O 97. DETECTION OF VOLATILE ORGANIC COMPOUNDS IN INDOOR INDUSTRIAL AIR

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ABSTRACT: With the rapid population growth, the industrial revolution and the developments in the industrial sector, the quantity and diversity of human demands have increased. In order to maintain healthy life which is the most basic requirement of human being, it has needed fresh air, it has left natural materials in order to meet increasing demands and it has accelerated production of synthetic and artificial products. The use of chemical materials in these products is very important for both cheap and easy production of the product. However, these chemicals, which are used to avoid cost and work load and can easily become volatile at ambient temperature, have started to be used in the indoor environment and have a negative impact on human health. In the past, the idea that "indoor air quality is cleaner than the outdoor air quality" was demolished by the current research. "What's the volatile organic compounds, what are the sources of spread and what are the effects on human health" began to be the subject of research.
In this study, to determination of volatile organic compounds that continue to spread at room temperature from the materials and processes used in industrial environment such as paint, wood, insulation materials and cleaning products production processes, evaluate the environmental standards, determine the impacts on environmental health and it is aimed to determine the activities that what can be done to reduce pollution.

Keywords: Industrial environment, Closed environment, Volatile organic compounds, VOC detection

1. INTRODUCTION

With the industrial revolution, mankind has followed a migration from village to city and more than 85% of the population has settled in cities. Human beings spend more than 90% of their time indoors. This has made the issue of indoor air a need to investigate. Indoor air; It is the breathable ambient air in the environments where daily life is experienced such as houses, workplaces without industrial production, schools and hospitals. Indoor environments; they must be able to meet the basic needs of people, healthy, sufficient sunshine, avoiding extreme temperatures and constantly getting fresh air. The indoor air quality is related to the cleanliness of the indoor air. For many years, it has been adopted that indoor air quality is cleaner than outdoor environment. However, as a result of the researches, indoor building materials, cleaning products, dyestuffs and pollutant concentrations caused by heating have a significant effect on indoor air quality (Soysal and Demiral, 2007).

Volatile Organic Compounds

Chemical structures that contain at least one carbon and hydrogen atoms in their structure are called organic compounds. Organic compounds are classified in three main branches: volatile organics, semi-volatile organics, and non-volatile organics. Volatile organic compounds are hydrocarbons of aliphatic or aromatic structure whose boiling points range from 50-260 ^{0}C. Volatile organic compounds are low-soluble compounds in water and can easily convert to volatile form at room temperatures due to their high vapor pressure. Table 1 gives information about boiling point temperatures and vapor pressures of some volatile organic compounds. (Alyüz and Sevil, 2006; URL-1)

Table 5. Boiling points and vapor pressures of some organic compounds (Alyüz and Sevil, 2006)

Volatile Organic Compound	**Boiling Point Temperature (^{o}C)**	**Vapor Pressure (mm Hg)**
Benzene	80.1	95.2 (25 ^{o}C)
Toleun	111	22 (20 ^{o}C)
Chloroform	62	160 (20 ^{o}C)
o-ksilen	144	7(20 ^{o}C)
1,1,1, Trichloroethane	74.1	10 (20 ^{o}C)
1,2,4- Trimethylbenzene	169	2.03 (25 ^{o}C)
p-ksilen	138	9 (20 ^{o}C)
Undekan	196	0.28 (20 ^{o}C)
1,3,5 Trimethylbenzene	165	1.86 (20 ^{o}C)
Ethylbenzene	136	10 (20 ^{o}C)
Styrene	145	5 (20 ^{o}C)
Carbon tetra chloride	76.8	91.3 (20 ^{o}C)
Dichloro benzene	174	10 (55 ^{o}C)
p-dichloro-benzene	174	10 (55 ^{o}C)
Methyl chloride	39.8	350 (20 ^{o}C)
Ethylene dibromide	131.5	11.0 (25 ^{o}C)

According to the reports of the European Commission Joint Research Center-Environmental Institute; chemical structures (alkanes, aromatic hydrocarbons, aldehydes, etc.), physical properties (boiling point, vapor pressure, carbon number, etc.) and potential health effects (irritants, neurotoxic, carcinogenic, etc.).

