Statistical analysis of trace metals content of cocaine using inductively coupled plasma-mass spectrometry calibrations

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Abstract: The trafficking of cocaine has become a global challenge now and Ghana is no exception. Cocaine is a whitish powder, which is, produced both from natural and synthetic means. This paper studied the metal content of seized cocaine in Ghana and the data used for batch identification. Ten metals, namely, Pb, Cu, Mg, Mn, Cr, As, Ni, Fe, Co and Ca were analyzed in 37 samples which were sampled from 2010 to 2014. Analyses of the metals were done using ICP-MS and data was analyzed using statistical tools. The results showed that, calcium recorded the highest amount in all the samples with a mean of 64.94mg/kg followed by Magnesium, Zinc and Iron with mean values of 24.35mg/kg, 6.25mg/kg and 2.65mg/kg, respectively. All the samples, within-seizure classification under class A showed to significant differences between each pair at a confidence level of 95%. With three sample pairs under class B in the within-seizure classification, one of the pairs; 10₃A and 10₅B showed no significant differences between them even though they were sampled from two different packages from the same seizure. Five

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PUBLIC INTEREST STATEMENT
Generally, illicit drugs are very dangerous drugs which can affect the human body in so many ways. Some of them such cocaine can even damage parts of the human brain which may lead to mental disorders in human beings. Governments all over the world are cracking down on illicit drugs trafficking and cocaine is no exception. This article studied the metal content of seized cocaine in Ghana. Ten metals which includes lead, Iron, Copper and Calcium were analyzed in 37 samples which were sampled from 2010 to 2014. From the research, it is confirmed that seized cocaine contained poisonous heavy metals like Lead, Arsenic and Chromium, which have the amount that could affect the user. The Authors are therefore appealing to the general public to desist from abusing of cocaine since the combination of pure cocaine and metals is deadly.
samples from five different seizures also showed a significant difference among them showing that they came from different batches or origin. It is confirmed that seized cocaine contained poisonous heavy metals like Lead, Arsenic and Chromium, which have the amount that could affect the user-provide figures. Based on the data gathered from the within-seizure class A group, it could be proposed that a missing cocaine could be identified by its metal content.

Subjects: Forensic Science; Chemistry; Material Science

Keywords: Trace metals; cocaine; statistical tools; inductively coupled plasma; mass spectrometry

1. Introduction

Illicit drug trafficking has become a global problem in recent years. Cocaine is one of the major concerns because most of the seized cocaine samples are classified under illicit natural cocaine because it is produced from the coca plant (UNODC, 2012). According to UNODC and Interpol recent publications, Colombia, Bolivia and Peru are the leading producers of illicit cocaine because the coca plant strives very well in these countries. Coca plant grown by South American countries like Argentina, Bolivia, Colombia, Ecuador and Peru falls in the Erythroxylaceae family. It has so many medicinal uses including pure cocaine, which is often referred to as pharmaceutical cocaine with a purity of 99.5% used for medical treatment. On the contrary, coca plant is the starting material for the production of cocaine. Cocaine as an illicit drug is one of the most commonly abused illicit drugs in the United States as documented by the National Institute on Drug Abuse and gradually Africa is becoming a victim. West Africa is often used, as a transiting point to transport illicit cocaine to Europe and Ghana happens to be part. In Ghana, aside battling with the issue of illicit cocaine trafficking to and from our harbours and airports, missing of seized cocaine in police custody has become the new challenge. On 28 April 2017, it was reported by The Finder, one of Ghana’s news agencies that, 10 bags of suspected cocaine, each weighing 50 kg hidden in a consignment of rice have vanished from the Tema port under mysterious circumstances. This is just one of the numerous cases that are reported concerning missing cocaine in Ghana. It is useful to know if an illicit drug sample comes from the same batch as a drug whose origin is already known in order to determine the source of illicit drug supply and thus to discover drug trafficking routes. The parameters for determining the origin of illicit cocaine can be based on the fact that the cocaine sold on the market comes with different kind of constituents, which can be classified, into contaminants, adulterants, impurities and additives (Bermejo-Barrera, Moreda-Pineiro, Moreda-Pineiro, & Bermejo-Barrera, 1999). Investigations on organic substances i.e. impurities, additives and adulterants have been conducted to establish the origin and batch of illicit cocaine. Cocaine seized in Madrid during the period from September 1985 to May 1987 contained about 52% of lidocaine as adulterants (Gomez & Rodriguez, 1989). Also in 1997 in Sao Paulo, Brazil, several adulterants and additives were identified in 389 cocaine samples analyzed (Carvalho & Midio, 2003). Several analytical methods such as Gas chromatography (GC) method and Ultra Violet (UV) spectrophotometry method have been used in identifying adulterants in illicit drugs (Campanella, Colapicchioni, Tomassetti, & Dezzi, 1996). Quite recently attention has been shifted on contaminants in illicit cocaine as a form of identifying its origin. Contaminants are present in cocaine as a consequence of contamination during the preparation of the final product from the coca leaves. The contaminants are usually classified into two different groups, namely, biotic and abiotic contaminants. Microorganisms such as fungus and bacteria are classified under biotic contaminants whereas metals or inorganic elements often make the abiotic contaminants (Bermejo-Barrera et al., 1999). Elements are found everywhere so in drug profiling, an elemental profile is only one of the various methods to be used in distinguishing one sample from another. An analytical pilot study conducted by Violante, Quaglia, Lopez, and Caroli (1992), the authors proposed that traced abiotic contaminants in cocaine and heroin could be used in characterizing illicit drugs. Electrothermal atomic absorption spectrometry (Bermejo-Barrera, Moreda-Pineiro,
Moreda-Pineiro, Bermejo-Barrera, 1996) and flameless atomic absorption spectrometry (Bermejo-Barrera et al., 1996) as techniques have been used to account for the amount of lead and chromium in illicit drugs respectively. The use of atomic absorption spectroscopy (AAS) in identifying and quantifying metal content in illicit drugs was employed but the operation of the instrument was tedious since metals had to be determined one after the other.

