Determination of Metals Contamination in Illicit Ecstasy Drug Samples Using ICP-OES and XRF

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ABSTRACT

The analysis of 248 illegal “ecstasy” tablets was performed by determining 11 elements (Zn, Al, Ca, Mg, K, Na, Ba, Fe, B, Cu, and Pt). The sample solutions were prepared with nitric acid, heated in a microwave oven, and analyzed by inductively coupled plasma optical emission spectrometry (ICP-OES). However, the measurement of Pt residuals from PtO₂ (which is frequently used as the catalyst during the synthesis stage of the

active substance) was performed by X-ray fluorescence (XRF) analysis.

The determination of boron residuals revealed that NaBH₄ was used in the production process. Barium was found to be present below the 0.1 µg/g level, but zinc was at 1.4 to 22.2 µg/g, aluminum at 10.8 to 350.3 µg/g, calcium at 33.4 to 416.8 µg/g, magnesium at 89.0 to 2474.4 µg/g, potassium at 12.4 to 88.7 µg/g, sodium at 90.6 to 4543.2 µg/g, iron at 1.6 to 654.6 µg/g, and copper at 0.1 to 3.7 µg/g.

(b) Tablets containing at least one substance, i.e., caffeine, paracetamol, theophylline, meta-chlorophenylpiperazine (m-CPP), diphenylhydramine, etc., as an additive in addition to the amphetamine-type stimulants (ATS).

(c) Tablets containing at least one of the additives, i.e., m-CPP, caffeine, paracetamol, or theophylline, but not any of the ATSs.

(d) Tablets not containing any of the ATSs and other additives (fake tablets).

(e) Tablets containing other organic (stimulants, medicine-active agents, heroin, pesticides) and/or inorganic chemicals apart from the active agents evaluated as ATSs and additives.

INTRODUCTION

MDMA (3,4-methylenedioxy-N-methamphetamine) is an empathogenic drug of the amphetamine and amphetamine-type stimulants (ATS) and has become known and sold as “ecstasy” in tablet form in Turkey since the year 2000 (1). Even though there was a decrease in use after 2007, the rate of ecstasy tablets sold was still high. The number of ecstasy and captagon (including amphetamine) tablets seized between 2007 and 2011 is presented in Figure 1 (2).

The chemical content of these seized illegal tablets can be classified in general as follows:

(a) Tablets containing at least one of the amphetamine-type stimulants, i.e., MDMA, amphetamine, methamphetamine, 3,4-methylenedioxyamphetamine (MDA), 3,4-methylenedioxyethylamphetamine (MDEA), etc.

Tablet Type	2007	2008	2009	2010	2011	2012
Ecstasy (Unit)	1,047,559	1,041,111	432,513	924,861	1,364,253	4,389,309
Captagon (Unit)	7,609,327	2,973,901	2,845,157	1,069,250	1,094,770	183,537
Total (Unit)	8,656,886	4,015,012	3,277,670	1,994,111	2,459,023	4,572,846

Fig. 1. The number of ecstasy and captagon tablets seized in Turkey between 2007 and 2012.

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The above-mentioned five tablet forms (a – e) have different chemical content and are also different in terms of their metallic residuals content.

The stimulant tablets mostly encountered in Turkey are amphetamine and MDMA. Both forms are generally produced with caffeine and/or paracetamol and/or theophylline, in addition to the tablets that include amphetamine only. The substance of m-CPP (under restriction in Turkey since 2009) was primarily added as an additive to amphetamine and accepted as an active agent by itself; however, use of m-CPP in illegal synthetic tablets has recently diminished. Tablets containing MDMA were primarily used in addition to tablets containing caffeine and/or paracetamol.