Table 6. Volatile organic compounds [Adapted from Darçın, 2014]

Organik bileşik	**Grup adı**		**Sık karşılaşılan kirleticiler**
Volatile Organic Compounds	Aliphatic Hydrocarbons		Methane, ethane, propane, butane, pentane, hexane, heptane, octane, nonane, cyclohexane, isobutane, isopentene, n-tridecane, decane, dodecane, undecane
	Aromatic Hydrocarbons	Single-Ring Aromatic Hydrocarbons	Benzene, ethylbenzene, diethylbenzene, trimethylbenzene, dimethyl-ethyl benzene, toluene, xylene, styrene, ethyl tolüene
		Polycyclic Aromatic Hydrocarbons	Naphthalene, phenanthrene, benzo [a] pyrene, DDT, dieldrin, permethrin, benz [a] anthracene
	Halogenated Hydrocarbons		Chloroform, dichloromethane (methylene chloride), trichlorethylene, tetrachlorethylene, p-dichlorobenzene (1,4-dichlorobenzene), methyl bromide, vinyl bromide, benzyl chloride, 1,1,1-

		trichloroethane (methyl chloroform), carbon tetrachloride
	Amines	2-naphthylamine, 4-aminobiphenyl
	Alcohols	N-butyl alcohol, 1-dodecanol, phenol, methyl alcohol (methanol), ethyl alcohol (ethanol), nonanol, isopropyl alcohol (isopropanol), propargyl alcohol, 2-ethyl-1-hexanol
	Ethers	Ethyl ether
	Aldehydes	Decanal, nonanal, formaldehyde, propenol (acrolein), acetaldehyde, furfural, hexanal
	Ketones	Acetone, methyl ethyl ketone (2-butanone)
	Terpenes	Pin-pinene, β-pinene, limonene, isoprene
	Esters	Ethyl acetate, 1-hexyl butanoate
	Glycol ethers	2-ethoxy ethanol
	Organic acids	Acetic acid, propanoic acid, hexanoic acid, pentanoic acid
	Compounds containing sulfur	Carbon disulfide
	Other compounds	1,3-butadiene, nitrosamines

Spread Sources of Volatile Organic Compounds

The type of volatile organic substances and their sources are important information for determination. These compounds generally have concentrations below the perceptible level of odor and are about five times greater than the level of the external environment (Alyuz and Sevil, 2006). Volatile organic compounds can be caused by many materials such as paint, varnish, adhesives, construction materials, cleaning products, heat exchanger systems, insulation materials, leaks in wood stoves and pipes. In the studies conducted, it is considered that volatile organic substances are frequently encountered in the indoor environment (Liotta, 2010; Soylu et al., 2010; Drobek et al., 2015). In office environments, printers and photocopiers are the most serious volatile organic material dispensers. In a photocopy process, there are 60 types of volatile organic matter (Wolkoff et al., 1993). Natural sources of volatile organic compounds are; anaerobic processes in trees, plants, wild animals, natural forest fires and swamps.

As a result of the studies conducted by the Environmental Protection Organization (Figure 1) shows that 29% of volatile organic compounds emitted from the environment are emitted from solvent use, 28% from vehicles, 19% from home/office equipment, 11% from industrial processes and 13% from other sources.

The chemicals used in the production of some materials can cause many types of volatile organic compounds to be released into the interior air (Table 2).