Due to this problem, Inductively Coupled Plasma Mass Spectrometry (ICP-MS) has been known to demonstrate powerful resolution and also analyse a lot of metals in a single run. This technique of ICP-MS was recently employed in identifying 16 inorganic elements in a total of 96 heroin samples seized in 2013–2014 in Malaysia (Kar-Weng, Zulkfeli, Leethavani, Muhammad-Hafis, & Md-Pauzi, 2016). Big seizures of cocaine been made in Ghana according to data from Narcotic Control Board leading to loud public outcry. To make matters worse some of the seizures got missing leading to the set-up of two committees of inquiry by the Government of Ghana to establish the whereabouts of the exhibits. Due to the lack of data on seized illicit cocaine samples, it has become very difficult tracing missing cocaine samples. Up to date, purity is the only analysis done on the seized cocaine, which is not enough marker for identification of batch. It is important to know if illicit cocaine comes from the same batch if the origin is already known in determining the source of illicit drug supply. Production of illicit cocaine allows the introduction of metallic contaminants, which is important in determining the source and the trafficking routes of the illicit cocaine sample in question (Tanner-Smith, 2006). Metal content has also been used in identifying seized cocaine samples from the same manufacturing bulk or batch using pattern recognition techniques (Bermejo-Barrera et al., 1999). In Ghana, no such work has been done on the seized illicit cocaine samples so this experiment can help in solving some of the missing cocaine sagas in the future if it may happen.

This work, therefore, studied the levels of trace and heavy metals in seized illicit cocaine in Ghana from 2010 to 2014 and to analyze the metal content as a model of batch identification for illicit cocaine and also to analyze the heavy metal content of illicit cocaine to identify the risk to addict. This is the first study of trace metals contents in seized cocaine in the country.

2. Materials and methods

2.1. Materials

2.1.1. Sample
Cocaine of average purity of 80% was supplied by the Ghana Standard Authority Forensic Department, Accra. The samples corresponded to confiscation carried out in Ghana especially at the airport and harbour over the period of 2009 to 2014. The cocaine seizures normally come in slabs, pellets or powder. The project samples were taken according to the Forensic Department sampling plan.

