Environmental Industry is a new concept. This mainly consists of the industries that affect the environment directly. This industry provides environmental products as well as services. Two distinct phases of the industry can be visualised. The first phase includes public infrastructure services and the second phase includes enforcement of environmental legislation. The environmental industry in the USA is divided into the following segments:

From the classifications given below, it can be seen that chemical analysis of environmental samples is of very high significance for the industry. Choice of the suitable analytical method depends on the nature of the sample as well as the information sought.

Gas chromatography (GC) provides quantitative analysis of volatiles and semivolatile found in gas, liquid as well as solid matrices. GC finds applications in pharmaceuticals, food, medical materials, pesticides, environmental and petroleum industries, to mention a few.

Gas chromatography is the analytical technique of separating and analysing the components of a mixture by volatilising them without decomposition. Gas-solid chromatography developed by Fritz Prior in 1947 and gas-liquid chromatography developed by A.J.P. Martin in 1950, were the predecessors of modern gas chromatography. The key parts of a gas chromatograph (GC) are a sample injector, a separator column, an oven (thermostat) for the separator, a source of inert gas for mobile phase, compatible detector for analytes in the sample and a data system. The past 60 years have seen tremendous developments in this analytical technique. Modifications in injection ports, separation columns, oven design, detector design and optimisation—all have helped gas chromatography in reaching a mature stature. Application

Advanced instrumentation allows for field sample analysis, which helps in curtailing loss of sample integrity and delay in sample analysis.

Environmental industries which have the maximum use of gas chromatography for the purpose of bulk composition analysis, carbon monoxide content, sulphurous compounds are landfill operations, biogas, petroleum and fuel, and water treatment plants.

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Industrialisation and neglect of clean-up and waste disposal have led to world-wide environmental pollution. Many nations have realised the situation and taken up activities for damage reduction and protection. Concerned laws have been passed and rules stipulated by regulatory bodies. In order to meet the legal requirements, suitable analytical protocols have to be established. Much advancement in analytical sciences has come about as a result of such stringent requirements. Trace analysis of specific molecules in complex matrix is an area that needed to be developed to meet this target. Gas chromatography is the technique that is specially required for organic trace analysis. In this case, sampling holds as much importance as detection. Mobile detectors were developed in order to save time from transportation of samples to distant laboratories. Preservation of analyte sample integrity, prevention of sample degradation and qualitative screening of samples before their selection for elaborate analysis—all could be achieved if the analytical tool is taken to the sample point. This gave a boost to the development of mobile gas chromatographs, portable as well as transportable. Some of them are simple hand-held machines whereas others are sophisticated enough to generate results of laboratory quality. This article highlights a few examples currently available in market.

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of GC techniques saw tremendous rise in the fields of research, production monitoring, quality check in chemical, petrochemical, pharmaceutical industries, efficient management of industries, forensic science etc. Thus stationary gas chromatographs of different sizes and configurations came about to be developed during the 70's and 80's. Industry requirement demanded the development of laboratory desk-top and process on-line as well as at line GCs. In later years, the requirement of trace analysis and analyte identification for environmental, legal and security reasons demanded the development of portable instruments. Here also, development was required at two scales- small portable hand-held instruments for quick, qualitative detection and medium sized transportable (taken to location on vehicles) instruments for quantitative on-site analysis.

Advanced instrumentation allows for field sample analysis, which helps in cutting loss of sample integrity and delay in sample analysis. The steps involved in laboratory analysis and field analysis are as follows:

Volatile Organic Compounds (VOCs)

Naturally occurring methane is mainly produced by methanogenesis which is a form of anaerobic respiration used by organisms that occupy landfill, ruminants and guts of termites. Other than methane, biological sources emit an estimated 1150 teragrams of carbon per year in the form of VOCs. The major constituent of VOCs produced by plants is isoprene which is the building block for terpene. Anthropogenic emission of VOCs is estimated at 142 teragrams of carbon per annum (0.14 million building block for terpene. Anthropogenic emission of VOCs is estimated at 142 teragrams of carbon per annum (0.14 million building block for terpene. Anthropogenic emission of VOCs is estimated at 142 teragrams of carbon per annum (0.14 million building block for terpene. Anthropogenic emission of VOCs is estimated at 142 teragrams of carbon per annum (0.14 million building block for terpene. 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a factor of 5. Standard calibration curves are generated and stored in the computer and sample data is compared with the stored data. The laboratory analysis of groundwater pollutants took 50 minutes using GCMS whereas the same sample could be analysed within 2 minutes using Model 4100 SAW/GC in the field.

