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Determination of hydrogen cyanide concentration in mainstream smoke of tobacco products by polarography

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Abstract

Background: There has been a worldwide concern for the health risks of cigarette smoking and hydrogen cyanide (HCN) considered as one of the hazardous tobacco compounds which is needed to be determined in order to reduce the dose related to smoke disease risk.

In this study, we prepare the experimental procedure to entrap the HCN from mainstream smoke of different brands of Tehran cigarette, through simulating human inhalation and determine its concentration applying polarography.

Results: The HCN level of the 50 commonly consumed tobacco products (47 cigarettes and 3 cigars) obtained from local store is ranged between 17.56 ± 1.02 and 1553.98 ± 0.56 μg per stick, this acquired amount is more than FDA approval (10 μg per stick), so the harmful effects of smoking is indicative.

Conclusions: The comparative study of the results shows that the price and the weight of each product do not indicate HCN level. As can be seen, R^2 value which is a statistical measure of how close the data are to the fitted regression line is low ($R^2 < 0.2$). So it should not be deceived by names such as ultra light or infinite gravity to suck, because this names or the price haven't effect on the amount of HCN and its destructive effects.

Keywords: Tobacco products, Cigarette, Hydrogen cyanide, Polarography

Background

Smoking is the major risk factor of mortality in the world according to the statistical information; the cigarette consumption during one century has increased over 100 times, which increases the concern over the safety of tobacco products [1, 2].

Tobacco smoke contains more than 5000 chemical compounds which 150 of these substances have been proved to be toxicants [3, 4]. Hydrogen cyanide is one of the tobaccos smoke poisonous substances which are formed from the combustion of the protein and nitrate compounds existed in tobacco at high temperatures in the oxygen deficient condition [5, 6] which it's chronic and low exposure causes neurological, respiratory, cardiovascular and thyroid effect [7–9].

The tobacco smoke pathway includes the part directly entered the mouth called mainstream and the part diffused in the surrounding, called side stream, which hazardous for nonsmoker. The level of HCN in mainstream smoke is ranged from 10 to 400 μg per cigarette (US Brands) which 0.6 to 27 % of these amounts exist in side stream smoke [10]. In the previous study the level of HCN in the non-filtered cigarette was between 400 to 500 μg per stick [11] and in another study the amount of HCN in the mainstream smoke of cigar, non-filtered cigarette and filtered cigarette was 1035, 59 and 448 μg per 1 g of tobacco, respectively and in small cigars it was between 510 to 780 μg per 1 g of tobacco [12].

There are different reported methods determine HCN in different samples including voltammetry [13], fluorometry [14, 15] gas chromatography [16], LC-MS-MS [17], HPLC-MS [18], potentiometry [19], spectrophotometry [20] and colorimetry [21]. Among them, polarography the subclass of voltammetry is the most precise and

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Table 1 Hydrogen cyanide concentration and price of different brands of cigars

