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OIL AND GREASE DETERMINATION, SOLVENT HAZARDS AND WASTE DISPOSAL WHEN USING TRICHLOROMETHANE (CHLOROFORM) FOR EXTRACTION

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OIL AND GREASE DETERMINATION,

SOLVENT HAZARDS AND WASTE DISPOSAL WHEN

USING TRICHLOROMETHANE (CHLOROFORM) FOR EXTRACTION

ABSTRACT

This publication introduces a new oil and grease (O&G) determination method which involves the use of a visible spectrophotometer or a filter photometer, and chloroform for O&G extraction. The laboratory equipment and chloroform are available in all water quality laboratories. The oil and grease concentration in aqueous phase as low as 0.1 mg/L can be quantitatively measured, provided that a quartz cell with light path length of 5 cm or longer is used. Selection of an appropriate organic solvent for oil and grease analysis is discussed in terms of chemist contact risk and hazardous solvent disposal. Current Standard Methods 5520B, 5520D, 5520E, and 5520G for oil and grease analysis adopt n-hexane for solvent extraction. The authors compare the selected solvent (chloroform) with n-hexane and conclude that chloroform is better than n-hexane considering the fire and accident prevention because n-hexane is very flammable, but chloroform is not flammable. In terms of the worker's health hazard, both chloroform and n-hexane are at the same level, but chloroform is a "select carcinogen" which needs extra personal protective equipment (PPE) and laboratory protective equipment (LPE). This new analytical method using popular chloroform for O&G extraction will provide extra flexibility. It is recommended that chloroform in analytical chemistry be eventually replaced by other solvent of non-"select carcinogen" type.

KEYWORDS: Memoir, Dedication, Aimee E. Thayer, Lenox Institute of Water Technology, Environmental Engineering, Water Pollution, Water Quality Analysis, Oil, Grease, Soaps, Hydrocarbons, Solvent Extraction, Colorimetry, Spectrophotometry, Trichloromethane, Chloroform, Risk Management, Hazardous Solvent Disposal, Solvent Recycle, n-Hexane Comparison, Standard Methods, Solvent Recommendation, Glossary of Solvent Hazards

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NOMENCLATURE AND ACRONYM

ACGIH: American Conference of Governmental Industrial Hygienists.

AEGL: Acute Exposure Guideline

CFR: Code of Federal Regulations

D: Extract dilution factor

DOT: US Department of Transportation

ERG: Emergency Response

ERPG: Emergency Response Planning

GLP: Good laboratory practice

IARC: International Agency for Research on Cancer

IRIS: Integrated Risk Information System

LEL: Lower explosive limit

LIWT: Lenox Institute of Water Technology

LPE: Laboratory protective equipment

NFPA: National Fire Protection

NIOSH:	National Institute for Occupational Safety and Health
NJDEP:	New Jersey Department of Environmental Protection.
NSTA:	National Science Teachers Association.
NTP:	National Toxicology Program
O&G:	Oil and grease
ODS:	Ozone-depleting substances
OSHA:	Occupational Safety and Health Administration
PAC:	Protective Action Criteria
PEOSHA:	New Jersey Public Employees Occupational Safety and Health Act
PPE:	Personal protective equipment
ppm:	Parts per million parts of air.
R&D:	Research and development
STEAM:	Science, Technology, Engineering, Arts, and Mathematics.
STEM:	Science, Technology, Engineering and Mathematics.
STEL:	Short Term Exposure
TLV:	Threshold Limit Values
TOG:	Total oil and grease, mg/L

UEL:	Upper explosive limit
USEPA:	US Environmental Protection Agency
UV:	Ultra Violet
V:	Volume of sample, L
W:	Weight of oil and grease determined from calibration plot, mg

OIL AND GREASE DETERMINATION, SOLVENT HAZARDS AND WASTE DISPOSAL WHEN USING TRICHLOROMETHANE (CHLOROFORM) FOR EXTRACTION

Lawrence K. Wang and Mu-Hao Sung Wang

1. INTRODUCTION

1.1 General Introduction

A knowledge of the concentration of oil and/or grease present in water, wastewater or liquid sludge is helpful in proper design and operation of treatment systems.

There are six methods [1-9] currently available for quantitative determination of oil, grease and related matter in water, wastewater and sludge: (a) liquid-liquid partition-gravimetric method; (b) partition-infrared method; (c) soxhlet extraction method; (d) extraction method for sludge samples; (e) hydrocarbons method; and (f) solid-phase, partition-gravimetric method.

The partition-gravimetric and soxhlet methods are very time consuming and do not provide the needed precision under certain environmental conditions

The partition-infrared method is designed for samples that might contain volatile hydrocarbons that otherwise would be lost in the solvent removal operations of the gravimetric procedure. When one liter portions of the sewage were dosed with 14.0 mg of a mixture of No. 2 fuel oil and Wesson oil, the recovery of the added oils was 99% with a standard deviation of 1.4 mg. The method may accurately measure as little as 0.2 mg oil and grease, but many water quality laboratories are not equipped with the required infrared spectrophotometer.

Selection of an appropriate method for oil and grease analysis is hinted by APHA-AWWA-WEF [1]. Of the Standard Methods [1], the liquid/liquid partition-gravimetric method (5520B), the partition-infrared method (5520C), the Soxhlet method (5520D), and the solid-phase, partition-gravimetric method (5520G) are for liquid samples. Standard Method 5520C is designed for samples that might contain volatile hydrocarbons that otherwise would be lost in the solvent-removal operations of the gravimetric procedure. Standard Method 5520D is the method of choice when relatively polar, heavy petroleum fractions are present, or when the levels of nonvolatile oil and greases may challenge the solubility limit of the solvent. Standard Method 5520C should be chosen for low levels of oil and grease (less than 10 mg/L) analysis. Standard Method 5520G can be used as an alternated to Standard Method 5520B to reduce solvent volumes and matrix problems [1]. Only Standard Method 5520E is suitable for oil and grease analysis of sludge or similar materials. It is noted that Standard Method 5520F can be used with 5520B, 5520C, 5520D, or 5520G to obtain a hydrocarbon measurement in addition to, or instead of, the oil and grease analysis.

With laboratory waste minimization and management in mind [10-12], the authors introduce three spectrophotometric and colorimetric procedures for rapid measurement of organic solvent extractable substances in water and wastewater [13-15]. Almost all the water quality laboratories in the USA are equipped with a filter photometer, a visible spectrophotometer, and/or a UV/visible spectrophotometer. Any one of the aforementioned instrumentation can be used in the newly developed rapid procedures. Furthermore, more than one organic solvents are recommended for adoption in order to provide an added flexibility [13-15].

It should be noted that the definition of oil and grease (O&G) is based on the procedure used. The oil and grease may include hydrocarbons, vegetable oils, animal fats, waxes, soaps, greases and other related substances. The source of the oil and/or grease, and the presence of extractable non-oily matter will influence the substance measured and interpretation of results. An Unknown Oil is defined as one for which a representative sample of the oil or grease is not available for preparation of a standard. The oil and grease in a mixed sewage or an unidentified oil slick on a surface water are typical examples of unknown oil. A Known Oil is defined as a sample of oil and/or grease that represents the only material of that type used or produced in the processes or represented by the process water or a wastewater.

1.2. Solvent Selection Based on Environmental Impacts, Solvent Hazards and Waste Disposal Technologies

It is necessary to review the history of Standard Methods, in turn, to understand the importance of solvent selection. It is the authors' view that the solvent selection for an analytical method development should be mainly decided by the seriousness of solvent hazards and the convenience of waste disposal. Environmental protection, such as minimization of ozone-depleting substance (ODS) discharge, can be done by a Good Laboratory Practice (GLP), such as solvent recycle, or proper laboratory waste management.