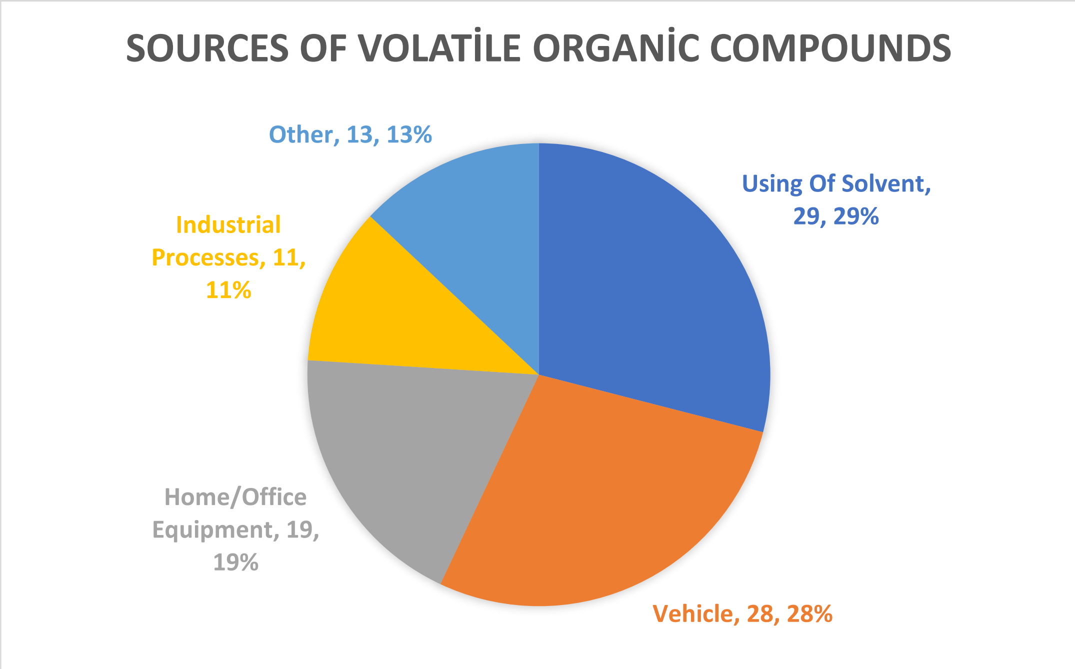

Figure 6. Sources of Volatile Organic Compounds

Tablo 4. Building products with indoor air pollutants [Darçın, adaptation from 2018]

Resources	**Pollutants**
Paints and Solvents	Hexane, benzene, xylene, styrene, toluene, trimethyl benzene, ethyl toluene, methylene chloride [Tucker, 2001], formaldehyde [Bernstein, et al., 2008], α-pinene, limonene [Zabiegala, 2006], tris (2-chloroethylene)) phosphate, phosphorous organic ester [Wensing, Uhde and Salthammer, 2005]
Varnishes and Varnishes	Nonane, decane, dodecane, undecane [Zabiegala, 2006], hexane, benzene, ethylbenzene, ethyl toluene, xylene, styrene, toluene, trimethyl benzene, methylene chloride [Tucker, 2001]
adhesives	Hexane [Zabiegala, 2006], ethyl benzene, ethyl toluene, xylene, toluene, trimethyl benzene [Tucker, 2001], formaldehyde [Bernstein, et al., 2008]
Sealers	Toluene, tetrachlorethylene [Tucker, 2001]
plasters	Ethylbenzene, xylene, toluene [Tucker, 2001]
Natural and Artificial Wood Sheets	Hexane, benzene, ethyl benzene, xylene, styrene, toluene, trimethyl benzene, p-dichlorobenzene, acetaldehyde [Tucker, 2001], formaldehyde [CEC, 1992], α-pinene, β-pinene, limonene [Salthammer and Fuhrmann, 1996] , tris (2-chloroethylene) phosphate, phosphorous organic ester [Wensing, Uhde and Salthammer, 2005]
Paper Coatings	Ethylbenzene, xylene, toluene [Tucker, 2001], formaldehyde [Balanli, Vural and

	Tuna Taygun, 2006], tris (2-chloroethylene) phosphate, phosphorus organic ester [Wensing, Uhde and Salthammer, 2005]
Plastic Sheets	N-tridecane, hexane, nonane, decane, dodecane, undecane [Gustafsson, 1992], benzene, ethylbenzene, xylene, styrene, toluene, trimethyl benzene, p-dichlorobenzene, acetaldehyde [Tucker, 2001], phenol [Wallace and Gordon, 2007], ortho-phthalic acid diester, fibutyl phthalate, di-2-ethyl-hexyl phthalates, 2-ethyl-1-hexanol [Clausen, et al., 2007]
Linoleum Sheets	Toluene, 2-butanone [Salthammer and Bahadir, 2009], hexanal, nonanal, octanal, propanoic acid, hexanoic acid, pentanoic acid [Jensen, Wolkoff and Wilkins, 1995]
Cork Sheets	Toluene, phenol, furfural, formaldehyde [Salthammer and Bahadir, 2009]
Carpets	Hexane, ethylbenzene, xylene, styrene, toluene, p-dichlorobenzene, acetaldehyde [Tucker, 2001], α-pinene, limonene [Godwin and Batterman, 2007], formaldehyde [Maroni, 1998]
Fabric Coatings	Hexane, benzene, xylene, toluene, styrene, chloroform, methylene chloride, trichlorethylene [Tucker, 2001], formaldehyde, tris (2-chloroethylene) phosphate, phosphorous organic ester [Wensing, Uhde and Salthammer, 2005]

