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Carbon monoxide formation from total volatile organic compounds from the use of household spray products

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ABSTRACT

Introduction: Air pollutants emitted from household spray products used in our homes and offices have adverse effects on human health. The quantification and identification of emission sources of air pollutants forms a foundation for an effective indoor exposure control. This study presents the results of a fundamental study conducted to evaluate the kinetics and emission trends Total Volatile Organic Compounds (TVOCs) and Carbon Monoxide (CO) from household spray products.

Materials and methods: Fortyfive (45) commonly used household spray products were selected for this study. The experiment was conducted in an isolated empty room of dimension (2.72×2.82×2.00) m^3 with no known/ significant indoor emission source(s). CO and TVOCs concentrations were measured with Aeroqual® 500 series monitor with CO and TVOCs head at 15 min, 1 h, 3 h, and 24 h, for all 45 samples of household spray products.

Results: Spontaneous second – order conversion of TVOCs to CO was observed for most of the spray products in the indoor environment. For the insecticides samples, TVOCs initial concentrations were 7.2–73±19.76 ppm which after one hour the concentrations became 1.8 – 17±7.20 ppm. CO measured initial concentration were 0 – 4±1.08 ppm which the concentration levels reduced to 0–7±2.16 ppm. TVOCs concentration was above the permissible limit set by USEPA and CO concentration for some of the air fresheners, perfume, shoe impregnation spray and hair sprays fall short the limit of 40,081.89 and 25,562.37 $\mu g/m^3$ set by United States Environmental Protection Agency (USEPA) and World Health Organization (WHO), respectively.

Conclusion: As the concentration of TVOCs decreased as the concentration the concentration, CO increased following a second order kinetics. The result obtained will help in the development of safer products and a proper guide on how to use them in a way it will not cause harm to both the user of the product and the environment.

Introduction

Indoor environment is an important component of the human habitat because it has a direct impact on human health and the concentration levels of the pollutants [1-4]. Most people spend about 85-90% of their time in indoor environment such as homes, offices, schools and others [5-

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7]. Exposure levels of pollutants in the indoor air are multiple times higher than pollutants in outdoor air due to the long residence times and elevated room concentrations as a result of inadequate ventilation [8]. According World Health Organization (WHO) about 91% of the world population is leaving where the air quality exceeds it guideline limits [9]. Every year there are 4.2 million death as a result of ambient air pollution and 3.8 million deaths as a result of household air pollution [9].

Household spray products are consumer products that are dispersed under pressure from disposable and refill containers. Household spray products have three main components and these include: the active ingredient(s), the propellant, and additives such as solvents, plasticizers, and emulsifiers which are used to improve the product.The active ingredients are designed for specific purpose such as odourising in the case of perfumes and air fresheners; and control of insects in insecticides. Propellants are fluids capable of exerting a pressure when held in a sealed container at room temperature while solvents are used to mix the active ingredient with the propellants [10]. Active ingredients in the domestic aerosol products include terpenes which are Volatile Organic Compounds (VOCs) [10, 11]. Terpenes are unsaturated volatile organic compounds that occur in nature and are presumed to be safe. However, many terpenes have been found to have serious health effects [12].

Concentrations of terpenes emitted from air fresheners are greater than those found in nature [13].Terpenes such as α-pinene, d-limonene, linalool, and citronellal react with transient compounds in the air to give secondary organic aerosols [14].Concentrations of this VOCs the indoor environment is higher than outdoor[15-19] as a result of poor ventilation because most modern on thermal comfort, odor control, perceived air quality, initial investment cost, energy use, and other performance issues [20]. Serious health challenges could arise due to accumulation of harmful air contaminants in confined spaces such as the interiors of an airplane, classrooms, submarines, shops, cinemas, households [21, 22]. Some of the health challenges caused by VOCs include irritation of the eyes and respiratory tract, visual disorders, dizziness, headaches, and memory problems. Sometimes it can cause a more serious symptoms and diseases such as nausea, fatigue, loss of coordination, damage to the kidneys, liver, and central nervous system, lung cancer [23], asthma and cancer [24]. VOCs are also ozone precursor [7, 25]. Inhaling air with high concentration of CO reduces the amount of oxygen that can be transported in the blood stream to the brain and heart. In enclosed environment, high concentration of CO can cause fatigue, unconsciousness and even death.

Although some of the VOCs will be converted to other pollutants like carbon monoxide (CO). VOCs react with free radicals such as and to form CO as shown in the Equations 1-5 [26-28] other radical and ionic reactions could also result in VOCs conversion to CO_2, H_2O and other products [29-31].

$$\mathrm{HCN + O\cdot \rightarrow CO + NH} \tag{1}$$

$$\mathrm{HCN + O\cdot \rightarrow \cdot CN + \cdot OH} \tag{2}$$

$$\mathrm{CO + \cdot OH \rightarrow CO_2 + H\cdot} \tag{3}$$

$$\mathrm{NH + \cdot OH \rightarrow H_2O + N\cdot} \tag{4}$$

$$\mathrm{\cdot CN + O\cdot \rightarrow CO + N\cdot} \tag{5}$$

The quantification and decay of this pollutants helps to develop a suitable control strategy for this pollutant. The aim of this study is to investigate the kinetics as well as the dynamic behavior of TVOCs emission and CO formation from common household aerosols emitted from household spray products in indoor environment.

Table 1. Consumer spray products used in this study

S/No.	Product ID	Product type	S/No.	Product ID	Product type
1	INST A	Insecticide	24	AFN I	Air Freshener
2	INST B	Insecticide	25	AFN J	Air Freshener
3	INST C	Insecticide	26	AFN K	Air Freshener
4	INST D	Insecticide	27	AFN L	Air Freshener
5	INST E	Insecticide	28	AFN M	Air Freshener
6	INST F	Insecticide	29	AFN N	Air Freshener
7	INST G	Insecticide	30	AFN O	Air Freshener
8	INST H	Insecticide	31	PEF A	Perfume/Body Spray
9	INST I	Insecticide	32	PEF B	Perfume/Body Spray
10	INST J	Insecticide	33	PEF C	Perfume/Body Spray
11	INST K	Insecticide	34	PEF D	Perfume/Body Spray
12	INST L	Insecticide	35	PEF E	Perfume/Body Spray
13	INST M	Insecticide	36	HSP A	Hair Spray
14	INST N	Insecticide	37	HSP B	Hair Spray
15	INST O	Insecticide	38	HSP C	Hair Spray
16	AFN A	Air Freshener	39	HSP D	Hair Spray
17	AFN B	Air Freshener	40	HSP E	Hair Spray
18	AFN C	Air Freshener	41	SPL A	Surface Polish
19	AFN D	Air Freshener	42	SPL B	Surface Polish
20	AFN E	Air Freshener	43	SPL C	Surface Polish
21	AFN F	Air Freshener	44	SSP A	Shoe impregnation spray
22	AFN G	Air Freshener	45	SSP B	Shoe impregnation spray
23	AFN H	Air Freshener			

Materials and methods

The experimental room used in the study is an isolated and unhabited room (2.72×2.82×2.00) m^3 [3]. No major indoor and outdoor particle generating sources was observed except the aerosols being released from the household product samples. The experimental room was fitted with a ceiling fan and a Heating, Ventilation and Air Conditioning (HVAC) unit. Measurements were taken in the experimental room under different environmental and ventilation conditions. Aerosols were released at the centre of the room at the height of 2 m above the ground and the portable sampling devices were placed at 1.5 m above the ground.