2.1.2. Chemicals
All chemicals used were of ultrapure grade, using ultrapure water, which was prepared by the Ghana Standards Authority, Accra

2.1.3. Argon gas
Argon Gas for the ICP-MS was obtained from Ghana Gas Company, Accra.

3. Method

3.1. Sampling method for cocaine samples
Samples were taken into rubber holders and properly sealed and labeled. The samples were taken based on the availability of the cocaine sample after test by the forensic department. The cocaine
stock samples were kept in a security-protected safe under a temperature of 4°C. Table 1 shows the sampling process and labeling.

The classification in Table 1 was done based on Figure 1.

For the submission/seizure that contained more packages, individual samples were taken from two randomly picked packages to form related samples. The related samples under class A were

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**Table 1. Sample plan employed for the cocaine samples**

| Sample Code (Cocaine seizures) | A B | C |
|-------------------------------|-----|---|
| 6                             | 6a, 6y | - |
| 18                            | 18a, 18c | - |
| 7                             | 7a, 7c | - |
| 29                            | 29a, 29b | - |
| 14                            | 14a, 14b | - |
| 23                            | 23a, 23b | - |
| 13                            | 13a, 13b | - |
| 24                            | 24a, 24b | - |
| 28                            | - 28a, 28b | - |
| 32                            | - 32a, 32b | - |
| 10                            | - 10a, 10b | - |
| 26                            | - 26a, 26b | - |
| 9                             | 9a, 9b | - |
| 15                            | 15a, 15b | - |
| 19                            | - 19a, 19b | - |
| 25                            | 25a, 25b | - |
| 4                             | - | 4 |
| 12                            | - | 12 |
| 20                            | - | 20 |
| 21                            | - | 21 |
| 31                            | - | 31 |

Total number of samples—37, ‘-’ Signifies no sample

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Figure 1. Levels of relationship for different kinds of cocaine samples seized (Kar-Weng et al., 2016).

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The classification in Table 1 was done based on Fig. 1.

A: Strongly related       B: Likely related       C: Likely unrelated       D: Strongly unrelated
13 groups and 3 groups under class B which constituted 16 groups equivalent to 16 seizures, which were used to evaluate within-seizure variability. In the three groups, sample 28$_2$ and 28$_3$ were from the same seizures but had different signs on the packages, same as 26$_{3A}$/26$_{5B}$ and 10$_{4A}$/10$_{6A}$. Under class C, 5 samples were used equivalent to 5 separate seizures, which were used to evaluate between-seizure variability. The 5 samples were selected because they had slight physical similarities especially the colour and appearance. None of the seizures could be grouped under the class D.

3.2. Sample weighing
The weighing of the samples was done using an electronic balance at Ghana Standards Authority Metallic and Contaminants Lab. Below is the specifications of the balance;

Model: KERN & Sohn GmbH
Type: ABS 220–4
No: WB0910296
Capacity: 220 g
Readability: 0.1 mg

The balance was made to stand for 1 h after switching it on and accuracy was done using standard weight for verification. Amounts of 0.5 g of the cocaine samples were weighed into 50 ml beaker. One weight each was done because of the lack of sample.

3.3. Preparation of nitric acid (2.0% v/v) as dissolving solution
Approximately 28.60 ml nitric acid was diluted with deionized water to obtain 1-l solution of HNO$_3$.

3.4. Pretreatment of samples
The samples were dissolved in 1 ml of ultrapure water and heated at 40 Degrees Celsius to aid complete dissolution. The solution was then transferred into a 100 ml volumetric flask. Into the volumetric flask, 2 ml of 2.0% (v/v) HNO$_3$ was added to aid in the stabilization of the solution. Afterwards, it was diluted to 30 ml with water. After complete mixing of the solution, the volumetric flask was properly sealed and labeled for analysis.

3.5. Standard solution preparation
An amount of 1 ml was withdrawn from the standard stock solution and then diluted with 2% HNO$_3$ to prepare three separate standard solutions in the following listed concentrations: Standard 1; 200ppb, Standard 2; 400ppb and Standard 3; 600ppb. The three prepared standards obtained were then used to perform the standard calibration check.

3.6. Blank preparation
A blank solution was prepared as per the same procedure applied to the cocaine samples outlined above.