| No. | Brand | Cyanide concentration (µg/cig.) | Number of cig. per pocket | The price of each pocket(\$) | Weight of each cig. (mg) | The price of each cig. (\$) |
|-----|-------------------------------------|---------------------------------|---------------------------|------------------------------|--------------------------|-----------------------------|
| 1 | Bahman | 368.067 | 20 | 0.58 | 828.4 | 0.02 |
| 2 | Bahman | 574.358 | 20 | 0.50 | 587.7 | 0.02 |
| 3 | Bahman | 57.655 | 20 | 0.50 | 547.8 | 0.02 |
| 4 | Bistoon | 227.491 | 20 | 0.41 | 943.7 | 0.02 |
| 5 | CAFÉ CRÈME | 791.067 | 10 | 2.08 | 921.6 | 0.20 |
| 6 | CAFÉ CRÈME (AROME) | 1464.900 | 10 | 2.08 | 1053.2 | 0.20 |
| 7 | CAFÉ CRÈME (BLUE) | 406.722 | 10 | 1.83 | 746.6 | 0.18 |
| 8 | CAMEL Lights | 184.825 | 20 | 1.62 | 810.1 | 0.08 |
| 9 | Cima | 237.400 | 20 | 0.66 | 863.9 | 0.03 |
| 10 | Cima classic | 120.720 | 20 | 0.60 | 687.6 | 0.03 |
| 11 | Dunhill | 300.717 | 20 | 2.25 | 781.9 | 0.11 |
| 12 | Eclipse | 740.235 | 20 | 12.50 | 1243.6 | 0.62 |
| 13 | ESSE Lights | 131.012 | 20 | 0.80 | 515.2 | 0.04 |
| 14 | ESSE Special Gold | 29.622 | 20 | 0.66 | 530.2 | 0.03 |
| 15 | Jewels sweet | 1553.584 | 20 | 1.62 | 6165.5 | 0.08 |
| 16 | Kent | 297.693 | 20 | 1.33 | 793.7 | 0.06 |
| 17 | Kent | 190.745 | 20 | 1.25 | 436.9 | 0.06 |
| 18 | Kent (Blue7) | 345.930 | 20 | 1.25 | 915.8 | 0.06 |
| 19 | Kent (White1) | 188.220 | 20 | 1.25 | 776.2 | 0.06 |
| 20 | King Edward | 598.518 | 5 | 1.41 | 3384.2 | 0.28 |
| 21 | Magna | 232.889 | 20 | 0.79 | 822.4 | 0.03 |
| 22 | Magna | 145.228 | 20 | 1.79 | 763.8 | 0.08 |
| 23 | Magna | 212.310 | 20 | 0.79 | 813.3 | 0.04 |
| 24 | Marlboro Gold (Germany) | 165.871 | 20 | 3.75 | 800.3 | 0.18 |
| 25 | Marlboro (Extra) (USA) | 164.309 | 20 | 4.16 | 900.2 | 0.20 |
| 26 | Marlboro (Switzerland) | 17.561 | 20 | 2.66 | 849.1 | 0.13 |
| 27 | Marlboro (Switzerland) | 47.892 | 20 | 2.91 | 969.7 | 0.14 |
| 28 | Marlboro Lights | 267.804 | 20 | 2.50 | 858.9 | 0.12 |
| 29 | Marlboro Lights (USA) | 42.916 | 20 | 2.91 | 776.4 | 0.14 |
| 30 | Marlboro Lights (Switzerland) | 74.536 | 20 | 2.91 | 786.5 | 0.14 |
| 31 | Marlboro Lights (Switzerland) | 69.344 | 20 | 1.83 | 816.5 | 0.09 |
| 32 | Marlboro Ultra Lights (Switzerland) | 127.336 | 20 | 2.66 | 835.1 | 0.13 |
| 33 | Montana | 332.493 | 20 | 0.50 | 855.6 | 0.02 |
| 34 | Pall Mall | 161.785 | 20 | 0.83 | 905.1 | 0.04 |
| 35 | Pall Mall (Blue) | 86.956 | 20 | 0.83 | 881.3 | 0.04 |
| 36 | PHILLIES BLUNT | 203.178 | 5 | 1.62 | 6974.5 | 0.32 |
| 37 | Pine (Blue) | 238.561 | 20 | 0.66 | 860.2 | 0.03 |
| 38 | Pine (supper slims) | 94.813 | 20 | 0.45 | 547.2 | 0.02 |
| 39 | Winston | 43.187 | 20 | 1.25 | 785.9 | 0.06 |
| 40 | Winston | 214.325 | 20 | 1.50 | 816.7 | 0.07 |
| 41 | Winston | 106.176 | 20 | 1.50 | 831.0 | 0.07 |