The majority of studies carried out for illicit drugs identify the organic structures as by-products and the intermediate products through synthesis, separation of active agents, and their qualitative and quantitative metals determination using an appropriate solvent, etc. (3-16). Studies performed to determine the metallic content of the tablets have been few in comparison to those identifying the organic structures. When analyzing the metallic content, the production methods used for the various drugs, the similarities and differences between the samples, the source determination and effects upon human health have been discussed (17-25). Bora et al. (19) determined 10 elements (Al, Ba, Ca, Cu, Fe, Mg, Mn, Cd, Pb, and Zn) in seized heroin samples using atomic absorption spectrometry (AAS) and inductively coupled plasma atomic emission spectrometry (ICP-AES). Infante et al. (23) determined Cd, Ca, Cu, Fe, Mn, and Zn in 198 heroin samples using AAS. Chan et al. (24-25) performed quantitative analysis of 16 elements (Na, Mg, Al, K, Ca, Cr, Mn, Fe, Ni,

Cu, Zn, As, Se, Cd, Ba, and Pb) in 309 heroin samples using inductively coupled plasma mass spectrometry (ICP-MS). Zhang et al. (22) revealed that neutron activation analysis (NAA) was possible for source determination of drugs and performed the analysis of 15 elements (Au, Ba, Br, Ca, Ce, Co, Cr, Fe, La, Na, Sb, Sc, Sm, Th, and Zn) in 62 heroin samples. Waddel et al. (18) determined 12 metals (Li, B, V, Cr, Mn, Ni, Cu, Zn, Br, Sr, Sn, Ba, Pt, and Pb) in ecstasy tablets. Koper et al. (20) determined Al, B, Ca, Cr, Fe, Mg, Mn, Na, P, Pt, S, Cu, Hg, Li, Nd, Ni, Rb, Sn, Th, U, Y, and Zn in ecstasy tablets using ICP-AES and inductively coupled plasma mass spectrometry (ICP-MS), and in particular, the presence of Pt and B was emphasized.

In the present study, 11 elements were determined which accumulate during the various stages of the manufacturing process of the ecstasy tablets from the catalysts, reducers, fillers, cutting agents, paints, and other chemicals (1,3,19) leaching out from the tablet manufacturing equipment. The quantitative ICP-OES determination of 10 elements (Zn, Al, Ca, Mg, K, Na, Ba, Fe, B, and Cu) was performed by first dissolving the samples in a microwave oven (1,19) with concentrated HNO₃. The qualitative

determination of Pt at trace levels was performed by XRF analysis.

EXPERIMENTAL

ICP-OES Instrumentation

The ICP-OES analyses were carried out using a PerkinElmer® Optima™ 5300 DV spectrometer. The instrumental operating conditions and analytical wavelengths are listed in Table I. The following elements were determined: Zn, Al, Ca, Mg, K, Na, Ba, Fe, B, and Cu. The values of the 10 elements measured by ICP-OES (mg L⁻¹) are listed in Table II.

X-Ray Fluorescence (XRF)

The Pt determinations in the tablets were performed with a Spectro X-LAB 2000 X-ray fluorescence spectrometer, equipped with three different energy-directed polarization techniques using Mo, Al₂O₃ and High Oriented Pyrolytic Graphite (HOPG) (Spectro Analytical Instruments GmbH, Germany). In this study, the HOPG analysis technique was used which is recognized as being appropriate for the Pt group elements. The XRF spectrum of a C4-coded tablet is demonstrated in Figure 2, highlighting the platinum peak. The concentrations of platinum in the ecstasy tablets analyzed by XRF are also listed in Table II.

