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Studies on Development of Low Cost Instrument for Gas Monitoring in Ambient Air

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Abstract: *We are living in age of Petroleum, using about 200 MMTof petroleum products daily around the globe. It is one of the most basic and most important sources of energy for us but of the most basic disadvantage of petroleum products usage is the releases of lots of VOC and unwanted substances in air when it is burned and used. We have found that there is a strong need of a technology that should be easy to use, less costly and fast, for monitoring the level of VOC'S in ambient air and petroleum industry or a petrochemical plant for fugitive emissions and point source emissions. We have chosen a simple electronic sensor that responds to change in concentration in VOC'S in contact air, we have interfaced it with microcontroller, programmed it and displayed the concentration of gas on digital display, thus developing a simple instrument for current state VOC'S level at any place. Further, this instrument is tested at different day-to-day places, and the results obtained from instrument are discussed with some future development scope in the field.*

Keywords: *VOC, Petroleum, Environment, Emissions*

1. INTRODUCTION

Imagine a world without usable energy, world without power, electricity, fuels, automated vehicles, how would be life then? That's makes us to think about the importance of usable energy in our day-to-day life. Usable Energy creation and its transformation from one form to another is so much important today that we cannot live without it even for a single day. Energy has made our lives very comfortable, science and technology together with this energy created several miracles today but all this comes with a cost. Thus using more and more energy is ultimately depleting our non-renewable source of energy stock and creating misbalance in the environment.Unfortunately use of energy has several severe side effects and one of the most important of them is pollution. Pollution is may be in terms of air, water or soil but inany case it affects our health and our future generation lives. It is one of the most basic and most important sources of energy for us but of the most basic disadvantage of petroleum products usage is the releases of lots of gases and unwanted substances in air when it is burned and used[1]. Lot of carbon and unburned hydrocarbon releases in air when we use petroleum products like diesel, gasoline or liquid petroleum gas.Peoples and industries are freely using these as basic fuels for their use without carrying any pain or effort to convert these poisonous gases to less harmful or clean air by any chemical conversion technology or at least by measuring that how harmfulemissions they are contributing to the environment so that they can take any corrective action if pollution level increases.VOC'S (Volatile organic compounds)is one them and it has harmful effect for human health and environment. By definition of world environmental agencies VOC'S is any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions, except those designated by EPA as having negligible photochemical reactivity[2].

Keeping the above discussion in mind we have found that there is a strong need of a technology that should be easy to use, less costly and fast, for monitoring the level of VOC'S in ambient air and petroleum industry or a petrochemical plant for fugitive emissions and point source emissions. We have chosen a simple electronic sensor that responds to change in concentration in VOC'S in contact air, We have interfaced it with microcontroller, programmed it and displayed the concentration of gas on digital display, thus developing a simple instrument for current state VOC'S level at any place. Further, this instrument is tested at different day-to-day places, and the results obtained from instrument are discussed with some future development scope in the field.

This technology is cheap and easy to use, but for further research and work one can develop a more advanced sensors with high sensitivity, accuracy and low response time, to make the technology more fruitful.

2. VOLATILE ORGANIC COMPOUNDS (VOC'S)IN PETROLEUM SECTOR

Volatile organic compounds (VOC'S) means any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric

photochemical reactions, except those designated by EPA as having negligible photochemical reactivity[2].

Volatile organic compounds or VOC'Ss are organic chemical compounds whose composition makes it possible for them to evaporate under normal indoor atmospheric conditions of temperature and pressure. This is the general definition of VOC'Ss that is used in the scientific literature, and is consistent with the definition used for indoor air quality. Since the volatility of a compound is generally higher the lower its boiling point temperature, the volatility of organic compounds are sometimes defined and classified by their boiling points.For example, the European Union uses the boiling point, rather than its volatility in its definition of VOC'Ss. A VOC'S is any organic compound having an initial boiling point less than or equal to 250° C measured at a standard atmospheric pressure of 101.3 kPa.