The 12th edition of the Standard Methods for the Examination of Water and Wastewater (i.e. Standard Methods) originally adopted the use of petroleum ether as the solvent for natural and treated waters and n-hexane for polluted waters. The 13th edition Standard Methods adopted trichlorotrifuoroethane as an optional solvent for all O&G sample types. In the 14th to 17th editions of Standard Methods, only trichlorotrifluoroethane was specified for O&G analysis. Since trichlorotrifuoroethane (commercially known as Freon 113, or CFC 113) is one of the major ozone-depleting substances (ODS) which destroys the Earth's precious ozone protection layer [16], an alternative solvent (80% n-hexane and 20% methyl-tert-butyl ether) was included for gravimetric methods in the 19th edition Standard Methods. In the 20th edition Standard Methods, trichlorotrifluoroethane was dropped from all gravimetric analytical procedures (retained for Standard Method 5520C, an infrared method), and replaced with n-hexane. In the latest 23th edition Standard Methods [1] , n-hexane is used for 5520B and trichlorotrifluoroethane is used for 5520C for O&G analysis.

In the authors' research, several organic solvents were investigated. Three organic solvents (trichlorotrifluoroethane, trichloromethane, and trichloroethane) were finally chosen for extraction and analysis of O&G. Accordingly three analytical methods have been developed and reported separately [13, 14, 15] for the convenience of the readers.

It is the authors' opinion that chemist's health (health hazard, PEL, REL, TLV, STEL, toxicity, etc.) and safety (flammability hazard, reactivity hazard, etc.) are as important as the solvent's environmental impacts (such as ozone layer protection, hazardous waste disposal). [10, 12, 17-20].

In each Lenox Institute of Water Technology (LIWT) research report [13, 14, 15], the principle, sampling, sample storage, apparatus, reagents, the analytical procedures for preparation of calibration curves of known oil reference standards, the analytical procedures for preparation of calibration curves of unknown oil reference standards, the procedures for sample analysis, precision and accuracy, typical example of calibration curve, risk management, solvent selection, hazardous solvent disposal, and glossary are presented.

Each selected solvent in this LIWT research is compared with n-hexane which is the standard solvent adopted by the Standard Methods [1] for O&G analysis. Trichloromethane, (chloroform, $CHCl_3$) was one of the three selected solvents in this investigation because chloroform is a popular organic solvent adopted by the Standard Methods [1] for examination of phenol (Standard Method 5530C), anionic surfactant (Standard Method 5540C), [1], and other anionic and cationic surfactants. [25-27]

1.3 Dedication

This publication is dedicated to the author's beloved colleague, Aimee E. Thayer (BS, MS) of the Lenox Institute of Water Technology, Massachusetts, USA.

1.4 Summary and Recommendation

n-Hexane is adopted by the Standard Methods [1] for O&G analysis. The authors compare the selected solvent (chloroform) with n-hexane and conclude that the chloroform is better than n-hexane considering the fire and accident prevention because n-hexane is very flammable, but chloroform is not flammable. In terms of the worker's health hazard, both chloroform and n-hexane are at the same level although chloroform is a "select carcinogen" which needs extra personal protective equipment (PPE) and laboratory protective equipment (LPE).

Since chloroform is widely used in regular laboratories for phenol, anionic surfactants, and cationic surfactants [1, 25-27], this new analytical method involving the use of popular chloroform for O&G extraction will provide extra flexibility.

It is recommended that eventually chloroform in analytical chemistry be replaced by other solvent of non-"select carcinogen" type.

2. PRINCIPLE

The liquid sample containing oil & grease is acidified to a low pH (equal to or less than pH 2) and extracted with an organic solvent (trichloromethane, or chloroform). Under controlled conditions, the oil and grease are extractable into a selected organic solvent, in which the intensity of yellow color is proportional to the oil and grease concentration. At the recommended wavelength and light-path, the oil and grease in the liquid sample can be qualitatively determined. The oil and grease is determined by comparison of the absorbance of the sample extract with oil standards.

3. SAMPLING AND SAMPLE STORAGE

A representative sample of at least 250 mL volume should be collected in a clean glass sample bottle, glass or Teflon stoppered. If the sample is known to have less than 0.1 mg/L of oil and grease, one liter volume of the representative sample should be collected in a large glass bootie, glass or Teflon stoppered.

If the sample volume cannot be readily measured in the field, the sample level in the sampling bottle should be marked for later determination of sample volume in the laboratory.

Losses of oil and grease may occur on sampling equipment; therefore, the collection of a composite sample for analysis is not practical. Individual portions collected at prescribed time intervals must be analyzed separately to obtain an average oil and grease concentration over an extended period of time.

Always collect a separate sample for an oil and grease determination and do not subdivide the sample in the laboratory.

If oil and grease analysis is to be done immediately, no sample preservation is required. Otherwise, the liquid sample should be preserved by the addition of 5 mL of 1:1 sulfuric acid or 1:1 hydrochloric acid per every liter of sample. For example, for exact 300 mL sample in a glass sample bottle, 1.5 mL of 1:1 sulfuric acid will be sufficient for sample preservation if the oil and grease analysis is to be delayed for more than a few hours. The readers are referred to the Standard Methods [1] for more technical information for O&G sample collection, preservation, and storage.

In sampling sludge, precaution must be taken to obtain a true representative sample. Sludge samples should be preserved with 1 mL concentrated hydrochloric acid per 80 grams of sludge sample if oil and grease analysis cannot be made immediately.

Never preserve any samples with organic solvent or other non-recommended chemicals.

4. INTERFERENCE

The selected organic solvent (trichloromethane, or chloroform) has the ability to dissolve not only oil and grease but also other organic substances.

Heavier residuals of petroleum may contain a significant portion of substances insoluble in the recommended organic solvents.

For reduction of interferences caused by synthetic surfactant or other known chemicals, special oil and grease standards should be prepared by the same solvent extraction procedure in the presence of synthetic surfactant, etc.

5. TRICHLOROMETHANE (CHLOROFORM) SPECTROPHOTOMMETRIC METHOD

5.1 Apparatus and Instrumentation

1. Separatory funnel: One liter capacity with inert Teflon stopcock (or equivalent). Note: Do not use glass stopcock lubricated with grease.

2. Analytical equipment: One of the following is required: (a) Spectrophotometer: For use at 400-500 nm, providing light paths of 1 cm, 5 cm and 10 cm; or (b) Filter photometer, providing light paths of 1 cm, 5 cm or longer and equipped with a color filter exhibiting maximum transmittance near 400-500 nm.

3. Cells: Quartz, 1 cm, 5 cm and 10 cm light path length.

4. Syringes or micropipettes: 10, 25, 50, 100 microliter capacity (optional)

5. Filter paper: Whatman No. 40 or equivalent, 11 cm diameter

6. Glass wool

7. Glass or Teflon graduate cylinders: 10, 50, 500, 1000 mL capacity

8. Volumetric flasks: 100-mL capacity, at least two; 50 mL capacity, at least seven.

9. pH paper: For measuring pH of water sample at pH 2 or lower

10. Graduated glass pipettes: For measuring oil standards in the 0-30 mL range.

11. Glass bottles: 50, 500 and 1000 mL capacity, glass or Teflon stoppered.

12. Glass or Teflon filter funnel cone to hold the filter paper with 11 cm diameter.

5.2 Reagents

1. Trichloromethane (chloroform), reagent grade. The solvent should leave no measurable residue on evaporation; distill if necessary. Do not use any plastic tubing to transfer solvent between containers.

2. Strong acid: One of the following is required: (a) Sulfuric acid, H_2SO_4, 1 + 1: Mix equal volumes of concentrated sulfuric acid and distilled water; (b) Hydrochloric acid, HC1, 1 + 1: Mix equal volumes of concentrated hydrochloric acid and distilled water.

3. Sodium sulfate, anhydrous crystal

4. N-hexadecane, reagent grade

5. Iso-octane, reagent grade

6. Benzene, reagent grade

5.3 Procedure for Preparation of Calibration Curves of Known Oil Reference Standard

1. Prepare a Known Oil Reference Standard Stock Solution if the oil and/or grease used or manufactured in the process is known. Accurately weigh slightly over 0.25 gram (i.e. about 0.5 mL) of known oil directly into a 100 mL tared, glass stoppered volumetric flask. Add 80 mL trichloromethane (chloroform) and dissolve the oil. (If, as in the case of a heavy fuel oil, all the oil does not go into solution, let stand overnight. The next day filter through a filter paper into another 100 mL volumetric flask) . Dilute with chloroform to the 100 mL mark. Treat analysis as if all oil had gone into solution. Calculate the volume of chloroform required and dilute the freshly prepared 100-mL oil-in- chloroform solution to a concentration that 1 mL of oil- chloroform mixture gives 2.500 mg oil.

