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EVALUATION OF COMPOSITION AND EVAPORATION BEHAVIOR OF COMMERCIAL THINNER SAMPLES EXPENDED IN MEXICO CITY

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ABSTRACT

The chemical composition of 34 thinner samples obtained in the Metropolitan Area of Mexico City was quantified by gas chromatography. Both the total number and the composition of each of the identified compounds showed great variations from one sample to another. Nonetheless, toluene, n-hexane, acetone and methanol were the most frequently and highest concentration compounds identified in this study. By using a thermodynamic model of solvent blend evaporation, which accounts for mixture non-idealities in terms of component activity coefficients, the evaporation time versus solvent composition (solvent balance) curves were calculated for 10 of the analyzed samples. The calculated evaporation rate showed a broad spectrum in their behavior (fast, intermediate and low). Regarding solvent balance, in the 10 samples considered, the low solvency components (diluents) were evaporated disproportionately slow in regard to latent and high solvency (active) solvents. The high solvency components rapidly became depleted in the residual solvent. This leads to the undesirable effect known as solvent imbalance. The appreciable differences observed in the total number of compounds and in their compositions, along with the evaporation behavior of the analyzed samples lead to conclude that apparently no technical, environmental or toxicological criteria were applied to formulate the commercial analyzed samples.

RESUMEN

Se presentan resultados de la composición química, obtenidos por medio de un estudio por cromatografía de gases, de 34 muestras de adelgazadores comerciales (tíner) obtenidas en diversas zonas geográficas de la Zona Metropolitana de la Ciudad de México. Tanto la cantidad como la concentración de los compuestos detectados denotaron una gran variabilidad en las diferentes muestras estudiadas. Sin embargo, se observó que el tolueno, el n-hexano, la acetona y el metanol fueron las sustancias que se presentaron con mayor frecuencia y en concentraciones más altas en todas las muestras de tíner. Con base en los valores de la composición de las muestras de tíner analizadas y empleando un modelo termodinámico, que consideró el comportamiento no ideal de éstas en términos de coeficientes de actividad, se calculó el comportamiento de evaporación de algunas de las muestras de tíner estudiadas. En general las muestras consideradas no presentaron un buen "balance disolvente". Las diferencias tan apreciables observadas tanto en el número de componentes como en la composición, así como en el comportamiento de evaporación de las muestras estudiadas indican que probablemente no se aplican normas ni criterios para definir sus características técnicas, ambientales o de toxicidad para aplicaciones comerciales e industriales específicas.

INTRODUCTION

A thinner is a commercial mixture of volatile organic compounds (VOC's) widely used to manufacture and apply many products such as paints, lacquers, adhesives, and inks. The thinner is formulated as a mixture from relatively pure solvents and each solvent has a specific function in the formulation. Depending on the solvent or solvency capacity towards a given polymer or resin, the components of the thinner are classified in three groups: active solvents, cosolvents or latent solvents and diluents. The active solvents are those VOC's which have the capacity to dissolve a polymer or resin in industrial and commercial products such as paints, adhesives and inks, and help to define important properties of these products such as viscosity, solids content and evaporation rate. The latent solvent is not a solvent by itself but enhances the solvent capacity of the active solvent with which it is generally blended. The diluent does not have any solvent effect but helps to control the costs in the solvent mixture production. The behavior of a pure VOC as active, latent or diluent depends on the polymer or resin to dissolve (Nelson *et al.* 1970). So, the specific use to which it is given and the final quality expected are factors that determine the type and concentration of each VOC in a thinner sample. Therefore, it is not possible to establish a generic thinner formula for a broad spectrum of applications (Walsham and Edwards 1971). However, some aspects to consider during thinner formulation are: (1) the concentration of VOC's in a thinner sample must vary according to the values given in **table I**, (2) the quality of a thinner is related to its diluent concentration as indicated in **table II** and (3) the content of the latent solvent must be in a 1:3 ratio with respect to the active solvent concentration (Gutiérrez-Flores 1975).