Table 1. Classifications of Inorganic Organic Pollutants

Description	Abbreviation	Range (°C)	Example Compounds
Very volatile (gaseous) organic compounds	VVOC'S	<0 to 50-100	Propane, butane, methyl chloride
Volatile organic compounds	VOC'S	50-100 to 240-260	Formaldehyde, d-Limonene, toluene, acetone, ethanol (ethyl alcohol) 2-propanol (isopropyl alcohol), hexanal
Semi volatile organic compounds	SVOC'S	240-260 to 380-400	Pesticides (DDT, chlordane, plasticizers (phthalates), fire retardants (PCBs, PBB))

VOC'Ss are sometimes categorized by the ease they will be emitted. For example, the World Health Organization (WHO) categorizes indoor organic pollutants as very volatile, volatile, and semi-volatile. The higher the volatility (lower the boiling point), the more likely the compound will be emitted from a product or surface into the air. Very volatile organic compounds (VVOC'Ss) are so volatile that they are difficult to measure and are found almost entirely as gases in the air rather than in materials or on surfaces. The least volatile compounds (SVOC'Ss) found in air constitute a far smaller fraction of the total present indoors while the majority will be in solids or liquids that contain them or on surfaces including dust, furnishings, and building materials[13].

2.1 CLASSIFICATIONS OF VOC'SS

When discussing indoor environments, all organic chemical compounds that can volatize under normal indoor atmospheric conditions of temperature and pressure are VOC'Ss. While the demarcation line between the Very Volatile Organic Compound (VVOC'S), Volatile Organic Compound (VOC'S), and Semi volatile Organic Compound (SVOC'S) classifications is somewhat arbitrary, it does show the wide range of volatility among organic compounds[17]. The three classifications are all important to indoor air, and are all considered to fall within the broad definition of indoor volatile organic compounds. Other than volatility (or boiling point) no other criteria are used to define VOC'Ss indoor [18].

2.2 OIL AND NATURAL GAS SECTOR VOC'S

In 1979, the Environmental protection agency listed crude oil and natural gas production on its priority list of source categories for promulgation of NSPS (44 FR 49222, August 21, 1979). On June 24, 1985 (50 FR 26122), the EPA promulgated a NSPS for the source category that addressed volatile organic compound (VOC'S) emissions from leaking components at onshore natural gas processing plants[19].

The oil and natural gas sector includes operations involved in the extraction and production of oil and natural gas, as well as the processing, transmission and distribution of natural gas. Specifically for oil, the sector includes all operations from the well to the point of custody transfer at a petroleum refinery. For natural gas, the sector includes all operations from the well to the customer. The oil and natural gas operations can generally be separated into four segments[20].

(1) Oil and natural gas production,

(2) Natural gas processing,

(3) Natural gas transmission

(4) Natural gas distribution.

2.3 VOC'SIN ENVIRONMENT AND ITS MONITORING

Volatile organic compounds (VOC'S) are emitted as gases from certain solids or liquids. VOC'S includes a variety of chemicals, some of which may have short-and long-term adverse health effects. Concentrations of many VOC'Ss are consistently higher indoors (up to ten times higher) than outdoors. VOC'Ss are emitted by a wide array ofproducts numbering in the thousands. Examples include: paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copiers and printers, correction fluids and carbonless copy paper, graphics and craft materials including glues and adhesives, permanent markers, and photographic solutions.

Organic chemicals are widely used as ingredients in household products. Paints, varnishes, and wax all contain organic solvents, as do many cleaning, disinfecting, cosmetic, degreasing, and hobby products. Fuels are made up of organic chemicals. All of these products can release organic compounds while you are using them, and, to some degree, when they are stored.

EPA's Office of Research and Development's "Total Exposure Assessment Methodology (TEAM) Study" (Volumes I through IV, completed in 1985) found levels of about a dozen common organic pollutants to be 2 to 5 times higher inside homes than outside, regardless of whether the homes were located in rural or highly industrial areas. TEAM studies indicated that while people are using products containing organic chemicals, they can expose themselves and others to very high pollutant levels, and elevated concentrations can persist in the air long after the activity is completed.