2. Use syringes or micropipettes to transfer 0.2 mL, 0.4 mL, 1 mL, 2 mL, 4 mL, and

8 mL of the Known Oil Reference Standard Stock Solution to six 50-mL volumetric flasks separately, and dilute each flask to the 50-mL mark with pure chloroform. There are now six Known Oil Reference Standard Working Solutions with the oil concentrations of 0.5 mg, 1.0 mg, 2.5 mg, 5.0 mg, 10.0 mg, and 20.0 mg, respectively.

3. Select appropriate wave length, and cell light path length for calibration curves preparation.

The following table serves as an approximate guide for the wave length range of 400-500 nm:

Light Path Length, cm	Oil & Grease Range, mg
1	2-40
5	<0.2-4
10	<0.05-2

Transfer the six Known Oil Reference Standard Working Solutions, one by one, to moisture-free clean cells. Use pure chloroform to zero the spectrophotometer (or a filter photometer) at a selected wave length, and take absorbance readings of these Standard Working Solutions, one by one, at this wave length. At least four wave lengths (400 nm, 425 nm, 450 nm and 500 nm) are recommended to be scanned for calibration curves preparation.

4. Prepare at least four calibration curves (absorbance versus mg oil) at wave lengths of 400 nm, 425 nm, 450 nm and 500 nm.

5. For reduction of interferences caused by synthetic surfactant or other known chemical, special oil and grease standard working solutions should be prepared by the solvent extraction procedure in the presence of synthetic .surfactant, etc.

5.4. Procedure for Preparation of Calibration Curves of Unknown Oil Reference Standard

1. Prepare an Unknown Oil Reference Primary Standard:

Pipette 30.0 mL n-hexadecane, 30.0 mL iso-octane, and 20.0 mL benzene into a 100 mL glass stoppered volumetric flask to prevent evaporation. Assume the specific gravity of this mixture to be 0.769 and maintain the integrity of the mixture by keeping stoppered except when withdrawing aliquots. 10 microliter (uL) = 7.69 mg of oil; or 1 mL = 769 mg of oil.

2. Prepare an Unknown Oil Reference Secondary Standard:

Micropipette 0.650195 mL (or 650.195 uL) of Unknown Oil Reference Primary Standard into a 100 mL glass stoppered volumetric flask, and dilute it with chloroform to the 100 mL mark. 1 mL of Secondary Standard gives 5.00 mg oil. The Secondary Standard remains valid within one week.

3. Use syringes or micropipettes to transfer 0.1 mL, 0.2 mL, 0.5 mL, 1 mL, 2 mL, and 4 mL of the Unknown Oil Reference Secondary Standard to six 50-mL volumetric flasks separately, and dilute each flask to the 50-mL mark with pure chloroform . There are now six Unknown Oil Reference Standard Working Solutions with the Oil concentrations of 0.5 mg, 1.0 mg, 2.5 mg, 5.0 mg, 10.0 mg and 20 mg, respectively.

4. Select appropriate wave length, and cell light path length for calibration curves preparation using the same guide as in last section. Transfer the six Unknown Oil Reference Standard Working Solutions, one by one, to moisture-free clean cells. Use pure chloroform to zero the spectrophotometer (or a filter photometer) at a selected wave length, and take absorbance readings of these Standard Working Solutions, one by one, at this wave length. At least four wave lengths (400 nm, 425 nm, 450 nm and 500 nm) are recommended to be scanned for calibration curves preparation.

5. Prepare at least four calibration curves (absorbance versus mg oil) at wave lengths of 400 nm, 425 nm, 450 nm and 500 nm.

6. For reduction of interferences caused by synthetic surfactant or other known chemicals, special oil and grease standard working solutions should be prepared by

the solvent extraction procedure in the presence of synthetic surfactants, etc.

5.5 Procedure For Sample Analysis

1. Measure exact sample volume on-site, or mark the sample bottle at the water meniscus for later determination of sample volume. If the sample was not acidified at the time of sample collection, add 5 mL/L of 1:1 sulfuric acid (or 1:1 hydrochloric acid) to the sample bottle. After mixing the sample, check the pH by touching pH sensitive paper to the cap to insure that the pH is 2 or lower. Add more acid if necessary.

2. Pour the sample into a separatory funnel. Record the sample volume.

3. Add 50 mL chloroform solvent to the sample bottle , stopper it and rotate the sample bottle to rinse the sides. Transfer the chloroform solvent into the separatory funnel containing known volume of sample. Extract by shaking vigorously for 2.5 minutes. Allow the water layer and chloroform solvent layer to separate. The chloroform solvent layer will stay below the water layer, and will be in yellow color if the chloroform now contains extractable oil and grease.

4. Insert a sufficient amount of glass wool in the stem of the separatory funnel.

5. Filter the chloroform solvent layer into a 100 mL volumetric flask through the glass wool first, then through a filter funnel cone containing a chloroform-moistened Whatman No. 40 filter. Note: An emulsion that fails to dissipate can be broken by pouring about 1 gram sodium sulfate into the filter paper cone and draining the emulsion through the salt. Additional 1 gram portions can be added to the cone as required.

6. Clean the cell thoroughly with chloroform and be sure there is no moisture in the cell. Transfer the oil sample's chloroform extract into the cell. Measure the extracts absorbance with a spectrophotometer or a filter photometer at a recommended wavelength in the range of 400-500 nm. For each extract’s absorbance measurement, the pure chloroform in an identical light path cell shall be used to zero the instrument.

7. Use a calibration plot of absorbance versus mg oil prepared from the standards to determine the mg oil (W) in the sample solution. If the absorbance from one calibration curve exceeds 0.8 for a sample, select another wavelength, or another shorter path length, or dilute sample as required.

8. Calculation:

$$TOG = (W \times D) / V$$

where TOG = total oil and grease concentration in mg/L; W = weight of oil and grease determined from calibration plot, in mg; D = extract dilution factor, if used; and V = volume of sample, either measured exactly on-site or determined by refilling sample bottle to mark line and correcting for acid addition if necessary, in L.

5.6 Precision and Accuracy

The oil and grease concentration as low as 0.1 mg/L can be quantitatively measured with a cell of 5 cm light path length. For determination of oil and grease concentrations below 0.1 mg/L, the use of a cell of 10 cm light path at optimum wave length is required.