TABLE I
ICP-OES Operating Conditions and
the Analytic Wavelengths of the Elements

RF Power	1.3 kW
Radio Frequency	40 MHz
Minimum Carrier	
Gas Flow Rate	0.8 mL min ⁻¹
Auxiliary Gas Rate	0.2 mL min ⁻¹
Plasma Gas Flow Rate	15 L min ⁻¹
Pump Uptake	1.2 mL min ⁻¹
Analytical Wavelengths (nm)	Zn 206.200, Ba 233.527, Al 396.153, Fe 238.204, Ca 317.933, Cu 327.393, Mg 285.213, K 766.490, Na 589.592, B 249.677

TABLE II
Values of 10 Elements Analyzed in Ecstasy Tablets by ICP-OES (mg L⁻¹) and Pt by XRF

Group	Zn	Al	Ca	Mg	K	Na	Ba	Fe	B	Cu	Pt
A1	7.1	350.3	194	181	22.4	301	*	13.7	65.4	2.1	-
A2	5.1	14.0	194	175	22.9	285	*	21.0	80.0	2.1	-
A3	12.4	15.2	308	171	25.9	256	*	20.9	206.3	0.2	-
A4	22.2	13.5	161	171	19.4	297	*	176.1	119.6	0.4	-
A5	2.3	14.1	190	170	21.2	388	*	21.0	200.0	0.8	-
A6	4.6	15.0	200	175	20.9	291	*	25.5	176.6	0.5	-
B1	1.9	22.0	80	926	80.0	129	*	36.8	1.1	0.6	+
B2	1.8	21.0	73	900	75.2	116	*	36.6	*	0.5	+
B3	2.0	21.9	74	846	88.7	119	*	30.0	*	0.6	+
B4	1.7	29.5	75	969	74.9	90	*	18.8	*	0.5	+
B5	2.5	19.1	78	914	75.5	113	*	34.8	*	0.4	+
B6	2.9	32.0	101	550	75.0	110	*	11.4	*	0.4	+
B7	6.1	28.5	416	432	73.2	131	*	20.1	3.0	0.6	+
B8	1.7	22.0	64	845	85.9	114	*	25.6	*	0.5	+
B9	1.4	24.6	70	920	21.5	109	*	22.8	*	0.6	+
B10	1.7	31.2	67	523	70.5	122	*	23.1	*	0.7	+
B11	1.4	44.3	112	1200	56.4	227	*	88.9	*	2.1	+
B12	3.1	25.6	70	840	78.3	121	*	24.4	*	0.4	+
B13	1.9	42.0	59	930	82.0	114	*	21.1	*	0.5	+
B14	3.2	21.2	70	865	83.8	110	*	23.4	*	0.6	+
C1	2.1	25.0	192	1450	18.4	2500	*	15.4	*	1.8	+
C2	2.5	23.1	207	1265	23.8	4543	*	6.9	*	0.3	+
C3	2.4	23.6	186	1200	18.4	2562	*	5.2	*	2.1	+
C4	2.8	22.5	166	1113	17.9	2650	*	26.8	*	1.1	+
D1	2.5	14.3	182	633	20.0	560	*	20.9	*	0.3	-
D2	1.8	15.5	251	644	24.4	720	*	30.0	*	1.2	-
D3	9.7	14.2	206	898	19.4	509	*	15.5	*	0.1	-
D4	2.3	22.4	312	150	34.3	323	*	67.4	*	0.9	+
E1	20.1	20.4	244	488	39.5	300	*	82.4	*	3.1	-
E2	15.7	23.8	207	2474	43.0	288	*	25.9	*	3.7	-
E3	17.8	20.5	233	1000	44.9	277	*	28.1	*	2.9	-
E4	16.0	21.9	228	720	40.2	295	*	90.0	*	2.9	-
F1	1.3	12.7	146	262	49.0	178	*	4.4	*	2.8	-
F2	1.3	11.9	155	230	46.0	182	*	5.6	*	2.6	-
F3	1.4	10.8	126	807	50.8	191	*	5.4	*	1.8	-
F4	1.4	10.8	116	755	47.8	188	*	1.6	*	0.1	-
G1	1.8	15.7	105	319	12.4	198	*	12.5	*	1.3	+
G2	2.3	120.6	142	881	42.7	507	*	47.5	*	1.2	+
G3	3.2	15.0	116	216	67.6	477	*	76.8	*	1.3	+
G4	*	24.8	290	89	22.1	252	*	87.5	*	3.8	+
H1	*	30.3	300	860	54.7	224	*	654.6	*	0.4	+
H2	0.1	27.4	243	3126	36.4	226	*	119.8	*	0.7	+
H3	0.2	14.1	135	2126	29.2	3509	*	28.7	*	*	+
H4	0.7	18.0	145	98	48.7	251	*	7.42	*	*	+
K1	0.1	14.5	125	1997	29.6	593	*	27.0	*	2.2	+
K2	3.7	15.0	176	1839	37.4	507	*	21.2	*	0.5	+
K3	2.9	19.4	170	1200	32.2	472	*	19.9	*	0.6	+
K4	2.1	20.5	33	233	46.6	552	*	45.7	*	1.2	+
K5	3.5	19.3	196	976	42.7	501	*	20.0	*	1.0	+