3. SOURCES AND MEASUREMENT OF DOMESTICVOC'S'S

Household products including: paints, paint strippers, and other solvents; wood preservatives; aerosol sprays; cleansers and disinfectants; moth repellents and air fresheners; stored fuels and automotive products; hobby supplies; dry-cleaned clothing[3].Knowledge about the VOC'Ss that are present at low concentrations normally found in indoor air. in any given situation is highly dependent on how they are measured. All available measurement methodsare selective in what they can measure and quantify accurately, and none are capable of measuring all VOC'Ss that are present. For example, benzene and toluene are measured by a different method than formaldehyde and other similar compounds. The range of measurement methods and analytical instruments is large and will determine the sensitivity of the measurements as well as their selectivity or biases. This is why any statement about VOC'Ss that are present in a given environment needs to be accompanied by a description of how the VOC'Ss were measured so that the results can be interpreted correctly by a professional. In the absence of such a description, the statement would have limited practical meaning[5].

4. HEALTH EFFECTS OF INDOOR AIR VOC'S

Eye, nose, and throat irritation, headaches, loss of coordination, nausea, damage to liver, kidney, and central nervous system. Some organics can cause cancer in animals; some are suspected or known to cause cancer in humans. Key signs or symptoms associated with exposure to VOC'Ss include conjunctiva irritation, nose and throat discomfort, headache, allergic skin reaction, dyspnea, declines in serum cholinesterase levels, nausea, emesis, epistaxis, fatigue, dizziness[4].

The ability of organic chemicals to cause health effects varies greatly from those that are highly toxic, to those with no known health effect. As with other pollutants, the extent and nature of the health effect will depend on many factors including level of exposure and length of time exposed. Eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment are among the immediate symptoms that some people have experienced soon after exposure to some organics. At present, not much is known about what health effects occur from the levels of organics usually found in homes. Many organic compounds are known to cause cancer in animals; some are suspected of causing, or are known to cause, cancer in humans[4].

5. OUTDOOR VOC'S AUTOMOBILE EMISSIONS

5.1 CARS AND POLLUTION

Emissions from an individual car are generally low, relative to the smokestack image many people associate with air pollution. But in numerous cities across the country, the personal automobile is the single greatest polluter, as emissions from millions of vehicles on the road add up. Driving a private car is probably a typical citizen's most "polluting" daily activity [5].

5.2 SOURCES OF AUTO EMISSIONS

The power to move a car comes from burning fuel in an engine. Pollution from cars comes from by-products of this combustion process (exhaust) and from evaporation of the fuel itself.

- **Exhaust Emissions**: It is the emission that comes from fuel exhaust.
- **Refueling Losses**: It is the emission that comes at the petrol pumps at the time of refueling of vehicle
- **Evaporative Emissions**: It is the emission that comes from the evaporation of fuel at higher temperature due to volatility of the fuel

The Combustion Process

Gasoline and diesel fuels are mixtures of hydrocarbons, compounds thatcontain hydrogen and carbon atoms. In a "perfect" engine, oxygen in the air wouldconvert all the hydrogen in the fuel to water and all the carbon in the fuel tocarbon dioxide. Nitrogen in the air would remain unaffected. In reality, thecombustion process cannot be "perfect," and automotive engines emit severaltypes of pollutants [6].

5.3 HYDROCARBONS EMISSIONS

Hydrocarbon emissions result when fuel molecules in the engine do not burn or burn only partially. Hydrocarbons react in the presence of nitrogen oxides and sunlight to form ground level ozone, a major component of smog. Ozone irritates the eyes, damages the lungs, and aggravates respiratory problems. It is our most widespread and intractable urban air pollution problem. A number of

exhaust hydrocarbons are also toxic, with the potential to cause cancer.

6. VOC'S EMISSIONS MONITORING

Gas detector is an automatic gas concentration indicating device. It only can detect if there is a gas leakage or the leaking concentration. Meanwhile, the monitoring system is a system that is used for displaying how much concentration of gas is in that place but viewing takes place in another remote computer, GSM networking or Internet server. Therefore, monitoring system give the advantages to users such that they can monitor the situation of the room or the place where leakage occurrence may happen at safe distance continuously.

