검색 하였으며 (Table 6), 이는 GLP 변이원성(유전독성)시험 수행의 가능성을 보기위해 경구, 경피 및 흡입독성시험 등의 수행결과가 있는 물질들을 찾기 위한 것이었다.

Table 2. Chemicals managed by OSH Act in Korea without any mutagenic information in their MSDSs

CAS No.	Chemical Name	Categories	Whether it has KOSHA MSDS or not	Physicochemical properties	Mutagenicity information in MSDS
68-11-1	Thioglycolic acid	a	O	viscous liquid	No data
75-04-7	Ethylamine	b/c/a	O	gas	No data
75-08-1	Ethanethiol	a	O	liquid	No data
76-06-2	Nitrotrichloromethane	a/d	O	oily liquid	No data
76-11-9	1,1,1,2-Tetrachloro-2,2-difluoroethane	a	O	solid	No data
78-10-4	Ethyl silicate	a	O	liquid	No data
79-04-9	Chloroacetyl chloride	a	O	liquid	No data
2536-05-2	Diphenylmethane-2,2'-diisocyanate	b/e	O	solid white to pale yellow solid at room temperature	No data
7440-06-4	Platinum	b/a	O		No data
7446-09-5	Sulfur dioxide	b/c/e/a	O		No data
7637-07-2	Boron trifluoride	a	O	gas compressed	No data
7719-09-7	Thionyl chloride	a	O	fumed liquid	No data
7783-06-4	Hydrogen sulfide	b/c/e/a	O	compressedliquifiedgas gas	No data
7783-07-5	Hydrogen selenide	a	O	gas	No data
7789-06-2	Strontium chromate	a	O	solid crystal powder	No data
100-25-4	1,4-Dinitrobenzene	a	O	solid crystal	No data
10025-67-9	Sulfur monochloride	a	O	fumed liquid	No data
10025-87-3	Phosphorus oxychloride	a	O	fumed liquid	No data
10026-13-8	Phosphorus pentachloride	a	O	fumed crystal	No data
10034-76-1	Calcium sulfate hemihydrate	a	O	solid	No data
10035-10-6	Hydrobromic acid	b/c/a	O	compressedliquifiedgas	No data
100-74-3	N-Ethylmorpholine	a	O		No data
101007-06-1	Acrinathrin	d	O	solid	No data
10102-43-9	Nitric oxide	b/c/e/a	O	compressedgas gas	No data
10102-45-1	Thallium nitrate	d	O	solid	No data
101-84-8	Phenyl ether(Vapor)	a	O		No data
10210-68-1	Cobalt carbonyl	a	O	solid crystal, powder	No data
1024-57-3	Heptachlor epoxide	a	O	solid crystal	No data
102-54-5	Dicyclopentadienyl iron	a	O	solid crystal	No data
10265-92-6	Methamidophos	d	O	solid crystal	No data
102-81-8	2-N-Dibutylaminoethanol	a	O	liquid	No data
10294-33-4	Boron tribromide	a	O		No data
10311-84-9	Dialifos	d	O	solid	No data
104-13-2	4-Butylaniline	b/c/e	X		No data
10476-82-1	Strychnine arsenate	d	X		No data
10476-87-6	Strychnine dimethylarsinate	d	X		No data
105-46-4	sec-Butyl acetate	a	O	liquid	No data
106-35-4	Ethylbutylketon	a	O		No data
106-44-5	p-Cresol	b/a	O		No data
106-49-0	p-Toluidine	a	O		No data
107-20-0	Chloroacetaldehyde	a	O	liquid	No data
107-30-2	Chloromethyl methyl ether	e/a	O	liquid	No data
107-49-3	TEPP	a	O	hygroscopic liquid	No data
107-87-9	Methyl propyl ketone	a	O	ICSC	No data
108-11-2	Methyl amyl alcohol	a	O	liquid	No data
108-18-9	Diisopropylamine	a	O	liquid	No data
108-21-4	Isopropyl acetate	b/c/a	O	liquid	No data

108-44-1	m-Toluidine	a	O	liquid	No data
108-83-8	Diisobutyl ketone	b/c/e/a	O	liquid	No data
108-84-9	sec-Hexyl acetate	a	O	liquid	No data
108-87-2	Methylcyclohexane	a	O	liquid	No data
108-98-5	Phenyl mercaptan	a	O	liquid	No data
109-59-1	Isopropoxyethanol	a	O		No data
109-60-4	n-Propyl acetate	b/c/a	O	liquid	No data
109-73-9	n-Butylamine	a	O	liquid	No data
109-79-5	n-Butanethiol	a	O	liquid	No data
109-87-5	Dimethoxymethane	a	O	volatile liquid	No data
109-94-4	Ethyl formate	a	O	liquid	No data
110-12-3	Methyl isoamyl ketone	a	O	liquid	No data
110-19-0	Isobutyl acetate	b/c/a	O	liquid	No data
110-43-0	Methyl n-amyl ketone	b/c/e/a	O	liquid	No data
110-49-6	2-Methoxyethyl acetate	b/c/e/a	O	liquid	No data
110-62-3	n-Valeraldehyde	a	O	liquid	No data
110-83-8	Cyclohexene	b/c/e/a	O	liquid	No data
111-42-2	Diethanolamin	b/c/a	O		No data
111-44-4	Dichloroethyl ether	a/d	O	liquid	No data
111-84-2	Nonane	a	O	liquid	No data
112-07-2	Ethylene glycol monobutyl ether acetate	b/c/e/a	O		No data
1126-78-9	N-Butylaniline	b/c/e	X		No data
115-86-6	Triphenyl phosphate	a	O	crystallined powder	No data
116-06-3	Aldicarb	d	O	solid(crystal)	No data
117-81-7	Bis(2-ethylhexyl)phthalate	a	O	viscous liquid	No data
118-52-5	1,3-Dichloro-5,5-dimethylhydantoin	a	O		No data
1189-85-1	tert-Butyl chromate(VI)	a	O	liquid	No data
12001-26-2	Mica	a	O	solid	No data
12079-65-1	Manganese cyclopentadienyl tricarbonyl	a	O		No data
121-14-2	2,4-Dinitrotoluene	b/c/e	O	solid, crystallined	No data
121-44-8	Triethylamine	b/c/a	O	liquid	No data
121-45-9	Trimethyl phosphite	a	O	liquid	No data
121-69-7	N,N-Dimethylaniline	b/b/c/c/e/e/a	O	viscous liquid (oily liquid)	No data
12172-73-5	Amosite asbestos	a/d	O	solid (fibrous)	No data
12179-04-3	Sodium tetraborate pentahydrate	a	O	solid	No data
12185-10-3	Yellow phosphorus	a	O	solid crystalin	No data
122-39-4	N,N-Diphenylamine	a	O		No data
123-19-3	Dipropyl ketone	a	O	liquid	No data
123-42-2	Diacetone alcohol	a	O	liquid	No data
123-51-3	Isoamyl alcohol	b/c/e/a	O	liquid	No data
123-86-4	n-Butyl acetate	b/c/a	O	liquid	No data
123-92-2	Isoamyl acetate	b/c/e/a	O	liquid	No data
124-38-9	Carbon dioxide	a	O	gas, liquid, solid	No data
12604-58-9	Ferrovandium alloy	a	O		No data
1300-73-8	Dimethylaminobenzene	a	O		No data
1302-74-5	Emery	a	O		No data
1303-28-2	Arsenic pentoxide	d	O	solid, hygroscopic powder	No data
1303-86-2	Boron oxide	a	O	hygroscopic crystal	No data
1303-96-4	Borax	a	O		No data
1304-82-1	Bismuth telluride	a	O	solid crystal	No data
1305-62-0	Calcium hydroxide	a	O		No data
1308-31-2	Chromite	f	O	solid	No data
1309-37-1	Ferric oxide	a	O	solid crystal, powder	No data

1309-48-4	Magnesium oxide	b/a	O	solid, powder	No data
1309-64-4	Antimony trioxide	a	O		No data
13121-70-5	Cyhexatin	a	O	solid	No data
1314-13-2	Zinc oxide	a	O		No data
1314-61-0	Tantalum pentoxide	a	O	solid crystal powder	No data
1314-80-3	Phosphorus sulfide	a	O	crystal	No data
1317-65-3	Limestone	a	O	solid crystal	No data
1321-64-8	Pentachloronaphthalene	a	O		No data
1321-65-9	Trichloronaphthalene	a	O		No data
1323-31-5	Strychnineglycerophosphate	d	X		No data
1332-58-7	Kaolin	a	O	solid	No data
1333-86-4	Carbon black	a	O		No data
1335-87-1	Hexachloronaphthalene	a	O		No data
1335-88-2	Tetrachloronaphthalene	a	O		No data
1336-21-6	Ammonia water	b/c	O	volatile ammonia solution	No data
1338-23-4	Methyl ethyl ketone peroxide	a	O	liquid	No data
13397-24-5	Phosphogypsum	a	O	solid, crystal, powder	No data
134098-61-6	Fenpyroximate	d	O	solid	No data
13463-39-3	Nickel carbonyl	a	O	volatile liquid	No data
13463-40-6	Iron pentacarbonyl	a	O	viscous liquid	No data
13494-80-9	Tellurium	a	O		No data
13530-65-9	Zinc chromate	f/a	O		No data
135-88-6	2-Naphthylamine, N-phenyl-	a	O	solid crystal, flake, powder	No data
136-78-7	Sesone	a	O		No data
137-05-3	Methyl 2-cyanoacrylate	a	O		No data
138-22-7	n-Butyl lactate	a	O		No data
141-66-2	Dicrotophos	a	O	liquid	No data
141-79-7	Mesityl oxide	a	O	viscous liquid	No data
1421-86-9	Strychnine hydrochloride	d	X		No data
142-64-3	Piperazine dihydrochloride	a	O		No data
142-82-5	Heptane	b/c/e/a	O	volatile liquid	No data
143-33-9	Sodium cyanide	b/c/e/a	O	solid granule, flake, crystal powder	No data
14414-68-7	Benzidine hydrochloride	d	X		No data
144-62-7	Oxalic acid	a	O		No data
14464-46-1	Cristobalite	a	O	solid crystal	No data
14484-64-1	Ferbam	a	O	solid powder	No data
148-01-6	3,5-Dinitro-o-toluamide	a	O		No data
150-76-5	4-Methoxyphenol	a	O		No data
151-50-8	Potassium cyanide	b/c/e/a	O	solid crystal, powder	No data
15468-32-3	Tridymite	a	O	solid crystal	No data
156-60-5	trans-1,2-Dichloroethylene	b/c/e	O	liquid	No data
1582-09-8	Trifluralin	d	O	crystal	No data
16245-79-7	4-Octylaniline	b/c/e	X		No data
16842-03-8	Cobalt hydrocarbonyl	a	O	liquified gas	No data
17702-41-9	Decaborane	a	O	solid, crystal	No data
1821-39-2	Aniline, 2-propyl-	b/c/e	X		No data
1836-75-5	Nitrofen	d	O	crystallined powder	No data
18540-29-9	Chromium hexavalent ion	a	O	solid	No data
1910-42-5	Paraquat dichloride	d	O		No data
19287-45-7	Diborane	a	O	compressedgas	No data
1929-82-4	Nitrapyrin	a	O		No data
19624-22-7	Pentaborane	a	O	liquid	No data