3.7. Quality control check
This was done using surface water. Surface water is a solution, which contains multi-metals and has a known concentration. It is often preferred because it's eliminating interference from the analyst. The surface water used was prepared into 1000ppb or 1ppm. The percentage of recovery obtained is then compared to the reference chart to determine the accuracy of the equipment.
3.8 Apparatus
An Agilent model ICP-MS version 7700 with standard nebulization was used. The metals determined were Calcium, Arsenic, Chromium, Iron, Magnesium, Nickel, Zinc, Copper, Manganese and Lead. The metals were picked because they were likely to be found in cocaine according to already reported works.

The Operational conditions for the ICP-MS are listed in Table 2.

Analytical results were calculated using linear calibration graphs. The ICP-MS records the results in two modes, namely, No Gas mode and Helium mode. The metal content in ppm is determined by the Equation (1) below:

\[
\text{Content} = \frac{(C - B) \times V}{W}
\]

C — Concentration of final solution, B — Concentration of blank solution
V — Final volume of solution, W — Weight of sample

4. Results and discussions

4.1 Statistical analysis of the samples
The ICP-MS data were analyzed statistically by means of Excel version 10.0. Each elemental concentration in ppm was considered as the variables for each cocaine sample. After the variables were defined, ANOVA was performed at 95% confidence level. The results as shown below in Table 3:

5. Amount of metals in cocaine samples: descriptive data
Table 4, displays the descriptive data for the 10 metal elements found in the cocaine samples seized from 2010 to 2014. As indicated by the standard deviation (SD), the 37 samples analyzed showed a wide range of concentrations for most of the metals which were measured in parts per million. The marked difference between the maximum and the third quartile (Q3) indicates the presence of outliers as presented by Calcium and Magnesium in Table 1. Due to these differences, it is much meaningful to use the median to measure the central tendency of the data.

Calcium was present in extremely high levels with a mean value of 64.94 mg/kg. This high level could be attributed to calcium-containing agents, which are added during the illicit cocaine production steps (Kar-Weng et al., 2016). At the final phase of the coca paste isolation, excess lime is added to neutralize the sulfuric acid in the solution. Lime is also known as calcium-containing inorganic mineral, thus the presence of Calcium. Since the production of illicit heroin involves the addition of lime, Calcium recorded a high amount around 4050 to 14,200 μg/g in 44 illicit heroin samples seized in Turkey (Tanner-Smith, 2006). It could also have originated from water, which was usually added during the cooking process in cocaine production (Kar-Weng et al., 2016). Magnesium, Zinc, and Iron with mean values of 24.35 mg/kg, 6.25 mg/kg and 2.65 mg/kg, respectively, had a moderate amount in the cocaine samples after Calcium. This could be

| Parameters       | Conditions   |
|------------------|--------------|
| RF Power         | 1 kW         |
| Radio frequency  | 40 mHz       |
| Carrier gas flow rate | 0.64 L/min   |
| Plasma gas flow rate | 15 L/min     |
| Plasma observation | Radial     |
| Pump uptake      | 1.5 ml/min   |