VOC'S is an acronym that stands for Volatile Organic Compounds. VOC'S are components of hydrocarbon liquids such as crude oil and condensate. VOC'S means any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions.

However, there is a list of compounds that are excluded from being VOC'S because they have negligible photochemical reactivity such as methane, ethane, and fluorinated and chlorinated hydrocarbons [4].

There are three types of emissions from hydrocarbon storage tanks:

1. Workinglosses.
2. Breathing losses
3. Flashing losses.

Working and breathing losses/VOC'S emissions from hydrocarbon storage tanks occur in addition to flashing losses/VOC'S emissions. Working losses are due to displacement of the vapors within the storage tank as a tank is filled. Breathing losses are due to displacement of vapors within the storage tank due to changes in the tank temperature and pressure throughout the day and throughout the year. Working and breathing losses/VOC'S emissions can be estimated with the latest EPA TANKS program or it's equivalent [8].

Flashing losses/VOC'S emissions occur when a liquid with entrained gases goes from a higher-pressure to a lower-pressure. As the pressure on the liquid drops some of the lighter compounds dissolved in the liquid are released or "flashed" and some of the compounds that are liquids at the initial pressure/ temperature transform from a liquid into a gas/vapor and are also released or "flashed" from the liquid. As these gases are released, some of the heavier compounds in the liquids may become entrained in these gases and will be emitted with them. Flashing losses/VOC'S emissions from hydrocarbon storage tanks include emissions of VOC'S, hazardous air pollutants (HAP), and toxic air contaminants (TAC)[7].

METHODOLOGY

The present work is divided into twoparts:

PART 1: Development of low cost Instrument

PART 2: Carrying out experiments to check the sustainability of instruments.

6.1 DEVELOPMENT OF INSTRUMENT INCLUDES

Developing Hardware.

Developing software/Code

Forthe hardware, itcanbecategorized into three different sections.

i. Microcontroller or processor –Arduino Uno
ii. Interfacing Gas sensors with microcontrollers
iii. Data Display and optional data logger

For software section, it is divided into two sections:

i. Microcontrollers Programming
ii. Data Loggers programming

6.2 EXPERIMENTATION

Following Several experiments on the instruments were performed to check the sustainability of instruments.

1. Testing VOC level on kitchen gas burner

2. Exhaust of petrol engine of car

3. Exhaust of diesel engine

4. Newly painted room

5. Office with printers and Xerox machines

7. RESULTS AND DISCUSSION

The Instrument we developed was tested for concentration of organic vapor sampler (VOC'S) and the results that we have found arepresented in table 1.

The data that was obtained from our instrument at several places thatare common to VOC'S's, such as house kitchen, computer printer room, welding shop, a newly painted room etc. are reported in table 1

TABLE 1: Data obtained from Instruments at various sites

S. No	Time Interval (Minutes)	Kitchen Burner	Petrol engine exhaust	Diesel Engine Exhaust	Newly painted room	Office with Printer	Petroleum Testing lab
1	0:00	0	10	37	3	3	34
2	0:05	0	6	39	6	4	32
3	0:10	33	9	41	4	4	37
4	0:15	54	13	38	5	5	35
5	0:20	168	11	40	4	5	36

S. No	Time Interval (Minutes)	Kitchen Burner	Petrol engine exhaust	Diesel Engine Exhaust	Newly painted room	Office with Printer	Petroleum Testing lab
6	0:25	177	9	41	3	5	33
7	0:30	172	8	39	5	4	42
8	0:35	171	8	40	4	5	43
9	0:40	176	7	41	3	3	43
10	0:45	168	8	42	4	4	41
11	0:50	169	9	43	5	6	38
12	0:55	154	12	39	4	5	37
13	1:00	135	15	40	3	6	38
14	1:05	143	15	41	3	6	38
15	1:10	110	12	42	4	6	35

7.1 KITCHEN GAS BURNER

As we are using Liquid petroleum gas as a domestic fuel in cooking and it is supplied in domestic cylinders in our houses. Basically it contains C_3-C_4 hydrocarbons. We have tested our instrument at the kitchen burner from starting when we are not using gas burner, then we have found its concentration was negligible as expected, we then slightly switched the burner on and found that the VOC'S reading in the screen of instrument starts increasing and as soon as gas spreading around in higher concentration.Within a span of 30 seconds the reading on the screen was 176 PPM that is quite high. After switching off the burner the gas spread around and the concentration slowly decreased as expected.