TABLE I. TYPICAL COMPOSITION OF A THINNER

Solvent	Composition (% volume)
Active	25 to 40
Latent	≤20
Diluent	45 to 60

TABLE II. THINNER QUALITY AS A FUNCTION OF ITS DILUENT CONCENTRATION

Thinner quality	Diluent concentration (% volume)
High	45 to 50
Medium	50 to 55
Low	> 55

The commercial thinners sold in Mexico City show great diversity in the number and type of VOC's they contain and in their composition as well (Barroso-Moguel and Romero-Díaz 1988, Lorenzana-Jiménez *et al.* 1988). Furthermore, highly toxic substances such as toluene, methanol, n-hexane, acetone, benzene, and xylenes have been found in relatively high concentrations. This leads to the availability of thinners of dubious quality from a technical point of view and notably harmful from a toxicity point of view. Thinner components represent an additional health risk due to their high volatility and persistence in the environment, their high capacity to be moved from their source to any place and to be transformed into other more toxic or dangerous substances to man and the environment (Bello *et al.* 1995).

Solvent inhalation abuse is a growing public health problem in Mexico and in other countries. Thousands of children and youngsters in Mexico City are deliberately inhaling thinner vapors in order to induce sensations of euphoria and exhilaration. Although the practice itself is not new, its occurrence in epidemic proportions through the City have brought the problem into nation-wide prominence. According to the Mexican Drug Addictions National Inquiry, 4.8% of the urban population between 12 and 65 years old used drugs at least once during their life. The organic solvents use was overpassed only by the use of marijuana and tranquilizers. Information supplied by the "Centros de Integración Juvenil" showed that 56% of the solvent abusers started using organic solvents when they were between 10 and 19 years old (Secretaría de Salud 1990). Acute intoxication with thinner affects the central nervous system disturbing perception and inducing hallucinations, higher levels of exposure induce serious effects to the liver, heart and the visual system (Press and Done 1967, Guzmán-Flores 1975, Barroso-Moguel and Romero-Díaz 1988). Due to its composition, thinner also must be considered as a highly toxic agent with mutagenic activity (Gómez-Arroyo and Castillo-Ruiz 1985). These adverse effects are of considerable importance and consequently an exposition of any magnitude to these harmful substances represents an unpredictable health risk.

The technical properties of a thinner sample such as density, viscosity and volatility, depend on the different VOC's present and the thinner noxious effects are also directly related to the concentration of highly toxic components. Emission of VOC's due to evaporative processes are considered an environmental problem due to their significance in the formation of photochemical oxidants, especially ozone (Andersson-Sköld *et al.* 1992). It has been suggested that Mexican authorities must implement regulations to set technical and toxicological criteria of formulation in order to generate new thinner samples suitable for several industrial and commercial applications, with a very low concentration of toxic components and hazardous air pollutants (Barroso-Moguel and Romero-Díaz 1988, Lorenzana-Jiménez *et al.* 1988). Unfortunately, to our knowledge, there are no regulations establishing technical, environmental and toxicological criteria to formulate thinners in Mexico.

Since thinners are solvent mixtures in which complicated chemical interactions and synergistic effects are present it is of the utmost importance to have a complete knowledge of their different VOC's and their composition in order to have reliable information. Hence, considering the critical importance that a chemical analysis of thinners samples has in several fields, in this work we have conducted a systematic laboratory study to determine the composition of several commercial thinner samples distributed in Mexico City with multifold objectives: (i) to obtain conclusions regarding the technical performance of the analyzed commercial samples through the calculation of the thinners evaporation time and their composition during evaporation, also known as solvent balance, using a thermodynamic model of solvent blend evaporation and through a comparison of their composition with recommended literature values for the composition of active, latent and diluent components; (ii) to generate data bases on which researches from different areas may base themselves to carry out clinical, pharmacological and toxicological studies and establish the neurotoxic properties of thinners and their individual components related to their chemical structure; (iii) to produce useful information to create data banks for the evaluation and distribution of atmospheric pollutants; (iv) to have reliable information to develop a proper legislation to establish standards on the formulation, production, distribution and use of solvent mixtures and products containing them.

MATERIALS AND METHODS

Chromatographic analysis of thinner samples

The gas chromatographic analysis of 34 thinner samples was performed on a Tremetrics model 541 gas chromatograph equipped with a 2 m x 3 mm stainless steel column filled with 15% Carbowax 20M on Chromosorb W-HP 100/120, flame ionization detector (FID) and a LabQuest™ chromatography data system (version 5.0). The operating conditions were as follows: nitrogen as carrier gas at 30 cm^3/min., hydrogen supplied to the detector at 30 cm^3/min. and air at 350 cm^3/min. The column temperature was 50 °C, the injector block temperature 190 °C and the detector block temperature 200 °C. A 0.5 microliter sample was injected.