2039-87-4	o-Chlorostyrene	a	O		No data
20816-12-0	Osmium tetroxide	a	O	various types of solid	No data
20859-73-8	Aluminium phosphide	d	O	solid crystal	No data
21136-70-9	Benzidine sulfate	d	O		No data
21351-79-1	Cesium hydroxide	a	O	hygroscopic crystal	No data
2179-59-1	Allyl propyl disulfide	a	O		No data
2234-13-1	Octachloronaphthalene	a	O		No data
2551-62-4	Sulfur hexafluoride	a	O	gas	No data
25551-13-7	Trimethylbenzenes	a	O		No data
25639-42-3	Methylcyclohexanol	b/c/e/a	O	viscous liquid	No data
26140-60-3	Terphenyls	a	O		No data
26447-40-5	Methylenediphenyl diisocyanate	b/e	O	solid	No data
26628-22-8	Sodium azide	a	O	hexagonal crystal	No data
26952-21-6	Isooctyl alcohol	a	O	liquid	No data
2696-84-6	4-Propylaniline	b/c/e	X		No data
2917-31-9	Pentachlorophenol copper salt; copper bis(pentachlorophenolate); PCP-Cu	d	O		No data
2917-32-0	Pentachlorophenol zinc salt; zinc bis(pentachlorophenolate); PCP-Zn	d	O		No data
2971-90-6	Clopidol	a	O		No data
297-78-9	Isobenzan	d	O	solid	No data
299-86-5	Crufomate	a	O		No data
3333-52-6	Tetramethylsuccinonitrile	a	O		No data
333-41-5	Diazinon	a	O	oily liquid	No data
334-88-3	Diazomethane	a	O		No data
3383-96-8	Temefos	a	O		No data
353-50-4	Carbonyl difluoride	a	O	hygroscopic gas	No data
3644-38-0	Tributyltin pentachlorophenolate	d	X		No data
4016-14-2	Isopropyl glycidyl ether	a	O		No data
409-21-2	Silicon carbide	a	O	solid crystal	No data
4098-71-9	Isophorone diisocyanate	a	O	liquid	No data
460-19-5	Cyanogen	a	O	gas	No data
463-51-4	Ketene	a	O		No data
479-45-8	Tetryl	a	O	solid	No data
492-80-8	Auramine	e	O	solid	No data
504-29-0	2-Aminopyridine	a	O	solid, powder or crystal	No data
506-77-4	Cyanogen chloride	a	O	gas compressed liquified	No data
50-78-2	Acetylsalicylic acid	a	O		No data
509-42-2	Strychnine phosphate	d	X		No data
510-15-6	Chlorobenzilate	d	O	crystal	No data
528-29-0	1,2-Dinitrobenzene	a	O	solid, crystal	No data
531-86-2	Benzidine sulfate (1:1)	d	O		No data
532-27-4	alpha-Chloroacetophenone	a	O	solid, crystal	No data
53469-21-9	Chlorodiphenyl (42% Cl)	a	O	liquid viscous liquid	No data
53558-25-1	Pyriminil	d	O	solid and powder	No data
540-88-5	tert-Butyl acetate	a	O	liquid	No data
541-85-5	5-Methyl-3-heptanone	a	O	liquid	No data
542-75-6	1,3-Dichloropropene	a	O	liquid	No data
542-88-1	Bis(chloromethyl) ether	e/a/d	O	liquid volatile liquid	No data
546-93-0	Magnesium carbonate	a	O	solid, crystal powder	No data
552-30-7	Trimellitic anhydride	a	O		No data
557-05-1	Zinc stearate	a	O		No data
55720-99-5	Hexachloro diphenyl ether	a	O	solid or liquid	No data

55751-54-7	2-sec-Butylaniline	b/c/e	X		No data
558-13-4	Tetrabromomethane	a	O	solid, crystal	No data
563-12-2	Ethion	a	O	liquid	No data
563-68-8	Thallium acetate	d	O	solid	No data
563-80-4	Methyl isopropyl ketone	a	O	liquid	No data
5714-22-7	Sulfur pentafluoride	a	O	liquid, gas	No data
57-24-9	Strychnine	a/d	O	crystal	No data
57-50-1	Sucrose	a	O	various types of solid	No data
583-59-5	o-Methylcyclohexanol	b/c	O	viscous liquid	No data
583-60-8	o-Methylcyclohexanone	b/c/e/a	O	liquid	No data
584-84-9	Toluene 2,4-diisocyanate	b/c/e/a	O	liquid or crystal	No data
587-02-0	m-Ethylaniline	b/c/e	X		No data
589-16-2	4-Ethylaniline	b/c/e	X		No data
589-91-3	4-Methylcyclohexanol	b/c	O	liquid	No data
591-23-1	3-Methylcyclohexanol	b/c	O	viscous liquid	No data
591-78-6	Methyl n-butyl ketone	b/c/e/a	O		No data
594-42-3	Perchloromethyl mercaptan	a	O	oily liquid	No data
594-72-9	1,1-Dichloro-1-nitroethane	a	O	liquid	No data
600-25-9	1-Chloro-1-nitropropane	a	O		No data
60-29-7	Diethyl ether	b/c/e/a	O	volatile liquid	No data
603-34-9	Triphenylamine	a	O	powder	No data
60-41-3	Strychnine sulphate	d	O	crystal or crystallined powder	No data
60491-10-3	Strychnine sulfate pentahydrate	d	X		No data
60676-86-0	Silica, vitreous	a	O	solid structure: vitreous	No data
612-52-2	2-Naphthylamine hydrochloride	d	O	solid	No data
613-29-6	N,N-Dibutylaniline	b/c/e	X		No data
61788-33-8	Polychlorinated terphenyls (PCT)	d	O	solid	No data
61790-53-2	Amorphous silica: diatomaceous earth (uncalcined)	a	O	micro-powder	No data
626-17-5	m-Phthalodinitrile	a	O		No data
626-38-0	sec-Amyl acetate	a	O	liquid	No data
627-13-4	n-Propyl nitrate	a	O	liquid	No data
62-74-8	Sodium fluoroacetate	a	O	various types of solid	No data
628-63-7	n-Amyl acetate	a	O	liquid	No data
628-96-6	Ethylene glycol dinitrate	b/c/e/a	O	oily liquid	No data
630-08-0	Carbon monoxide	b/c/e/a	O	compressed gas	No data
638-21-1	Phenylphosphine	a	O		No data
640-19-7	Fluoroacetamide	d	O	crystallined powder	No data
64-18-6	Formic acid	b/c/a	O	fumed liquid	No data
64-19-7	Acetic acid, glacial	b/c/a	O	liquid	No data
6423-43-4	1,2-Propanediol dinitrate	a	O		No data
65996-93-2	volatile Pitch, coal tar	f/e/a	O	solid	No data
65997-15-1	Portland cement	a	O	solid, powder	No data
67-72-1	Hexachloroethane	a	O		No data
681-84-5	Methyl silicate	a	O	liquid	No data
684-16-2	Hexafluoroacetone	a	O	gas	No data
71-23-8	n-Propanol	a	O	liquid	No data
7429-90-5	Aluminum	b/a	O	solid powder	No data
7439-89-6	Iron, elemental	b/a	O	solid	No data
7439-96-5	Manganese	b/a	O	solid powder	No data
7439-98-7	Molybdenum	a	O	solid	No data
7440-02-0	Nickel	b/a	O	metal	No data

7440-16-6	Rhodium	a	O		No data
7440-21-3	Silicon, elemental	a	O	polished solid	No data
7440-22-4	Silver	b/a	O	solid	No data
7440-31-5	Tin	b/a	O	solid powder	No data
7440-33-7	Tungsten	b/a	O		No data
7440-36-0	Antimony, elemental	b/a	O	fragile solid or powder	No data
7440-38-2	Arsenic	f/a	O	fragile metallic crystal	No data
7440-39-3	Barium	b/a	O	various types of solid	No data
7440-41-7	Beryllium, elemental	f/a	O	solid, powder	No data
7440-48-4	Cobalt	b/a	O		No data
7440-50-8	Copper	b/a	O	solid	No data
7440-58-6	Hafnium	a	O	solid, powder	No data
7440-61-1	Uranium	a	O	solid	No data
7440-65-5	Yttrium	a	O		No data
7440-66-6	Zinc, elemental	b	O	solid powder	No data
7440-67-7	Zirconium	b/a	O	solid flake(white with a hard, glossy), powder(amorphous gray)	No data
7440-74-6	Indium	a	O		No data
7446-18-6	Thallium sulfate	d	O	crystal	No data
74-90-8	Hydrogen cyanide	b/c/e/a	O	gas or liquid	No data
74-93-1	Methanethiol	a	O	gas	No data
74-96-4	Ethyl bromide	a	O	liquid	No data
74-97-5	Chlorobromomethane	a	O	liquid	No data
74-99-7	Methylacetylene	a	O		No data
75-31-0	Isopropylamine	a	O	liquid	No data
75-34-3	1,1-Dichloroethane	a	O	liquid	No data
75-43-4	Dichlorofluoromethane	b/c/e/a	O	gas	No data
75-47-8	Iodoform	a	O		No data
75-50-3	Trimethylamine	a	O	compressed liquified gas	No data
7553-56-2	Iodine	b/a	O	solid crystal	No data
75-55-8	Propyleneimine	b/c/a	O		No data
75-61-6	Dibromodifluoromethane	a	O	gas or liquid	No data
75-63-8	Bromotrifluoromethane	a	O	gas	No data
75-69-4	Trichloromonofluoromethane	a	O		No data
7572-29-4	Dichloroacetylene	a	O		No data
75-74-1	Tetramethyl lead	a	O	liquid	No data
7580-67-8	Lithium hydride	a	O	various types of hygroscopic solid	No data
75-99-0	2,2-Dichloropropionic acid	a	O	liquid, solid with various types, deliquescent	No data
76-14-2	Dichlorotetrafluoroethane	a	O	gas	No data
76-15-3	Chloropentafluoroethane	a	O	gas	No data
7616-94-6	Perchloryl fluoride	a	O	gas	No data
76-22-2	Camphor (artificial)	a	O	solid, crystallined	No data
7647-01-0	Hydrochloric acid	b/c/e/a	O	compressedliquifiedgas	No data
7664-38-2	Phosphoric acid	b/c/a	O	solid hygroscopic	No data
7664-93-9	Sulfuric acid	b/c/e/a	O	liquid	No data
7697-37-2	Nitric acid	b/c/e/a	O	liquid	No data
769-92-6	p-tert-Butylaniline	b/c/e	X		No data
7726-95-6	Bromine	b/c/e/a	O	fumed liquid	No data
77536-66-4	Asbestos, actinolite	a/d	O	solid fiber	No data
77536-68-6	Asbestos, tremolite	a/d	O	solid crystal	No data
7773-06-0	Ammonium sulfamate	a	O		No data

77-73-6	Dicyclopentadiene	a	O	crystallined solid with pure substance, liquid with goods	No data
7778-73-6	Pentachlorophenol potassium salt; potassium pentachloroheolate	d	O		No data
7782-41-4	Fluorine	b/c/e/a	O	compressed gas	No data
7782-42-5	Graphite	a	O	solid, crystal, powder	No data
7782-49-2	Selenium, elemental	b	O	various types of solid	No data
7782-65-2	Germanium tetrahydride	a	O	gas	No data
7783-41-7	Fluorine monoxide	a	O	gas, liquid	No data
7783-54-2	Nitrogen trifluoride	a	O	gas	No data
7783-60-0	Sulfur tetrafluoride	a	O		No data
7783-79-1	Selenium hexafluoride	a	O	gas	No data
7783-80-4	Tellurium hexafluoride	a	O	gas	No data
7784-40-9	Lead arsenate	a/d	O		No data
7784-42-1	Arsenic trihydride	b/c/e/a	O	compressed liquified gas	No data
7789-30-2	Bromine pentafluoride	a	O	fumed liquid	No data
7790-91-2	Chlorine trifluoride	a	O		No data
7803-52-3	Stibine	a	O	gas	No data
7803-62-5	Silane	a	O	gas	No data
78-30-8	Tri-o-cresyl phosphate	a	O	liquid	No data
78-34-2	Dioxation	a	O		No data
78-92-2	sec-Butyl alcohol	b/c/e/a	O	liquid	No data
79-27-6	Tetrabromoacetylene	a	O	sticky liquid	No data
79-41-4	Methacrylic acid	a	O	liquid or crystallined solid	No data
8002-74-2	Paraffin	a	O		No data
8003-34-7	Pyrethrum	a	O		No data
8006-64-2	Turpentine oil	e/a	O	liquid	No data
8008-20-6	Kerosene	a	O	fragile viscous liquid	No data
81-81-2	Warfarin	a	O	solid crystal powder	No data
83-26-1	Pindone	a	O	crystal	No data
83-79-4	Rotenone	a	O	crystal	No data
84-66-2	Diethyl phthalate	a	O		No data
85-44-9	Phthalic anhydride	b/c/e/a	O	solid crystal, flake	No data
86-88-4	alpha-Naphthylthiourea	a/d	O	crystallined powder	No data
87-00-7	Diquat dibromide	a	X		No data
88-12-0	N-Vinyl-2-pyrrolidone	a	O	liquid	No data
88-89-1	2,4,6-Trinitrophenol	a	O	crystal	No data
89-72-5	o-sec-Butylphenol	a	O		No data
9004-34-6	Cellulose	a	O	solid, powder	No data
9005-25-8	Starch	a	O	solid	No data
91-59-8	2-Naphthylamine	e/a/d	O	solid flake	No data
92-93-3	p-Nitrobiphenyl	a/d	O	solid crystal	No data
93763-70-3	Perlite	a	O	solid powder	No data
94-75-7	2,4-D	a	O	crystal or powder	No data
95-13-6	Indene	a	O		No data
95-48-7	Orthocresol	b/a	O		No data
96-22-0	Diethyl ketone	a	O	liquid	No data
96-69-5	4,4'-Thiobis(6-tert-butyl-3-cresol)	a	O		No data
98-51-1	p-t-Butyltoluene	a	O	liquid	No data
999-61-1	2-Hydroxypropyl acrylate	a	O		No data

a) It has TLV, b) It is managed in OSH Act, c) Chemicals with working environment measurement, d) Chemicals with prohibition, e) Chemicals for special health examination, f) Chemicals with permission

Table 3. Searching for mutagenicity information by National Toxicology Program(NTP)