Selection of household spray products

Forty five (45) common and available household sprayproducts in Nigerian market were considered for investigation in this study. The selected samples comprised offifteen (15) different brands of air fresheners, fifteen (15) different brands of insecticides, five (5) different brands of hairsprays, five (5) different brands of perfumes, two (2) different brands of shoe impregnation sprays and three (3) different brands of surface polish as presented in Table1. The samples include the locally manufactured ones and those that are imported from other countries in order to have a wider view on aerosol generated and asess human exposure from the use of the commercially available spray products.

Since the specific information on products comprehensive description and ingredients are rare, the criterion for product selection was the packaging label which indicates they are aerosolized products. The ingredient list on the labels of most of the samples selected indicates that they contain the active ingredient and the propellant which accounts for between sixty and ninety percent (60-90%) of their total volume. The active ingredient in the fragrance product were simply termed "fragrance'. Detailed information were not available on the ingredient listing. The most common propellants listed and declared for the selected samples include butane, isobutane and propane.

Total volatile organic compounds (TVOCs) and carbon monoxide (CO) measurement

Total Volatile Organic Compounds (TVOCs) was measured using Aeroqual 500 series with TVOCs head. The instantaneous readings were taken up to 24 h after spraying. Carbon Monoxide (CO) measurements were taken using an insitu non-integrated single gas Carbon Monoxide monitor (Aeroqual 500 series with CO head). The equipment used were used and freshly calibrated.

Reaction kinetics of CO formation from VOCs

Reaction kinetics indicates how fast a chemical component is converted into another by a chemical reaction. The reaction order was obtained by fitting the concentration decay data to kinetic models such as zero, first and second order as shown by Eqs. 7-19 that can be obtained from the order of the reaction. A reaction is first order when the concentration of the reactant does not affect the amount of product formed. For a first order reaction, the rate doubles when the concentration doubles. In the case of a second order reaction, concentration of the reactant doubles, the rate of reaction increases by a factor of 4. Considering a reaction. For a zero-order reaction the initial concentration does not have any effect on the rate of reaction. For a given chemical reaction [32]. The initial concentration of VOCs was taken to be the concentration measured immediately when the insecticide before it is converted to CO. The concentration of VOCs and CO was measured simultaneously for one hour (1 h) and then extrapolated for 3, 8 and 24 h.

$$A \rightarrow Product \quad (6)$$

For a zero-order reaction

$$\frac{dC_A}{dt} = -k \quad (7)$$

The equation can be written as

$$dC_A = -kdt \quad (8)$$

Where C_A is the concentration of the reactant A; C_{A0} is the initial concentration of reactant A, t is the time and k is the rate constant

To obtain the rate constant by integrating

$$\int_{Ca0}^{Ca} dC_A = -\int_0^t kdt \quad (9)$$

$$C_A - C_{A0} = kt \quad (10)$$

Thus, a plot of concentration of A versus time will be linear with a slope of −k and ca as the intercept

For a first order irreversible reaction the rate is given by;

$$-r_A = -kC_A \quad (11)$$

So that the design

$$\frac{dC_A}{dt} = -kC_A \quad (12)$$

The Equation(12) can be written as

$$\frac{dC_A}{C_A} = -kdt \quad (13)$$

To obtain the rate constant by integrating

$$\int_{Ca0}^{Ca} \frac{dC_A}{C_A} = -\int_0^t kdt \quad (14)$$

$$-ln\frac{C_A}{C_{A0}} = kt \quad (15)$$

A plot of $-ln\frac{C_A}{C_{A0}}$ versus t will yield a linear plot where the slope of the line gives the rate constant k

for a second order of reaction

$$\frac{dC_A}{dt} = -k{C_A}^2 \quad (16)$$

The equation can be written as

$$\frac{dC_A}{{C_A}^2} = -k \quad (17)$$

To obtain the rate constant by integrating

$$\int_{Ca0}^{Ca} \frac{dC_A}{{C_A}^2} = -\int_0^t kdt \quad (18)$$

$$\frac{1}{C_A} - \frac{1}{C_{A0}} = kt \quad (19)$$

To determine the rate constant and test for the order of reaction. The reciprocal of concentration can be plotted against time which gave a line with slope equal to k and y-intercept equal to the inverse of initial concentration of 'A' [32-34].

Results and discussion

Measurement of carbon monoxide (CO)

The concentrations of the TVOCs were in the range of 173765.7 and 17115.09 µg/m^3 for insecticides. INST L emitted the highest concentration of TVOCs (Fig 1) and INST O is the least emitter of TVOCs in all the insecticides investigated. The average concentration of TVOCs emission from insecticides is 55085.24 µg/m^3 with a standard deviation of 47007.51 µg/m^3.

Air fresheners samples have a TVOCs concentration range of 1663.97 and 23533.25 µg/m^3. AFN O emitted the highest TVOCs concentration and AFN L emitted the least. The mean emitted concentration is 7337.30 µg/m^3 with a standard deviation of 5750.04 µg/m^3.

For Perfumes, Hairsprays, Surface Polish and shoe impregnated sprays samples presented in Figs. 2 and 3, TVOCs emission ranged from 2377.10 – 87477.14 µg/m^3; 49919.02 - 560996.98 µg/m^3 ; 189312.27 – 441149.70 µg/m^3 and 118450.43 – 161175.95 µg/m^3 with respective average concentrations of 61091.37 µg/m^3, 166254.10 µg/m^3, 281263.19 and 139813.19 µg/m^3. In all the hairspray samples considered in this study, HSP A emitted the highest concentration of TVOCs with a concentration of 560996.98 µg/m^3 .

Generally, the average TVOCs emission from all the investigated samples were in the range of 1664 µg/m^3 and 71039.59 µg/m^3 with an average of 560994.7 µg/m^3. Molhave et al. (1997) and Zabiegala (2006) considered TVOCs concentration below 200 - 600 µg/m^3 to be within the comfort range, 200 – 3000 µg/m^3 as the multifactoral exposure range which is considered to be a health hazard ; 3000 – 25000 µg/m^3 being the discomfort range that could bring strong discomfort to inhabitants of indoor environment and concentration greater than 25000 µg/m^3 as toxic range.

The measured concentration of TVOCs from the samples used are either in the discomfort range or toxic range. This indicates that occupants are often exposed to hazardous and toxic levels of TVOCs whenever the samples are used in the indoor environment. Also, recent investigations have suggested that TVOCs concentration in consumer spray products fall short of the general regulatory requirements as they were found to be far above the recommended limits.

Carbon monoxide concentration were monitored simultaneously alongside TVOCs. The averaged concentrations of the measured CO for 1 h were reported in Figs. 1, 2 and 3 alongside the measured TVOCs concentration. The concentrations of CO indicated on the figures represent the intial CO concentration (concentration measured while spraying). Generally, initial CO concentration ranged from 0 to 83629.04 µg/m^3 with an average of 9368.49 µg/m^3 and standard deviation of 19371.27 µg/m^3 for all the samples.