Standards

The identification of the different components of the thinner samples was made by comparison with the corresponding retention time of pure reference substances obtained from commercial sources of the highest purity available, generally greater than 99.9 % mol.

The basic steps of the method for the thinner analysis include the transfer, with a volumetric pipet, of a 5 cm^3 aliquot from the commercial sample, kept in an ice box, to a clean 5.5 cm^3 vial without headspace and immediately covered. A sample was taken from the vial with a microsyringe for analysis and injected by hand into the chromatograph. Four injections were carried out for each thinner sample and the reported composition results represent the average.

The retention times for the pure reference substances were obtained each time after the analysis of about 5 samples of different thinners to verify the quality of the chromatographic method.

Five calibration standards containing up to ten reference substances each one, at different known concentrations, were prepared by weight and analyzed in order to verify the quantitative reliability of the method. A total number of 18 different compounds were used to prepare the calibration standards.

Summarizing, the quality of the results was evaluated using the information from five repeated runs to obtain retention times for 30 reference substances, which gave about 300 experimental retention time points, and from the comparison between the known and chromatographically derived composition of the five calibration standards mentioned above, which in turn gave about 100 concentration points. Thus, the reported results for the composition of the thinner samples analyzed in this work had an accuracy and precision of 3 %.

Duplicates

Duplicate analysis were performed for several thinner samples. The number of analytical duplicates was 20 % of the total number of thinner samples analyzed by the same procedure described. The relative percent differences between the first analysis and the duplicates were all within the accuracy given above.

Calculation of solvent evaporation

Evaporation time and solvent balance are important properties of solvent blends used in coating systems. A mathematical model of solvent blend evaporation for films which accounts for mixture non idealities in terms of component activity coefficients was used in this work to calculate the evaporation behavior of some of the analyzed thinner samples, at 25 °C.

The total evaporation rate, R_m, for a mixture of n components was calculated as (Sletmoe 1970, Walsham and Edwards 1971, Yoshida 1972):

$$R_m = \sum_{i=1}^{n} a_i R_i^0 \tag{1}$$

or

$$R_m = \sum_{i=1}^{n} \gamma_i C_i R_i^0 \tag{2}$$

where a_i is the activity of component i, R_i^o is the rate of evaporation of pure i, C_i is the concentration by weight of i, and γ_i is the activity coefficient of component i.

The method chosen in this work for calculating activity coefficients of the multicomponent mixture constituents studied was similar to the one described by Walsham and Edwards (1971). This method allows the prediction of component active coeffcients in binary mixtures by interpolation from the values of activity coefficients at infinite dilution, γ_{12}^∞ , γ_{21}^∞ , of components 1 in 2 and 2 in 1, respectively. Component activity coefficients at any mixture composition were calculated by interpolation from a matrix of binary system infinite dilution activity coefficients. The composition of each component in the evaporated sample was obtained with the following expression (Sletmoe 1970):

$$V_i = \frac{R_i}{R_m} = \frac{\gamma_i C_i R_i^0}{R_m} \tag{3}$$

where V_i represents the composition of component i in the vapor. The change in composition caused by the evaporation of a small liquid fraction was determined by an equilibrium mass balance.

A plot of weight of solvent evaporated against time is typically nonlinear for multicomponent systems. However, the rate of evaporation can be considered constant during the time t required for evaporation of a small incremental weight wt of a mixture, as given by equation 4. The time t can be as small as desired by entering the number into the computer program. In this work, t was fixed at 5 seconds.

$$\frac{w}{t} = \sum_{i=1}^{n} \gamma_i w_i R_i^0 \tag{4}$$

In a new liquid composition, a new set of activity coefficients was calculated and the evaporation rate was determined. In this way, a curve of evaporation rate versus time was calculated and the composition of the remaining liquid was also followed during the evaporation process.

RESULTS

Chromatographic analysis of thinner samples

The chromatographic analysis of the 34 commercial thinner samples studied showed a number of components between 8 and 30. However, it is important to point out that many of the identified compounds were in low concentration (< 1 wt %) and were regarded as impurities.

Table III shows the mean composition of the main components identified in the 34 analyzed samples, whereas the nine components more frequently found are shown in the **table IV**. It may also be observed that all the samples contained compounds in relatively small concentration which were not identified.