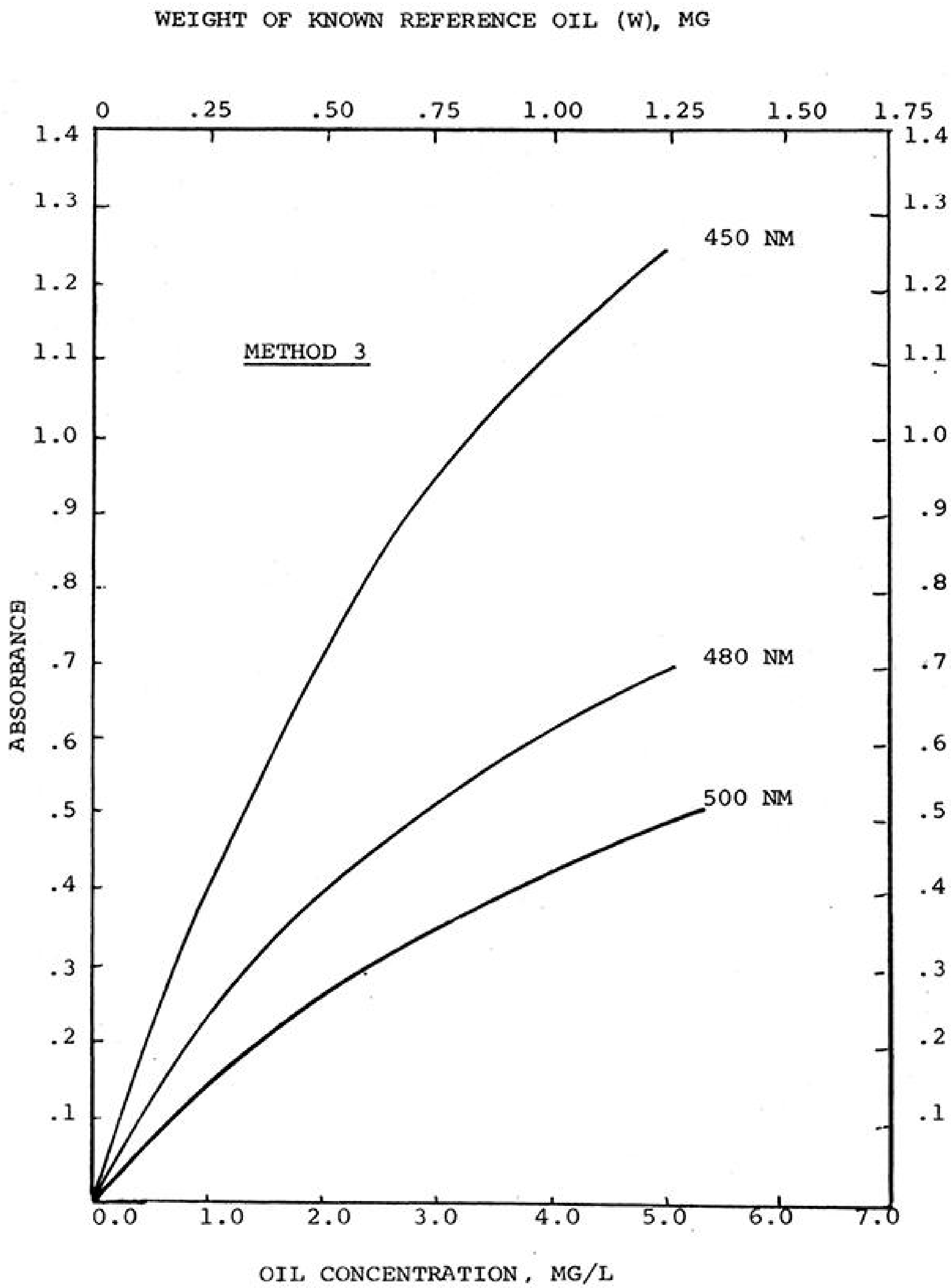
If a filter photometer or field spectrophotometer (such as HACH Spectrophotometer DL-4) is used, the standard deviation for oil and grease measurement is 1 mg/L.

6. TYPICAL EXAMPLE OF CALIBRATION CURVE OF KNOWN OIL REFERENCE STANDARD

The following are the general analytical conditions:

1. Instrument = Bausch & Lomb Spectronic 710 or equivalent
2. Cells = Quartz
3. Sample Size (V) = 250 mL
4. Organic Solvent Volume = 50 mL
5. Blank (Zeroing the Instrument) = Pure Organic Solvent
6. Dilution Factor = 1 (Note: No Dilution)
7. Known Oil = Kendall SAE 30, Dual Action Heavy Duty Motor Oil, Part # 531-7113, M.L-L-46152.
8. Calibration Curve For Trichloromethane (Chloroform) Extraction Spectrophotometric Method (5㎝ Light Path Length) -- See Figure 1.

Figure 1. Calibration Curves For Trichloromethane (Chloroform) Extraction Spectrophotometric Method (5 cm Light Path Length)



7. SOLVENT HAZARDS, RECYCLE AND WASTE DISPOSAL

Table 1 and Table 2 indicate the physical properties and the exposure limits, respectively, of Trichloromethane (chloroform) (Source: OSHA).

Chloroform is a colorless organic liquid (trichloromethane, $CHCl_3$), with a pleasant, sweet odor, which is used as a laboratory or industrial solvent, and to make refrigerants, resins, and plastics, but it is no longer used as an anesthetic. Its chemical numbers are: CAS No. = 67-66-3, DOT No. = UN 1888. Its NJDOH hazard rating are: health = 3 (serious); flammability = 0 (minimal); reactivity = 0 (minimal). Additional hazard information are: hazard class = 6.1; OSHA legal airborne permissible exposure limit PEL = 50 ppm; NIOSH airborne recommended exposure limit REL = 2 ppm, which should not be exceeded in any 60-minute work period; and ACGIH threshold limit value TLV = 10 ppm averaged over an 8-hour work-shift. It is a carcinogen, and its poisonous gases are produced in fire. It can affect workers when inhaled and may absorbed through the skin. It may damage the developing fetus. Its exposure can cause headache, dizziness, lightheadedness and passing out. High exposure can cause the heart to beat irregularly or to stop.

n-Hexane is currently adopted by the Standard Methods for determination of O&G in water and wastewater [1]. n-Hexane is a colorless liquid (normal hexane, $C_{16}H_{14}$), with a gasoline-like odor. Is used in laboratories and as a solvent to remove vegetable oils from crops. It is also found in gasoline and rubber cement.. Its chemical numbers are: CAS No. = 110-54-3, RTK substance No. = 1340; DOT No. = UN 1208. Its NJDOH hazard rating is: health = 2 (moderate); NFPA hazard rating are: flammability = 3 (serious); reactivity = 0 (minimal). It is flammable. Poisonous gases are produced in fire. Its containers may explode in fire. Additional hazard information are: hazard class = 3 (flammable); OSHA legal airborne permissible exposure limit PEL = 500 ppm averaged over an 8-hour workshift; NIOSH airborne recommended exposure limit REL = 50 ppm averaged over a 10-hour workshift; and ACGIH threshold limit value TLV = 50 ppm averaged over an 8-hour workshift. The above exposure limits are for air levels only. n-hexane can affect a chemist when inhaled and by passing through the skin. It can cause reproductive damage, so it must be handled with extreme caution. Contact can irritate and burn the skin and eyes. Prolonged or repeated contact can cause a skin rash, dryness and redness. Inhaling n-hexane can irritate the nose, throat and lungs. Exposure can cause headache, nausea, vomiting, dizziness, lightheadedness and passing out. Higher levels can cause coma and death. n-hexane may damage the nervous system causing numbness, tingling, blurred vision, "pins and needles", and weakness in the hands and feet. n-hexane is a very flammable liquid and a dangerous fire hazard. [21]

n-Hexane is adopted by the Standard Methods [1] for O&G analysis. The authors compare the selected solvent (chloroform) with n-hexane and conclude that the chloroform is better than n-hexane considering the fire and accident prevention because n-hexane is very flammable, but chloroform is not flammable. In terms of the worker's health hazard, both chloroform and n-hexane are at the same level, but chloroform is a "select carcinogen" which needs extra personal protective equipment (PPE) and laboratory protective equipment (LPE). The readers are referred to the section of "Glossary of Organic Solvent Hazards" of this publication for technical information on PPE, LPE, laboratory fume hood, laboratory waste disposal, select carcinogen, etc.

Since chloroform is widely used in regular laboratories for phenol, anionic surfactants, and cationic surfactants [1, 25-27], this newly developed O&G analytical method involving the use of popular chloroform for O&G extraction will provide extra flexibility.

Recycling and reclamation have limited potential in small water quality laboratories, due to the fact that the waste volumes generated are generally too small for economical waste management and reagent purity requirements are too high. However, organic solvents often can be distilled and recovered for reuse. Figure 2 shows the setup of distillate recovery apparatus (Source: APHA-AWWA-WEF) [1]. Alternatively, a water quality laboratory may use commercially available solvent recovery equipment.