Table 2. ICP-MS operational parameters used
| Sample 6          | Source of Variation | SS   | df  | MS   | F     | P-value  | F crit |
|------------------|---------------------|------|-----|------|-------|----------|--------|
|                  | Rows                | 1079.104 | 9   | 119.9004 | 6.402736 | 0.005392 | 3.178893 |
|                  | Columns             | 20.43838 | 1   | 20.43838 | 1.091419 | 0.323404 | 5.117355 |
|                  | Error               | 168.5379 | 9   | 18.72643 |       |          |        |
|                  | Total               | 1268.08 | 19  |       |       |          |        |
| Sample 18        | Source of Variation | SS   | df  | MS   | F     | P-value  | F crit |
|                  | Rows                | 22,964.43 | 9   | 2551.604 | 684.9746 | 1.14E-11 | 3.178893 |
|                  | Columns             | 2.355038 | 1   | 2.355038 | 0.632207 | 0.447008 | 5.117355 |
|                  | Error               | 33.52597 | 9   | 3.725107 |       |          |        |
|                  | Total               | 23,000.32 | 19  |       |       |          |        |
| Sample 7         | Source of Variation | SS   | df  | MS   | F     | P-value  | F crit |
|                  | Rows                | 7681.983 | 9   | 853.5536 | 7.101859 | 0.003727 | 3.178893 |
|                  | Columns             | 118.4871 | 1   | 118.4871 | 0.985854 | 0.346701 | 5.117355 |
|                  | Error               | 1081.686 | 9   | 120.1873 |       |          |        |
|                  | Total               | 8882.156 | 19  |       |       |          |        |
| Sample 29        | Source of Variation | SS   | df  | MS   | F     | P-value  | F crit |
|                  | Rows                | 418.0879 | 9   | 46.45421 | 63.12959 | 4.67E-07 | 3.178893 |
|                  | Columns             | 0.453306 | 1   | 0.453306 | 0.616026 | 0.452692 | 5.117355 |
|                  | Error               | 6.622693 | 9   | 0.735855 |       |          |        |
|                  | Total               | 425.1639 | 19  |       |       |          |        |
| Sample 14        | Source of Variation | SS   | df  | MS   | F     | P-value  | F crit |
|                  | Rows                | 298.4433 | 9   | 33.16037 | 82.57644 | 1.43E-07 | 3.178893 |
|                  | Columns             | 0.335405 | 1   | 0.335405 | 0.835231 | 0.384594 | 5.117355 |
|                  | Error               | 3.614146 | 9   | 0.401572 |       |          |        |
|                  | Total               | 302.3929 | 19  |       |       |          |        |
| Sample 23        | Source of Variation | SS   | df  | MS   | F     | P-value  | F crit |
|                  | Rows                | 4695.235 | 9   | 521.6928 | 3.02482 | 0.057351 | 3.178893 |
|                  | Columns             | 268.6005 | 1   | 268.6005 | 1.557369 | 0.243541 | 5.117355 |
|                  | Error               | 1552.236 | 9   | 172.4707 |       |          |        |
|                  | Total               | 6516.072 | 19  |       |       |          |        |
| Sample 13        | Source of Variation | SS   | df  | MS   | F     | P-value  | F crit |
|                  | Rows                | 341.8538 | 9   | 37.98375 | 173.1062 | 5.37E-09 | 3.178893 |
|                  | Columns             | 0.225569 | 1   | 0.225569 | 1.028002 | 0.337109 | 5.117355 |
|                  | Error               | 1.974821 | 9   | 0.219425 |       |          |        |
|                  | Total               | 344.0541 | 19  |       |       |          |        |
| Sample 24        | Source of Variation | SS   | df  | MS   | F     | P-value  | F crit |
|                  | Rows                | 514.701 | 9   | 57.189 | 145.2892 | 1.17E-08 | 3.178893 |
|                  | Columns             | 0.172608 | 1   | 0.172608 | 0.438513 | 0.524433 | 5.117355 |
|                  | Error               | 3.542597 | 9   | 0.393622 |       |          |        |
|                  | Total               | 518.4162 | 19  |       |       |          |        |
| Sample 28        | Source of Variation | SS   | df  | MS   | F     | P-value  | F crit |
|                  | Rows                | 906.9165 | 9   | 100.7685 | 324.8468 | 3.23E-10 | 3.178893 |
|                  | Columns             | 2.755789 | 1   | 2.755789 | 8.88382 | 0.015435 | 5.117355 |
|                  | Error               | 2.791828 | 9   | 0.310203 |       |          |        |

(Continued)
attributed to the metal pot used in the heating processes in the manufacturing process as reported by Tanner-Smith (2006). Furthermore, Iron, Magnesium, calcium may have originated from tap water because it naturally contains these elements in high levels. All the metals with the exception of Calcium were not detected in some of the samples, which accounts for the high levels of Calcium in the environment as earlier reported.

6. Batch identification using metal content

From the illustration in Figure 1, the samples analyzed were grouped into class A, B and C based on the descriptions given. From Table 1, 14 pairs of the cocaine samples fell under class A. According
to the P-values outlined in Table 5 at 95% confidence level ($p \geq 0.05$), it showed that there were no significant differences between the pairs in the samples selected with reference to metals analyzed. This could confirm the fact that the pair of samples were taken from the same package during the seizure from 2010 to 2014.