* = <0.1 mg L⁻¹

Fig. 2. XRF spectrum of C4 sample, indicating the Pt peak.

TABLE III
Temperature and Time Schedule in the Microwave Oven

Step	1	2	3	4
T °C	145	165	180	200
Rate (min)	5	2	2	2
Wait (min)	10	10	10	10

Microwave Oven

A Berghoff speed wave MWS-3+ microwave sample dissolution system was used for decomposing the tablets (Berghoff Instruments, Germany). The temperature and time program is listed in Table III.

Sample Selection and Sample Preparation

The tablets used in this study and their physical properties are listed in Table IV. They were randomly chosen from a total of 248 synthetic tablets seized by the Ankara Police during 49 different illicit drug raids.

For the ICP-OES analysis, the samples were placed in a mortar and pulverized (1,19). The crushed samples were weighed out as $300 \text{ mg} \pm 0.1 \text{ mg}$ on an analytical balance, then put into Teflon® (PTFE) sample vessels, and 3 mL 65% concentrated HNO_3 was

added. In order to prevent the solid particles from sticking to the inner walls of the vessels, instant heating was not applied and the vessels were left open for 20 minutes, then closed, and the dissolution process was finished using the microwave oven temperature-time schedule listed in Table III. The sample solution was brought to 10-mL volume with Millipore® water and prepared for analysis. All measurements were obtained by reading each sample three times.

For the Pt determinations, the samples were qualitatively analyzed by taking 300 mg of the crushed powder, spreading it over a transparent polypropylene film, and measuring it by X-ray fluorescence (XRF).

Reagents and Reference Material

Calibration curves for quantification were plotted by measuring the blanks and standard solutions within the concentration range of 0.1 and $20 \mu\text{g} \cdot \text{mL}^{-1}$ depending on the element's response. Ultrapure (Type I) water obtained from a Direct-Q® 8 UV system (Merck Millipore, France) was used for all dilutions. Nitric acid (% 65, Merck, Germany) was of analytical purity. A reagent blank solution was prepared in accordance with the same procedure applied to the samples.

RESULTS AND DISCUSSION

Although the metal content of the ecstasy tablets analyzed may not cause sudden severe health problems, a frequent and overdose use of such illicit tablets by drug addicts can cause serious health problems. Additional negative effects to the addicts might also be due to the metallic content in ecstasy tablets.

The physical characteristics of the tablets having the same logo and coded with the same letters (A-K) were evaluated between each other within the same group and are listed in Table IV. The purpose of analyzing the tablets for their elemental content was to understand the metallic additions in all stages of production from tablet pressing to the containers used in the process of adding active agents, from filling materials and additives, catalysts, chemical intermediates and raw materials used during the tableting stage. The minimum, maximum, and average values of the elements determined in the tablets by ICP-OES are listed according to their groups in Table V.

Among the 49 different code-numbered analyzed tablets, magnesium was the most concentrated element present in 32, sodium in 14, calcium in 2, and aluminum in 1. Analysis of the samples showed that barium was present below 0.1 mg L^{-1} .