Toluene was found in each one of the 34 analyzed samples. It was the most abundant compound, reaching concentrations up to 87.5 wt %. Acetone was the second component in frequency as it was identified in 76 % of the samples analyzed, with concentrations up to 31.5 wt%. n-Hexane was the third most frequent component with concentrations up to 13 wt %. Methanol, methyl butyl ketone and benzene were identified in 62 % of the samples analyzed, however, it is important to remark that, while benzene and methyl butyl ketone have concentrations lower than 10 wt %, methanol can reach concentrations up to 41 wt %. 2-Propanol, xylene and 3-methyl pentane had similar composition values; these compounds were present in 59 % of the samples analyzed. The rest of the identified compounds listed in **table III** had a frequency lower than 50 %.

The fact that toluene was present in high concentrations in all the samples studied, according to the studies of Lorenzana-Jiménez *et al.* (1988), suggests that it may be responsible to a great extent for the psychic stimulation when thinner is intentionally inhaled. Toluene is a very toxic substance (Hayden *et al.* 1977). It has proven to be an inducer of chromosomal alterations (Gómez-Arroyo *et al.* 1986). The nervous system is particularly vulnerable to this substance due to its high lipid solubility (Devathasan *et al.* 1984). Carlsson and Linquist (1977) showed toluene concentration in fatty tissue to be 80 times higher than in blood. Acute toxicity by toluene inhalation may result in death due to cerebral edema, pulmonary edema or myocardial involvement (Devathasan *et al.* 1984).

TABLE III. AVERAGE COMPOSITION OF THE MAIN COMPONENTS IDENTIFIED IN 34 COMMERCIAL THINNER SAMPLES OBTAINED IN THE METROPOLITAN AREA OF MEXICO CITY

Component	Average composition (wt%)
Toluene	59.9
Hexane	8.2
Acetone	5.2
Methanol	4.8
Xylene	4.1
Aromatics ($\geq C_8$)	3.0
Propyl acetate	2.8
Cellosolve	2.0
Methyl isobutyl ketone	1.8
2-Propanol	1.7
Butyl cellosolve	1.6
Methyl butyl ketone	1.6
Butyl acetate	1.1
Benzene	0.3
Not identified	1.9

TABLE IV. FREQUENCY AND COMPOSITION RANGE OF SOME VOC's IDENTIFIED IN 34 COMMERCIAL THINNER SAMPLES OBTAINED IN THE METROPOLITAN AREA OF MEXICO CITY

Component	Frequency (%)	Composition range (wt%)
Toluene	100	0.06-87.47
Acetone	76	0 -31.46
Hexane	65	0 -13.07
Methanol	62	0 -40.93
Methyl butyl ketone	62	0 - 9.72
Benzene	62	0 - 2.21
2-Propanol	59	0 -39.06
Xylene	59	0 -18.69
3-Methyl pentane	59	0 - 9.42
Not identified	100	0.10-29.63

Toluene impairs central nervous system (CNS), thus the dysfunction of the CNS due to the inhalation of toluene could be considered to appear as disturbed equilibrium due to the impairment of the vermis, disturbed skillfulness of the extremities due to the impairment of the cerebellar hemispheres and mental retardation due to diffuse cerebral atrophy. Cerebral and cerebellar atrophy have been well documented (Grabski 1961, Malm and Tunell 1980, King *et al.* 1981); visual dysfunction has also been reported (Takeuchi *et al.* 1981a). Toluene has also been implicated as a causative agent in cardiac arrhytmias (Taylor and Harris 1970).

It has been determined that a glue-soaked cloth in a paper bag may create a toluene concentration of 200 ppm up to 50 fold higher than the TWA (the time-weighted average concentration for normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect). Toluene has a TWA value of 50 ppm (ACGIH 1994).

May be n-Hexane is the most highly toxic member of the alkane series of homologues because, as most organic solvents, it is highly lipophilic, hence it is actively absorbed by the mammalian system and accumulated in body tissues, proportionally in the lipid content; it is an anesthetic that, when ingested, causes nausea, vertigo, bronchial and general intestinal irritation and central nervous system effects (Sandmeyer 1981a). *Per se* n-Hexane is considered to have no particular neurotoxicity, but it is metabolized *in vivo* into neurotoxic substances (Spencer *et al.* 1978; Couri *et al.* 1978). It has been reported that the neurotoxicity of n-hexane may be easily modified by other solvents for example, methyl ethyl ketone (Altenkirch *et al.* 1978; Takeuchi *et al.* 1981b).