Insecticides samples CO emission were in the range of 0 and 4582.41µg/m^3 with an average concentration of 916.48µg/m^3 and standard deviation of 1239.92 µg/m^3. CO concentration obtained for all the insecticide samples considered are below 40.081.89 and 25,562.37 µg/m^3 limits recommended by Environmental Protection Agency (EPA) and World Health Organization (WHO) respectively. Air freshener samples emitted CO concentrations of 0 - 5728.02 µg/m^3, an average of 2214.83 µg/m^3. However, for perfumes, hairsprays, surface polish and shoe polish, ranges of 6873.62 and 42387.32 µg/m^3 (21537.34±16629.01µg/m^3); 1145.60 and 79046.63µg/m^3 (33909.86±31929.26 µg/m^3); 3436.81 and 5728.02 µg/m^3 (4582.51±1145.60µg/m^3) and 0 and 83629.04 µg/m^3 (41814.52±59134.06 µg/m^3), respectively were observed. Of all the perfumes samples investigated (Fig. 3), PEF D emitted the highest concentration of 42387.32 µg/m^3. PEF B, PEF E, PEF C and PEF A emitted an average concentrations of 36659.3, 11456.03, 10310.43 and 6873.62 µg/m^3 respectively. The average concentration of CO recorded for perfumes (21537.34 µg/m^3) is about 2.29 folds and 4.7 folds of the average concentration recorded for insecticides and air fresheners samples respectively. The average concentration of CO emission from the hairspray samples (33909.86 µg/m^3) represents about 37 and 15.3 folds of the average concentration recorded for Insecticides and air freshener samples, respectively.

The highest concentration of CO in all the spraying product was observed in a shoe impregnation spray sample (SSP A). It emitted a concentration of 83629.04 µg/m^3 (Fig. 3) which is far above the concentrations obtained for insecticides and air freshener samples. The concentration of CO obtained air fresheners I, J and M out of all the air fresheners sampled were above the EPA and WHO which is 40.081.89 µg/m^3 and 25,562.37 µg/m^3. Only PEF D, SSP A and HSP B out of perfume, shoe impregnation spray and hair sprays.

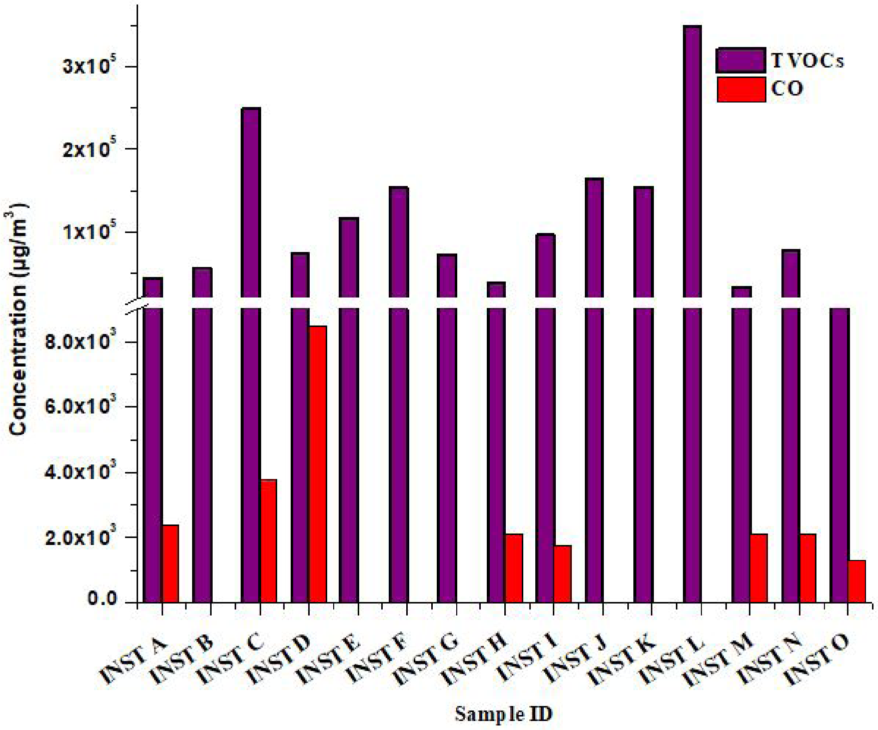


Fig. 1. Average TVOCs and CO concentration distribution in Insecticides sampled for 1 h

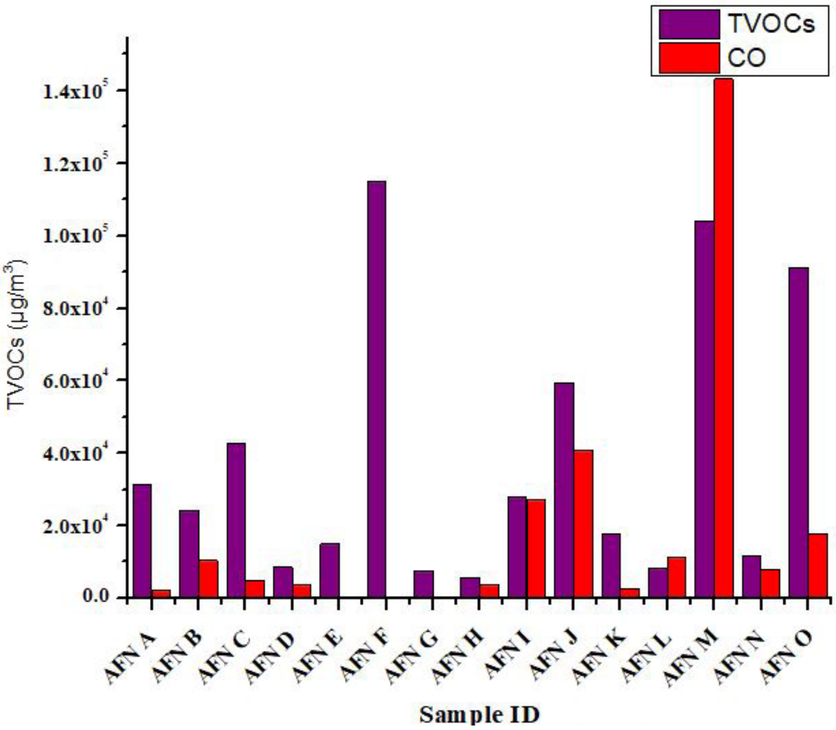


Fig. 2. Average TVOCs and CO concentration distribution in Air Fresheners Sampled for 1 h