The laboratory personnel should follow the Standard Methods 1090 Laboratory Occupational Health and Safety [1] to handle and dispose of all laboratory wastes. Each laboratory chemical, biological, microbiological, thermal, or radiological operations shall have a plan to include waste disposal training, equipment preparation, facility readiness, fire prevention, explosion hazard response, health hazard emergency response, operational procedures, and leadership assignments in case of accidents. The following contaminants should not be discharged to the sewer: (a) concentrated acids or bases; (b) highly toxic, malodorous, infectious, flammable, lachrymatory, or ozone-depleting substances; (c) contaminants, such as soluble heavy metals, that might interfere with the biological activity of wastewater treatment plants; and (d) large waste solid particles that might plug the sewer system. [1, 10]

The laboratory hazardous wastes may be sent off site for further treatment and disposal. Extreme care must be taken in selecting a reputable waste handler and disposal firm because liability does not disappear when the waste leaves the generator's facility. A good waste management firm will assist laboratories in packaging and manifesting "lab packs" 19-L to 208-L (5-gal to 55-gal) drums containing several smaller containers of wastes. A laboratory manager must ensure that the laboratory receives a copy of the completed manifest and certificate of treatment and/or disposal. [1, 10, 22-24]

Figure 2. A Setup Of Distillate Recovery Apparatus (Source: APHA-AWWA-WEF) [1].

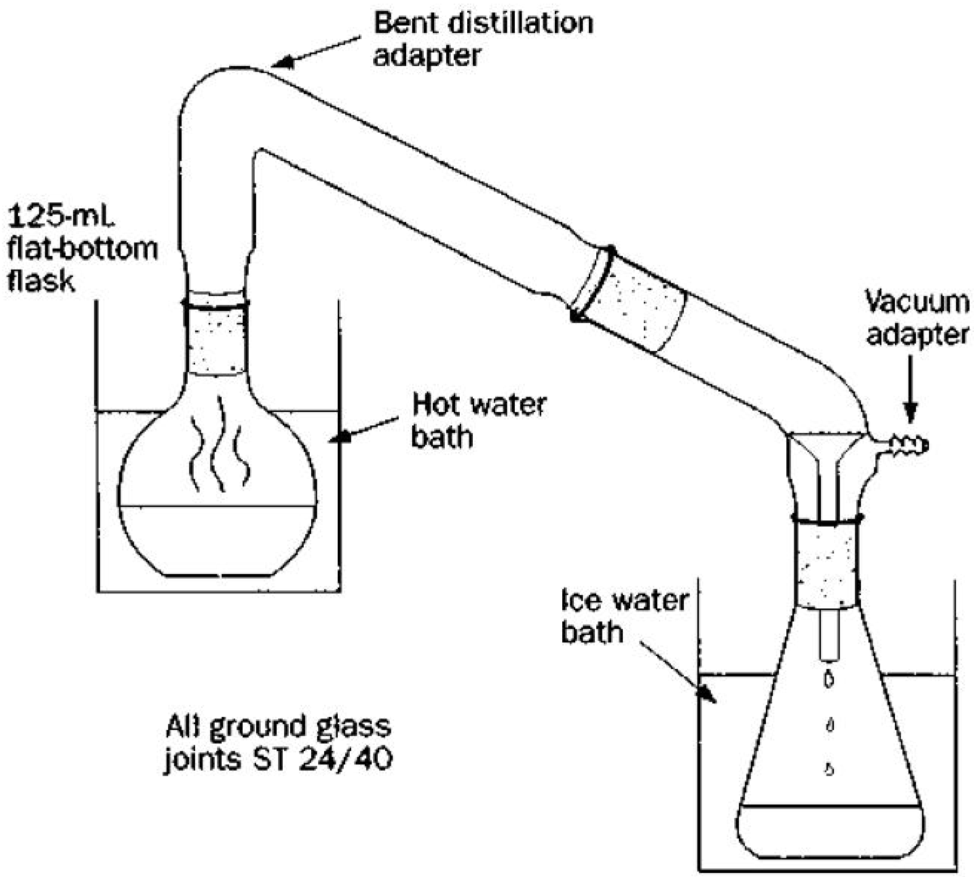


Table 1. Physical Properties of Trichloromethane (Chloroform) (Source: OSHA)

CHLOROFORM (TRICHLOROMETHANE)†

Chemical Identification	
CAS #	67-66-3
Formula	$CHCl_3$
Synonyms	methane trichloride; trichloromethane

Physical Properties			
Physical description	Colorless liquid with a pleasant odor.		
Boiling point	143°F	Molecular weight	119.4
Freezing point/melting point	-82°F	Vapor pressure	160 mmHg
Flash point		Vapor density	4.12
Specific gravity	1.48	Ionization potential	11.42 eV
Lower explosive limit (LEL)		Upper explosive limit (UEL)	
NFPA health rating	2	NFPA fire rating	0
NFPA reactivity rating	0	NFPA special instruction	
Vapor hazard ratio (VHR)			
Historical exceedance percentage			

Table 2. Exposure Limits of Trichloromethane (Chloroform) (Source: OSHA)

Exposure Limits							
OSHA PEL 8-hour TWA (ST) STEL (C) Ceiling Peak		**NIOSH REL** Up to 10-hour TWA (ST) STEL (C) Ceiling		**ACGIH TLV©** 8-hour TWA (ST) STEL (C) Ceiling		**CAL/OSHA PEL** 8-hour TWA (ST) STEL (C) Ceiling Peak	
PEL-TWA		**REL-TWA**		**TLV-TWA**	10 ppm [1990]	**PEL-TWA**	2 ppm (9.78 mg/m³)
PEL-STEL		**REL-STEL**	2 ppm (9.78 mg/m³) [60 minutes]	**TLV-STEL**		**PEL-STEL**	
PEL-C	50 ppm (240 mg/m³)	**REL-C**		**TLV-C**		**PEL-C**	
Skin notation	N	**Skin notation**	N	**Skin notation**	N	**Skin notation**	N
Notes: See 29 CFR 1910.1000 Table Z-1.		**Notes:** CARCINOGEN (Ca): REDUCE EXPOSURE TO LOWEST FEASIBLE CONCENTRATION. See Appendix A		**Notes:**		**Notes:**	
Health factors: See NIH-NLM PubChem.		**IDLH**	500 ppm				
Carcinogenic classifications: IARC-2B, NIOSH-Ca, NTP-R, TLV-A3, EPA-B2; L; NL		**Notes:** Ca					
AIHA emergency response planning guidelines - ERPG-1/ERPG-2/ERPG-3: --/50 ppm/5000 ppm							

8. GLOSSARY OF ORGANIC SOLVENT HAZARDS

1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113): It is a colorless liquid (CFC 113, $C_2Cl_3F_3$), with a faint, sweet or ether-like odor at high concentrations. Is used as a refrigerant, heat transfer medium, solvent and chemical intermediate. Its chemical numbers are: CAS No. = 76-13-1, RTK substance No. = 1904. Its NJDOH hazard rating are: health = 2 (moderate); flammability = 0 (minimal); reactivity = 0 (minimal). It does not burn, although poisonous gases may be produced in fire. Additional hazard information are: hazard class = 6 (poison); OSHA legal airborne permissible exposure limit PEL = 1000 ppm averaged over an 8-hour workshift; NIOSH airborne recommended exposure limit REL = 1000 ppm averaged over a 10-hour workshift and 1250 ppm , not be exceeded during any 15-minute work period; and ACGIH threshold limit value TLV = 1000 ppm averaged over an 8-hour workshift, and 1250 ppm as a STEL (short-term exposure limit). Contact can irritate and burn the skin and cause frostbite. It is not classifiable as to its potential to cause cancer. There is no evidence that it may affect reproduction. Its prolonged or repeated exposure may cause bronchitis s to develop with coughing, phlegm, and/or shortness of breath.

ACGIH: American Conference of Governmental Industrial Hygienists.

Action level: A concentration designated in 29 CFR Part 1910 for a specific substance, calculated as an eight (8)-hour time-weighted average, which initiates certain required activities such as exposure monitoring and medical surveillance.

Acute Exposure Guideline Levels (AEGLs): AEGLs are established by the US Environmental Protection Agency (USEPA). They describe the risk to humans resulting from once-in-a lifetime, or rare, exposure to airborne chemicals.

Allergen: A substance which produces an allergic reaction upon contact with body tissues.
Assistant Secretary: The Assistant Secretary of Labor for Occupational Safety and Health, U.S. Department of Labor, or designee.

American Conference of Governmental Industrial Hygienists (ACGIH) : It is an organization which publishes guidelines called Threshold Limit Values (TLVs) for exposure to workplace chemicals.