The TRIDION®-9 GCMS (Torion® Technologies Inc./Irtech) was awarded the most innovative product in 2012 at ExpoLAB 2012, Poland. High speed LTM capillary GC is combined with miniaturised toroidal ion trap mass spectrometer (TMS). It weighs about 14.5 kg, operates on rechargeable battery along with on-board helium carrier gas cartridge. T-9 is portable, fast, and reliable. Analysis time is about 3 minutes. Variety of compounds like chemical warfare agents, environmental pollutants, hazardous materials and food contaminants can be analysed by this instrument. The cost of analysis is low compared to traditional laboratory based GCMS. Sample introduction is by regular syringe injection or CUSTODION® SPME syringes.

Solid phase micro extraction (SPME) is a solvent-free technique that combines extraction and concentration of analytes in a simple step. Analytes can be extracted from gases, liquids and dissolved solids.

INFLEXION NAPSTE Smart Plus Chemical Identification System

This instrument aids in the fast detection, identification and quantification of toxic industrial chemicals (TIC) and chemical warfare agents (CWA) on-site. Hapstone Smart Plus is a person- portable GCMS that gives laboratory-quality results in short time. Use of concentrator for both initial sampling and low-level detection in the ppb/ppm level reduces the time of switch. Special facility of "Survey Sample Indicator" changes colour to specify when a good sample is achieved by adjusting the probe distance. The analysis results are matched with database of NIOSH & IDLH # and the compounds identified and quantified.

**FROG-4000**, a hand-held, portable system from Defiant Technologies. Defiant Technologies have developed a hand-held portable system, FROG-4000 for the detection of BTEX (benzene, toluene, ethyl benzene & xylenes) and VOCs (volatile organic compounds like TCE, PCE) in water and soil, as well as VOCs in pharmaceuticals. It can be used as a field sample analyser as well as a screening machine in laboratories. The instrument, when set up in the field, gives the appearance of a frog.

**Canary-Three** is an intelligent handheld GC/SAW system from Defiant Technologies for monitoring liquid and semivolatile organic compounds (SVOCs). The smart sampling system ensures selection of appropriate sample volume depending on the analyte concentration so that the detector is not overloaded. Canary-Three has a detector in one pathway for rapid screening and another detector in the pathway containing a microGC for more detailed analysis. The two-detector system enables quick analysis of samples.

**Custodion® Spme Syringe**

**Gas phase analysis system components**

- A. Diaphragm pump, circulates carrier gas through the system
- B. Preconcentrator, collects and injects VOCs into the GC Column
- C. Micro gas chromatography column, separates VOCs
- D. Photionisation detector, 10.6 eV Lamp, detects VOCs
- E. Sparge Valve, directs pump flow into sparge bottle to purge out VOCs from sample
- F. Flow Selection Valve, determines flow direction during SPARGE or ANALYSIS mode
- G. Bypass valve, allows VOCs to get collected on preconcentrator (B) and bypass micro-GC (C) and PID (D)
- H. Pump split, provides a small leak in pump flow for improved flow control

**FROG-4000 in field analysis**

Scrubbed ambient air is used as carrier gas. The instrument weighs just 2.2 kg (lbs). Dimensions are 10 x 7.5 x 14.5 inches. The microelectromechanical systems (MEMS) fabrication technology has made the miniaturisation of the laboratory instrument gas chromatograph adaptable for field analysis like rechargeable battery operation and no requirement for carrier gases. Performs lab-quality GC analysis of BTEX content in water samples in less than 5 minutes. Method Detection Limits (MDL) for BTEX components are reported as < 0.5 µg/ml with % RSD >20.