CAS No.	Chemical Name	Mutagenicity information provided by NTP
68-11-1	Thioglycolic acid	•Salmonella (301735) Negative
75-04-7	Ethylamine	•Salmonella (042347) Negative
76-06-2	Nitrotrichloromethane	•In Vitro Cytogenetics (CA/SCE) (405202) ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Positive
78-10-4	Ethyl silicate	•Drosophila (149367) ◦Reciprocal Translocation/Sex-Linked Recessive Lethal Equivocal
100-25-4	1,4-Dinitrobenzene	•Salmonella (643495) Positive
100-74-3	N-Ethylmorpholine	•Salmonella (678673) Positive •suspicion of carcinogenicity based on a significant increase in unscheduled DNA synthesis in rat hepatocytes, some positive genetic toxicity results in tests with structurally related chemicals
102-54-5	Dicyclopentadienyl iron	•Salmonella (A98443) On Test •Salmonella (432404) Weakly Positive •In Vitro Cytogenetics (CA/SCE) (203142) ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Negative
102-81-8	2-N-Dibutylaminoethanol	•In Vitro Cytogenetics (CA/SCE) (674566) ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Negative
106-44-5	p-Cresol	•Drosophila (455288) ◦Sex-Linked Recessive Lethal Positive ◦Reciprocal Translocation Positive
106-49-0	p-Toluidine	•Salmonella (077744) Negative
107-20-0	Chloroacetaldehyde	•Salmonella (373521) Equivocal
107-87-9	Methyl propyl ketone	•Salmonella (483456) Negative
108-18-9	Diisopropylamine	•Salmonella (296300) Negative
108-21-4	Isopropyl acetate	•Salmonella (388990) Negative
108-44-1	m-Toluidine	•Salmonella (G11425) Negative
108-83-8	Diisobutyl ketone	•Salmonella (900181) Positive
108-98-5	Phenyl mercaptan	•Salmonella (123958) Negative
109-73-9	n-Butylamine	•Salmonella (199477) Negative
109-94-4	Ethyl formate	•Salmonella (819934) Negative
110-49-6	2-Methoxyethanol acetate	•Salmonella (819934) Negative •Salmonella (167375) Negative •In Vitro Cytogenetics (CA/SCE) (216435) ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Positive
110-62-3	n-Valeraldehyde	•Salmonella (327882) Equivocal •Salmonella (655694) Weakly Positive
111-42-2	Diethanolamine	•Salmonella (768372) Negative •In Vitro Cytogenetics (CA/SCE) (095123) ◦Sister Chromatid Exchange Negative ◦Chromosome Aberrations Negative
111-44-4	Dichloroethyl ether	•Mouse Lymphoma (375254) Mice Negative •Micronucleus (A08796) Mice:B6C3F1 ◦Male Negative ◦Female Negative •Salmonella (310797) Negative
		•Drosophila (167375) ◦Sex-Linked Recessive Lethal Positive ◦Reciprocal Translocation Negative

111-84-2	Nonane	<ul style="list-style-type: none"> •Salmonella (492689) WeaklyPositive •Salmonella (579121) Equivocal
115-86-6	Triphenyl phosphate	<ul style="list-style-type: none"> •Salmonella (735213) Negative •Salmonella (888679) Negative •In Vitro Cytogenetics(CA/SCE) (512453) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Negative •Mouse Lymphoma(NCI) (145873) <ul style="list-style-type: none"> ◦Mice ◦Mouse Lymphoma-NCI Positive
116-06-3	Aldicarb	<ul style="list-style-type: none"> •MouseLymphoma(NCI) (566841) <ul style="list-style-type: none"> ◦Mice ◦Mouse Lymphoma-NCI Positive •Salmonella(NCI) (N-9316) <ul style="list-style-type: none"> ◦Salmonella ◦Salmonella-NCI Negative •Salmonella (087997) Negative •Chromosome Aberrations (A15927) <ul style="list-style-type: none"> ◦ Mice ◦Negative(Nonstandard Protocol) •In Vitro Cytogenetics(CA/SCE) (008270) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Not Tested •In Vitro Cytogenetics(CA/SCE) (426348) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Weakly Positive ◦Chromosome Aberrations Not Tested •In Vitro Cytogenetics(CA/SCE) (515010) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Not Tested •In Vitro Cytogenetics(CA/SCE) (587571) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Equivocal ◦Chromosome Aberrations Not Tested •In Vitro Cytogenetics(CA/SCE) (594940) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Negative ◦Chromosome Aberrations Weakly Positive •In Vitro Cytogenetics(CA/SCE) (759843) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Negative ◦Chromosome Aberrations Negative
117-81-7	Di-(2-ethylhexyl) phthalate	<ul style="list-style-type: none"> •In Vitro Cytogenetics(CA/SCE) (890544) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Equivocal ◦Chromosome Aberrations Not Tested •In Vitro Cytogenetics(CA/SCE) (923560) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Negative •In Vitro Cytogenetics(CA/SCE) (978423) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Equivocal ◦Chromosome Aberrations Not Tested •Drosophila (507426) <ul style="list-style-type: none"> ◦Reciprocal Translocation/Sex-Linked Recessive Lethal Negative •Drosophila (967176) <ul style="list-style-type: none"> ◦Reciprocal Translocation/Sex-Linked Recessive Lethal Negative •MouseLymphoma (913224) <ul style="list-style-type: none"> ◦Mice ◦Negative •Micronucleus (A04384) <ul style="list-style-type: none"> ◦Male Equivocal ◦Female Positive •Micronucleus (A15851) <ul style="list-style-type: none"> ◦Male Negative ◦Female Negative •Micronucleus (A15927) <ul style="list-style-type: none"> ◦Female Equivocal

		<ul style="list-style-type: none"> •Salmonella (064176) Negative •Salmonella (195347) Negative •Salmonella (483211) Negative •Salmonella (894518) Negative •Salmonella (960176) Negative •Salmonella (965968) Negative
118-52-5	1,3-Dichloro-5,5-dimethylhydantoin	<ul style="list-style-type: none"> •In Vitro Cytogenetics(CA/SCE) (807055) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Negative ◦Chromosome Aberrations Negative •Drosophila (006881) <ul style="list-style-type: none"> ◦Sex-Linked Recessive Lethal Positive ◦Reciprocal Translocation Negative •Drosophila (220251) <ul style="list-style-type: none"> ◦Reciprocal Translocation/Sex-Linked Recessive Lethal Negative •Mouse Lymphoma (659873) <ul style="list-style-type: none"> ◦Mice ◦Positive •Salmonella (695748) Negative •In Vitro Cytogenetics(CA/SCE) (322897) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Negative •Drosophila (050763) <ul style="list-style-type: none"> ◦Sex-Linked Recessive Lethal Positive ◦Reciprocal Translocation Negative
121-14-2	2,4-Dinitrotoluene	<ul style="list-style-type: none"> •Drosophila (957177) <ul style="list-style-type: none"> ◦Reciprocal Translocation /Sex-Linked Recessive Lethal Equivocal •MouseLymphoma (693724) <ul style="list-style-type: none"> ◦Mice ◦Positive •Salmonella(NCI) (N-9340) <ul style="list-style-type: none"> ◦Salmonella ◦Salmonella-NCI Positive •Salmonella (683014) Positive •Micronucleus (A58209) <ul style="list-style-type: none"> ◦Mice: B6C3F1
121-44-8	Triethylamine	<ul style="list-style-type: none"> ◦Male Equivocal ◦Female Negative •Salmonella (456286) Negative •In Vitro Cytogenetics(CA/SCE) (609568) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Positive
121-69-7	Dimethylaniline	<ul style="list-style-type: none"> •MouseLymphoma (365373) <ul style="list-style-type: none"> ◦Mice ◦Positive •Salmonella (840758) Negative
122-39-4	N,N-Diphenylamine	<ul style="list-style-type: none"> •Salmonella (127784) Negative
123-42-2	Diacetone alcohol	<ul style="list-style-type: none"> •Salmonella (A13216) Negative •Salmonella (A89957) Negative.
123-86-4	n-Butyl acetate	<ul style="list-style-type: none"> •Salmonella (182914) Negative
123-92-2	Isoamyl acetate	<ul style="list-style-type: none"> •Drosophila (315522) <ul style="list-style-type: none"> ◦Reciprocal Translocation/Sex-Linked Recessive Lethal Negative •Salmonella (795519) Negative
1309-64-4	Antimony trioxide	<ul style="list-style-type: none"> •Comet Assay (G10676C) <ul style="list-style-type: none"> ◦Rats •Comet Assay (G10676D) <ul style="list-style-type: none"> ◦Mice •Micronucleus (G10676B) <ul style="list-style-type: none"> ◦Mice: B6C3F1 ◦Male Positive ◦Female Positive

		<ul style="list-style-type: none"> •Micronucleus (G10676) <ul style="list-style-type: none"> ◦Rats: Wistar Han ◦Male Negative ◦Female Negative •In Vitro Cytogenetics(CA/SCE) (774268) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Positive •Mouse Lymphoma (091264) <ul style="list-style-type: none"> ◦Mice <ul style="list-style-type: none"> ◦Positive
1338-23-4	Methyl ethyl ketone peroxide	<ul style="list-style-type: none"> •Micronucleus(A70805) <ul style="list-style-type: none"> ◦Mice: B6C3F1 ◦Male Negative ◦Female Negative •Salmonella (594981) Negative •Salmonella (784039) Positive •In Vitro Cytogenetics(CA/SCE) (796411) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Weakly Positive ◦Chromosome Aberrations Negative
135-88-6	2-Naphthylamine, N-phenyl-	<ul style="list-style-type: none"> •Mouse Lymphoma (945201) <ul style="list-style-type: none"> ◦Mice <ul style="list-style-type: none"> ◦Positive •Salmonella (585564) Negative
137-05-3	Methyl 2-cyanoacrylate	<ul style="list-style-type: none"> •Salmonella (488843) Positive
143-33-9	Sodium cyanide	<ul style="list-style-type: none"> •Salmonella (022418) Negative
144-62-7	Oxalic acid	<ul style="list-style-type: none"> •Salmonella (596374) Negative
14464-46-1	Silica, crystalline - cristobalite	<ul style="list-style-type: none"> •RCS and glass fibers caused a significant increase in DNA migration, measured as tail length in both cell lines, at almost all concentrations tested.
150-76-5	4-Methoxyphenol	<ul style="list-style-type: none"> •Salmonella (029584) Negative •Salmonella (205793) Negative •Chromosome Aberrations (560707) <ul style="list-style-type: none"> ◦Mice <ul style="list-style-type: none"> ◦Negative (Nonstandard Protocol) •In Vitro Cytogenetics(CA/SCE) (894098) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Negative ◦Chromosome Aberrations Negative
156-60-5	trans-1,2-Dichloroethylene	<ul style="list-style-type: none"> •Micronucleus (A15171) <ul style="list-style-type: none"> ◦Mice: B6C3F1 ◦Male Negative ◦Female Negative •Micronucleus (B15171) <ul style="list-style-type: none"> ◦Mice: B6C3F1 ◦Male Negative ◦Female Negative •Salmonella (046471) Negative •Sister Chromatid Exchanges (560707) <ul style="list-style-type: none"> ◦Mice <ul style="list-style-type: none"> ◦Sister Chromatid Negative (Nonstandard Protocol) •In Vitro Cytogenetics(CA/SCE) (363245) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Negative ◦Chromosome Aberrations Negative
1836-75-5	Nitrofen	<ul style="list-style-type: none"> •Mouse Lymphoma (927047) <ul style="list-style-type: none"> ◦Mice <ul style="list-style-type: none"> ◦Positive •Salmonella(NCI) (N-9367) <ul style="list-style-type: none"> ◦Salmonella ◦Salmonella-NCI Positive
1910-42-5	Paraquat dichloride	<ul style="list-style-type: none"> •Mouse Lymphoma (540279) <ul style="list-style-type: none"> ◦Mice <ul style="list-style-type: none"> ◦Positive