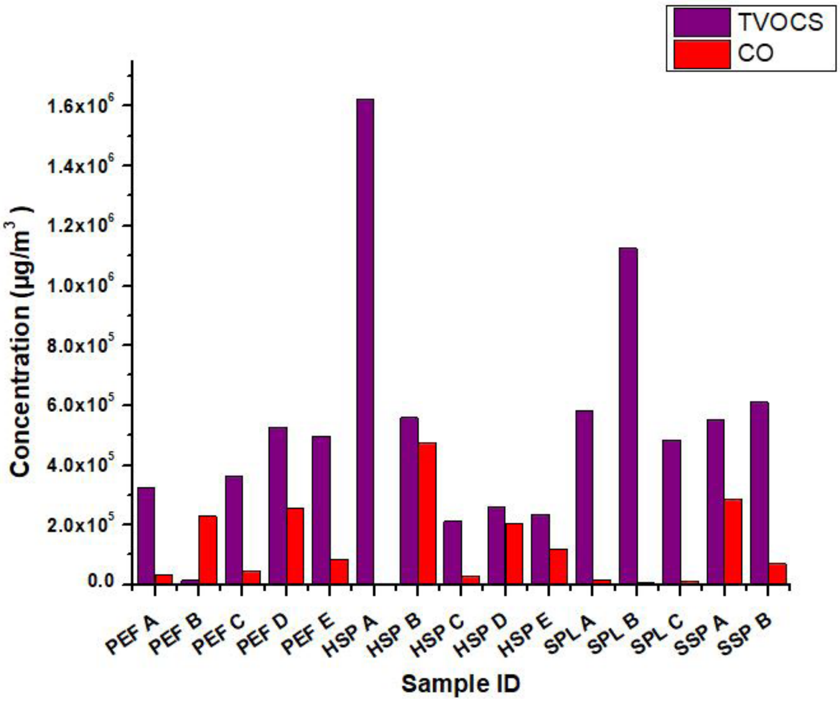


Fig. 3. Average TVOCs and CO concentration distribution in Perfumes, Hairsprays, Surface Polish and shoe impregnation sprays sampled for 1 h

Carbon monoxide (CO) and total volatile organic compounds (TVOCs) trend

Concentration variation of Carbon monoxide (CO) detected alongside Total Volatile Organic Compounds (TVOCs) during experimentation were presented in Figs. 4-8. For insecticides samples, TVOCs initially emitted were 7.2–73±19.76 ppm which after one hour reduced to 1.8–17±7.20 ppm. CO measured initial concentration were 0 - 4±1.08 ppm which after 1 hour became 0–7±2.16 ppm. As expected, TVOCs were detected in all the insecticide samples while CO were detected in about 53.33 % of the samples.The presence of CO indicates that they were either emitted or formed as observed in Fig. 4. CO were formed over time in 66.7% of insecticide samples.

For air freshener samples TVOC were detected in all the samples. The initial TVOC emitted ranged between 0.6–9.9±2.41 ppm which after 1 hour reduced to 0.3–5.5±1.29 ppm. CO which were either emitted or formed were detected in about 93.33 % of air freshener samples. CO concentration were 0–5±1.49 which after 1 hour became 0–7±1.67 ppm as shown in Fig. 5a and b.

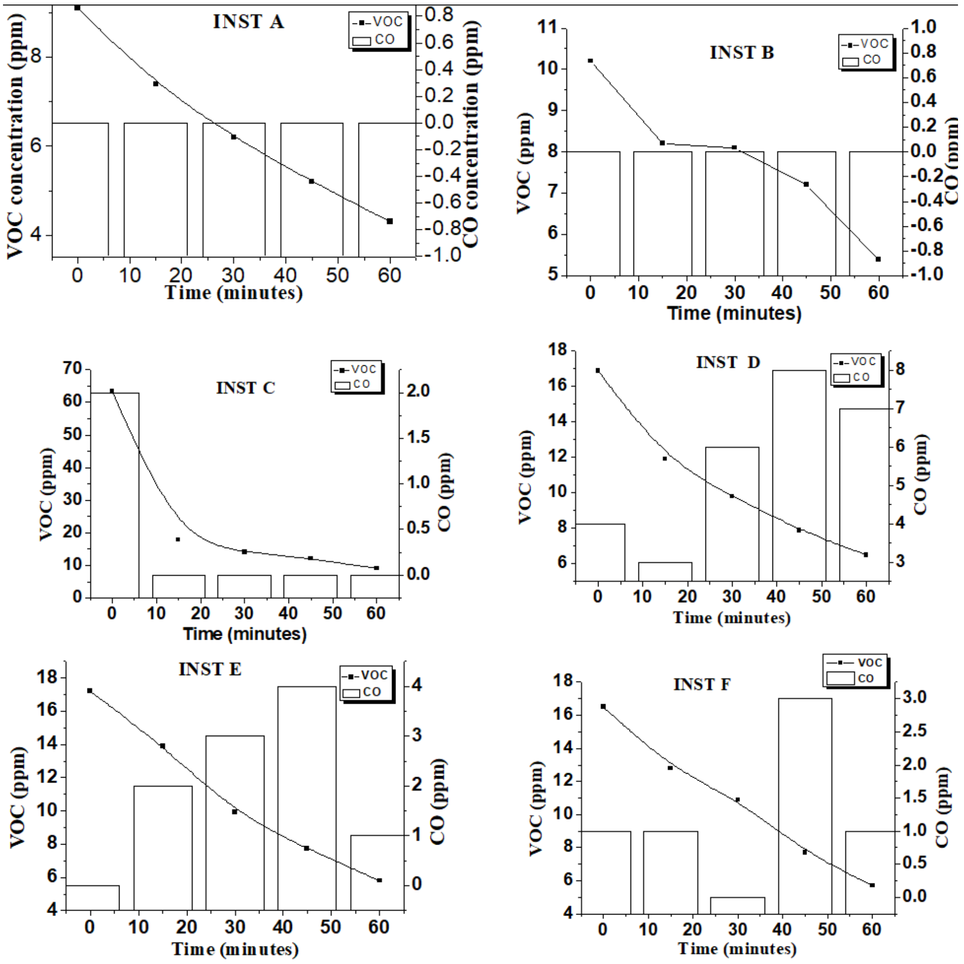
TVOC and CO were also detected in all the hairspray samples as shown in Fig. 6. TVOCs emitted from hairspray samples were higher than those measured for insecticides and hair fresheners. The initial concentration of TVOC measured were 21–236±93.06 ppm which later reduced to 3.1 – 6.7±1.41 ppm after 1 hour. CO measured were also on the high side as they were 1 – 22±8.29 ppm initially after spraying and later became 1 – 2±0.55 ppm.

For perfumes, TVOCs and CO were detected in all the samples investigated as shown in Fig. 7. TVOC initially measured were 1–36.8±14.36 ppm which became 0.5–2.7±1.03 ppm after 1 h. CO initially measured concentration were 8–37±14.10 ppm which later changed to

0-5±2.07 ppm. CO detected were either formed or emitted during spraying. Surface polish samples measured initial TVOCs concentration were 54.5–127±39.99 ppm as shown in Fig. 8. After 1 h in the test room, TVOCs concentration changed to 1.9 – 12.8±6.24 ppm. CO concentration were 3 – 5±1.00 ppm which later changed to 3–5±1.15 ppm. Shoe polish emitted TVOC concentration of 28.1–46.4±12.94 ppm which later became 1–57± 39.60 ppm as shown in Fig. 8 CO concentration were 7–73±46.67 ppm which later became 3–6±2.12 ppm.

Generally for all the samples, TVOCs initial concentration were in the range of 0.6 and 236 ppm (26.37±40.30 ppm) which later became 0.3 and 57 ppm (5.18±8.73 ppm) after 1 h. CO initial measured concentration range was 0 and 73 ppm (6±12.77 ppm) which later became 0 and 7 ppm (1.91±1.90 ppm) after 1 h. Highest initial TVOCs concentration were observed in HSP A and it is about 393 folds of the lowest with TVOCs concentration (AFN M). SSP B emitted the highest concentration of CO while least air freshener and insecticide samples were the least emitters of CO.