The major functional sections are i) the purge and trap (P&T) system and ii) the gas phase analysis system. The P&T system is related to the loading of sample, sparging of liquid samples to release VOCs, and introduction of gas phase analytes to the analyser system. The gas module is the heart of FROG-4000. It consists of miniaturised preconcentrator, microGC and photoionosation detector.

**Canary-One**

Liquid sample injection port, Canary-3

**Cycle Time:** 2 minutes,
**Dimensions & weight:** 12 x 6 x 4 inches, 3.7 kgs
**Carrier gas:** Ambient Air
**Can - analyse selected and programmed chemicals in both liquid and air samples**
**Micromachined (MEMS) column and SAW detector**

Choice of 3 thermal desorption preconcentrator inlets for samples of different volatility. For high volatiles, a tortuous path preconcentrator having very high surface area to volume, finned structure that supports sorptive coatings is designed. The coatings are sol-gels, which provide high capacity, selective sorption, and low mass. Upon heating, the low thermal mass releases the analytes in a plug to the GC. The column is a work of micromachined art. It is a three-layer sandwich called the LIGA-GC.

The center is a nickel coupon with an array of holes. The “bread” is a...
Portable / Field Testing

Annexure

REL – II - Recommended exposure limit recommended air-borne exposure limit for coal-tar pitch volatiles, (cyclohexane extractable fraction), averaged over 10-hour work shift

MCL – II - Minimum Contaminant Level

NIOSH & DLH # - National institute for Occupational safety and Health & Immediately Dangerous to Life or Health

Detectors for SRI Environmental and BTEX GC


Analytical Methods

EPA Methods

8010 – Halogenated volatile organics by gas chromatography
8015 – Nonhalogenated volatile organics by gas chromatography : Total Petroleum Hydrocarbons by GC/FID
8021 – Halogenated volatiles by gas chromatography using photoionisation and electrolytic conductivity detectors in series: Capillary Column Technique

TO-14 – Volatile organic compounds in ambient air using Summa canister sampling and gas chromatography (GC) analysis

ISO Methods

ISO 6974-4:2000 Natural gas – Determination of composition with defined uncertainty by gas chromatography – Part 4: Determination of nitrogen, carbon dioxide and C1 to C5 and C6+ hydrocarbons for a laboratory and on-line measuring system using two columns

GPA Methods

GPA 2172-09 Calculation of Gross Heating Value, Relative Density, Compressibility and Theoretical Hydrocarbon Liquid Content for Natural Gas Mixtures for custody transfer: STANDARD published 01/01/2009 by Gas Processors Association

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10. Toxicity of Polynuclear Aromatic Hydrocarbons (PAHs)
12. Surface Acoustic Wave/Gas Chromatography System for Trace Vapour Analysis
14. Measurement of purgeable organic compounds in water by capillary column gas chromatography/ mass spectrometry
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Quadrex SRI Model 310C

Quadrex SRI Model 310C is reportedly the smallest custom-configured, transportable, full Featured GC available presently. Footprint dimensions are 12.5”W x 14.5”D x 13”H. The instrument can be used for both field and desk-top applications. It provides ambient to 400ºC temperature programming capability, multiple ramps, choice of 4 detectors and 2 injectors. The fast cooling system enables high sample throughput. Options of standard detectors like FID, PID, ECD, DELCD, TCD, NPD, PFD & HD. Preconfigured and custom featured portable GCs are made by Quadrex. As in the case of full-fledged laboratory gas chromatographs, accessories such as gas sampling valves, purge and trap, headspace and microevaporators are available for fitting with the bigger models of Quadrex portable GCs. Environmental and BTEX samples can be analysed. For laboratory or mobile field testing of environmental samples, Environmental GC is one of the good configurations. Equipped with purge and traps, FID and PID/DELCD combination detectors, certification quality data for EPA methods 8010, 8015, 8021, TO-14 and many others can be generated. DELCD is very similar to ECD in sensitivity but is much more selective to halogens and unresponsive to oxygen. SRI DELCD differs from conventional delco detectors in that it neither uses a solvent electrolyte nor is a nickel reaction tube and the reaction products are detected in the gas phase. In the high sensitivity mode, DELCD is capable of detecting picogram levels of halogen containing compounds.