19287-45-7	Diborane	•Salmonella (911372) Negative
1929-82-4	Nitrapyrin	•Salmonella (193869) Positive
2039-87-4	o-Chlorostyrene	•Salmonella (248687) Negative
2179-59-1	Allyl propyl disulfide	•Salmonella (431045) Negative
2234-13-1	Octachloronaphthalene	•Salmonella (A21226) Negative •In Vitro Cytogenetics(CA/SCE) (166603) ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Negative
26628-22-8	Sodium azide	•Salmonella(NCI) (N-9164) ◦Salmonella ◦Salmonella-NCI Positive •Salmonella (201201) Positive •Salmonella (A90612) Positive •Salmonella (G10164) Positive
3333-52-6	Tetramethylsuccinonitrile	•Salmonella (412531) Negative •In Vitro Cytogenetics(CA/SCE) (140422) ◦Sister Chromatid Exchange Negative ◦Chromosome Aberrations Negative •Mouse Lymphoma (180250)
333-41-5	Diazinon	◦Mice ◦Positive •Salmonella(NCI) (N-9278) ◦Salmonella ◦Salmonella-NCI Negative •Salmonella (217556) Negative •Drosophila (311488) ◦Sex-Linked Recessive Lethal Positive ◦Reciprocal Translocation Positive •Salmonella (508505) Positive
4016-14-2	Isopropyl glycidyl ether	•Salmonella (225422) Negative •Salmonella (393331) Negative •Salmonella(NCI) (N-9365) ◦Salmonella ◦Salmonella-NCI Negative •Salmonella (329111) Negative •Salmonella (336292) Negative •In Vitro Cytogenetics(CA/SCE) (486951) ◦Sister Chromatid Exchange Negative ◦Chromosome Aberrations Negative •Drosophila (427493) ◦Reciprocal Translocation /Sex-Linked Recessive Lethal Negative •Mouse Lymphoma (159650)
4098-71-9	Isophorone diisocyanate	•Salmonella (225422) Negative
504-29-0	2-Aminopyridine	•Salmonella (393331) Negative •Salmonella(NCI) (N-9365) ◦Salmonella ◦Salmonella-NCI Negative •Salmonella (329111) Negative •Salmonella (336292) Negative •In Vitro Cytogenetics(CA/SCE) (486951) ◦Sister Chromatid Exchange Negative ◦Chromosome Aberrations Negative •Drosophila (427493) ◦Reciprocal Translocation /Sex-Linked Recessive Lethal Negative •Mouse Lymphoma (159650)
50-78-2	Acetylsalicylic acid	◦Salmonella-NCI Negative •Salmonella (329111) Negative •Salmonella (336292) Negative •In Vitro Cytogenetics(CA/SCE) (486951) ◦Sister Chromatid Exchange Negative ◦Chromosome Aberrations Negative •Drosophila (427493) ◦Reciprocal Translocation /Sex-Linked Recessive Lethal Negative •Mouse Lymphoma (159650)
510-15-6	Chlorobenzilate	◦Mice ◦Negative •Mouse Lymphoma (252225) ◦Mice ◦Positive •Salmonella (313686) Negative •Salmonella (373410) Negative •Salmonella (374565) Negative
528-29-0	1,2-Dinitrobenzene	•Salmonella (A78426) On Test (NTP) •In Vitro Cytogenetics(CA/SCE) (037856) ◦Sister Chromatid Exchange Negative ◦Chromosome Aberrations Weakly Positive •Salmonella (961999) Negative
532-27-4	alpha-Chloroacetophenone	•Chromosome Aberrations (208737) ◦Mice ◦Positive •In Vitro Cytogenetics(CA/SCE) (129307)
542-75-6	1,3-Dichloropropene	•In Vitro Cytogenetics(CA/SCE) (129307)

		<ul style="list-style-type: none"> ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Negative
		<ul style="list-style-type: none"> •Drosophila (072802) ◦Sex-Linked Recessive Lethal Positive ◦Reciprocal Translocation Negative
		<ul style="list-style-type: none"> •Mouse Lymphoma (725960) ◦Mice ◦Positive
		<ul style="list-style-type: none"> •Micronucleus (441206) ◦Mice: B6C3F1 ◦Male Negative
		<ul style="list-style-type: none"> •Micronucleus (A15433) ◦Mice: B6C3F1 ◦Male Positive
		<ul style="list-style-type: none"> •Salmonella (172972) Positive
		<ul style="list-style-type: none"> •Sister Chromatid Exchanges (208737) ◦Mice ◦Sister Chromatid Negative(Nonstandard Protocol)
552-30-7	Trimellitic anhydride	<ul style="list-style-type: none"> •Salmonella (931027) Negative •Mouse Lymphoma(NCI) (341303) ◦Mice ◦Mouse Lymphoma-NCI Negative
57-50-1	Sucrose	<ul style="list-style-type: none"> •Mouse Lymphoma(NCI) (774043) ◦Mice ◦Mouse Lymphoma-NCI Negative •Mouse Lymphoma (330941) ◦Mice ◦Negative
		<ul style="list-style-type: none"> •In Vitro Cytogenetics(CA/SCE) (644663) ◦Sister Chromatid Exchange Equivocal ◦Chromosome Aberrations Negative
584-84-9	Toluene 2,4-diisocyanate	<ul style="list-style-type: none"> •Mouse Lymphoma (445615) ◦Mice ◦Positive
587-02-0	3-Ethylaniline	<ul style="list-style-type: none"> •Salmonella (928398) Positive
589-16-2	4-Ethylaniline	<ul style="list-style-type: none"> •Salmonella (G08030) Negative
594-42-3	Perchloromethyl mercaptan	<ul style="list-style-type: none"> •Salmonella (G09036) Negative
594-72-9	1,1-Dichloro-1-nitroethane	<ul style="list-style-type: none"> •Salmonella (446807) Positive
600-25-9	1-Chloro-1-nitropropane	<ul style="list-style-type: none"> •Salmonella (682897) Positive
603-34-9	Triphenylamine	<ul style="list-style-type: none"> •Salmonella (699995) Positive
64-18-6	Formic acid	<ul style="list-style-type: none"> •Salmonella (720130) Negative
64-19-7	Acetic acid, glacial	<ul style="list-style-type: none"> •Salmonella (739982) Negative
		<ul style="list-style-type: none"> •Salmonella (811661) Negative
		<ul style="list-style-type: none"> •Salmonella (393868) Negative
		<ul style="list-style-type: none"> •In Vitro Cytogenetics(CA/SCE) (415312) ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Negative
67-72-1	Hexachloroethane	<ul style="list-style-type: none"> •Salmonella (188925) Negative •Salmonella (248997) Negative
		<ul style="list-style-type: none"> •Micronucleus (A57655) ◦Mice: B6C3F1 ◦Male Negative ◦Female Negative
7440-48-4	Cobalt	<ul style="list-style-type: none"> •Salmonella (A79569) Positive
		<ul style="list-style-type: none"> •In Vitro Cytogenetics(CA/SCE) (496296) ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Negative
74-96-4	Ethyl bromide	<ul style="list-style-type: none"> •Salmonella (024373) Negative •Salmonella (811571) Positive

74-97-5	Chlorobromomethane	•Salmonella (392737) Positive
74-99-7	Methyl acetylene	•Salmonella (648636) Positive
75-31-0	Isopropylamine	•Salmonella (517217) Negative
75-34-3	1,1-Dichloroethane	•In Vitro Cytogenetics(CA/SCE) (508873) ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Negative •Salmonella (777132) Negative
75-47-8	Iodoform	•In Vitro Cytogenetics(CA/SCE) (123235) ◦Sister Chromatid Exchange Weakly Positive ◦Chromosome Aberrations Negative •Salmonella (367919) Positive •Salmonella (837276) Positive
75-55-8	Propyleneimine	•Salmonella(NCI) (N-9051) ◦Salmonella ◦Salmonella-NCI Positive
75-69-4	Trichloromonofluoromethane	•Salmonella (714291) Negative •Salmonella (A12906) Negative
75-74-1	Tetramethyl lead	•Salmonella (566782) Negative
76-22-2	Camphor, synthetic	•Micronucleus (A69097) ◦Mice: B6C3F1 ◦Male Negative ◦Female Negative
77-73-6	Dicyclopentadiene	•In Vitro Cytogenetics(CA/SCE) (A02442) ◦Chromosome Aberrations Negative •Salmonella (298766) Negative •In Vitro Cytogenetics(CA/SCE) (472509) ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Negative
78-34-2	Dioxation	•MouseLymphoma (272327) ◦Mice ◦Negative •Salmonella (907385) Positive
78-92-2	sec-Butyl alcohol	•Salmonella (A17644) Negative
79-27-6	Tetrabromoacetylene	•Salmonella (612759) Negative
79-41-4	Methacrylic acid	•Salmonella (187641) Equivocal •Salmonella (637375) Negative
8006-64-2	Turpentine oil	•Salmonella (A20309) Negative
8008-20-6	Kerosene	•Salmonella (695827) Negative
83-26-1	Pindone	•Salmonella (468575) Negative •In Vitro Cytogenetics(CA/SCE) (195015) ◦Sister Chromatid Exchange Not a Valid Test ◦Chromosome Aberrations Negative •In Vitro Cytogenetics(CA/SCE) (743095) ◦Sister Chromatid Exchange Weakly Positive ◦Chromosome Aberrations Not Tested
83-79-4	Rotenone	•Mouse Lymphoma (542524) ◦Mice ◦Positive •Salmonella (635953) Negative
84-66-2	Diethyl phthalate	•In Vitro Cytogenetics(CA/SCE) (306322) ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Negative •In Vitro Cytogenetics(CA/SCE) (913646) ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Negative •Salmonella (364986) Negative •Salmonella (576172) Negative

85-44-9	Phthalic anhydride	<ul style="list-style-type: none"> •In Vitro Cytogenetics(CA/SCE) (164933) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Negative ◦Chromosome Aberrations Negative •Mouse Lymphoma (358037) <ul style="list-style-type: none"> ◦Mice ◦Positive •Salmonella (050139) Negative •Salmonella (648374) Negative
88-89-1	2,4,6-Trinitrophenol	<ul style="list-style-type: none"> •In Vitro Cytogenetics(CA/SCE) (685362) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Negative •Drosophila (400385) <ul style="list-style-type: none"> ◦Reciprocal Translocation/Sex-Linked Recessive Lethal Negative •Drosophila (868177) <ul style="list-style-type: none"> ◦Reciprocal Translocation/Sex-Linked Recessive Lethal Negative •Drosophila (969621) <ul style="list-style-type: none"> ◦Sex-Linked Recessive Lethal Positive ◦Reciprocal Translocation Negative •Salmonella (192631) Positive
89-72-5	2-sec-Butylphenol	<ul style="list-style-type: none"> •Salmonella (001911) Negative •Chromosome Aberrations (080086) <ul style="list-style-type: none"> ◦ Mice ◦Equivocal •In Vitro Cytogenetics(CA/SCE) (829306) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Positive •Mouse Lymphoma(NCI) (700736) <ul style="list-style-type: none"> ◦Mice ◦Mouse Lymphoma-NCI Positive
91-59-8	beta-Naphthylamine	<ul style="list-style-type: none"> •Mouse Lymphoma (NCI) (914276) <ul style="list-style-type: none"> ◦Mice ◦MouseLymphoma-NCI Positive •Micronucleus (829306) <ul style="list-style-type: none"> ◦Mice: B6C3F1 ◦Male Negative •Salmonella(NCI) (N-9057) <ul style="list-style-type: none"> ◦Salmonella ◦Salmonella-NCI Positive •Salmonella (828041) Positive •Sister Chromatid Exchanges (080086) <ul style="list-style-type: none"> ◦Mice ◦Sister Chromatid Positive
94-75-7	2,4-D	<ul style="list-style-type: none"> •In Vitro Cytogenetics(CA/SCE) (079515) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Positive •Drosophila (846375) <ul style="list-style-type: none"> ◦Reciprocal Translocation/Sex-Linked Recessive Lethal Negative •Salmonella (541375) Negative •Salmonella (843375) Negative
95-48-7	Orthocresol	<ul style="list-style-type: none"> •Micronucleus (A02909) <ul style="list-style-type: none"> ◦Mice: B6C3F1 ◦Male Negative ◦Female Negative •Salmonella (478797) Negative
96-69-5	4,4'-Thiobis (6-t-butyl-m-cresol)	<ul style="list-style-type: none"> •In Vitro Cytogenetics(CA/SCE) (395386) <ul style="list-style-type: none"> ◦Sister Chromatid Exchange Positive ◦Chromosome Aberrations Negative •Salmonella (755282) Negative
98-51-1	p-tert-Butyltoluene	<ul style="list-style-type: none"> •Salmonella (021139) Negative

Table 4. Searching for mutagenicity information by European Chemicals Agency(ECHA)