The presence of CO in the samples could be attributed to the oxidative reaction between the terpenes (which are the basic components of the fragrances used) and the ambient ozone and hydroxyl radicals from outdoor air. The CO formed under this situation is an ozonolysis product [35-37].



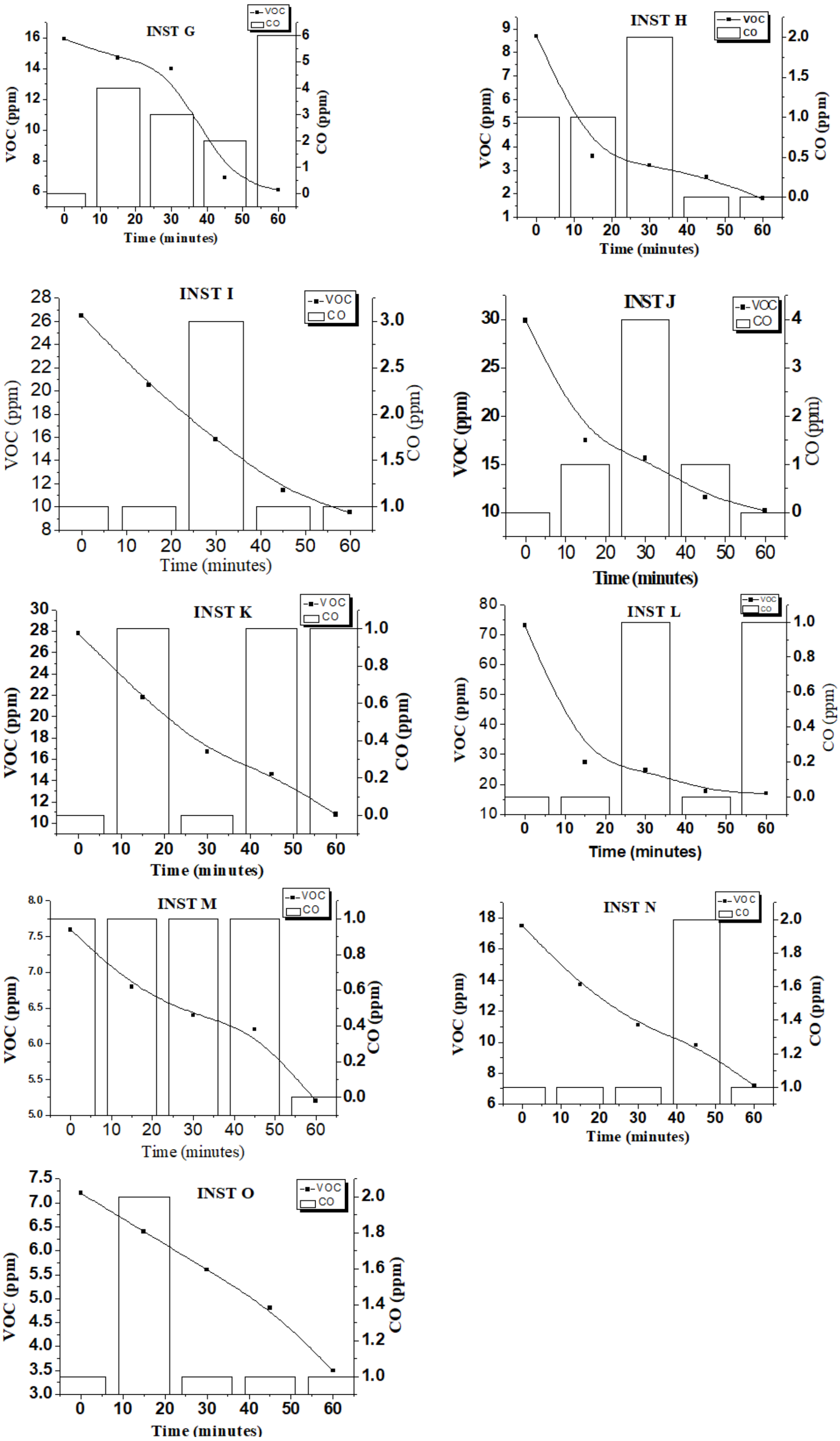
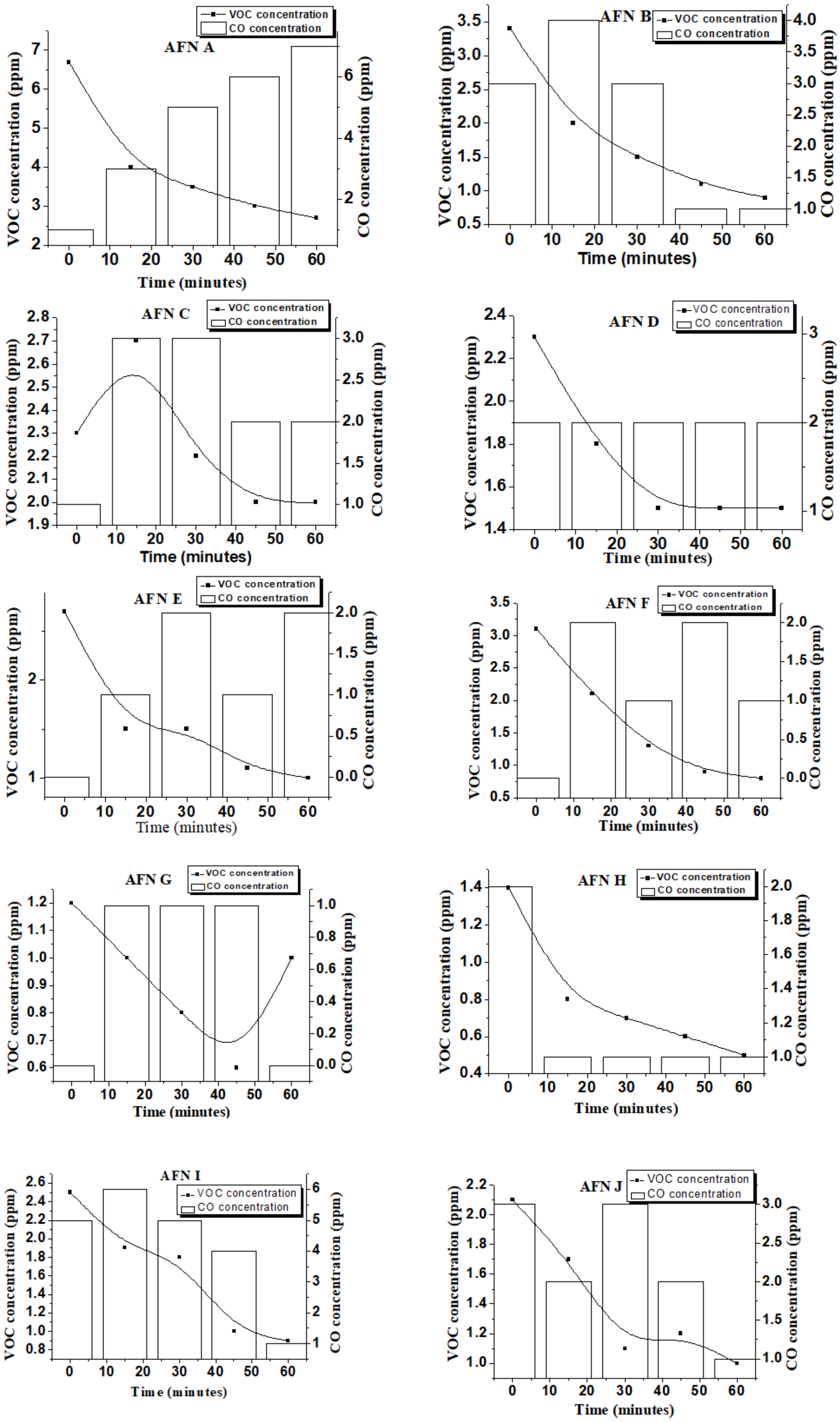