Table 1 Hydrogen cyanide concentration and price of different brands of cigars (Continued)

| | | | | | | |
|----|------------------------------------|---------|----|------|-------|------|
| 42 | Winston Blue (Europe) | 99.244 | 20 | 1.83 | 537.3 | 0.09 |
| 43 | Winston Lights | 66.326 | 20 | 2.50 | 943.1 | 0.12 |
| 44 | Winston Lights (Imported) | 209.294 | 20 | 4.58 | 814.0 | 0.22 |
| 45 | Winston Lights (USA) | 102.132 | 20 | 2.08 | 808.7 | 0.10 |
| 46 | Winston Ultra Lights (USA) | 42.634 | 20 | 2.25 | 794.1 | 0.11 |
| 47 | Winston Ultra Lights (USA) | 25.554 | 20 | 2.25 | 818.4 | 0.11 |
| 48 | Winston Ultra Lights (Switzerland) | 254.322 | 20 | 2.25 | 812.0 | 0.67 |
| 49 | Zest Lights | 150.623 | 20 | 0.66 | 829.9 | 0.03 |
| 50 | Zika | 288.120 | 20 | 2.91 | 924.0 | 0.14 |

inexpensive method based on the oxidation and reduction mechanism [22].

The aim of this study is focused on the determination of the HCN in mainstream smoke of different brands of cigarette consumed in Tehran using polarography method.

Materials and methods

Collection of samples

A total of 50 types of different brands of the most consumed or available cigarettes (47) and cigars (3) were collected from local stores at September 2012. The 20 % of the samples were from Winston company, 18 % from Marlboro, 6 % from Magna, 8 % from KENT and 8 % from local or officially imported companies and the rest, 40 % are from a different companies (as shown in Table 1).

Reagents and chemicals

All chemicals used were of analytical reagent grade from Merck (Germany). Buffer solutions were prepared by dissolving boric acid (0.2 M) and potassium hydroxide (0.17 M) in 1000 ml ultrapure water and adjusting the solution to pH 10.2. Cyanide standard solution (1 g/L) was prepared by dissolving 0.2503 g KCN in 100 ml KOH 0.01 M in ultrapure water.

Apparatus

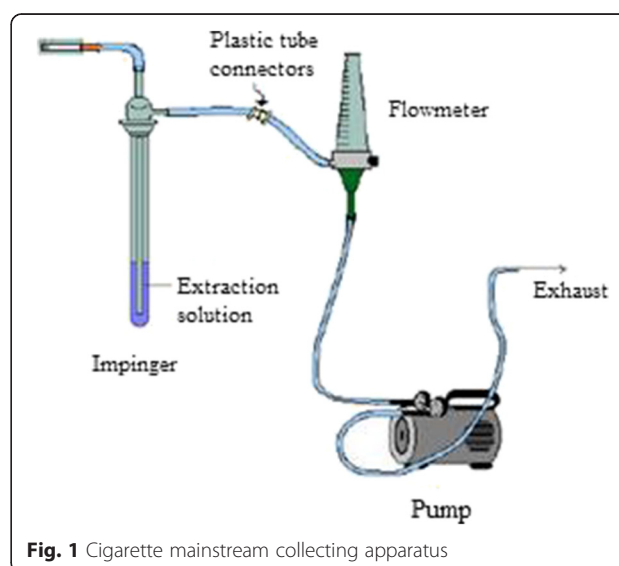
Analysis was conducted by the Metrohm Polarography device 797 VA Computrace, three electrode systems consisting of a dropping mercury electrode (DME) as the working electrode, an Ag/AgCl reference electrode and platinum counter electrode. The device outfitted in the following conditions: stirrer speed 2000 rpm, mode DP, purge time 300 s, equilibration time 5 s, pulse amplitude 50 mV, start potential 0 V, end potential -500 mV, voltage step 8 mV, voltage step time 0.8 s, sweep rate 10 mV/s, peak potential CN⁻ -240 mV. All instrumental settings were those recommended in the manufacturer's manual book and the instrumental conditions with the method

of AB110-Det of cyanide [23]. All potentials quoted were measured against an Ag/AgCl reference electrode and the polarographic cell volume was 20 ml.

Method of analysis

The HCN in each cigarette and cigar mainstream smoke were collected using mainstream apparatus (Fig. 1) [24, 25]. The cigarette was applied to the entrance station and suction force obtained by the vacuum pump simulate the human inhalation and extract the tobacco smoke, the flow of smoke were passed through the glass tube filled with 100 ml NaOH (0.1 M) solution to entrap HCN as CN⁻ ion.