Acetone has been considered to be one of the least toxic solvents used in the industry. However, exposure to high concentrations can produce central nervous system depression and narcosis; prolonged or repeated skin contact may damage the skin and produce dermatitis (Krasavage *et al.* 1981).

Methanol toxicity is low as measured by lethality but sublethal doses can cause serious effects to the central nervous system, the liver and particularly to the visual system. Methanol is mildly irritating upon direct contact with the eyes and upon prolonged contact with the skin. Ingestion has caused serious illness and deaths (Rowe and McCollister 1982).

As shown in **tables III** and **IV**, benzene was also found in some of the analyzed samples. The concentrations detected were low, however its presence in the commercial thinners is worrying, since benzene is a very harmful substance. Some cases have been reported involving death from acute benzene poisoning by deliberate inhalation (Winek *et al.* 1967; Winek and Collom 1971). Benzene is a lipid soluble compound that when inhaled in high concentrations, accumulates in the brain and body fat and acts as a typical narcotic poison (Winek and Collom 1971). The main effects in benzene intoxication appears to be CNS lesions, impairment of hearing, dermal and cardiac sensitization, dyspnea and tachycardia; benzene decreases arterial pressure and is considered a "suspect carcinogen" (Greenburg *et al.* 1939, Sandmeyer 1981b). Benzene also depresses bone marrow and is therefore a potential source of anemia and other blood abnormalities (Glaser and Massengale 1962).

It is important to consider that, although present in lower concentrations, other components such as xylene, 2-propanol and methyl butyl ketone can cause additional toxic effects in the solvent blend. Also, toxic effects that results of the feasible synergetic interaction between the different component in the solvent blend should be considered during voluntary and inadvertant solvent exposure.

Additionally, from an environmental point of view once in the atmosphere, the different VOC's which constitute the thinners represent an additional health risk due to their high volatility and persistence in the environment, their high capacity to be moved and their capacity or photoreactivity to be transformed into more toxic and dangerous substances to humans and other living organisms (Bello *et al.* 1995).

Calculation of solvent evaporation

In order to verify the reliability of the calculation method used in this work to estimate the evaporation behavior of solvent blends, the global evaporation as a function of time, was calculated for four mixtures studied experimentally and reported in the litérature (Walsham and Edwards 1971). The comparison between the experimental and calculated evaporation rate for the four mixtures, throughout the composition range between 0 and 90 wt %, shows a mean difference of 2.3 min. (standard deviation 5.4 min.), which we consider to be highly acceptable.

Once the reliability of the calculation method to estimate the evaporation rate of solvent blends was determined, the evaporation rate for 10 out of the 34 analyzed thinner samples was calculated. The selected thinner samples were those with high concentration of highly toxic substances such as toluene, hexane, methanol, methyl isobutyl ketone and xylene. In order to simplify the calculations, the original components found in the chromatographic analysis with low concentration were added to the higher concentration value of those components with similar chemical structure. The rounded up composition of each of the 10 samples is shown in **table V**.

Also in **table V** the different components of the thinners were classified as active, latent and diluent solvents following the considerations given by Gutiérrez-Flores (1975) to classify the components of industrial solvents used in the lacquer, paint and ink industries. Thus, **table VI** gives a summary of the total composition of active, latent and diluent solvents contained in each one of the 10 samples, as well as the ratios of latent to active solvents and active to diluent solvents.

It is important to point out that none of the thinners presented in **tables V** and **VI** fulfill the formulation criteria for a typical thinner shown in **table I**. Also, taking the high concentration of diluent into account, that was always greater than 50 wt %, and the criteria of **table II**, it can be concluded that the 10 thinner samples analyzed have low quality. A similar behavior was observed for the other 24 studied samples.

The global evaporation rate, as a function of time, estimated for the 10 indicated samples, is presented in **table VII**, from 5 up

TABLE V. ROUNDED COMPOSITION (wt%) OF 10 COMMERCIAL THINNER SAMPLES OBTAINED IN THE METROPOLITAN AREA OF MEXICO CITY

	Thinner									
Solvent	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Acetone^A	10.41	31.49	-	7.57	-	-	-	-	-	-
Methyl isobutyl ketone^A	6.23	-	7.10	-	5.96	7.24	-	-	-	-
Propyl acetate^A	5.94	-	-	-	-	-	-	-	-	8.88
Butyl acetate^A	-	-	-	-	-	-	5.34	5.52	8.51	-
Methanol^L	20.02	-	9.47	41.56	17.09	19.52	-	13.40	-	8.16
2-Propanol^L	-	-	13.46	-	12.97	14.54	13.89	7.94	-	13.74
Hexane^D	4.63	3.29	-	15.45	-	-	-	-	-	-
Toluene^D	37.38	65.22	69.97	35.42	63.98	58.70	77.18	73.14	84.44	69.22
Xylene^D	15.39	-	-	-	-	-	3.59	-	7.05	-