Only two pairs of the samples were classified under Class B i.e. samples 26 and 28. The p-values showed that there were significant differences between the pairs in the two cocaine samples with reference to the metals. With sample 26, subsample A did not record the presence of eight metals showing the presence of only Calcium and Manganese as compared to the other pair 26, subsample B. Similarly with 28, subsample 2 and 3, both did not show the presence of Zinc with 28, subsample 3 showing the absence of other metals like Iron, Magnesium, Nickel, Copper, Manganese, and Lead. These differences showed between the samples can be attributed to within bulk variety. There are some critical parameters measured during production processes, which can affect the consistency in a bulk batch produced under the same conditions and personnel, e.g. mixing speed and time.

Five of the samples had slightly similar physical properties (physical inspection) but were from different seizures (class C) encountered from the year in review; 2010 to 2014. The samples were 4, 12, 20, 21 and 31 as shown in Table 1. They had a different composition with reference to the amount of metal elements. Sample 4 did not contain iron, nickel and zinc; while sample 21 and 31 did not contain lead and iron, respectively. This clearly shows that those samples are probably from different production batches and origin or country as shown in Table 6. Nonetheless, these samples could be from the same bulk but having undergone different degrees of contamination after they have been dispersed from the main bulk. Such samples may have had their metal profiles altered. These samples also did not have any correlation with the other others used for this experiment.

All the samples used for the experiment appeared similar so none of them were grouped under class D. Sample 10 had a unique metal profile between the pair though they had different signs on the packages, the content did not show any significant difference between them. This can mean that they can be from the same production batch but they were packed differently.

**7. Heavy metal content: health hazards on cocaine users**

According to Table 7, the heavy metal content of seized cocaine with reference to lead, arsenic, and chromium were higher than the ones contained in water, animal fats and edible fats and oils as the acceptable limits outlined in Codex standard 193: 1995.

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**Table 4. Descriptive data of 10 elements in 37 cocaine samples**

| Element | Mean | SD  | Minimum | Q1   | Median | Q3  | Maximum |
|---------|------|-----|---------|------|--------|-----|---------|
| Ca      | 61.94| 54.60| 13.13   | 17.39| 30.94  | 34.87| 960.43  |
| As      | 0.32 | 0.13 | 0       | 0.26 | 0.34   | 0.42| 0.52    |
| Cr      | 1.66 | 0.55 | 0       | 1.57 | 1.81   | 1.99| 2.21    |
| Fe      | 2.65 | 2.41 | 0       | 1.65 | 2.11   | 3.42| 11.54   |
| Mg      | 24.35| 78.06| 0       | 0.84 | 1.73   | 3.04| 352.42  |
| Ni      | 0.09 | 0.09 | 0       | 0.03 | 0.07   | 0.13| 0.35    |
| Zn      | 6.25 | 14.12| 0       | 0    | 0.59   | 4.70| 54.23   |
| Cu      | 0.52 | 0.65 | 0       | 0.16 | 0.30   | 0.57| 2.52    |
| Mn      | 0.54 | 0.72 | 0       | 0.06 | 0.27   | 0.61| 2.58    |
| Pb      | 0.52 | 2.55 | 0       | 0    | 0.06   | 0.17| 15.60   |

Q1 = 1st Quartile  
Q3 = 3rd Quartile  
Q1–3rd Quartile

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Table 5. Within-seizure presentation of some metals in cocaine samples at 95% confidence level