Fig. 4. TVOCs and CO Trend for Insecticides


AFN A
VOC concentration
CO concentration
VOC concentration (ppm)
CO concentration (ppm)
Time (minutes)
AFN B
AFN C
AFN D
AFN E
AFN F
AFN G
AFN H
AFN I
AFN J
0
10
20
30
40
50
60

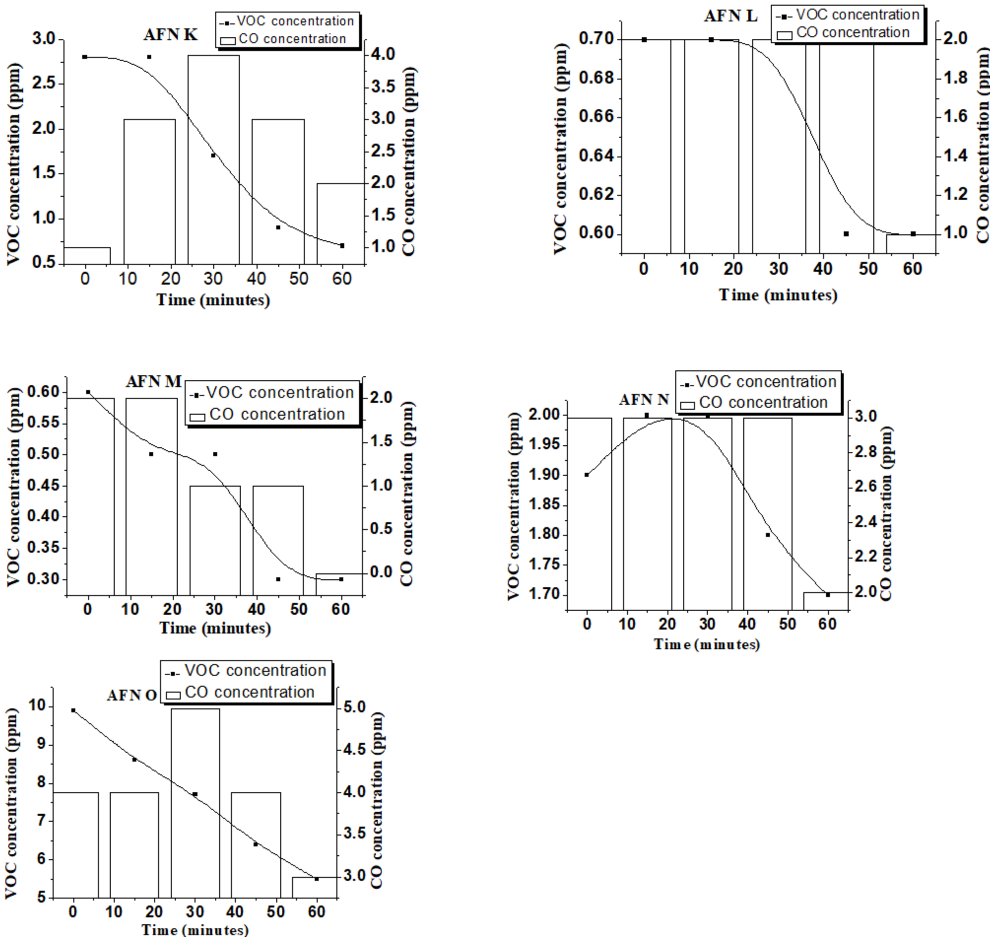
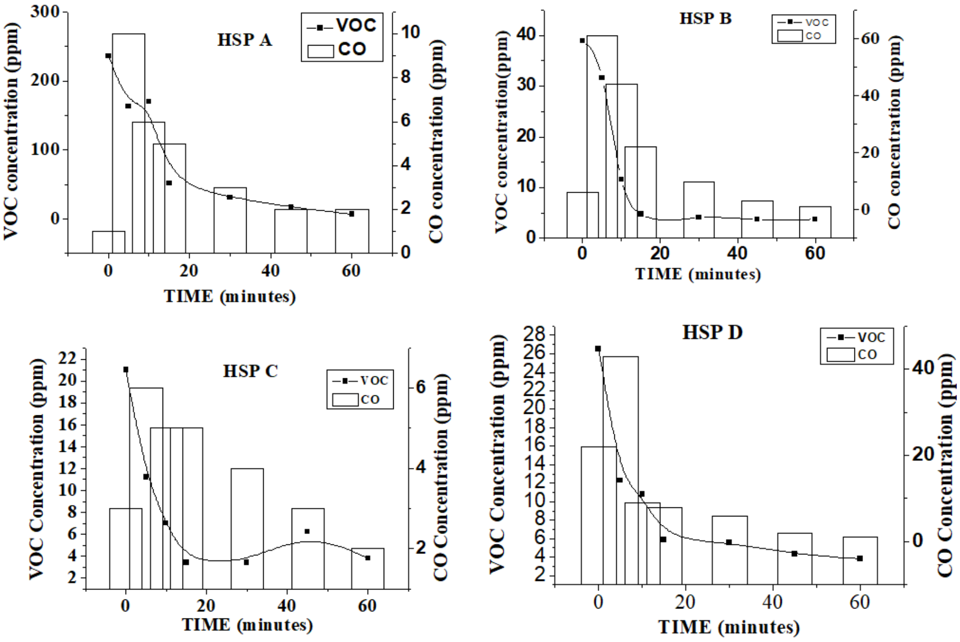