^{A}Active solvent, ^{L}Latente solvent, ^{D}Diluent to 90 wt% evaporated, and are shown in **figure 1**. It can be observed that the samples present a wide spectrum of evaporation rates. The samples 2, 4, 5 and 6 evaporate relatively fast, while samples 9 and 7 show the lowest evaporation rates, remaining samples have middle evaporation rates.

TABLE VI. ACTIVE, LATENT AND DILUENT SOLVENT CONCENTRATION (wt%) OF 10 COMMERCIAL THINNER SAMPLES OBTAINED IN THE METROPOLITAN AREA OF MEXICO CITY

	Initial concentration of solvent (wt %)			**Initial ratio**	
Mixture	**Active solvent**	**Latent solvent**	**Diluent**	**Latent:Active**	**Active:Diluent**
1	22.58	20.02	57.40	1:1.12	1: 2.54
2	31.49	0	68.51	-	1: 2.18
3	7.10	22.93	69.97	1:0.30	1: 9.85
4	7.57	41.56	50.87	1:0.18	1: 6.72
5	5.96	30.06	63.98	1:0.20	1:10.73
6	7.24	34.06	58.70	1:0.21	1: 8.11
7	5.34	13.89	80.77	1:0.38	1:15.13
8	5.52	21.34	73.14	1:0.26	1:13.25
9	8.51	0	91.49	-	1:10.75
10	8.88	21.90	69.22	1:0.40	1: 7.80

The values calculated for the change of composition of the active, latent and diluent solvents in the remaining liquid (solvent balance) during the evaporation process of the 10 thinner samples, are included in **table VIII** and in **figure 2**, from which the following remarks can be derived:

With exception of the behavior observed for samples 4 and 9, in the other eight cases the concentration of diluent on the remaining liquid always increases during the evaporation. In sample 1 the concentration of the active solvent is almost constant throughout the evaporation, decreasing a little at the end of the evaporation, the diluent concentration increases appreciably while that for the latent solvent diminishes until it runs out. A similar behavior is observed for mixtures 3, 5, 7, 8 and 10.

TABLE VII. EVAPORATION RATE AS A FUNCTION OF TIME FOR 10 COMMERCIAL THINNER SAMPLES OBTAINED IN THE METROPOLITAN AREA OF MEXICO CITY

	wt% evaporated										
Thinner	**5**	**10**	**20**	**30**	**50**	**60**	**70**	**75**	**80**	**85**	**90**
	time (s)										
1	7	14	30	46	81	106	132	147	167	179	197
2	7	14	29	44	77	95	115	125	136	148	160
3	9	17	35	53	89	108	129	139	150	162	173
4	5	9	19	29	53	66	80	88	95	102	109
5	8	17	34	51	85	102	120	129	139	147	156
6	8	17	34	51	85	102	120	129	138	147	156
7	10	20	40	60	106	132	160	174	189	203	217
8	9	17	34	52	90	111	136	149	162	175	189
9	14	28	57	85	143	173	204	219	235	252	269
10	9	18	35	53	90	109	127	138	147	157	167

Sample 2 was formulated only with active solvents and diluents. During the evaporation process, the concentration of the diluent increases at the expense of the active solvent concentration. When 70% of the sample is evaporated, 90 wt % of the remaining liquid is diluent. Sample 9 was also only formulated with active solvents and diluent. The initial diluent concentration in this thinner sample is too high, during the evaporation course this concentration increases and at the end of the evaporation the diluent concentration in the remaining liquid is still of 78 wt %. It is evident that the solvent balance of this sample is poor.