Boiling point: It is the temperature at which a substance can change its physical state from a liquid to a gas.

Carcinogen: A carcinogen is a substance that causes cancer.

CAS number: It is unique, identifying number, assigned by the Chemical Abstracts

CFR 29 Section 1910 Subpart Z: The section of OSHA regulations addressing Toxic and Hazardous Substances. Contains the Air Contaminants Standard (or PELs) in Section 1910.1000.

Chloroform: It is a colorless organic liquid (trichloromethane, $CHCl_3$), with a pleasant, sweet odor, which is used as a laboratory or industrial solvent, and to make refrigerants, resins, and plastics, but it is no longer used as an anesthetic. Its chemical numbers are: CAS No. = 67-66-3, DOT No. = UN 1888. Its NJDOH hazard rating are: health = 3 (serious); flammability = 0 (minimal); reactivity = 0 (minimal). Additional hazard information are: hazard class = 6.1; OSHA legal airborne permissible exposure limit PEL = 50 ppm; NIOSH airborne recommended exposure limit REL = 2 ppm, which should not be exceeded in any 60-minute work period; and ACGIH threshold limit value TLV = 10 ppm averaged over an 8-hour work-shift. It is a carcinogen, and its poisonous gases are produced in fire. It can affect workers when inhaled and may absorbed through the skin. It may damage the developing fetus. Its exposure can cause headache, dizziness, lightheadedness and passing out. High exposure can cause the heart to beat irregularly or to stop.

Code of Federal Regulations (CFR): It is the Code of Federal Regulations, which are the regulations of the US government. The collection of rules and regulations originally published in the Federal Register by various governmental departments and agencies. OSHA regulations are found in 29 CFR; US Environmental Protection Agency regulations in 40 CFR; and US Department of Transportation regulations in 49 CFR.

Combustible liquid: Any liquid having a flashpoint at or above 100°F, but below 200°F, except any mixture having components with flashpoints of 200°F, or higher, the total volume of which make up 99% or more of the total volume of the mixture.

Combustible substance: A combustible substance is a solid, liquid or gas that will burn.

Compressed gas: (a) A gas or mixture of gases having, in a container, an absolute pressure exceeding 40 psi at 70°F; or (b) A gas or mixture of gases having, in a container, an absolute pressure exceeding 104 psi at 130°F regardless of the pressure at 70°F; or (c) A liquid having a vapor pressure exceeding 40 psi at 100°F as determined by ASTM D-323-72.

Corrosive (OSHA): A chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact.

Corrosive (USEPA): A waste is corrosive if it has either of the following properties: (a) It is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5; (b) It is a liquid and corrodes steel (SAE 1020) at a rate greater than 6.35 mm (0.250 inch) per year at a test temperature of 55 ^{o}C (130 ^{o}F).

Corrosive substance: A corrosive substance is a gas, liquid or solid that causes destruction of human skin or severe corrosion of containers.

Critical temperature: It is the temperature above which a gas cannot be liquefied, regardless of the pressure applied.

Designated area: An area which may be used for work with "select carcinogens", reproductive toxins or substances which have a high degree of acute toxicity. A designated area may be the entire laboratory, an area of a laboratory or a device such as a laboratory hood.

Emergency Response Guidebook (ERG): ERG is a guide for emergency responders for transportation emergencies involving hazardous substances.

Emergency Response Planning Guideline (ERPG): ERPG values provide estimates of concentration ranges where one reasonably might anticipate observing adverse effects.

Emergency: Any occurrence such as, but not limited to, equipment failure , rupture of containers or failure of control equipment which results in an uncontrolled release of a hazardous chemical into the workplace.

Explosive: A chemical that causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden shock, pressure or high temperature.

Fetus: A fetus is an unborn human or animal.

Flammable substance: A flammable substance is a solid, liquid, vapor or gas that will ignite easily and burn rapidly.

Flammable: A chemical that falls into one of the following categories: (a) Aerosol flammable means an aerosol that, when tested by the method described in 16 CFR 1500.45, yields a flame protection exceeding 18 inches at full valve opening, or a flashback at any degree of valve opening; (b) Gas flammable means: (b1) A gas that, at ambient temperature and pressure forms a flammable mixture with air at a concentration of 13% by volume or less; or (b2) A gas, that at ambient temperature and pressure, forms a range of flammable mixtures with air wider than 12% by volume, regardless of the lower limit. (c) Liquid flammable means any liquid having a flashpoint below 100°F, except any mixture having components with flashpoints of 100°F or higher, the total of which make up 99% or more of the total volume of the mixture. (d) Solid flammable means a solid, other than blasting agent or explosive as defined in § 1910.109(a), that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited burn so vigorously and persistently as to create a serious hazard. A chemical shall be considered to be a flammable solid if, when tested by the method described in 16 CFR 1500.44, it ignites and burns with a self-sustained flame at a rate of one-tenth of an inch per second along its major axis.

Flashpoint: The minimum temperature at which a liquid or solid gives off a vapor in sufficient concentration to ignite with air when tested by one of the following methods: (a) Tagliabue Closed Tester. (b) Pensky- 10 Martens Closed Tester. (c) Setaflash Closed Tester. Organic peroxides, which undergo auto accelerating thermal decomposition, are excluded from any of the flashpoint determination methods specified above.

Hazard warning: Any words, pictures, symbols, or combination thereof appearing on a label or other appropriate form of warning which convey the hazard(s) of the chemical(s) in the container(s).

Hazardous chemical: A chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees.

Health hazard: Includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic system and agents which damage the lungs, skin, eyes, or mucous membranes.

Highly toxic: A chemical falling within any of the following categories: (a) A chemical that has a median lethal dose (LD50) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each; (b) A chemical that has a median lethal dose (LD50) of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each; (c) A chemical that has a median lethal concentration (LC50) in air of 200 parts per million by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

Integrated Risk Information System (IRIS): It is the Integrated Risk Information System database on human health effects that may result from exposure to various chemicals, maintained by federal USEPA.

International Agency for Research on Cancer (IARC): It is an international scientific group involving in cancer research.

Ionization potential: It is the amount of energy needed to remove an electron from an atom or molecule. It is measured in electron volts.

Known oil: A Known Oil is defined as a sample of oil and/or grease that represents the only material of that type used or produced in the processes or represented by the process water or a wastewater.

Laboratory scale: Work with substances in which the containers used for reactions, transfers, and other handling of substances are designed to be easily and safely manipulated by one person. "Laboratory scale" excludes those workplaces whose function is to produce commercial quantities of materials.

Laboratory use of hazardous chemicals: Handling or use of such chemicals in which all of the following conditions are met: (a) Chemical manipulations are carried out on a "laboratory scale"; (b) Multiple chemical procedures or chemicals are used; (c) The procedures involved are not part of a production process, nor in any way simulate a production process; and (d) "Protective laboratory practices and equipment" are available and in common use to minimize the potential for employee exposure to hazardous chemicals.

Laboratory: A facility where the "laboratory use of hazardous chemicals" occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis.

Laboratory protective equipment (LPE): The LPE is for protection of a group of workers and the entire facility, including fume hoods, air conditioning & ventilation facility, lighting controls, noise controls, radioactivity controls, disease/infection controls, fire controls, accident controls, etc. As a rule of thumb, use a fume hood or other local ventilation device when working with any appreciably volatile substance with a TLV less than 50 ppm.

Laboratory-type hood: A device located in a laboratory, enclosure on five sides with a moveable sash or fixed partial enclosed on the remaining side; constructed and maintained to draw air from the laboratory and to prevent or minimize the escape of air contaminants into the laboratory; and allows 11 chemical manipulations to be conducted in the enclosure without insertion of any portion of the employee’s body other than the hands and arms. Provide at least an 8-cm space around all items used in hoods, and ensure that they are at least 15 cm from the front of the hood.