CAS No.	Chemical Name	Mutagenicity information provided by European Chemicals Agency(ECHA)
75-08-1	Ethanethiol	<ul style="list-style-type: none"> •bacterial reverse mutation assay(e.g., Ames test) negative •mammalian cell gene mutation assay positive •sister chromatid exchange assay in mammalian cells positive •micronucleus assay negative
79-04-9	Chloroacetyl chloride	<ul style="list-style-type: none"> •bacterial reverse mutation assay(e.g., Ames test) No mutagen without S9(in domain) •bacterial reverse mutation assay(e.g., Ames test) negative
2536-05-2	2,2'-Methylenediphenyl diisocyanate	<ul style="list-style-type: none"> •bacterial reverse mutation assay (e.g., Ames test) negative
7789-06-2	Strontium chromate	<ul style="list-style-type: none"> •sister chromatid exchange assay in mammalian cells positive if chromate was solubilised •in vitro mammalian cell transformation assay positive
108-11-2	Methyl amyl alcohol	<ul style="list-style-type: none"> •mammalian cell gene mutation assay negative •in vitro mammalian chromosome aberration test negative •bacterial reverse mutation assay(e.g., Ames test) negative •in vitro gene mutation assay in fungi negative
108-87-2	Methylcyclohexane	<ul style="list-style-type: none"> •bacterial reverse mutation assay(e.g., Ames test) negative •chromosome aberration negative
109-59-1	Isopropoxyethanol	<ul style="list-style-type: none"> •in vitro mammalian chromosome aberration test negative •bacterial reverse mutation assay(e.g., Ames test) negative
109-60-4	n-Propyl acetate	<ul style="list-style-type: none"> •bacterial reverse mutation assay(e.g., Ames test) negative •mammalian cell gene mutation assay negative
110-12-3	Methyl isoamyl ketone	<ul style="list-style-type: none"> •bacterial reverse mutation assay(e.g., Ames test) negative •in vitro mammalian chromosome aberration test negative •mammalian cell gene mutation assay negative •in Vitro Transformation of BALB/3T3 Cells negative
110-19-0	Isobutyl acetate	<ul style="list-style-type: none"> •in vitro mammalian chromosome aberration test negative •bacterial reverse mutation assay(e.g., Ames test) negative
110-43-0	Methyl-n-amylketone	<ul style="list-style-type: none"> •mammalian cell gene mutation assay negative •in vitro mammalian chromosome aberration test negative •DNA binding negative •bacterial reverse mutation assay(e.g., Ames test) negative •DNA adduct negative
110-83-8	Cyclohexene	<ul style="list-style-type: none"> •in vitro mammalian chromosome aberration test negative •bacterial reverse mutation assay(e.g., Ames test) negative
1305-62-0	Calcium hydroxide	<ul style="list-style-type: none"> •in vitro mammalian chromosome aberration test negative •bacterial reverse mutation assay(e.g., Ames test) negative
1308-31-2	Chromite	No data
1309-37-1	Ferric oxide	<ul style="list-style-type: none"> •bacterial reverse mutation assay(e.g., Ames test) negative •Comet assay negative
1314-13-2	Zinc oxide	<ul style="list-style-type: none"> •in vitro mammalian chromosome aberration test positive
13494-80-9	Tellurium	<ul style="list-style-type: none"> •bacterial reverse mutation assay(e.g., Ames test) negative
141-79-7	Mesityl oxide	<ul style="list-style-type: none"> •mammalian cell gene mutation assay negative •bacterial reverse mutation assay(e.g., Ames test) negative
142-82-5	Heptane	<ul style="list-style-type: none"> •in vitro mammalian chromosome aberration test negative •bacterial reverse mutation assay(e.g., Ames test) negative •mitotic recombination in Saccharomyces cerevisiae negative

151-50-8	Potassium cyanide	<ul style="list-style-type: none"> •mammalian cell gene mutation assay negative •chromosom eaberration negative •in vitro mammalian chromosome aberrationtest negative •bacterial reverse mutation assay(e.g., Ames test) positive between 10-0.04 mg •mammalian cell gene mutation assay negative
26140-60-3	Terphenyls	<ul style="list-style-type: none"> •bacterial reverse mutation assay(e.g., Ames test) negative •DNA damage and repair assay, unscheduled DNA synthesis in mammalian cells in vitro negative •mammalian cell gene mutation assay negative
540-88-5	tert-Butyl acetate	<ul style="list-style-type: none"> •micronucleus assay negative •in vitro mammalian chromosome aberration test negative •bacterial reverse mutation assay(e.g., Ames test) negative
557-05-1	Zinc stearate	<ul style="list-style-type: none"> •bacterial reverse mutation assay(e.g., Ames test) negative
563-80-4	Methyl isopropyl ketone	<ul style="list-style-type: none"> •mammalian cell gene mutation assay negative •in vitro mammalian chromosome aberration test negative •bacterial reverse mutation assay(e.g., Ames test) negative
583-59-5	Cyclohexanol, o-methyl-	<ul style="list-style-type: none"> •bacterial reverse mutation assay (e.g. Ames test) : negative with metabolic and without activation
65996-93-2	Pitch, coal tar, high-temp.	<ul style="list-style-type: none"> •bacterial reverse mutation assay (e.g. Ames test) : positive reproducible, dose response
681-84-5	Methyl silicate	<ul style="list-style-type: none"> •bacterial reverse mutation assay(e.g., Ames test) negative •micronucleus assay negative
71-23-8	n-Propanol	<ul style="list-style-type: none"> •in vitro mammalian chromosome aberration test negative
7440-22-4	Silver	<ul style="list-style-type: none"> •bacterial reverse mutation assay(e.g., Ames test) negative •in vitro mammalian cell micronucleus test positive •in vitro mammalian chromosome aberration test negative •mammalian cell gene mutation assay positive •micronucleus assay negative •single cell gel/comet assay in rodents for detection of DNA damage ambiguous •chromosome aberration assay(nanomaterial) positive
7440-33-7	Tungsten	<ul style="list-style-type: none"> •in vitro mammalian chromosome aberrationtest negative •mammalian cell gene mutation assay negative •bacterial reverse mutation assay(e.g., Ames test) negative •bacterial reverse mutation assay(e.g., Ames test) negative •mammalian cell gene mutation assay negative
7553-56-2	Iodine	<ul style="list-style-type: none"> •mammalian cell gene mutation assay negative •DNA damage and repair assay, unscheduled DNA synthesis in mammalian cells in vitro negative •sister chromatid exchange assay in mammalian cells positive •in vitro mammalian chromosome aberration test positive
7782-42-5	Graphite	<ul style="list-style-type: none"> •in vitro mammalian chromosome aberration test negative •bacterial reverse mutation assay(e.g., Ames test) negative •mammalian cell gene mutation assay negative
88-12-0	N-Vinylpyrrolidone	<ul style="list-style-type: none"> •bacterial reverse mutation assay(e.g., Ames test) negative •in vitro mammalian chromosome aberration test negative •in vitro mammalian cell transformation assay negative •mammalian cell gene mutation assay negative *DNA damage and repair assay, unscheduled DNA synthesis in mammalian cells in vitro negative •bacterial reverse mutation assay(e.g., Ames test) negative •micronucleus assay negative

Table 5. Searching for mutagenicity information by GENETOX webpage

CAS No.	Chemical Name	ECHA	Mutagenicity information provided by GENETOX
1024-57-3	Heptachlor epoxide	No data	•Dominant lethal test Negative •Sex-Linked Recessive Lethal gene mutation No conclusion •Histidine reverse gene mutation, Ames assay No conclusion
13530-65-9	Zinc chromate	No data	•Sister-chromatid exchange(SCE) in vitro Positive •Cell transformation, viral enhanced Positive •In vivo carcinogenicity studies Positive
141-66-2	Dicrotophos	No data	•Sister-chromatid exchange(SCE) in vitro Positive •Mitotic recombination or gene conversion Positive
142-64-3	Piperazine dihydrochloride	No data	•Forward and reverse gene mutation, host-mediated assay Positive
14484-64-1	Ferbam	No data	•Chromosome Aberrations Positive •Rec-assay, spot test, DNA effects(bacterial DNA repair) No conclusion
20816-12-0	Osmium tetroxide	No data	•Rec-assay, spot test, DNA effects(bacterial DNA repair) Positive •Sex-Linked Recessive Lethal gene mutation No conclusion
334-88-3	Diazomethane	No data	•Reverse gene mutation Positive •Reverse gene mutation Positive •In vivo carcinogenicity studies Positive
463-51-4	Ketene	No data	•Chromosome Aberrations Positive •Histidine reverse gene mutation, Ames assay Positive
53469-21-9	Chlorodiphenyl (42% Cl)	No data	•Chromosome Aberrations in vivo Negative •Dominant lethal test Negative
563-12-2	Ethion	No data	•Sister-chromatid exchange(SCE) in vitro Negative •Rec-assay, spot test, DNA effects (bacterial DNA repair) No conclusion •Rec-assay, DNA effects (bacterial DNA repair) No conclusion •Unscheduled DNA synthesis(UDS) in vitro, DNA effects Negative •Histidine reverse gene mutation, Ames assay Negative •Mitotic recombination or gene conversion Negative •Histidine reverse gene mutation, Ame sassy Negative
7440-38-2	Arsenic	No data	•Sister-chromatid exchange(SCE) in vivo Positive
7440-66-6	Zinc, elemental	No data	•Chromosome Aberrations in vivo No conclusion
75-99-0	2,2-Dichloropropionic acid	No data	•Chromosome Aberrations Positive
7664-38-2	Phosphoric acid	No data	•Cell transformation, viral enhanced Negative
7726-95-6	Bromine	No data	•Chromosome Aberrations Positive

위의 여러 기관 홈페이지에서 검색한 변이원성(유전독성)시험 결과정보에 따라, 최종적으로 GLP 유전독성(변이원성)시험 결과정보들이 없는 각 물질들에 대해, 그 유해성을 예측하여 추가적인 시험의 필요성을 검증하고자 미국 환경청(US Environmental Protection Agency, EPA)에서 제공하는 화학물질의 잠재적 유해성에 대한 전산독성정보 모음 사이트인 ACToR (Aggregated Computational Toxicology Resource)에서 Cobalt carbonyl 등의 각 물질들에 대한 유해성을 예측하였으며(Table 7), 최종적으로 GLP 변이원성(유전독성)시험이 필요한 물질 중 각 시험의 현실적인 가능여부를 판단하기 위해 국제적인 화학물질 판매처(예, Sigma-Aldrich 등)의 홈페이지를 통해 구입가능

여부를 추가확인 하였다.

이와 같은 일련의 자료검색 과정을 거쳐 추후 산업안전보건연구원의 화학물질 유해성시험평가 사업 중 GLP 변이원성(유전독성)시험에 반영하여 실시할 물질들을 각 GLP시험별(미생물복귀돌연변이시험, Ames; 염색체이상시험, CA; 및 소핵시험, MN 등 총 58시험)로 구분하여 제시하였다(Table 7).

안전보건공단 산업안전보건연구원(화학물질센터)에서는 국내에서 사용되는 화학물질 중 국내외적으로 독성정보가 없거나 부족한 화학물질 중 그 사용량과 취급 근로자수가 많으면서 독성이 강하게 예측되는 유해물질에 대해 GLP 유전독성시험을 수행하여 왔으며, 이를 통해 많은 화학물질 유해성시험 정

Table 6. Searching for other toxicity information and commercially availability by ChemIDplus and Sigma-Aldrich webpage, respectively