TABLE IV
Details of Physical Characteristics of the Samples Seized and Analyzed

Sample No.	Code	Unit of Tablet	Logo	Shape	Color	Mass (average mg)	Diameter (average mm)	Thickness (average mm)
1	A1	6	xxx	Round	Yellow	255.6	8.03	4.43
2	A2	3	xxx	Round	Yellow	245.3	8.03	4.38
3	A3	5	xxx	Round	White	243.7	8.04	4.50
4	A4	3	xxx	Round	White	242.5	8.05	4.05
5	A5	5	xxx	Round	Rose	200.1	8.09	3.35
6	A6	4	xxx	Round	White	257.6	8.02	4.55
7	B1	7	Mitsubishi	Round	White	217.2	7.11	4.60
8	B2	5	Mitsubishi	Round	White	211.3	7.10	4.51
9	B3	6	Mitsubishi	Round	White	223.8	7.09	4.77
10	B4	3	Mitsubishi	Round	White	216.1	7.10	4.70
11	B5	4	Mitsubishi	Round	White	219.7	7.10	4.66
12	B6	4	Mitsubishi	Round	White	219.9	7.08	4.80
13	B7	5	Mitsubishi	Round	White	221.4	7.10	4.71
14	B8	6	Mitsubishi	Round	White	219.4	7.10	4.64
15	B9	4	Mitsubishi	Round	White	212.8	7.10	4.55
16	B10	5	Mitsubishi	Round	White	216.9	7.13	4.54
17	B11	4	Mitsubishi	Round	White	165.4	7.03	3.65
18	B12	8	Mitsubishi	Round	White	227.3	7.08	4.80
19	B13	5	Mitsubishi	Round	White	215.8	7.10	4.60
20	B14	5	Mitsubishi	Round	White	220.7	7.11	4.65
21	C1	4	—	Heart	Rose	298.8	—	5.90
22	C2	5	—	Heart	Green	233.5	—	4.78
23	C3	6	—	Heart	Green	236.5	—	5.00
24	C4	4	—	Heart	Yellow	265.5	—	5.37
25	D1	5	Smiling Face	Round	Grey	249.4	8.10	3.86
26	D2	4	Smiling Face	Round	Brown	241.0	8.10	3.80
27	D3	3	Smiling Face	Round	Grey	238.4	8.09	3.70
28	D4	3	Smiling Face	Round	Yellow	234.0	8.16	4.19
29	E1	10	Captagon	Round	Yellow	173.6	8.03	3.61
30	E2	8	Captagon	Round	Rose	174.3	8.00	3.63
31	E3	8	Captagon	Round	Rose	173.2	8.00	3.45
32	E4	9	Captagon	Round	Yellow	169.9	8.15	3.20
33	F1	5	Moon	Round	Beige	285.8	9.15	3.60
34	F2	4	Moon	Round	Beige	287.0	9.14	3.60
35	F3	4	Moon	Round	Beige	295.8	9.15	3.70
36	F4	6	Moon	Round	Beige	278.5	9.13	3.63
37	G1	5	Diamond	Round	White	241.3	8.02	4.30
38	G2	5	Diamond	Round	White	280.9	8.01	4.70
39	G3	5	Diamond	Round	White	275.5	8.00	4.65
40	G4	6	Diamond	Round	Green	238.4	9.00	3.15
41	H1	4	007	Round	White	284.5	8.04	4.60
42	H2	5	007	Round	White	296.9	8.07	4.66
43	H3	4	007	Round	Blue	203.4	8.07	3.50
44	H4	4	007	Round	Yellow-White	237.7	8.17	4.40
45	K1	4	Dollar	Round	Rose	253.5	7.15	5.20
46	K2	5	Dollar	Round	Rose	252.3	7.13	5.14
47	K3	6	Dollar	Round	Rose	254.6	7.15	5.30
48	K4	5	Dollar	Round	Yellow	242.4	7.15	5.36
49	K5	5	Dollar	Round	Rose	274.5	7.17	5.55