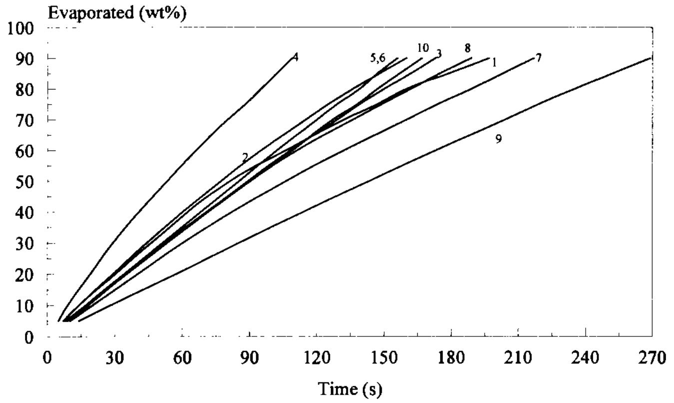

Fig. 1. Global evaporation rate as a function of time for 10 mixtures of commercial thinner samples obtained in the Metropolitan Area of Mexico City

Sample 4 presents a solvent balance that differs with the other samples because its diluent concentration diminishes from 51 wt % at beginning of evaporation to 34.7 wt % when the total sample evaporated is 90 wt%; the latent solvent concentration increases from 41.5 to 62.1 %; however, the active solvent concentration diminishes in a such manner that, at end of evaporation, its concentration is hardly of 3.2 wt%. Therefore, this sample does not exhibit a good solvent balance as well.

The estimated balance solvent during evaporation shows that for the 10 samples considered the low solvency components evaporate disproportionately slow in regard to the active and latent solvents, in such a manner that the high solvency components will rapidly become depleted in the residual solvent during evaporation. This leads to the undesirable effect of solvent imbalance. Generally, if the mixture was formulated to be out of solvent balance from the beginning, the solvent imbalance will