Laboratory waste disposal: The laboratory personnel should follow the Standard Methods 1090 Laboratory Occupational Health and Safety [1] to handle and dispose of all laboratory wastes. Each laboratory chemical, biological, microbiological, thermal, or radiological operations shall have a plan to include waste disposal training, equipment preparation, facility readiness, fire prevention, explosion hazard response, health hazard emergency response, operational procedures, and leadership assignments in case of accidents. The following contaminants should not be discharged to the sewer: (a) concentrated acids or bases; (b) highly toxic, malodorous, infectious, flammable, lachrymatory, or ozone-depleting substances; (c) contaminants, such as soluble heavy metals, that might interfere with the biological activity of wastewater treatment plants; and (d) large waste solid particles that might plug the sewer system. [1, 10]

Lower Explosive Limit (LEL): It is the lowest concentration of a combustible substance (gas or vapor) in the air capable of continuing an explosion.

Median Lethal Concentration (LC50): The concentration of a material in air that on the basis of laboratory tests (respiratory route) is expected to kill 50% of a group of test animals as a single exposure in a specified time period.

Median Lethal Dose (LD50): The single dose of a substance that causes the death of 50% of an animal population from exposure to the substance by any route other than inhalation. Medical consultation: A consultation which takes place between an employee and a licensed physician for the purpose of determining what medical examinations or procedures, if any, are appropriate in cases where a significant exposure to a hazardous chemical may have taken place.

Methyl chloroform: It is a colorless organic liquid (1,1,1-trichloroethane, or methyltrichloromethane, $C_2H_3Cl_3$), with a ether-like odor, which is used as a laboratory or industrial solvent, spot cleaner, or degreaser, and a raw material in making other chemicals. Its chemical numbers are: CAS No. = 71-55-6, DOT No. = UN 2832. Its NFPA hazard rating are: health = 2 (moderate); flammability = 1 (slight); reactivity = 0 (minimal). Additional hazard information are: hazard class = 6 (poison); OSHA legal airborne permissible exposure limit PEL = 350 ppm averaged over an 8-hour workshift; NIOSH airborne recommended exposure limit REL = 350 ppm, which should not be exceeded during any 15-minute work period; and ACGIH threshold limit value TLV = 350 ppm averaged over an 8-hour workshift, and 450 ppm as a STEL (short-term exposure limit). It is not classifiable as to its potential to cause cancer. It may cause mutations or genetic changes. There is limited evidence that methyl chloroform may damage the developing fetus in animals. Its prolonged or repeated contact can cause a skin rash, dryness and redness. Its exposure to very high levels may cause irregular heartbeat.

mg/m^3 : It means milligrams of a chemical in a cubic meter of air. It is a measure of concentration (weight/volume).

MSDS: It is Material Safety Data Sheet. See Safety Data Sheet.

Mutagen: A mutagen is a substance that causes mutations.

Mutation: A mutation is a change in the genetic material in a body cell. Mutations can lead to birth defects, miscarriages, or cancer.

National Fire Protection Association (NFPA): It is an organization that classifies substances according to their fire and explosion hazard.

National Institute for Occupational Safety and Health (NIOSH): NIOSH is an organization that tests equipment, evaluates and approves respirators, conducts studies of workplace hazards, and proposes standards to OSHA.

National Toxicology Program (NTP): It is a US national program which tests chemicals and reviews evidence for cancer.

NFPA: National Fire Protection Association.

n-Hexane : It is a colorless liquid (normal hexane, $C_{16}H_{14}$), with a gasoline-like odor. Is used in laboratories and as a solvent to remove vegetable oils from crops. It is also found in gasoline and rubber cement.. Its chemical numbers are: CAS No. = 110-54-3, RTK substance No. = 1340; DOT No. = UN 1208. Its NJDOH hazard rating is: health = 2 (moderate); NFPA hazard rating are: flammability = 3 (serious); reactivity = 0 (minimal). It is flammable. Poisonous gases are produced in fire. Its containers may explode in fire. Additional hazard information are: hazard class = 3 (flammable); OSHA legal airborne permissible exposure limit PEL = 500 ppm averaged over an 8-hour workshift; NIOSH airborne recommended exposure limit REL = 50 ppm averaged over a 10-hour workshift; and ACGIH threshold limit value TLV = 50 ppm averaged over an 8-hour workshift. The above exposure limits are for air levels only. n-hexane can affect a chemist when inhaled and by passing through the skin. It can cause reproductive damage, so it my be handled with extreme caution. Contact can irritate and burn the skin and eyes.. Prolonged or repeated contact can cause a skin rash, dryness and redness. Inhaling n-hexane can irritate the nose, throat and lungs. Exposure can cause headache, nausea, vomiting, dizziness, lightheadedness and passing out. Higher levels can cause coma and death. n-hexane may damage the nervous system causing numbness, tingling, blurred vision, "pins and needles", and weakness in the hands and feet. n-hexane is a very flammable liquid and a dangerous fire hazard.

NJDEP: It is the New Jersey Department of Environmental Protection, USA..

Occupational Safety and Health Administration (OSHA): It is the US federal agency which adopts and enforces health and safety standards.

Oil and grease (O&G): The O&G definition is based on the procedure used. The oil and grease may include hydrocarbons, vegetable oils, animal fats, waxes, soaps, greases and other related substances. The source of the oil and/or grease, and the presence of extractable non-oily matter will influence the substance measured and interpretation of results.

Organic peroxides: An organic compound that contains the bivalent -O-O-structure and which may be considered to be a structural derivative of hydrogen peroxide where one or both of the hydrogen atoms has been replaced by an organic radical.

OSHA: Occupational Safety and Health Administration.

Oxidizer: A chemical other than a blasting agent or explosive as defined in §1910.109(a), that initiates or promotes combustion in other materials, thereby causing fire either of itself or though the release of oxygen or other gases.

PEOSHA: It is the New Jersey Public Employees Occupational Safety and Health Act, which adopts and enforces health and safety standards in public workplaces.

Permeated: It is the movement of chemicals through protective materials.

Permissible Exposure Limit (PEL): The maximum air contaminant concentration a worker can be exposed to on a repeated basis without developing adverse effects. Published and enforced by OSHA as a legal standard.

Personal protective equipment (PPE): PPE are the personal equipment that protect each worker from harmful hazardous substances or energy, so the each worker can be healthy and safe. PPE include: (a) eye protection equipment, such as safety goggles, dark eye glasses, face shields, etc.; (b) skin protection equipment, such as gloves, chemical protective cloths, thermal protective cloths, helmets, etc.; (c) respiratory protection equipment, such as masks, respirators, etc.; and (d) other special protective equipment, such as radioactive protective shields, safety shoes, ear protective equipment, etc. Contact lenses are not recommended to be used in a laboratory, and a worker who wears contact lenses must report to the laboratory manager.

Physical hazard: A chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer pyrophoric, unstable or water reactive.

ppm : It means parts of a substance per million parts of air. It is a measure of concentration by volume in air.

Principal investigator: An individual with primary responsibility for a program or project in a specific laboratory.

Protective Action Criteria (PAC): They are values established by the US Department of Energy and are based on AEGLs and ERPGs. They are used for emergency planning of chemical release events.

Protective laboratory practices and equipment: Those laboratory procedures, practices and equipment accepted by laboratory health and safety experts as effective, or that the employer can show to be effective, in minimizing the potential for employee exposure to hazardous chemicals.

Reactive (EPA): A waste is reactive if it has any of the following properties: (a) It is normally unstable and readily undergoes violent change without detonating; (b) It reacts violently with water; (c) It forms potentially explosive mixtures with water; (d) When mixed with water, it generates toxic gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment; (e) It is a cyanide or sulfide bearing waste which, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment; (f) It is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement; (g) It is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure; (h) It is identified by the DOT as a forbidden explosive, Class A explosive, or Class B explosive.

Reactive substance: A reactive substance is a solid, liquid or gas that releases energy under certain conditions.

Reproductive Toxins: Chemicals which affect the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis).

Safety Data Sheet (SDS): Written or printed material concerning a hazardous chemical which is prepared in accordance with the requirements of the Hazard Communication Standard.