Subsequently, the mixture of above mentioned solution contain cigarette smoke (10 ml) and buffer solution (10 ml) was added to the polarographic vessel and deoxygenated for 10 min with high-purity nitrogen and achieved the peak of CN⁻ in the range of -0.5-0 V. To determine the CN⁻ concentration by standard addition method, 50 μ l cyanide standard solution was added (two times) and the polarogram was obtained (Fig. 2).

**Fig. 1** Cigarette mainstream collecting apparatus

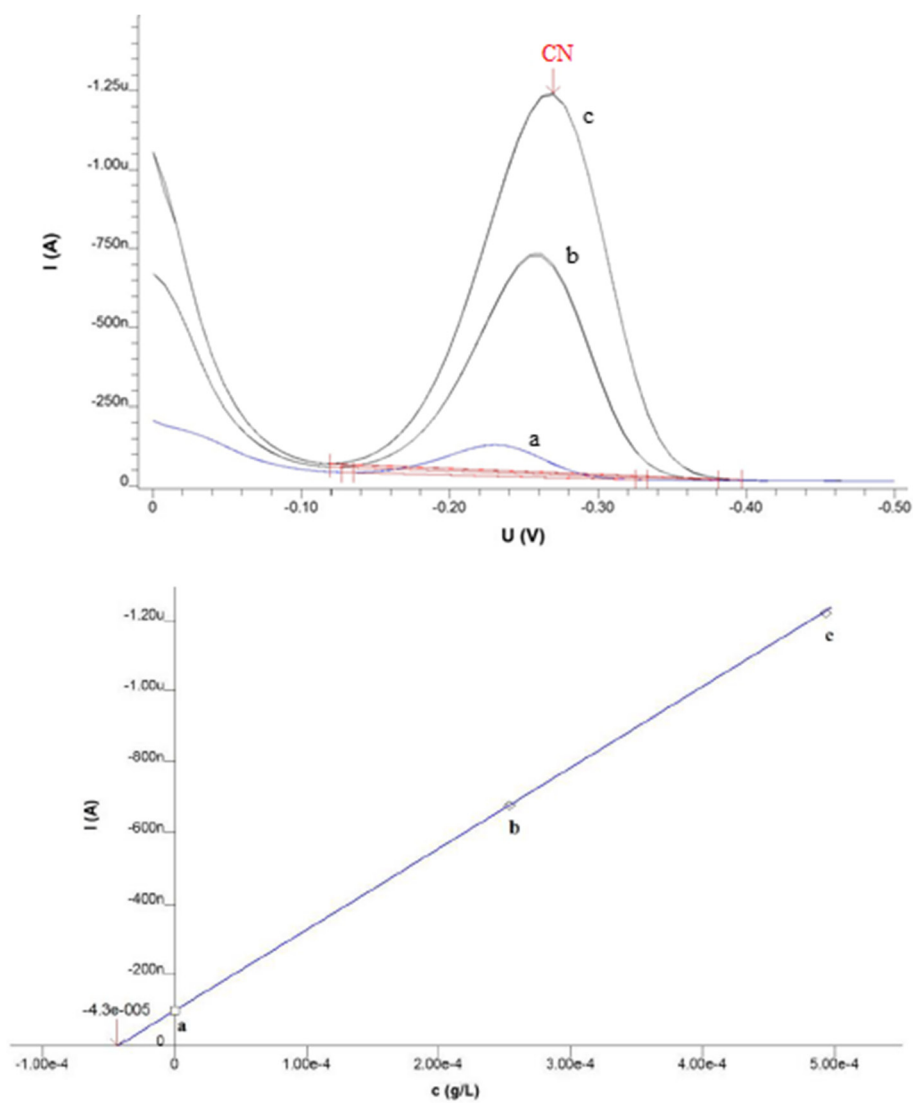


Fig. 2 The differential pulse polarogram of cyanide ion in cigarette smoke sample. **a** the peak of sample solution **b** the peak of first dilution of standard addition **c** the peak of second dilution of standard addition

Statistical analysis

All statistical analyses were performed using the statistical software for social sciences (SPSS Inc. Chicago, IL, Version 21). Statistical analyses of each sample were characterized by mean \pm standard deviation. The mean levels of cyanide were compared across categories of price, and weight of each cigarette or cigars. The significance level was defined at 0.05 for the regression equations.