TABLE V
Minimum, Maximum, and Average Values of the Elements Determined by ICP-OES (mg L⁻¹)

	Zn	Al	Ca	Mg	K	Na	Fe	B	Cu
Group A									
Min	2.3	13.5	161	170	19.4	256	13.7	65.4	0.2
Max	22.2	350.3	308	181	25.9	388	176.1	206.3	2.1
Mean (n=6)	9.0	70.4	208	174	22.1	303	46.4	141.3	1.0
Group B									
Min	1.4	19.1	59	432	21.5	90	11.4	1.1	0.4
Max	6.1	44.3	416	1200	88.7	227	88.9	3.0	2.1
Mean (n=14)	2.4	27.5	101	833	72.9	123	29.8	2.1	0.6
Group C									
Min	2.1	22.5	166	1113	17.9	2500	5.2	*	0.3
Max	2.8	25.0	207	1450	23.8	4543	26.8	*	2.1
Mean (n=4)	2.5	23.6	188	1257	19.6	3064	13.6	*	1.3
Group D									
Min	1.8	14.2	182	150	19.4	323	15.5	*	0.1
Max	9.7	22.4	312	898	34.3	720	67.4	*	0.9
Mean (n=4)	4.1	16.6	238	581	24.5	528	33.5	*	0.6
Group E									
Min	15.7	20.4	207	488	39.5	277	25.9	*	2.9
Max	20.1	23.8	244	2474	44.9	300	90.0	*	3.7
Mean (n=4)	17.4	21.7	228	1170	41.9	290	56.6	*	3.2
Group F									
Min	1.3	10.8	116	230	46.0	178	1.6	*	4.3
Max	1.4	12.7	155	807	50.8	191	5.6	*	2.8
Mean (n=4)	1.4	11.6	136	514	48.4	185	4.3	*	1.8
Group G									
Min	1.8	15.0	105	89	12.4	252	12.5	*	1.2
Max	3.2	20.6	290	881	67.6	507	87.5	*	3.8
Mean (n=4)	1.8	44.0	163	376	36.2	361	56.1	*	1.9
Group H									
Min	0.1	14.1	135	98	29.2	224	7.4	*	0.4
Max	0.7	30.3	300	3126	54.7	3509	654.6	*	0.7
Mean (n=4)	0.3	22.5	206	1552	42.3	1052	202.6	*	0.4
Group K									
Min	2.1	15.0	33	233	32.2	472	19.9	*	0.5
Max	3.5	20.5	196	1839	46.6	552	45.7	*	2.2
Mean (n=5)	3.1	18.6	144	1062	39.7	508	26.7	*	1.1

* = < 0.1 mg L⁻¹

These data also revealed that no catalyst, including barium or a by-product, was used to produce the tablets. In general, the sources for metallic impurities of the ecstasy tablets were found to come from the catalyst and the reducing agents used during the production process and include Pt, Fe, B, Mg, Hg, Li, Pd, and Ni from additives and from filling materials such as Al, Mg, Si, and P, as well as from the coloring agents used for the tablets (20).

The most common method of producing MDMA through illegal techniques is the reduction of MDP-2-P (3,4,5,7). In the MDMA production, the method is performed under pressure in which PtO_2 is used as the catalyst for the reductive amination method (Figure 3 b). In addition, the Cold Method, in which NaBH_4 is the reducing agent, is one of the most frequently preferred methods (Figure 3 c). The most common method for amphetamine production is the Leuckart-Wallach method (Figure 3 a) for which formic acid is used as the reducing agent.