Select carcinogen: Any substance which meets one of the following criteria: (a) It is regulated by OSHA as a carcinogen; or (b) It is listed under the category, "known to be carcinogens" in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) (latest edition); or (c) It is listed under Group 1 ("carcinogenic to humans") by the International Agency for Research on Cancer Monographs (IARC) (latest editions); or (d) It is listed in either Group 2A or 2B by IARC or under the category, "reasonably anticipated to be carcinogens" by NTP, and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria: (A) After inhalation exposure of 6-7 hours per day, 5 days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m^3 ; (B) After repeated skin application of less than 300 (mg/kg of body weight) per week; or (C) After oral dosages of less than 50 mg/kg of body weight per day.

Sensitizer: A chemical that causes a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the chemical.

Short Term Exposure Limit (STEL): STEL is usually a 15minute exposure that should not be exceeded at any time during a work day.

Teratogen: A teratogen is a substance that causes birth defects by damaging the fetus.

Threshold Limit Value (TLV): Represents the air concentrations of chemical substances to which it is believed that workers may be exposed daily without adverse effect. Published by the ACGIH.

Unknown oil: An Unknown Oil is defined as one for which a representative sample of the oil or grease is not available for preparation of a standard. The oil and grease in a mixed sewage or an unidentified oil slick on a surface water are typical examples of unknown oil.

Unstable (reactive) (OSHA): A chemical which is the pure state, or as produced or transported, will vigorously polymerize, decompose, condense, or will become self-reactive under conditions of shocks, pressure or temperature.

Upper Explosive Limit (UEL): UEL is the highest concentration in air above which there is too much fuel (gas or vapor) to begin a reaction or explosion.

USDOT: It is the US Department of Transportation, the federal agency that regulates the transportation of chemicals.

USEPA: It is the US Environmental Protection Agency, the federal agency responsible for regulating environmental hazards and drinking water, and other environmental affairs.

Vapor Density is the ratio of the weight of a given volume of one gas to the weight of another (usually Air), at the same temperature and pressure.

Vapor pressure: The vapor pressure is a force exerted by the vapor in equilibrium with the solid or liquid phase of the same substance. The higher the vapor pressure the higher concentration of the substance in air.

Water reactive: A chemical that reacts with water to release a gas that is either flammable or presents a health hazard.

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APPENDIX A

Editors of

"EVOLUTIONARY PROGRESS IN SCIENCE, TECHNOLOGY, ENGINEERING, ARTS AND MATHEMATICS (STEAM)"

1. Dr. Lawrence K. Wang (王 抗 曝)

Editor Lawrence K. Wang has served the society as a professor, inventor, chief engineer, chief editor and public servant (UN, USEPA, NY, Albany) for 50+ years, with experience in entire field of environmental science, technology, engineering, arts and mathematics (STEAM). He is a licensed NY-MA-NJ-PA-OH Professional Engineer, a certified NY-MA-RI Laboratory Director, a MA-NY Water Operator, and an OSHA Train-the-Trainer Instructor.

He has special passion, and expertise in developing various innovative technologies, educational programs, licensing courses, international projects, academic publications, and humanitarian organizations, all for his dream goal of promoting world peace. He is a retired Acting President/Professor of the Lenox Institute of Water Technology (LIWT), USA, a United Nations Industrial Development Organization (UNIDO) Senior Advisor in Vienna, Austria, and a former professor/visiting professor of Rensselaer Polytechnic Institute, Stevens Institute of Technology, University of Illinois, National Cheng Kung University, Zhejiang University, and Tongji University.

Dr. Wang is the author of 750+ papers and 60+ books, and is credited with 29 invention patents. He holds a BSCE degree from National Cheng Kung University, Taiwan, ROC, a MSCE degree from the University of Missouri, a MS degree from the University of Rhode Island and a PhD degree from Rutgers University, USA. Currently he is the book series editor of CRC Press, Springer Nature Switzerland, Lenox Institute Press, World Scientific Singapore, and John Wiley.

Dr. Wang has been a Delegate of the People to People International Foundation, an American Academy of Environmental Engineers (AAEE) Diplomate, a member of WEF, AWWA, ASCE, AIChE, ASPE, CIE and OCEESA, and a recipient of WEF Kenneth Research Award (NY), Five-Star Innovative Engineering Award (first DAF drinking water plant in Americas), and Korean Pollution Control Association Award (Transfer of flotation technology to South Korea).

2. Dr. Hung-ping Tsao (曹 恆 平)

Editor Hung-ping Tsao has been a mathematician, a university professor, and an assistant actuary, serving private firms and universities in the United States and Taiwan for 30+ years. Dr. Tsao has been an Associate Member of the Society of Actuaries and a Member of the American Mathematical Society.

His research have been in the areas of college mathematics, actuarial mathematics, management mathematics, classic number theory and Sudoku puzzle solving. In particular, bikini and open top problems are presented to share some intuitive insights and some type of optimization problems can be solved more efficiently and categorically by using the idea of the boundary being the marginal change of a well-rounded region with respect to its inradius; theory of interest, life contingency functions and pension funding are presented in more simplified and generalized fashions; the new way of the simplex method using cross-multiplication substantially simplified the process of finding the solutions of optimization problems; the generalization of triangular arrays of numbers from the natural sequence based to arithmetically progressive sequences based opens up the dimension of explorations; the introduction of an innovative way to solve Sudoku puzzles makes everybody's life so much easier and other STEAM project development.

Dr. Tsao is the author of 10+ books and over 40 academic publications. Among all of the above accomplishments, he is most proud of solving manually in the total of ten hours the hardest Sudoku posted online by Arto Inkala in early July of 2012 and introducing an easy way to play Sudoku in 2019.

He earned his high school diploma from the High School of National Taiwan Normal

University, his BS and MS degrees from National Taiwan Normal University, Taipei, Taiwan, his second MS degree from the UWM in USA, and a PhD degree from the University of Illinois, USA.

Editors of the eBOOK Series of the *"EVOLUTIONARY PROGRESS IN SCIENCE, TECHNOLOGY, ENGINEERING, ARTS AND MATHEMATICS (STEAM)"*

Dr. Lawrence K. Wang (王抗曝) - - left

Dr. Hung-ping Tsao (曹恆平) -- right

APPENDIX B

THE E-BOOK SERIES OF

"EVOLUTIONARY PROGRESS IN SCIENCE,TECHNOLOGY, ENGINEERING, ARTS AND MATHEMATICS (STEAM)"

The acronym STEM stands for “science, technology, engineering and mathematics”. In accordance with the National Science Teachers Association (NSTA), “A common definition of STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy”.

The problem of this country has been pointed out by the US Department of Education that “All young people should be prepared to think deeply and to think well so that they have the chance to become the innovators, educators, researchers, and leaders who can solve the most pressing challenges facing our nation and our world, both today and tomorrow. But, right now, not enough of our youth have access to quality STEM learning opportunities and too few students see these disciplines as springboards for their careers.” STEM learning and applications are very popular topics at present, and STEM related careers are in great demand.

According to the US Department of Education reports that the number of STEM jobs in the United States will grow by 14% from 2010 to 2020, which is much faster than the national average of 5-8 % across all job sectors. Computer programming and IT jobs top the list of the hardest to fill jobs.

Despite this, the most popular college majors are business, law, etc., not STEM related. For this reason, the US government has just extended a provision allowing foreign students that are earning degrees in STEM fields a seven month visa extension, now allowing them to stay for up to three years of “on the job training”. So, at present STEM is a legal term.

The acronym STEAM stands for “science, technology, engineering, arts and mathematics”. As one can see, STEAM (adds “arts”) is simply a variation of STEM. The word of “arts” means application, creation, ingenuity, and integration, for enhancing STEM inside, or exploring of STEM outside.

It may also mean that the word of “arts” connects all of the humanities through an idea that a person is looking for a solution to a very specific problem which comes out of the original inquiry process. STEAM is an academic term in the field of education. The University of San Diego and Concordia University offer a college degree with a STEAM focus.

Basically STEAM is a framework for teaching or R&D, which is customizable and functional, thence the “fun” in functional. As a typical example, if STEM represents a normal cell phone communication tower looking like a steel truss or concrete column, STEAM will be an artificial green tree with all devices hided, but still with all cell phone communication functions. This e-book series presents the recent evolutionary progress in STEAM with many innovative chapters contributed by academic and professional experts.