7.2 EXHAUST OF PETROL ENGINE

During the Combustion of hydrocarbon fuel, some un-burnt hydrocarbon left and come out of combustion chamber through exhaust pipe, as we tested the instrument through the exhaust of Maruti-Suzuki car Swift Desire during stand still car working engine exhaust through silencer outlet pipe, we have found that there is a concentration of VOC'S in the exhaust pipe that reaches up to 10-15 PPM. We should use hydrocarbon adsorbing material at the outlet of exhaust, so that emissions to the environment can be controlled or minimized.

7.3 EXHAUST OF DIESEL ENGINE

Diesel is also a hydrocarbon and when it burns with the air, some hydrocarbon comes un-burnt and exits out in the environment, thus creating pollution. We have detected this VOC'S that is coming out through diesel engine exhaust and found that their concentration is quite higher than as compared to concentration of VOC'S in petrol engine. India is a country of agriculture, deprived of electricity hence we are mostly depend upon diesel engines for water supply, electricity production, and due to higher patrol prices we are moving toward diesel vehicles, this creates more and more consumption of diesel and higher VOC'S emission. We should thus have good quality higher efficiency engines and provide better VOC'S absorbers at the exit of engines.

7.4 VOCLEVEL OF NEWLY PAINTED ROOM

We have tested the instrument capability for solvent VOC'S detection, in the case of newly painted room we have our self-observed that there is a lot of smell of chemical, some of these chemical are VOC'S, We have tested the air of one corner of newly painted room and found some concentration of VOC'S (Up to 5 PPM which higher than the limit set by EPA), this is due to the presence of solvents in the paint for pigments and dyes, after painting this solvent slowly emits out of wet paint thus we get concentration of VOC'S in the room. As theVOC'S content in paint at 250 grams per liter for flat finishes and 380 g/l for other finishes (low-luster, semi-gloss, etc.). So it is advised to use low VOC'S paints orwater based paints as higher VOC'S in our living area is very dangerous and we even cannot feel its polluting effect in short span of time.

7.5 OFFICE WITH COMPUTER PRINTER AND XEROX MACHINE

In the printing dyes that are used in offices and printing factories are also based on VOC'S and that is why we get the concentration of VOC'S during printing works at offices. We should use higher quality Low VOC'S content inks and dyes for printers.

Table 1shows the result obtained from petroleum testing laboratory. During testing of petroleum products and their chemical reactions, we get the very high concentration of VOC'S as it was expected because of obvious reasons of volatile organic compound presence in laboratory. This implies that our instruments works also well in the case of higher concentration. We should do proper ventilation in the laboratory and it is highly desirable also that during the burning and chemical reactions, use of properfume hood is advised as it should be installed in the laboratory to avoid the accumulation of VOC'S fumes in the lab.

8. CONCLUSIONS

From the above few Chapters about VOC'S and its harmful effect on health and environment, even some of VOC'S are reported to be the one of the cause of lung cancer and other severe disease. As VOC'Sare generally odor less and color less so we do not generally count it as pollution, but WHO and CPCB have direct guidelines for its concentration measurement and reporting. Many refineries and chemical plants in India and abroad are following these guideline using imported high cost instruments that are not easily approachable by common people. We have found that there is a strong need of a technology that should be easy to use, less costly and lesser response time, for monitoring the Level of VOC'S in ambient air and petroleum industry or a petrochemical plant for fugitive emissions and point source emissions.

With the use of an electrochemical sensor and a microcontroller, we have developed a new instrument

exploiting the property of sensor that changes its resistance upon change in gas concentration around it. The instrument that is developed is cheap and easy to use.We can get the direct reading of VOC'S in PPM on the instrument screen and even it can record the data of gas concentration with real time monitoring with date and time stamping in a memory card. We have tested the instrument at several critical locations around us and found the working of our instrument quite satisfactory. As an example, Exhausts from various engines are detected and reported in PPM while some indoor locations like petroleum testing laboratories are also tested and the result that was found was comparable with the results of other investigators.