Agilent LTM 5975T GCMS System

Although GCMS has long been considered as the most important instrument for environmental laboratories, potential of field application has not been explored fully. Design modification in terms of ruggedness and miniaturisation is necessary to put the instrument to field use. Low thermal mass fast GC is the most recent technique and field instruments are being designed based on this principle. E.g. LTM series II rapid heating/cooling technique by Agilent. The technology combines a fused silica capillary column with heating and temperature sensing components wound around it, which gives faster temperature ramp rates. Compared to conventional GCs where the oven is heated by air bath technology, direct resistive heating of capillary in LTM technology enables fast heating and cooling, thus reducing the analysis cycle and permitting high sample throughput.

Agilent LTM II 5975T is the first commercial transportable GCMS system that delivers the same quality of results as the high-end 5975 GCMSD instruments. The dimensions of the basic instrument without any accessories is 41 cm H x 60.8 cm W x 65 cm D; 31.8 kg weight. The dimensions of the basic system that delivers the same quality of results as the high-end Agilent LTM II 5975T is the first commercial transportable GCMS analysis cycle and permitting high sample throughput. The technology enables fast heating and cooling, thus reducing the cycle time of analysis.

Agilent LTM II 5975T loaded on a vehicle

Gas chromatography became the work-horse for vapourisable organic compounds analysis by 1980s. Petroleum refining and chemical industries made the maximum use of this technique. Concerns of trace impurities in pharmaceuticals, food and drinking water led to improvement in the sensitivity and detection limit of GC techniques. Last few decades of the twentieth century saw developments in preconcentration techniques, separation techniques, column design and detector concepts. Environmental concern & laws enforced by the close of the millennium, which led to the development of sensors and detectors that can give indication about hazardous materials at point-of-source. Thus, the turn of the century is seeing a flurry of activities in mobile detector technology. Specific sensors may have better detection capabilities but they are limited in applicability. To detect and analyse specific entities in complex matrices, separation techniques are also important. This has given boost to gas chromatography, which can use selected detectors as per the requirement of analysis. The necessity for analysis of trace organic compounds at point-of-source has led to developments in mobile gas chromatography. The progress in electrochemical miniaturisation, separation techniques, electronics devices and computation, has helped in downsizing gas chromatographs. Portable and transportable gas chromatographs are presently getting wide acceptance in environment monitoring. Examples of a few mobile GCs presently available commercially are discussed in this article.

Summary:

Gas chromatography became the work-horse for vapourisable organic compounds analysis by 1980s. Petroleum refining and chemical industries made the maximum use of this technique. Concerns of trace impurities in pharmaceuticals, food and drinking water led to improvement in the sensitivity and detection limit of GC techniques. Last few decades of the twentieth century saw developments in preconcentration techniques, separation techniques, column design and detector concepts. Environmental concern & laws enforced by the close of the millennium, which led to the development of sensors and detectors that can give indication about hazardous materials at point-of-source. Thus, the turn of the century is seeing a flurry of activities in mobile detector technology. Specific sensors may have better detection capabilities but they are limited in applicability. To detect and analyse specific entities in complex matrices, separation techniques are also important. This has given boost to gas chromatography, which can use selected detectors as per the requirement of analysis. The necessity for analysis of trace organic compounds at point-of-source has led to developments in mobile gas chromatography. The progress in electrochemical miniaturisation, separation techniques, electronics devices and computation, has helped in downsizing gas chromatographs. Portable and transportable gas chromatographs are presently getting wide acceptance in environment monitoring. Examples of a few mobile GCs presently available commercially are discussed in this article.