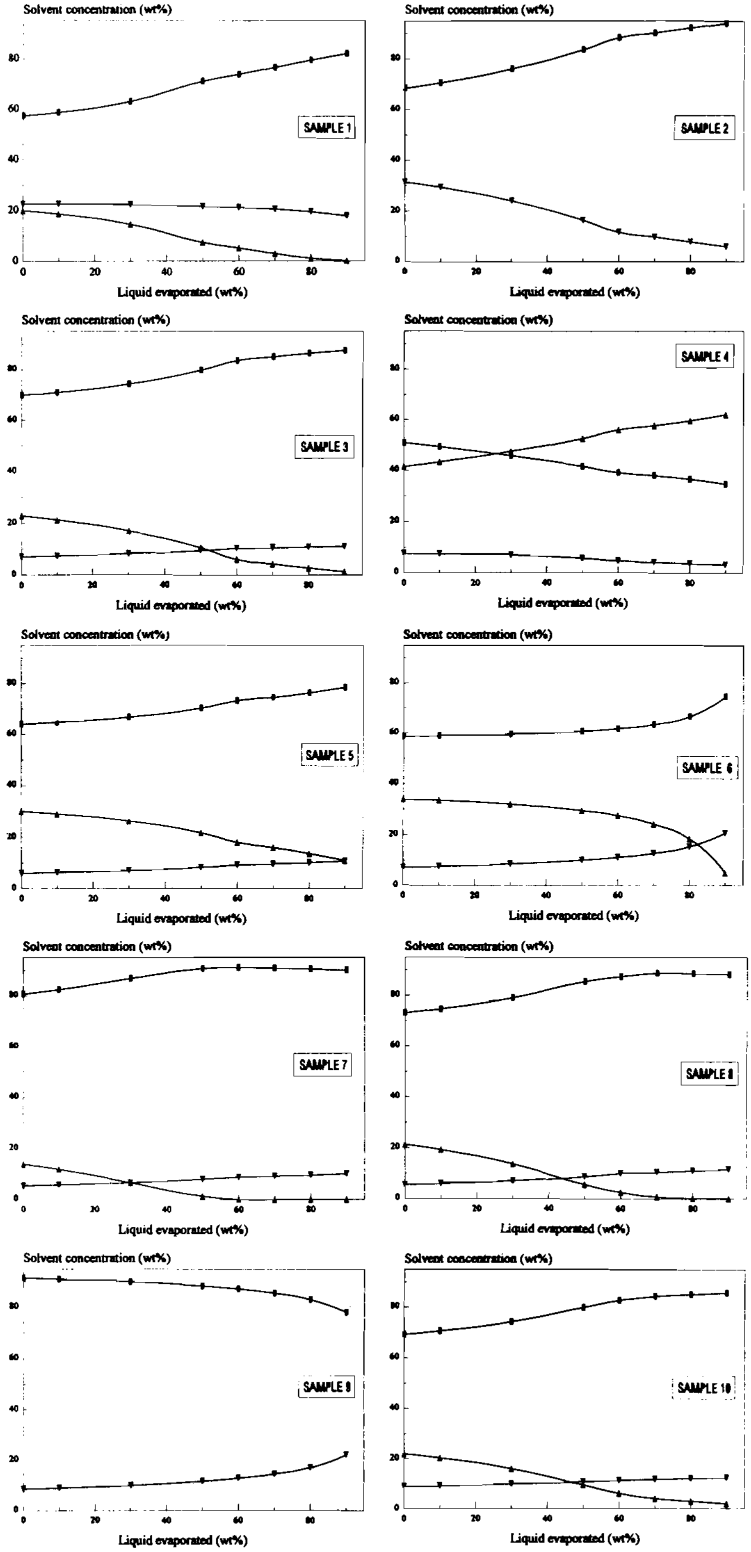

Fig. 2. Solvent composition during evaporation of 10 thinner samples obtained in the Metropolitan Area of Mexico City. ▼: Active solvent, ▲: Latent solvent, ■ : Diluent

TABLE VIII. EVAPORATION BEHAVIOUR FOR 10 COMMERCIAL THINNER SAMPLES OBTAINED IN THE METROPOLITAN AREA OF MEXICO CITY

		wt% evaporated			
Thinner	**solvent**	**0**	**30**	**60**	**90**
		wt% remaining liquid			
1	Active	22.58	22.35	21.17	17.83
	Latent	20.02	14.60	5.12	0.18
	Diluent	57.40	63.05	73.71	81.99
2	Active	31.49	23.94	18.63	5.89
	Latent	-	-	-	-
	Diluent	68.51	76.06	88.37	91.11
3	Active	7.10	8.32	10.33	11.08
	Latent	22.93	17.17	6.12	1.42
	Diluent	69.97	74.51	83.54	87.50
4	Active	7.57	6.91	4.65	3.19
	Latent	41.51	47.41	56.07	62.07
	Diluent	50.87	45.69	39.28	34.74
5	Active	5.96	7.05	9.13	10.60
	Latent	30.06	26.28	17.89	10.85
	Diluent	63.98	66.67	73.07	78.55
6	Active	7.24	8.54	11.05	20.54
	Latent	34.06	31.98	27.45	4.93
	Diluent	58.70	59.48	61.60	74.53
7	Active	5.38	6.70	8.82	10.07
	Latent	13.85	6.69	0.15	0
	Diluent	80.77	86.81	91.03	89.93
8	Active	5.52	7.04	9.93	11.61
	Latent	21.34	13.71	2.60	0.12
	Diluent	73.13	79.25	87.47	88.27
9	Active	8.50	9.99	12.77	22.03
	Latent	-	-	-	-
	Diluent	91.50	90.01	87.23	77.97
10	Active	8.88	9.88	11.29	12.38
	Latent	21.90	15.99	6.13	1.98
	Diluent	69.21	74.13	82.58	85.64

most likely grow worse during evaporation. In general it can be observed that the 10 samples evaluated do not exhibit a good solvent balance, so they are deficient from a technical point of view and hence are inappropriate to be used in many domestics and industrial applications.

CONCLUSIONS

The 34 commercial thinner samples analyzed showed great variability both in number and in the concentration range of their constituents. Toluene, acetone, hexane, methanol, xylene, 2-propanol, methyl butyl ketone, benzene and 3-methyl pentane were the more frequently identified compounds.

By using a thermodynamic model, the evaporation behavior for 10 of the 34 analyzed samples was computed. The calculated evaporation rates exhibited a broad range in evaporation time. Regarding the solvent balance, it was observed that the samples studied were formulated with too low concentration of high solvency components and too high concentration of low solvency components.

Based on the appreciable differences in the number of components, their concentrations, evaporation and solvent balance behavior of the actual commercial thinner samples, besides from the toxicity of the compounds, it may be concluded that a criteria to determine the composition characteristics during thinner formulation does not exist and that, in order to obtain superior solvent blend formulations from technical, environmental and toxicological points of view further research must be done.

It is highly recommendable that Mexican authorities set regulations to define thinner formulation criteria in order to develop and produce improved solvent blends with adequate solvency and evaporation properties according to specific applications, including a decrease in the concentration of highly toxic substances, in order to reduce their noxious effects to solvent sniffers, workers and the environment.

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