Result and discussion

The result of mainstream smoke HCN determination by polarography (Table 1) showed that among 50 samples the average amount of HCN was 184.825 μ g per stick which the highest level of HCN pertain to Jewel sweet cigar, 1553.98 \pm 0.56 μ g per cigar, and the lowest was

Swiss Marlboro with 17.56 \pm 1.02 μ g per cigarette. Moreover, the average amount of HCN in cigarettes and cigar were 218 μ g and 785.09 μ g, respectively, In addition the average weight of cigarette and cigar samples was 800 mg and 5500 mg, respectively, and the average weight of whole samples was 1084.24 mg.

The changes in the HCN levels are dependent on the preparation procedure of tobacco, which lead to the diverse amount of proteins and nitrate compounds of cigarette which render the conversion of HCN level emission. In addition it may be possible to assess the quality of cigarette especially ultralight by determining the amount of HCN as it is increased in the unfeigned products.

Furthermore, based on our study there is no connection between price, weight and appearance of cigarette,

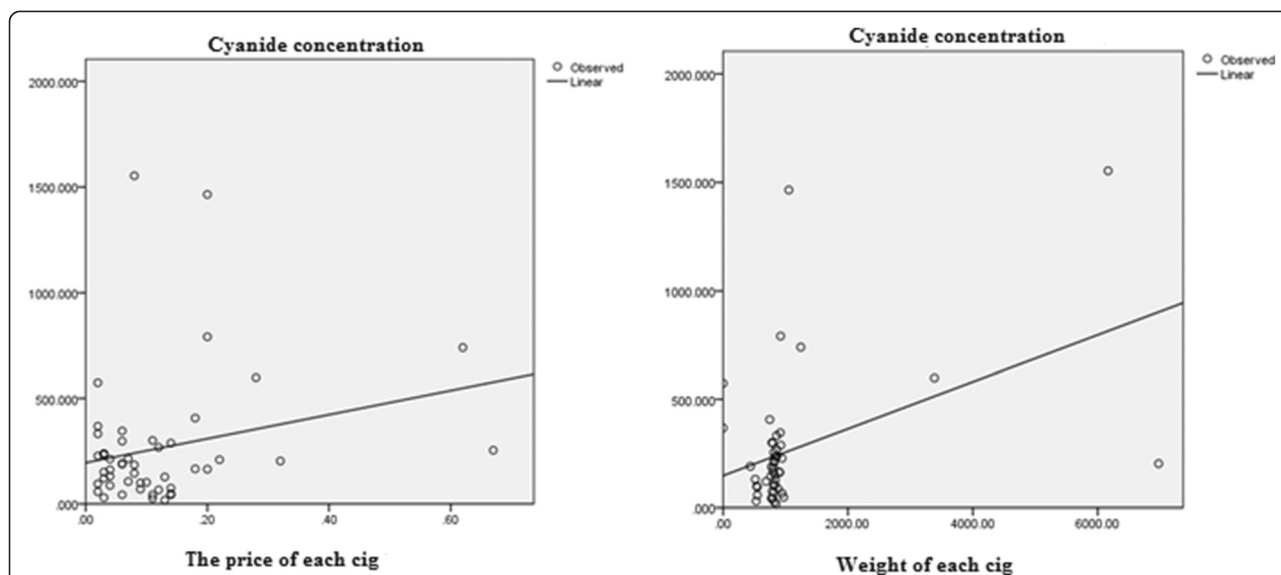


Fig. 3 The relationship between cyanide, weight and price each of cigarettes

cigar and HCN level. For instance, Jewels sweet and PHILLIES BLUNT cigars have the same price, but different level of HCN doesn't necessarily cause the higher HCN level emission. The regression method was applied for the development of the mentioned model. Validation of the method was conducted by analyzing the different set of independent data from the same source. As can be seen the R^2 which is a statistical measure of how close the

data are to the fitted regression line is low (0.20) (Fig. 3). So it means the model is useless for prediction based on cigar and cigarette weight and its price.