Fig. 5. TVOCs and CO trend for air fresheners



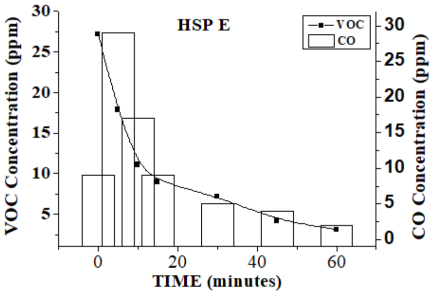


Fig. 6. TVOCs and CO trend for hairsprays

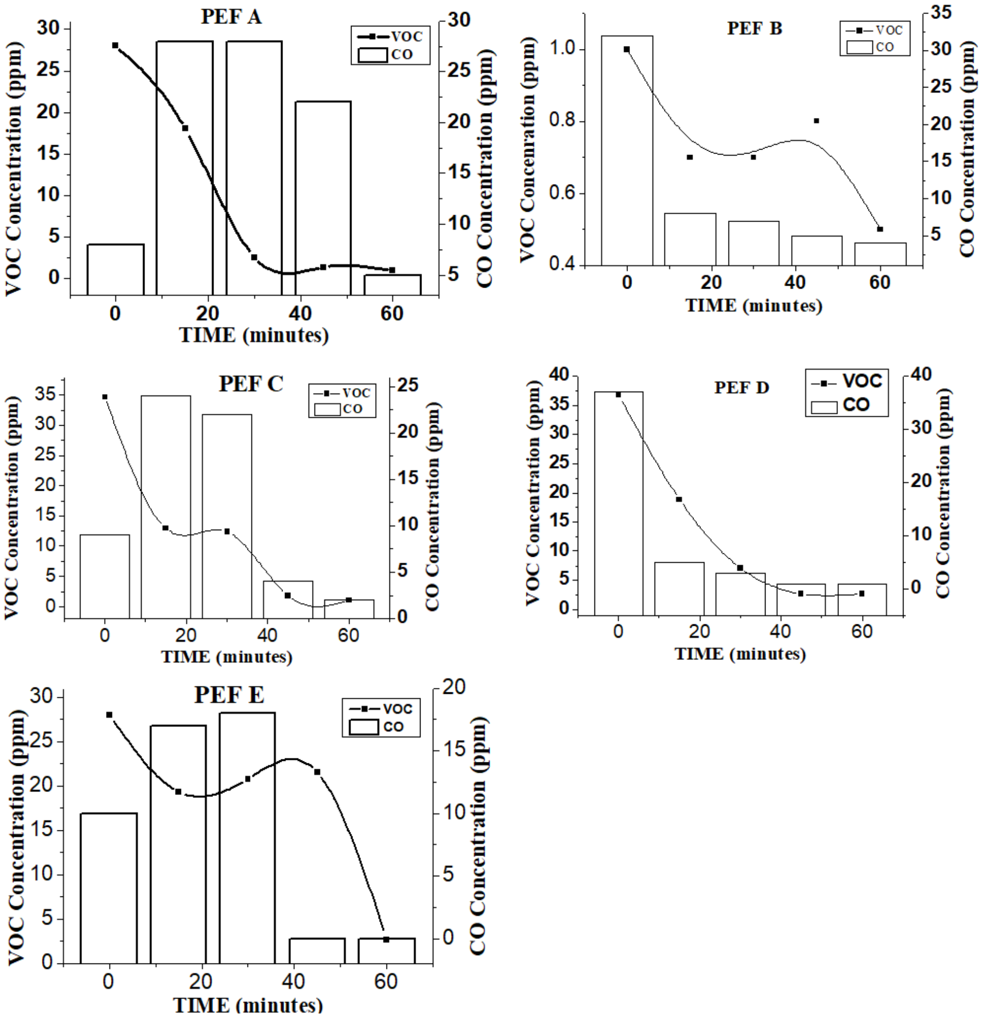


Fig. 7. TVOCs and CO trend for perfumes

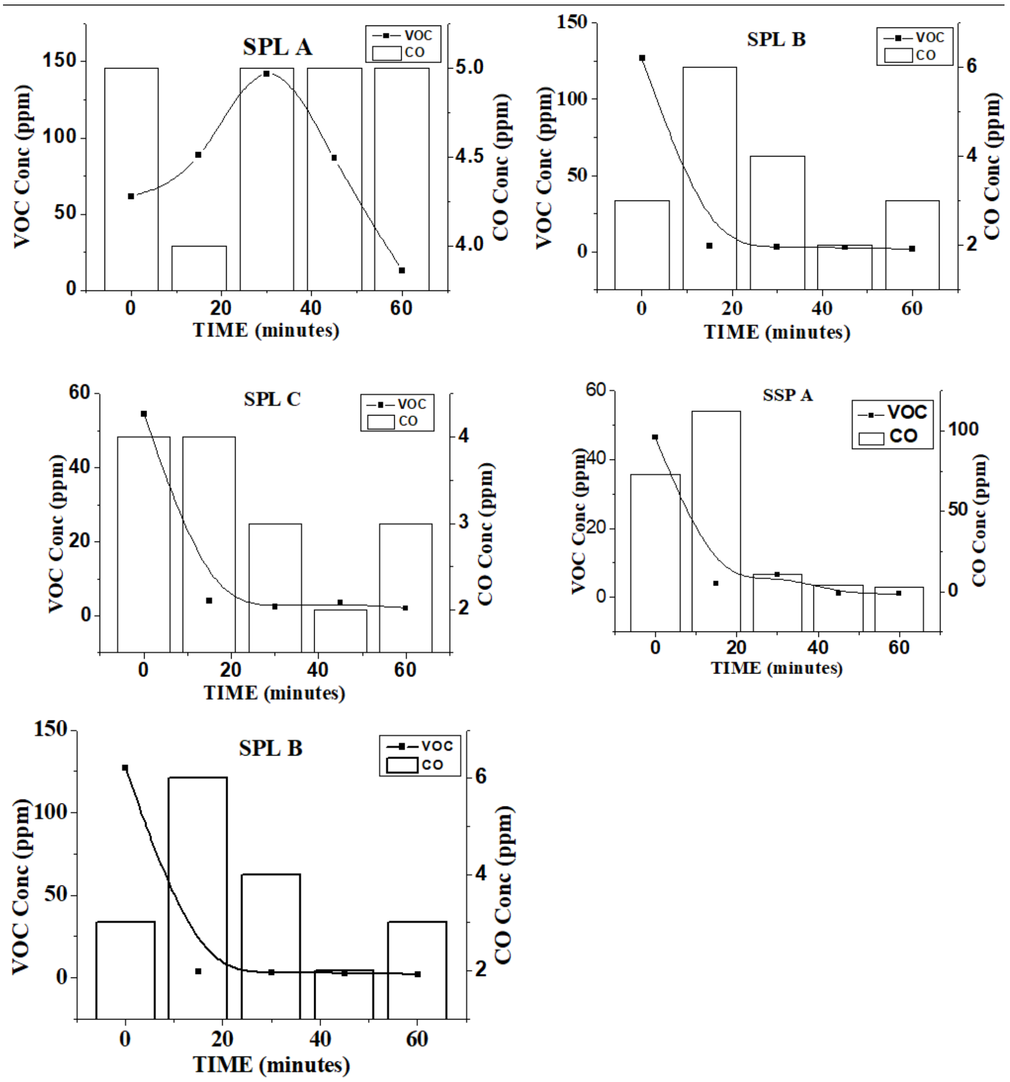


Fig. 8. TVOCs and CO trend for surface polish and shoe impregnation sprays

For hairsprays, perfumes, surface sprays and shoe impregnated sprays, the trend of emission of CO and TVOC do not follow a specified pattern (Figs. 5-8). The trend of TVOC increase may be attributed to the resuspension of aerosols from the surfaces being sprayed onto.In most of the samples considered, TVOC concentration decrease as the observation time increase. The decrease of TVOC concentration is due to the concentration decay of aerosol impregnated TVOC through deposition and fresh air exchange.

The high CO emission in hairsprays, perfumes, surface sprays and shoe impregnated sprays (Figs. 5-8) are presumed to be as a result of the oxidation of terpenes in fragrances and the chlorinated hydrocarbons solvents used as propellants. Examples of this type of reaction has earlier been reported by [38, 39].