We can replacemore advanced sensors which high sensitivity, results accuracy and low response time, this technology will be more fruitful. This all is possible with the above technology with the replacement of sensor and its program. We can transmit the obtained data through any wireless module like internet dongle, Zigbee wireless module or Local area networkso that the above all data can be uploaded to any server like of PCB or SPCB or organization, company own website and this data should me made visible to authorities for continuous watch on pollution. Also, if we have control panel, the above data can be linked with the relevant security system of the Chemical/Petrochemical Plant to avoid accidents.

9. FURTHER RESEARCH SCOPE

Further research can be done in this field for developing more advanced sensors with high accuracy and less response time, so that they can be used as potential sensors for all these above discussed environmental parameters and can give us better idea of actual happening and conditions in our environment on actual basis acting like active samplers for air and water testing.

We strongly found that there is much scope of online or continuous monitoring of environmental parameters like temperature, humidity, wind speed, direction, gases concentration and waste effluent water PH, TDS, TSS, BOD, COD.

With the recent orders from central pollution control board for installing online air and water analyzers in each large chemical plant or industry, there is a large scope of electronic or chemical engineers to develop such instrument and sale into Indian market, as the current scenario is that we have no single Indian manufacturer that is into online water pollution testing instruments.

REFERENCES

[1] Energy Information Administration, International Energy Outlook, DOE/EIA-0484 Washington DC, 2001.

[2] Hamza M.Report on VOC'S& LDAR program submitted to Gujarat state pollution control board for Vapi district organic chemical plants, CleanEnviro, Vapi Gujarat, 2011.

[3] Oil and natural gas sector standards of performance for crude oil and natural gas production, transmission, and distribution incorporated 501, Easton, suite 250 Chapel Hill, north Carolina, 2003.

[4] Harrison R.Setting health-based air quality standards, Inair pollution and health, issues in environmental sciences and technology, 10, Cambridge the royal society of chemistry, 1998, 57-73.

[5] Kalaboka, P. D.; Bartzis, J.; Papagiannakopoulis, J. G. Atmospheric concentrations of saturated and aromatic hydrocarbons around a Greek refinery. Atmos. Environ, 2000, 3(14), 2545-2555.

[6] Code of Federal Regulations, 40.Chapters 1, Subchapter C, Part 51, Subpart F, 51100, 2009.

[7] Atkinson, R. Atmospheric chemistry of VOC'Ss and NOx. Atmos. Environ, 2000, 34(12-14), 2063-2101.

[8] Pandya, G. H.; Concentration of volatile organic compounds (VOC'Ss) at an oil refinery. International, Environ Studies, 2006, 6(3), 337-351.

[9] Garriazo; Pelliccioni, C.; Filipo, A.; Sallusti, D.; Cecinato, F.A monitoring & analysis of volatile organic compounds around an oil refinery, Water, Air & Soil Poll. 2005, 16(1-4), 17-38.

[10] Park, K. H; Personal volatile organic compound (VOC'S) exposure of children attending elementary schools adjacent to industrial complex. Atmos. Environ. , 2004, 38(9), 1303–1312.

[11] Pandya, G. H; Kondawar; Gavane, A. G; An integrated investigation of volatile organic compounds emission in the atmosphere from refinery and its offsite facilities. Indian J. Chem. Tech., 2007, 14(3), 283-291.

[12] Lin, T. Y.; Sree, U.; Tseng, S. H.; Volatile organic compound concentrations in ambient air of Kaohsiung petroleum refinery in Taiwan. Atmos. Environ, 2004, 38(25), 4111-4122.

[13] Chambers, A. K.; Strosher, M. H.; McCready, J.; Direct measurement of fugitive emissions of hydrocarbons from a refinery, air & waste manag. assoc. 2008, 58(8), 1047-1056.

[14] American standards for testing and materials, in method d3686-95, standard practice for sampling atmosphere to collect organic compound vapors (activated charcoal tube adsorption method), annual book of ASTM standards,2000, 188.