CAS No.	Chemical Name	Water solubility	Toxicological information provided by ChemIDplus	Commercially available
76-11-9	1,1,1,2-Tetrachloro-2,2-difluoroethane	100mg/L.25EXP	•rat LCLo inhalation 20000 ppm/30M(20000ppm) •rat LD50 oral >8 gm/kg	X
10210-68-1	Cobalt carbonyl	insoluble	•mouse LC50 inhalation 26900 ug/m3/2H(26.9mg/m3) •mouse LD50 oral 378 mg/kg •rat LC50 inhalation 165 mg/m3 •rat LD50 oral 754 mg/kg	http://www.sigmaaldrich.com/catalog/product/aldrich/60811?lang=ko&region=KR
1024-57-3	Heptachlor epoxide	0.2 mg/L 25 EXP	•mouse LD50 intracerebral 8 mg/kg •mouse LD50 oral 39 mg/kg •mouse LDLo intravenous 10 mg/kg •rabbit LD50 oral 144 mg/kg •rat LD50 oral 15 mg/kg	X
104-13-2	4-Butylaniline	190 mg/L 25 EST	•mouse LD50 intraperitoneal 81 mg/kg	http://www.sigmaaldrich.com/catalog/product/aldrich/11266?lang=ko&region=KR
105-46-4	sec-Butyl acetate	6200 mg/L 20 EXP	•rat LCLo inhalation 24000 ppm/4H •rat LD50 oral 3200 mg/kg	http://www.sigmaaldrich.com/catalog/product/aldrich/242594?lang=ko&region=KR
106-35-4	Ethyl butyl ketone	4300 mg/L 20 EXP	•rat LCLo inhalation 2000 ppm/4H •rat LD50 oral 2760 mg/kg	http://www.sigmaaldrich.com/catalog/product/aldrich/h6511?lang=ko&region=KR
108-84-9	sec-Hexyl acetate	1300 mg/L 20 EXP	•human TCLo inhalation 100 ppm •rabbit LD50 skin >20 mL/kg •rat LCLo inhalation 2000 ppm/4H •rat LD50 oral 6160 mg/kg	X
109-79-5	Butanethiol	597 mg/L 20 EXP	•mouse LC50 inhalation 2500 ppm/4H •mouse LD50 oral 3 gm/kg •rat LC50 inhalation 4020 ppm/4H •rat LD50 intraperitoneal 399 mg/kg •rat LD50 oral 1500 mg/kg	http://www.sigmaaldrich.com/catalog/product/aldrich/112925?lang=ko&region=KR
112-07-2	Ethylene glycol monobutyl ether acetate	9000 mg/L 20 EXP	•guinea pig LDLo skin 5 mL/kg •mouse LD50 oral 3200 mg/kg •rat LD50 oral 2400 mg/kg	http://www.sigmaaldrich.com/catalog/product/aldrich/307289?lang=ko&region=KR
1126-78-9	N-Butylaniline	67 mg/L 25 EST	•mammal (species unspecified) LD50 unreported 282 mg/kg •rabbit LD50 skin 5990 uL/kg •rat LD50 oral 1620 mg/kg	http://www.sigmaaldrich.com/catalog/product/sial/366196?lang=ko&region=KR
121-45-9	Trimethyl phosphite	7200 mg/L 25 EST	•mouse LDLo inhalation 32700 mg/m3/6H(32700 mg/m3) •mouse LD50 intraperitoneal 4180 mg/kg •rabbit LD50 skin 2600 mg/kg •rat LCLo inhalation 32700 mg/m3/6H(32700 mg/m3) •rat LD50 oral 1600 mg/kg	http://www.sigmaaldrich.com/catalog/product/aldrich/240907?lang=ko&region=KR
123-19-3	Dipropyl ketone	3200 mg/L 25 EXP	•mouse LDLo intravenous 271 mg/kg •rabbit LD50 skin 5660 uL/kg •rat LC50 inhalation 2690 ppm/6H •rat LD50 oral 3730 uL/kg	http://www.sigmaaldrich.com/catalog/product/aldrich/101745?lang=ko&region=KR
123-51-3	Isoamyl alcohol	2.67E+04 mg/L 25 EXP	•mouse LD50 intravenous 234 mg/kg •mouse LDLo intraperitoneal 233 mg/kg •mouse LDLo subcutaneous 7480 mg/kg •rabbit LD50 oral 3438 mg/kg •rabbit LD50 skin 3970 uL/kg •rabbit LDLo intravenous 1570 mg/kg •rat LD50 oral 1300 mg/kg •rat LDLo intraperitoneal 813 mg/kg	http://www.sigmaaldrich.com/catalog/product/aldrich/w205702?lang=ko&region=KR
1300-73-8	Dimethylaminobenzene	1110 mg/L 25 EXP	•mouse LD50 skin 1670 mg/kg •rabbit LD50 oral 600 mg/kg	X

1303-96-4	Sodium tetraborate decahydrate		<ul style="list-style-type: none"> •rabbit LD50 skin 1500 mg/kg •rabbit LDLo intravenous 240 mg/kg •rat LD50 skin 2 gm/kg •rat LDLo oral 610 mg/kg •rat LDLo oral 610 mg/kg •man LDLo oral 709 mg/kg •mouse LD50 intraperitoneal 2711 mg/kg •mouse LD50 intravenous 1320 mg/kg •mouse LD50 oral 2 gm/kg •rabbit LDLo subcutaneous 150 mg/kg •rat LD50 oral 2660 mg/kg 	http://www.sigmaaldrich.com/catalog/product/sial/s9640?lang=ko&region=KR
1309-48-4	Magnesium oxide	water solubility <5%	<ul style="list-style-type: none"> •human TCLo inhalation 400 mg/m3 •mouse LC50 inhalation 290 mg/m3 •mouse LD50 oral 275 mg/kg •mouse LD50 unreported 780 mg/kg •quail LD50 oral 255 mg/kg 	X
13121-70-5	Cyhexatin	8.24E-03 mg/L 25 EST	<ul style="list-style-type: none"> •rabbit LD50 oral 458 mg/kg •rabbit LD50 skin 2422 mg/kg •rat LC50 inhalation 244 mg/m3 •rat LD50 intraperitoneal 13 mg/kg •rat LD50 oral 180 mg/kg •rat LD50 skin 446 mg/kg •mouse LD50 oral >4 gm/kg 	http://www.sigmaaldrich.com/catalog/product/fluka/45411?lang=ko&region=KR
1314-61-0	Tantalum	insoluble	<ul style="list-style-type: none"> •rat LD intraperitoneal >5 gm/kg •rat LD50 oral 8 gm/kg 	X
1314-80-3	Phosphorus pentasulfide	react with water	<ul style="list-style-type: none"> •rabbit LD50 skin 3160 mg/kg •rat LD50 oral 389 mg/kg 	X
13397-24-5	Phosphogypsum	water solubility: 0.24%	<ul style="list-style-type: none"> •human TCLo inhalation 194000 mg/m3 •mouse LC50 inhalation 2190 mg/m3 •mouse LD50 intraperitoneal 60 mg/kg •mouse LD50 oral 62 mg/kg •rabbit LCLo inhalation 250ppm 	X
13463-40-6	Iron pentacarbonyl	insoluble	<ul style="list-style-type: none"> •rabbit LD50 intravenous 11 mg/kg •rabbit LD50 oral 12 mg/kg •rabbit LD50 skin 56 mg/kg •rabbit LD50 subcutaneous 240 mg/kg •rat LC50 inhalation 10 ppm/4H •rat LD50 oral 25 mg/kg 	http://www.sigmaaldrich.com/catalog/product/aldrich/481718?lang=ko&region=KR
13530-65-9	Zinc chromate	insoluble	<ul style="list-style-type: none"> •mouse LDLo intravenous 30 mg/kg 	X
136-78-7	Sesone	2.50E+05 mg/L 25 EXP	<ul style="list-style-type: none"> •mammal(species unspecified) LD50 oral 1230 mg/kg •rat LD50 oral 480mg/kg •mouse LDLo subcutaneous 11 gm/kg 	X
138-22-7	n-Butyl lactate	4.00E+04 mg/L 20 EXP	<ul style="list-style-type: none"> •rabbit LD50 oral >5 gm/kg •rabbit LD50 skin >5 gm/kg •rat LD50 oral >5 gm/kg •rat LD50 subcutaneous 12 gm/kg •mouse LD50 intraperitoneal 9500 ug/kg •mouse LD50 intravenous 9900 ug/kg •mouse LD50 oral 11 mg/kg •mouse LD50 subcutaneous 11500 ug/kg •pigeon LD50 oral 2 mg/kg 	http://www.sigmaaldrich.com/catalog/product/aldrich/283320?lang=ko&region=KR
141-66-2	Dicrotophos	solubility 1.00E+06mg/L25 EXP	<ul style="list-style-type: none"> •quail LD50 oral 4 mg/kg •rabbit LD50 skin 168 mg/kg •rat LC50 inhalation 90 mg/m3 •rat LD50 oral 13 mg/kg •rat LD50 skin 42 mg/kg •rat LD50 subcutaneous 8137 ug/kg •rat LD50 unreported 22 mg/kg 	X
1421-86-9	Strychnine		<ul style="list-style-type: none"> •mouse LD50 intravenous 650 ug/kg 	X

142-64-3	hydrochloride Piperazine dihydrochloride		<ul style="list-style-type: none"> •rat LD50 subcutaneous 2730 ug/kg •mouse LD50 intraperitoneal 1970 mg/kg •mouse LD50 subcutaneous 2030 mg/kg •rat LD50 oral 4900 mg/kg •mouse LD50 intraperitoneal 3 gm/kg •mouse LD50 oral 3400 mg/kg 	X	
14484-64-1	Ferbam	130 mg/L 25 EXP	<ul style="list-style-type: none"> •rabbit LDLo intraperitoneal 1500 mg/kg •rabbit LDLo oral 3 gm/kg •rat LD50 intraperitoneal 2700 mg/kg •rat LD50 oral 1130 mg/kg 	X	
148-01-6	3,5-Dinitro-o-tolu amide	1000mg/L EXP	<ul style="list-style-type: none"> •dog LD50 intravenous 75 mg/kg •rat LD50 oral 600 mg/kg 		http://www.sigmaaldrich.com/catalog/product/aldrich/524417?lang=ko&region=KR
15468-32-3	Silica, crystalline tridymite	insoluble	<ul style="list-style-type: none"> •human TCLo inhalation 16 mppcf •rat LDLo intratracheal 200 mg/kg •mouse LC50 inhalation 12 ppm/4H •mouse LD50 intraperitoneal 33 mg/kg •mouse LD50 oral 41 mg/kg •mouse LD50 skin 317 mg/kg •rabbit LD50 intraperitoneal 28 mg/kg •rabbit LD50 skin 71 mg/kg •rat LC50 inhalation 46 ppm/4H •rat LD50 oral 64 mg/kg •rat LD50 skin 740 mg/kg 	X	
17702-41-9	Decaborane		<ul style="list-style-type: none"> •rat LD50 oral 64 mg/kg •rat LD50 skin 740 mg/kg 		http://www.sigmaaldrich.com/catalog/product/aldrich/278815?lang=ko&region=KR
1821-39-2	Aniline, 2-propyl-		<ul style="list-style-type: none"> •mouse LD50 intraperitoneal 250 mg/kg 		http://www.sigmaaldrich.com/catalog/product/aldrich/237337?lang=ko&region=KR
19624-22-7	Pentaborane	react with water	<ul style="list-style-type: none"> •mouse LC50 inhalation 3400 ppb/4H •rat LC50 inhalation 6 ppm/4H •rat LD50 intraperitoneal 11100 ug/kg(11.1mg/kg) •man TCLo inhalation 133 ug/m3(133 mg/m3) •mouse LCLo inhalation 40 ppm/4H •mouse LD50 intraperitoneal 13500 ug/kg(13.5 mg/kg) •mouse LD50 oral 162 mg/kg(162 mg/kg) •rabbit LCLo inhalation 1316 mg/m3 •rat LCLo inhalation 40 ppm/4H •rat LD50 intraperitoneal 14100 ug/kg(14.1 mg/kg) •man LCLo inhalation 2800 mg/m3(2800 mg/m3) •man LDLo oral 86 mg/kg •man TDLo oral 21 mg/kg •women LDLo oral 180 mg/kg •women TDLo oral 60 mg/kg 	X	
20816-12-0	Osmium tetroxide		<ul style="list-style-type: none"> •mouse LD50 oral 162 mg/kg(162 mg/kg) •rabbit LCLo inhalation 1316 mg/m3 •rat LCLo inhalation 40 ppm/4H •rat LD50 intraperitoneal 14100 ug/kg(14.1 mg/kg) •man LCLo inhalation 2800 mg/m3(2800 mg/m3) 	X	
20859-73-8	Aluminum phosphide	react with water	<ul style="list-style-type: none"> •man LDLo oral 86 mg/kg •man TDLo oral 21 mg/kg •women LDLo oral 180 mg/kg •women TDLo oral 60 mg/kg 	X	
25551-13-7	Trimethylbenzene s	insoluble	<ul style="list-style-type: none"> •rat LD50 oral 8970 mg/kg 	X	
25639-42-3	Methylcyclohexan ol		<ul style="list-style-type: none"> •rabbit LDLo oral 1750 mg/kg •rabbit LDLo skin 6800 mg/kg •rat LD50 oral 1660 mg/kg •rat LD50 subcutaneous 2900 mg/kg 	X	
26952-21-6	Isooctyl alcohol	640mg/L EXP (insoluble)	<ul style="list-style-type: none"> •mouse LD50 oral 1670 mg/kg •rabbit LD50 skin 2520 mg/kg •rat LD50 oral 1480 mg/kg 	X	
2696-84-6	4-Propylaniline	782 mg/L 25 EST	<ul style="list-style-type: none"> •mouse LD50 intraperitoneal 201 mg/kg 		http://www.sigmaaldrich.com/catalog/product/aldrich/237345?lang=ko&region=KR
2971-90-6	Clopidol	10 mg/L 25 EXP	<ul style="list-style-type: none"> •guinea pig LD50 oral >8 gm/kg •rabbit LD50 oral >8 gm/kg •rat LD50 oral 18 gm/kg 		http://www.sigmaaldrich.com/catalog/product/fluka/33988?lang=ko&region=KR
299-86-5	Crufomate	200 mg/L 25 EXP	<ul style="list-style-type: none"> •rabbit LD50 oral 400 mg/kg •rabbit LD50 skin 2 gm/kg •rat LCLo inhalation 12 mg/m3/4H 		http://www.sigmaaldrich.com/catalog/product/fluka/32086?lang=ko&region=KR