Reaction kinetics of the household spray products

The concentration time data obtained was used to fit three kinetic models that is zero order, first order and second order. From the kinetic study, all samples (A-O) of Air fresheners, insecticide, shoe spray and surface polish show the reaction is

2nd order because it has the best fit with Pearson's correlation coefficient values close to 1as shown in Table 2.This implies that when the concentration of air freshener is doubled the concentration rate at which CO is formed is multiplied by a factor of 4 [33]. The reaction rate constants obtained for the insecticide samples A-O are 1.52494E-8, 1.20653E-7, 8.04531E-8, 1.03289E-7, 1.18555E-7, 1.28185E-7, 1.06698E-7, 3.93377E-7, 7.21213E-8, 6.6511E-8, 6.22197E-8, 4.05047E-8, 1.17721E-7, 9.33095E-8 and 1.8929E-7. The rate constants of Insecticide B, D, E, F, G. H, M and O is higher in values when compared with that of A,C,I,J,K,L and N which implies the rate of reaction is relatively faster. Perfumes A, B and C on exhibited a first order kinetics while perfumes D and E shows a second order kinetics. As for the hair spray samples, A shows a first order kinetics. While samples B-E shows a second order kinetics. The variation in the order of reaction across the spray products considered in this study because they are made from different ingredient. Not all chemicals contained in this spray product are written on the label, which means the constituent of most of this spray cannot be identified through the information provided [40-43].

Table 2. Order of reaction for the consumer spray products

	Pearson's correlation coefficient			Slope and Intercept for best fit	
Sample	Zero	First	Second	A(intercept)	B(slope)
INST A	-0.71158	0.84424	**0.94378**	7.87345E-5	1.52494E-8
INST B	-0.74915	0.86089	**0.94794**	6.33284E-5	1.20653E-7
INST C	-0.47823	0.6992	**0.90565**	3.12031E-5	8.04531E-8
INST D	-0.65272	0.81221	**0.93426**	5.00583E-5	1.03289E-7
INST E	-0.63216	0.79573	**0.92748**	5.3716E-5	1.18555E-7
INST F	-0.65079	0.79924	**0.92591**	5.3606E-5	1.28185E-7
INST G	-0.68922	0.813	**0.92782**	4.71075E-5	1.06698E-7
INST H	-0.56245	0.73416	**0.91357**	1.63547E-4	3.93377E-7
INST I	-0.64913	0.80415	**0.92943**	3.30108E-5	7.21213E-8
INST J	-0.62021	0.79422	**0.92951**	3.13208E-5	6.6511E-8
INST K	-0.6575	0.8141	**0.93446**	3.0079E-5	6.22197E-8
INST L	-0.52257	0.7351	**0.91733**	1.82997E-5	4.05047E-8
INST M	-0.82575	0.90684	**0.96577**	7.21841E-5	1.17721E-7
INST N	-0.67881	0.82323	**0.93608**	4.51245E-5	9.33095E-8

Table 2 (continued)

	Pearson's correlation coefficient			Slope and Intercept for best fit	
INST O	-0.72717	0.84677	**0.94251**	9.50111E-5	1.8929E-7
PEF A	-0.35475	**0.41674**	0.38747	1.66232	0.00156
PEF B	-0.51413	**0.45191**	0.32113	2.82339	6.00138E-4
PEF C	-0.35633	**0.35273**	0.06681	1.3912	0.00129
PEF D	-0.36347	0.48082	**0.64351**	1.69454E-4	1.9803E-5
PEF E	-0.38473	0.54585	**0.81122**	1.3868E-4	2.16556E-7
HSP A	-0.37834	**0.28282**	-0.05556	-1.41193	8.08751E-4
HSP B	-0.40147	0.58921	**0.86229**	7.51014E-5	1.32281E-7
HSP C	-0.49054	0.68155	**0.88106**	6.16413E-5	9.56902E-8
HSP D	-0.40253	0.54314	**0.72887**	1.01573E-4	1.297E-7
HSP E	-0.45082	0.53127	**0.5611**	5.74919E-5	5.07394E-8
SPL A	-0.53396	0.66021	**0.87869**	3.54079E-5	1.26056E-7
SPL B	+-0.36039	0.55568	**0.89228**	8.40784E-5	2.29191E-7
SPL C	-0.37933	0.59654	**0.89466**	8.8441E-5	2.3966E-7
SSP A	-0.35672	0.53809	**0.89109**	2.74733E-4	7.081532E-7
SSP B	-0.52763	0.65333	**0.87743**	7.5337E-5	2.71954E-7
AFN A	-0.6075	0.7785	**0.9216**	1.33475E-4	1.87661E-7
AFN B	-0.59058	0.7543	**0.89771**	2.98995E-4	4.86685E-7
AFN C	-0.65987	0.80579	**0.91902**	1.81877E-4	2.51734E-7
AFN D	-0.7929	0.850180	**0.93727**	2.85011E-4	3.36584E-7
AFN E	-0.60306	0.77049	**0.90662**	3.46011 E-4	5.19761 E-7
AFN F	-0.57835	0.72558	**0.82211**	3.878177E-4	6.99176 E-6
AFN G	-0.69389	0.81278	**0.91664**	5.87945E-4	1.16494 E-4
AFN H	-0.66875	0.82561	**0.94021**	5.66406E-4	1.00936E-4
AFN I	-0.66637	0.80167	**0.92472**	3.35295E-4	7.76534E-7

Table 2 (continued)

	Pearson's correlation coefficient			Slope and Intercept for best fit	
AFN J	-0.72301	0.84169	**0.93995**	3.27382E-4	6.20298E-5
AFN K	-0.60811	0.74107	**0.90106**	3.73335E-4	1.06627E-6
AFN L	-0.69934	0.8217	**0.93142**	0.00104	2.28778E-6
AFN M	-0.69502	0.82864	**0.93649**	0.00108	2.24523E-6
AFN N	-0.85378	0.92041	**0.97037**	2.39179E-4	2.39864E-5
AFN O	-0.76128	0.86523	**0.94869**	6.21667E-5	1.18452E-7

Conclusion

TVOCs emitted from sprayproducts were mostly of second order kinetics. CO were suspected to be formed as intermediate oxidation product. The rate of reaction of some of the household spray product is relatively faster than others because of variation in the composition of the products which were mostly undisclosed in the product labels.

Real-time emission profiles TVOCs and CO emission were detected from a wide category of household spray products in a controlled indoor environment. In general, there was correlation between the TVOCs and CO concentration in all samples of consumer spray products considered in this study. It will also help in the development of safer products and a proper guide on how to use them in a way it will not cause harm to both the user of the product and the environment.

Hence, to prevent or resolve dangers caused spray products efficiently and effectively. their use must be avoided where practicable. Ventilation system in buildings should be properly designed, operated and maintained as this will help reduce the concentration of pollutants in indoor environment in a short time. Educating people regarding indoor air quality is very important. People should be given information about contents and pollutants that may be emitted from consumer spray products.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author's contribution

Adeniran, Jamiu Adetayo conceived and designed the study. Adeniran, Jamiu Adetayo collected the data. Adeniran, Jamiu Adetayo and Atanda Ayodele Sarat wrote the paper. All authors wrote and approved the final draft of the manuscript.

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Ethical considerations

"Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely ob-served by the authors".

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