The boron and platinum values given in Table II probably attract the most attention. It was found that of the 49 samples, 30 samples contained Pt residuals, 2 samples contained both Pt and boron residuals, 6 samples contained boron residuals, and 11 samples contained neither boron nor Pt residuals. Although the samples containing boron were in the A-coded tablets, Pt was found in the B-, C-, G-, H- (apart from H4), D4-, and K-coded tablets. The tablets not containing boron and platinum were the D- (apart from D4), E-, and F-coded tablets. Also different boron values were found in tablets containing boron.

In the A group tablets, the values of groups Al (aluminum): A3: Zn and Ca; A4: Zn and Fe; and A5: Na were rather different than from the other A group tablets. Although

differences in quantity were observed in all A group tablets, boron was detected at 65.4 – 206.3 mg/L. When boron was found as a residual, it was considered to come from the NaBH_4 used in the Cold Method. In contrast, the presence of Pt (Figure 2) was considered to be from the PtO_2 used as a catalyst. Moreover, the tablets not containing Pt and B proved that the amphetamine-type stimulant, synthesized with the Leuckart-Wallach method, also do not contain any active and cutting agents.

In the B-group tablets, the presence of Pt residuals proved that the active agents used in the production were completely different from the tablets included in the A group. The B7 tablets were found to have high calcium and low magnesium and the B11 tablets high magnesium, sodium, and iron. In the B1 and B7 tablets, both boron and platinum residuals were determined. However, the boron values of B1 and B7 were much lower than in the

A-group tablets. This proves that boron in the B1 and B7 tablets can be contaminated by impurities from the previous production.

In the XRF analysis of the C-group tablets, Pt was determined as in the B-group tablets. Although the tablets in this group were not in general similar to each other, they had much higher concentrations for sodium, magnesium, and calcium than the other groups, which was a property common in the C-group.

Only the D4-coded tablets contained Pt residuals. When the tablets in this group were compared, the differences were quite remarkable. Furthermore, the Al, Ca, Mg, K, Na, and Fe values within the impurities existing in the D4 tablets were significantly different from the concentrations found in the other tablets.

When the values related to the E-group were analyzed, it was noticed that the E1, E4, E2, and E3

Fig. 3 (a, b, c). The most common methods used for production routes of illicit amphetamine and MDMA:

(a) Leuckart-Wallach Method for amphetamine production.

(b) Reductive Amination Under Pressure Method for MDMA production.

(c) Cold Method for MDMA production.

tablets were similar to each other. The tablets not containing platinum and the captagon-logo tablets containing amphetamine suggested that the E-group tablets containing the amphetamine were produced with the Leuckart-Wallach method. The Zn amounts measured in this group were higher than the amounts found in the other groups.

In the F-group tablets, B and Pt were not present. When the values of the G-group tablets were analyzed, it was noticed that the metallic impurity levels of the F1 and F2 tablets were very similar within the scope of experimental error. In addition, the F3 and F4 metallic content values were similar to each other.

There were no significant differences between the values of the G-coded tablets. Pt was used as the catalyst in the production of the tablets in this group.

Another tablet group in which Pt was used as the catalyst was the H-group. There were no significant differences found between the H-group values.

In the K-group, the values of K4 were different in comparison to all other members of the group.

CONCLUSION

In this study, it was planned to establish a relationship between the different "ecstasy" tablets seized in the fight against illicit drugs. However, only the analysis of the elemental residuals was performed in order to understand the similarities and differences between the tablets in the various production processes. For instance, boron was present as a residual derived from sodium borohydride used as the reducing agent in the Cold Method process. Moreover, the Pt determined was found to be derived from PtO_2 used as the Adams catalyst. The presence of Mg in the tablets was identified as coming from magnesium stearate

which has lubricant properties and is necessary for shaping the tablets. Furthermore, the Ba levels revealed that barium compounds were not used in any of the stages of tablet production.

From this study, it can be concluded that the elemental determinations provided good agreement for the one-to-one comparison of the synthetic tablets. Moreover, the elemental values found verified that the chemical and physical properties of the tablets can be used as supporting evidence in identifying and establishing the differences between the various forms of illegal drugs.

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