Effects of Volatile Organic Compounds on Human Health

Indoor environments are the places where people meet many needs during the day and spend most of their time. Therefore, the indoor air must be clean. Unfortunately, indoor air is often 10 times more polluted than outdoor air. Pollutants that disrupt indoor air quality by the Environmental Protection Organization (EPA) include volatile organic compounds and formaldehyde as the major pollutants (EPA, 1998; Hines et all., 1993). Volatile organic compounds are constantly exposed to the indoor environment as a result of human activities and goods. In the last 10 years, the type and amount of volatile organic compounds have increased due to the increasing use of chemical and synthetic structures. Humans may be affected by volatile organic compounds by inhalation, odor and skin or eye contact. Pollutants must accumulate in the body at a certain concentration in order to pose a health problem. As a result of the high concentration of volatile organic compounds in the interior and the presence of people in these spaces for a long time, a series of symptoms have been observed (Viegi, et al., 2004). The global health organization calls the general name of these symptoms “Patient Building Syndrome”. In people with this syndrome, headache, nausea, eye irritation, respiratory system diseases, drowsiness and general weakness is seen (Kostiainen, 1995). As a result of VOC exposure, diseases such as neurological toxicity, lung cancer, eye and throat irritation may also be encountered (Guo et all., 2004).

Norback et al. Investigated the relationship between asthma symptoms and building properties and concentration of volatile organic compounds in residences. It was concluded that indoor VOCs and formaldehyde may cause asthma-like symptoms. In order to keep the VOCs at a reasonable level, attention should be paid to the selection of construction materials, building construction and indoor activities (Norbäck et all., 1995).

Sampling and Storage Methods for Determination of Volatile Organic Compounds

The first condition for realistic measurement of volatile organic compounds is that sampling and storage are performed correctly and in accordance with standards. Flue gas sampling and ambient air sampling methods for analysis differ. When sampling the flue gas, it is necessary to take samples under conditions where the plant is stable. After sampling, leakage check should be performed. The flue gas temperature during sampling should not exceed 40 ° C. In order to avoid condensation in the sample cup, the flue gas can be passed through a cooling chamber and then cooled to take the sample. If the concentration of organic compounds is at risk of exceeding the capacity of the sorbent tubes, sampling should be carried out by dilution in the sampling process. A sampling process of at least 10 minutes is important for the realistic results of the analysis. Blank samples should be taken twice as much as the sample volume taken.

Samples taken from the flue gas should be taken immediately to a cool, dark environment. For prolonged storage it should be stored in a container that is not contaminated by solvent below 4 ° C (TS EN 13649, 2003).

For a sample to be taken from ambient air; For passive sampling, a sampling tube suitable for analysis should be collected and used within one month of sampling. If sampled with a circular plate, it can be stored in microporous activated carbon. After sampling, it can be stored in a cool and dark environment and used during analysis (TS EN 13528, 2003).

Removal Methods of Volatile Organic Compounds

Many methods have been developed for the control of volatile organic compounds. These methods include the modification of processes and equipment to which the VOC is deployed, as well as the addition of control techniques. Control techniques are divided into two as destruction and recovery. Destruction; It is eliminated by digestion of VOCs by microorganisms of different types of oxidation, such as thermal and catalytic oxidation under aerobic conditions. During the recovery phase, VOCs are removed by densification, absorption, absorption and membrane separation processes.

Before performing volatile organic matter removal in industrial environments, cost-benefit analysis should be carried out in the environment and the amount of VOC at which point, the best detection method and the most appropriate sampling method should be selected. Since economic constraints and technologies are limited in an improvement to be implemented in the environment, it is important to perform the most appropriate removal method at the most appropriate point.

In the literature, the removal of VOCs by oxidation and absorption is widely mentioned. It is seen that the removal of volatile organic compounds is also very effective in photocatalysts with high oxidation properties and activated carbon with high absorption properties. VOC removal is also possible with the ozonation system. Ozonation systems are a method that provides oxidation by applying ozone directly to the air drawn by an air motor (OLGUN et al .; TÜRKER et al., 2015).

2. RESULTS

The only effective way to remove pollutants from indoor environments is at source control. Furthermore, the complete elimination of indoor air pollutants is generally not feasible or practical. In this context, a different way should be preferred without using materials such as equipment, paints, cleaning products and wooden surfaces to be used indoors. In the environment, a special ventilation system should be provided to the voc source and protective equipment should be provided to the personnel or person working there. Continuous voc control in the environment can be carried out by means of suitable commercially available sensors (conductometric solid state sensors). In addition, removal of voc in the medium can be realized by adsorption and oxidation methods.

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