In addition, previous studies demonstrated that even exposure to lower concentrations of cyanide may result in a range of non-specific features include headache, dizziness, throat discomfort, chest tightness and eye irritation which these symptoms would grow by more

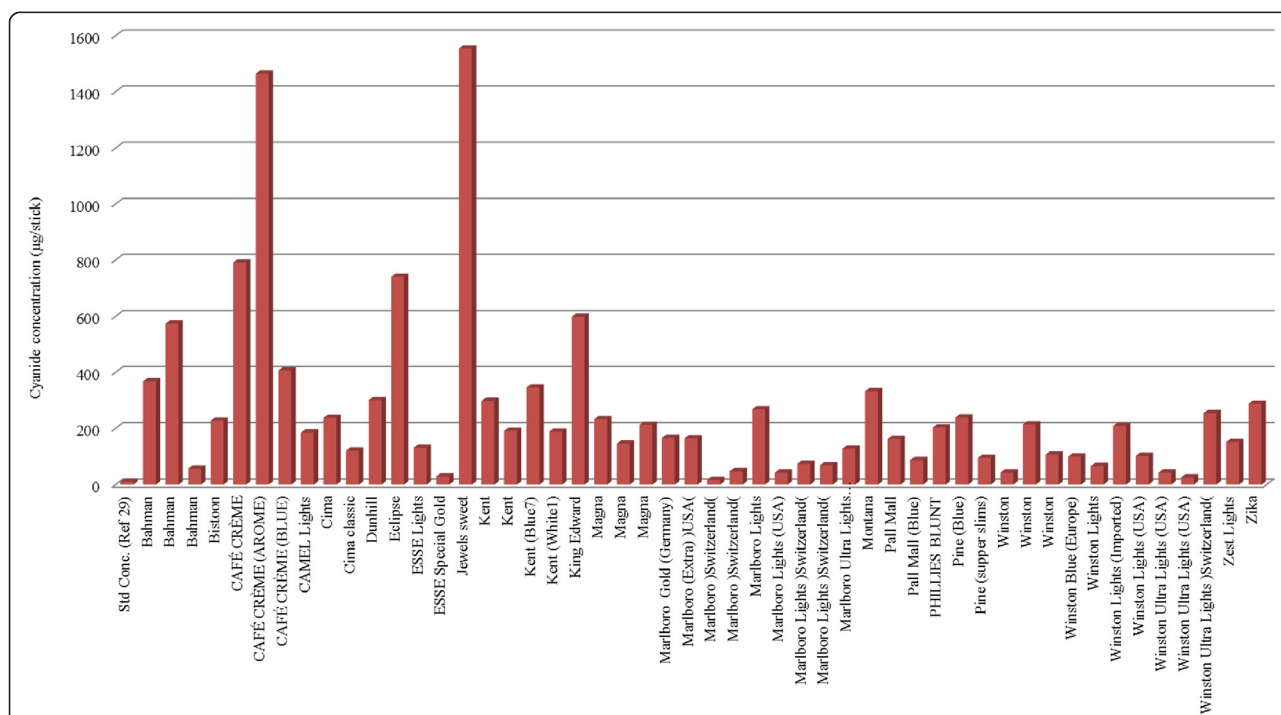


Fig. 4 Cyanide concentrations in different kind of Cig

substantial exposure [26–28]. Moreover the results of our study indicate that cyanide concentration of all samples, even light cigarette is above established levels for chronic toxic doses [9] (Fig. 4).

Conclusions

In this study, HCN of the toxic components of the tobacco smoke was determined by polarographic method. The results shows that the ranges of HCN level of 50 samples were varied between 17.56 ± 1.02 - 1553.98 ± 0.56 μg per stick. This acquired amount is more than FDA approval (10 μg per stick).

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors contributed to the concept and design, providing and analysis of data, drafting, revising and final approval. MA is responsible for the study registration. AA is responsible for collection. SM is responsible for experiments performing, assembly of data, data analysis, interpretation, SM and GK are responsible for writing the manuscript and correcting. All authors read and approved the final manuscript.

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