334-88-3	Diazomethane	2550 mg/L 25 EST	<ul style="list-style-type: none"> •rat LD50 oral 460 mg/kg •rat LD50 unreported 770 mg/kg •cat LC50 inhalation 175 ppm 	X
3383-96-8	Temefos	0.27 mg/L 20 EXP	<ul style="list-style-type: none"> •mouse LD50 intraperitoneal 683 mg/kg •mouse LD50 oral 223 mg/kg •pigeon LD50 oral 50 mg/kg •quail LD50 oral 75 mg/kg •rabbit LD50 oral 313 mg/kg •rabbit LD50 skin 970 mg/kg •rat LD50 intraperitoneal 912 mg/kg •rat LD50 oral 1 gm/kg •rat LD50 skin 1370 mg/kg •rat LD50 subcutaneous 2302 mg/kg •rat LD50 unreported 8600 mg/kg 	http://www.sigmaaldrich.com/catalog/product/fluka/31526?lang=ko&region=KR
353-50-4	Carbonyl difluoride		<ul style="list-style-type: none"> •rat LC50 inhalation 360 ppm/1H 	X
463-51-4	Ketene	3.63E+05 mg/L 25 EST	<ul style="list-style-type: none"> •mouse LCLo inhalation 23 ppm •rabbit LCLo inhalation 53 ppm/2H •mouse LDLo oral 5 gm/kg 	X
479-45-8	Tetryl	74mg/L EXP	<ul style="list-style-type: none"> •rabbit LD skin >2 gm/kg •rat LDLo oral 5 gm/kg •rat LDLo oral 5 gm/kg 	X
492-80-8	Auramine	53.5 mg/L 25 EST	<ul style="list-style-type: none"> •mouse LD50 intraperitoneal 103 mg/kg 	http://www.sigmaaldrich.com/catalog/product/fluka/51362?lang=ko&region=KR
53469-21-9	Chlorodiphenyl (42% Cl)	0.277 mg/L 20 EXP	<ul style="list-style-type: none"> •rabbit LDLo skin 1269 mg/kg •rat LD50 oral 4250 mg/kg •mouse LCLo inhalation 3484 ppm/4H 	X
541-85-5	5-Methyl-3-heptanone	1370 mg/L 25 EST	<ul style="list-style-type: none"> •mouse LD50 oral 3800 mg/kg •rabbit LD50 skin >16 gm/kg •rat LCLo inhalation 3484 ppm/8H •rat LD50 oral 3500 mg/kg 	http://www.sigmaaldrich.com/catalog/product/aldrich/67260?lang=ko&region=KR
558-13-4	Tetrabromomethane	240 mg/L 30 EXP	<ul style="list-style-type: none"> •mouse LD50 intravenous 56 mg/kg •mouse LD50 subcutaneous 298 mg/kg •mouse LD50 intraperitoneal 35 mg/kg •mouse LD50 oral 40 mg/kg •rat LC50 inhalation 864 mg/m3 	http://www.sigmaaldrich.com/catalog/product/aldrich/c11081?lang=ko&region=KR
563-12-2	Ethion	2 mg/L 25 EXP	<ul style="list-style-type: none"> •rat LD50 intraperitoneal 26 mg/kg •rat LD50 oral 13 mg/kg •rat LD50 skin62 mg/kg •rat LD50 unreported 55 mg/kg •mouse LD50 intraperitoneal 200 mg/kg •mouse LDLo intravenous 270 mg/kg 	X
583-60-8	o-Methylcyclohexanone	5140 mg/L 25 EST	<ul style="list-style-type: none"> •rabbit LD50 skin 1770 uL/kg(1.77 mL/kg) •rat LCLo inhalation 2800 ppm/4H •rat LD50 oral 2140 uL/kg(2.14 mL/kg) 	http://www.sigmaaldrich.com/catalog/product/aldrich/m38400?lang=ko&region=KR
591-23-1	m-Methylcyclohexanol	5990 mg/L 25 EST	<ul style="list-style-type: none"> •mouse LD50 intramuscular 1 gm/kg 	X
591-78-6	Methyl n-butyl ketone	1.75E+04 mg/L 20 EXP	<ul style="list-style-type: none"> •mouse LD50 oral 2430 mg/kg •rabbit LD50 skin 4800 mg/kg •rat LC50 inhalation 8000 ppm/4H •rat LD50 oral 2590 mg/kg •rat LD50 unreported 914 mg/kg •rat LDLo intraperitoneal 914 mg/kg •mouse LDLo intraperitoneal 40 mg/kg 	http://www.sigmaaldrich.com/catalog/product/sial/103004?lang=ko&region=KR
60676-86-0	Silicon dioxide (vitreous)	insoluble	<ul style="list-style-type: none"> •rabbit LDLo intravenous 35 mg/kg •rat LDLo intraperitoneal 400 mg/kg •rat LDLo intraperitoneal 400 mg/kg •rat LDLo intratracheal 120 mg/kg 	http://www.sigmaaldrich.com/catalog/product/aldrich/342858?lang=ko&region=KR

626-17-5	m-Phthalodinitrile	1.05E+04 mg/L 25 EST	<ul style="list-style-type: none"> •mouse LD50 intraperitoneal 450 mg/kg •mouse LD50 oral 178 mg/kg •mouse LD50 unreported 548 mg/kg •rabbit LD50 oral 250 mg/kg •rabbit LD50 skin >2 gm/kg •rabbit LD50 unreported 350 mg/kg •rat LC50 inhalation >8970 mg/m3/1H •rat LD50 intraperitoneal 520 mg/kg •rat LD50 oral 860 mg/kg •rat LD50 oral 860 mg/kg •rat LD50 skin >5 gm/kg •rat LD50 unreported 1708mg/kg 	http://www.sigmaaldrich.com/catalog/product/aldrich/145858?lang=ko&region=KR	
626-38-0	sec-Amyl acetate	1070 mg/L 25 EST	<ul style="list-style-type: none"> •guinea pig LCLo inhalation 1000 0ppm/5H •human TCLo inhalation 200 ppm 		X
627-13-4	n-Propyl nitrate	3290 mg/L 25 EXP	<ul style="list-style-type: none"> •mouse LCLo inhalation 5816 ppm/4H •rabbit LD50 intravenous 200 mg/kg •rat LCLo inhalation 5816 ppm/4H •rabbit LD50 intravenous 300 ug/kg(.3 mg/kg) •rabbit LD50 oral 340 ug/kg(.34 mg/kg) •rabbit LD50 subcutaneous 281 ug/kg(.281 mg/kg) •rat LD50 intraperitoneal 1940 ug/kg(1.94 mg/kg) •rat LD50 oral 100 ug/kg(.1 mg/kg) •rat LD50 skin 48 mg/kg •rat LD50 unreported 15 mg/kg 		X
62-74-8	Sodium fluoroacetate	1.11E+06 mg/L 25 EXP	<ul style="list-style-type: none"> •rabbit LD50 oral 7400 mg/kg •rat LC inhalation >3000 ppm/6H •rat LD50 oral >1600 mg/kg •mouse LD50 oral 540 mg/kg •rabbit LDLo subcutaneous 300 mg/kg •rat LD50 oral 460 mg/kg •rat LD50 skin 3800 mg/kg 	http://www.sigmaaldrich.com/catalog/product/aldrich/w504009?lang=ko&region=KR	X
628-63-7	n-Amyl acetate	1700 mg/L 20 EXP	<ul style="list-style-type: none"> •rabbit LD50 oral 7400 mg/kg •rat LC inhalation >3000 ppm/6H •rat LD50 oral >1600 mg/kg •mouse LD50 oral 540 mg/kg •rabbit LDLo subcutaneous 300 mg/kg •rat LD50 oral 460 mg/kg •rat LD50 skin 3800 mg/kg 	http://www.sigmaaldrich.com/catalog/product/aldrich/w504009?lang=ko&region=KR	X
628-96-6	Ethylene glycol dinitrate	6800 mg/L 20 EXP	<ul style="list-style-type: none"> •rabbit LDLo subcutaneous 300 mg/kg •rat LD50 oral 460 mg/kg •rat LD50 skin 3800 mg/kg 		X
638-21-1	Phenylphosphine		<ul style="list-style-type: none"> •rat LC50 inhalation 38 ppm/4H •mouse LD50 intraperitoneal 1047 mg/kg •mouse LD50 oral 1525 mg/kg •mouse LD50 subcutaneous 1208 mg/kg •rat LD50 intraperitoneal 479 mg/kg •rat LD50 oral 250 mg/kg •rat LD50 subcutaneous 463 mg/kg 		X
6423-43-4	Propylene glycol dinitrate		<ul style="list-style-type: none"> •mouse LD50 intraperitoneal 1047 mg/kg •mouse LD50 oral 1525 mg/kg •mouse LD50 subcutaneous 1208 mg/kg •rat LD50 intraperitoneal 479 mg/kg •rat LD50 oral 250 mg/kg •rat LD50 subcutaneous 463 mg/kg 		X
7440-21-3	Silicon, elemental	insoluble, react with water blisteringly and explosively	<ul style="list-style-type: none"> •rat LD50 oral 3160 mg/kg 		X
7440-36-0	Antimony, elemental	react with water blisteringly and explosively	<ul style="list-style-type: none"> •mouse LD50 intraperitoneal 90 mg/kg •rat LD50 intraperitoneal 100 mg/kg •rat LD50 oral 7 gm/kg •mouse LD50 intraperitoneal 46200 ug/kg(46.2 mg/kg) •mouse LD50 oral 145 mg/kg •rabbit LDLo subcutaneous 300 mg/kg •rat LD50 intraperitoneal 13390 ug/kg(13.39 mg/kg) •rat LD50 oral 763 mg/kg 		X
7440-38-2	Arsenic	insoluble	<ul style="list-style-type: none"> •mouse LD50 intraperitoneal 46200 ug/kg(46.2 mg/kg) •mouse LD50 oral 145 mg/kg •rabbit LDLo subcutaneous 300 mg/kg •rat LD50 intraperitoneal 13390 ug/kg(13.39 mg/kg) •rat LD50 oral 763 mg/kg 		X
7440-50-8	Copper	insoluble, react with water blisteringly and explosively	<ul style="list-style-type: none"> •mouse LD50 intraperitoneal 3500 ug/kg(3.5mg/kg) •rabbit LDLo subcutaneous 375 mg/kg 		X
7440-66-6	Zinc, elemental	react with water	<ul style="list-style-type: none"> •duck LDLo oral 388 mg/kg •human TCLo inhalation 124mg/m3 		X
75-99-0	2,2-Dichloropropionic acid	5.02E+05 mg/L 25 EXP	<ul style="list-style-type: none"> •rat LD50 skin >5 gm/kg 		X
7664-38-2	Phosphoric acid	548 g/100 ml (dissolve in cold	<ul style="list-style-type: none"> •rabbit LD50 skin 2740 mg/kg •rat LC50 inhalation >850mg/m3 		X

		water)	<ul style="list-style-type: none"> •rat LD50 oral 1530 mg/kg •mouse LC50 inhalation 750 ppm •mouse LD50 oral 3100 mg/kg •rabbit LCLo inhalation 180ppm •rabbit LD50 oral 4160 mg/kg •rat LC50 inhalation 2700 mg/m3 •rat LD50 oral2600 mg/kg 	X
7726-95-6	Bromine			
7773-06-0	Ammonium sulfamate		<ul style="list-style-type: none"> •mouse LD intraperitoneal >500 mg/kg •mouse LD50 oral 3100 mg/kg •rat LD50 oral 2 gm/kg •rat LDLo intraperitoneal 800 mg/kg 	http://www.sigmaaldrich.com/catalog/product/sial/228745?lang=ko&region=KR
7783-41-7	Oxygen difluoride	water solubility: 0.02% (decomposition)	<ul style="list-style-type: none"> •mouse LC50 inhalation 1.5ppm •rat LC50 inhalation 2600 ppb/1H(2.6 ppm) 	X
7783-60-0	Sulfur tetrafluoride	react with water blisteringly	•rat LCLo inhalation 19 ppm/4H(19 ppm)	X
7790-91-2	Chlorine trifluoride	react with water	<ul style="list-style-type: none"> •mouse LC50 inhalation 178 ppm/1H(178 ppm) •rat LC50 inhalation 299 ppm/1H(299 ppm) •mouse LD50 intraperitoneal 1960 mg/kg •mouse LD50 oral 900 mg/kg •mouse LDLo subcutaneous 12500 mg/kg •rabbit LD50 skin >3700 mg/kg 	X
78-30-8	Tri-o-cresyl phosphate	0.102 mg/L 25 EST	<ul style="list-style-type: none"> •rabbit LDLo intramuscular 135 mg/kg •rabbit LDLo intraperitoneal 100 mg/kg •rabbit LDLo intravenous 100 mg/kg •rabbit LDLo oral 100 mg/kg •rabbit LDLo subcutaneous 100 mg/kg •rat LD50 intraperitoneal 2500 mg/kg •rat LD50 oral 1160 mg/kg 	http://www.sigmaaldrich.com/catalog/product/fluka/51885?lang=ko&region=KR
8003-34-7	Pyrethrum		<ul style="list-style-type: none"> •mouse LD50 oral 370 mg/kg •mouse LDLo intraperitoneal 25 mg/kg •rabbit LD50 skin 300 mg/kg •rat LD50 intraperitoneal 200 mg/kg •rat LD50 oral 200 mg/kg •rat LD50 skin 1350 mg/kg •rat LC50 inhalation 320 mg/m3 •rat LD50 oral 1600 ug/kg(1.6 mg/kg) 	http://www.sigmaaldrich.com/catalog/product/fluka/33739?lang=ko&region=KR
81-81-2	Warfarin	17 mg/L 20 EXP	<ul style="list-style-type: none"> •rat LD50 skin 1400 mg/kg •rat LD50 unreported 50 mg/kg •rat LDLo intraperitoneal 420 mg/kg •rabbit LD50 skin >2 gm/kg 	http://www.sigmaaldrich.com/catalog/product/fluka/a2250?lang=ko&region=KR
9004-34-6	Cellulose	insoluble	<ul style="list-style-type: none"> •rat LC50 inhalation >5800 mg/m3 •rat LD50 intraperitoneal >31600 mg/kg •rat LD50 oral >5 gm/kg 	X
9005-25-8	Starch	insoluble	•mouse LD50 intraperitoneal 6600 mg/kg	X
93763-70-3	Perlite	insoluble	•mouse LD50 oral 12960 mg/kg	X
95-13-6	Indene	332 mg/L 25 EST	<ul style="list-style-type: none"> •mouse LD50 unreported 1800 mg/kg •rat LC50 inhalation 14 gm/m3 •rat LD50 unreported 2300 mg/kg •mouse LD50 intravenous 513 mg/kg •mouse LD50 oral 3100 mg/kg 	http://www.sigmaaldrich.com/catalog/product/aldrich/193828?lang=ko&region=KR
96-22-0	Diethyl ketone	4.81E+04 mg/L 25 EXP	<ul style="list-style-type: none"> •rabbit LD50 skin 20 mL/kg •rat LCLo inhalation 8000 ppm •rat LD50 oral 2140 mg/kg •rat LDLo intraperitoneal 1250 mg/kg 	http://www.sigmaaldrich.com/catalog/product/sial/127604?lang=ko&region=KR
999-61-1	2-Hydroxypropyl acrylate	1.00E+06 mg/L 25 EXP	<ul style="list-style-type: none"> •mouse LD50 oral 1056 mg/kg •rabbit LD50 skin 160 uL/kg(.16 mL/kg) •rat LD50 oral 250 mg/kg 	http://www.sigmaaldrich.com/catalog/product/aldrich/s511951?lang=ko&region=KR

*EST, estimated; EXP, experiment

Table 7. Searching for potential chemical hazards by EPA ACToR (Aggregated Computational Toxicology Resource) webpage and assign the required mutagenicity(GLP genotoxic) tests

CAS No.	Chemical Name	EPA ACToR	Ames test	CA test	MN test
10210-68-1	Cobalt carbonyl	Ha, Cr, Ca, D, R			O
104-13-2	4-Butylaniline	Ha	O		
105-46-4	sec-Butyl acetate	Ha, Cr, Ca, D, R			O
106-35-4	Ethyl butyl ketone	Ha, Cr, Ca, D, R			O
109-79-5	Butanethiol	Ha, Cr, Ca, D, R			O
112-07-2	Ethylene glycol monobutyl ether acetate	Ha, Cr, Ca, G, D, R	O	O	O
1126-78-9	N-Butylaniline	Ha, Ca, D	O	O	
121-45-9	Trimethyl phosphite	Ha, Cr, Ca, D, R			O
123-19-3	Dipropyl ketone	Ha, Cr, Ca, D, R			O
123-51-3	Isoamyl alcohol	Ha, Cr, Ca, G, D, R	O	O	O
1303-96-4	Borax	Ha, Cr, Ca, G, D, R	O	O	O
13121-70-5	Cyhexatin	Ha, Cr, Ca, G, D, R	O	O	O
13463-40-6	Iron pentacarbonyl	Ha, Cr, Ca, G, D, R	O	O	O
138-22-7	n-Butyl lactate	Ha, Cr, Ca, D, R			O
148-01-6	3,5-Dinitro-o-toluamide	Ha, Cr, Ca, D, R			O
17702-41-9	Decaborane	Ha, Cr, Ca, D, R			O
1821-39-2	Aniline, 2-propyl-	Ha	O		
2696-84-6	Aniline, 4-propyl-	Ha	O		
2971-90-6	Clpidol	Ha, Cr, Ca, D, R			O
299-86-5	Crufomate	Ha, Cr, Ca, D, R			O
3383-96-8	Temefos	Ha, Cr, Ca, G, D, R	O	O	O
492-80-8	Auramine	Ha, Cr, Ca, D, R			O
541-85-5	5-Methyl-3-heptanone	Ha, Ca	O	O	
558-13-4	Tetrabromomethane	Ha, Cr, Ca, D, R			O
583-60-8	2-Methylcyclohexanone	Ha, Cr, Ca, D, R			O
591-78-6	Methyl n-butyl ketone	Ha, Cr, Ca, G, D, R	O	O	O
60676-86-0	Silica, vitreous	Ha, Cr, Ca	O	O	
626-17-5	m-Phthalodinitrile	Ha, Cr, Ca, G, D, R	O	O	O
628-63-7	n-Amyl acetate	Ha, Cr, Ca, D, R			O
7773-06-0	Ammonium sulfamate	Ha, Cr, Ca, D, R			O
78-30-8	Tri-o-cresyl phosphate	Ha, Cr, Ca, G, D, R	O	O	O
8003-34-7	Pyrethrum	Ha, Cr, Ca, D, R			O
81-81-2	Warfarin	Ha, Cr, Ca, D, R			O
95-13-6	Indene	Ha, Cr, Ca, D, R			O
96-22-0	Diethyl ketone	Ha, Cr, Ca, D, R			O
999-61-1	2-Hydroxypropyl acrylate	Ha, Cr, Ca, D, R			O

*Ha, Hazard; Cr, Chronic; Ca, Carcinogenicity; G, Genotoxicity; D, Developmental; R, Reproductive
CA, Chromosomal aberration; MN, Micronucleus

보를 생산하여 KOSHANET MSDS를 통해 사업장에 제공하여왔다. 우선적으로는 산업안전보건법 상의 노출기준설정, 특수건강검진대상, 작업환경측정대상 등의 관리대상물질들에 대한 GLP 유전독성(변이원

성) 시험을 수행하여 왔고(Kim et al., 2006), 그 시험 결과를 KOSHANET MSDS에 반영하여 왔다. 또한 변이원성(유전독성) 시험결과 양성으로 판정되는 경우는 급성 및 아만성 흡입독성시험을 수행하여 만

성·발암성의 규명을 할 수 있는 기초자료의 생성에 노력하여 왔다(Rim et al., 2014).

현재까지 산업안전보건연구원에서 수행한 기존화학물질의 GLP 유전독성(변이원성)시험은, 그 대상물질을 선정하기 위해 위에 언급한 바와 같이 산업안전보건법상 관리대상물질 중 MSDS DB에 그 시험결과와 자료가 “자료없음”으로 되어 있는 물질을 우선적으로 선별하여 국내의 화학물질 유해성 관련 인터넷 정보 사이트에서 해당물질의 CAS 번호 및 화학물질명을 키워드로 하여 검색함으로써 시험자료의 유무를 다시 한 번 확인하고, 시험자료가 확실히 존재하지 않는 경우 그 화학물질의 유통량, 취급근로자수 등의 시험의 필요성을 확인하여 시험대상물질로 편입하여 왔으며, 본 사례보고에서는 이와 같은 목적으로 진행되는 산업안전보건연구원의 사업에 도움이 되고자, 산업안전보건법 상 관리대상물질의 유전독성(변이원성) 시험정보를 얻는 과정에 대한 고찰을 통해 GLP 유전독성(변이원성) 시험이 필요한 시험대상 후보물질 목록 및 우선필요 시험을 함께 제안하고자 노력한 사례를 보고하였다.

사업장 화학물질의 유해성 시험평가 사업은 유해화학물질로 인한 근로자의 건강장해 예방을 위해 GLP 독성시험을 수행하여 MSDS 자료보완 및 근로자의 교육 등 건강보호조치를 함으로써 사업주나 근로자들의 자발적인 예방활동을 돕는데 목적이 있다. 평가대상물질의 특성에 따라 GLP 원칙의 독성시험을 실제로 적용하거나, 원료 및 사용 중 작업장 내 발생 성분에 대한 정성분석, 구성성분에 대한 체계적인 유해성 정보자료 검색 등을 통해 종합적으로 해당물질의 유해성을 평가하여 결과를 제시함으로써 효율적인 사업장 화학물질 관리를 위한 과학적인 근거를 제공하고 있으며, 해마다 노사관계에서 주요하게 요구되는 근로자 건강보호를 위한 사업장 화학물질의 유해성 정보를 투명하게 제공해 줌으로써 근로자의 알권리를 충족시키고 있다.

한편 산업안전보건연구원에서는 화학물질 유해성 정보의 제공은 분류기준의 일관성 부족, 각종 자료의 불분명한 표현 등으로 인한 근로자들의 알권리를 100% 만족시켜주지 못하는 실정을 개선하고자 화학물질 분류 및 경고표지의 통일화 방안인 GHS 기준에 따라 화학물질의 유해성·위험성을 분류하고 이

에 따라 전 세계적으로 통일된 형태의 화학물질정보를 작성하여 체계적인 자료로 개선되어가고 있으며, 이에 따라 더욱 정확하고 보기 쉬운 화학물질정보를 검색하고 활용할 수 있게 되었다. 또한 지속적인 질적 향상을 위해 화학물질의 노출기준, 독성정보, 물리·화학적 특성, 화학물질 유해성·위험성 지수 등의 주요 관심정보들을 우선적으로 제공·보완해 나가고, 자체적인 독성시험 및 물리화학적 위험성 시험결과를 활용하는 등의 과학적인 자료생산에 역점을 두어 수행하고 있다. 이 과정에서 OECD 대량생산화학물질 초기유해성평가(Screening Information Data Set, SIDS) 프로그램 및 미국 NTP 등의 화학물질 유해성시험 결과 등을 적극 활용하고 있다. 그 중 한 분야가 GLP 변이원성(유전독성)시험으로 수요자 중심의 종합적인 정보제공 체계구축을 위해 미제공되고 있는 산업안전보건법 관리대상 영역의 화학물질들 및 그 혼합물에 대한 다양한 변이원성 시험결과들을 내실있게 제공하여 타 기관과 비교우위의 정보제공 시스템을 구축하기 위해 지속적인 노력과 많은 성과들이 있을 것으로 기대된다.

IV. 결 론

안전보건공단 산업안전보건연구원(화학물질센터)에서는 국내에서 사용되는 화학물질 중 국내외적으로 독성정보가 없거나 부족한 화학물질 중 그 사용량과 취급 근로자수가 많으면서 독성이 강하게 예측되는 유해물질에 대해 GLP 유전독성시험을 수행하여 왔으며, 우선적으로는 산업안전보건법 상의 노출기준 설정, 특수건강검진대상, 작업환경측정대상 등의 관리대상물질들에 대한 GLP 유전독성(변이원성) 시험을 수행하여 그 시험결과를 KOSHANET MSDS에 반영하여 왔다. 본 사례보고서에서 변이원성 시험자료의 검색을 통해 산업안전보건법상 관리대상물질을 포함한 기존화학물질 중 안전보건공단에서 KOSHANET을 통해 서비스하는 물질안전보건자료의 내용 중에 변이원성시험자료가 없는(“자료없음”으로 표기되어 있는) 물질들에 대해 인터넷 정보 사이트를 참고하여 그 GLP 변이원성(유전독성) 시험결과 정보들을 검색하여, 변이원성(유전독성)시험 결과정보들을 찾을 수 있는 물질들에 대해 그 구체적인 정보들을 제시하였

고, 이는 GLP 변이원성(유전독성)시험 수행의 가능성을 찾기 위한 노력의 일환으로 수행하였으며, 일련의 자료검색 과정을 거쳐 추후 산업안전보건연구원의 화학물질 유해성시험평가 사업 중 GLP 변이원성(유전독성)시험에 반영하여 실시할 물질들을 각 GLP 시험별(미생물복귀돌연변이시험, Ames; 염색체이상시험, CA; 및 소핵시험, MN)로 구분하여 제시하였다.

또한 지속적인 질적 향상을 위해 사업장에서 필요로 하는 화학물질의 주요 관심정보들을 우선적으로 제공·보완해 나가고, 자체적인 독성시험 및 물리·화학적 위험성 시험결과를 활용하는 등 과학적인 자료생산에 역점을 두어 수행하고 있으며, 그 중 한 분야가 GLP 변이원성(유전독성)시험으로 수요자 중심의 다양한 변이원성 시험결과들을 내실 있게 제공하여 타 기관과 비교우위의 정보제공 시스템을 구축하여 많은 성과들이 있을 것으로 기대된다.

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