| Code | Ca  | As  | Cr  | Fe  | Mg  | Ni  | Zn  | Cu  | Mn  | Pb  | P-values |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----------|
| 6_1 | 34.52 | 0.21 | 1.88 | ND  | 0.83 | ND  | 0.59 | 0.28 | 0.04 | 0.07 | 0.3234   |
| 6_4 | 15.09 | 0.24 | 1.89 | ND  | 0.64 | ND  | 0.24 | 0.03 | 0.06 |     |          |
| 18_3 | 118.64 | 0.12 | 1.41 | 1.70 | 13.91 | 0.06 | 1.93 | 0.12 | 0.38 | 0.23 | 0.4470   |
| 18_4 | 110.23 | 0.16 | 1.27 | 2.37 | 14.42 | 0.32 | 2.29 | 0.16 | 0.37 | 0.05 |          |
| 7_1 | 88.77 | 0.25 | 1.53 | 1.78 | 28.23 | 0.13 | 6.10 | 0.45 | 0.32 | 0.13 | 0.3467   |
| 7_6 | 40.16 | 0.26 | 1.58 | 6.68 | 24.82 | 0.09 | 4.70 | 0.31 | 0.22 | 0.18 |          |
| 29_1 | 14.24 | 0.40 | 1.98 | 2.74 | 1.73 | 0.07 | ND  | 0.07 | 0.63 | ND  | 0.4527   |
| 29_8 | 17.39 | 0.29 | 1.74 | 1.22 | 3.04 | 0.06 | ND  | 0.38 | 0.58 | 0.17 |          |
| 14_1 | 13.53 | 0.32 | 1.57 | 2.39 | 0.38 | 0.06 | ND  | 0.54 | 0.09 | 0.06 | 0.3846   |
| 14_8 | 13.13 | 0.51 | 1.99 | 2.45 | 3.11 | 0.03 | ND  | 0.26 | 0.06 | ND  |          |
| 23_2 | 82.31 | 0.29 | 1.64 | 4.56 | 2.63 | 0.15 | 9.62 | 0.67 | 2.05 | 0.18 | 0.2435   |
| 23_5 | 22.56 | 0.33 | 2.05 | 2.05 | 1.26 | 0.05 | 1.98 | 0.41 | 0.07 | 0.07 |          |
| 13_1 | 13.18 | 0.35 | 1.71 | 1.65 | 0.62 | 0.03 | ND  | 0.53 | 0.09 | 0.06 | 0.3371   |
| 13_6 | 15.17 | 0.42 | 1.91 | 1.91 | 0.84 | 0.03 | ND  | ND  | 0.06 | ND  |          |
| 24_4 | 18.59 | 0.36 | 2.13 | 4.88 | 1.51 | 0.09 | ND  | 0.16 | 0.09 | 0.95 | 0.5244   |
| 24_6 | 16.12 | 0.51 | 2.04 | 5.29 | 1.75 | 0.06 | ND  | 0.86 | 0.06 | 0.19 |          |
| 28_2 | 23.22 | 0.46 | 2.07 | 2.11 | 0.90 | 0.05 | ND  | 0.94 | 0.05 | 0.12 | 0.0154   |
| 28_3 | 22.36 | 0.05 | 0.05 | ND  | ND  | ND  | ND  | ND  | ND  | ND  |          |
| 32_1 | 15.07 | 0.28 | 1.31 | 0.52 | ND  | 1.01 | 0.26 | 0.02 | 0.02 | 0.0752  |
| 32_4 | 16.18 | 0.35 | 1.83 | 2.03 | 0.42 | 0.05 | 0.59 | 0.57 | 0.10 | ND  |          |
| 10A6 | 33.23 | ND  | ND  | ND  | ND  | ND  | ND  | ND  | ND  | ND  | 0.2186   |
| 10_1A | 35.33 | 0.42 | 2.04 | 4.82 | 1.68 | 0.18 | 54.23 | 2.46 | 1.52 | 0.24 |          |
| 26_3A | 34.77 | ND  | ND  | ND  | ND  | ND  | ND  | ND  | 0.01 | ND  | 0.0072   |
| 26_5B | 34.87 | 0.39 | 2.21 | 3   | 0.96 | 0.25 | 1.82 | 0.59 | 2.46 | 0.10 |          |
| 9A   | 34.81 | 0.41 | 1.78 | 1.83 | 47.11 | 0.07 | 1.19 | 0.18 | 0.27 | ND  | 0.3142   |

(Continued)
| Code | Ca     | As | Cr  | Fe  | Mg   | Ni  | Zn   | Cu  | Mn  | Pb  | P-values |
|------|--------|----|-----|-----|------|-----|------|-----|-----|-----|----------|
| 9b   | 31.37  | 0.42| 1.81| 2.59| 47.04| 0.09| ND   | 0.09| 0.30| ND  |          |
| 15A6 | 77.08  | 0.36| 1.92| 3.42| 352.42| 0.10| 10.15| 0.73| 1.40| ND  | 0.4656   |
| 15A10| 111.83 | 0.52| 2.14| 7.93| 332.82| 0.35| 21.52| 0.17| 2.58| 0.20|          |
| 19s  | 29.42  | 0.31| 1.67| 4.05| 1.56 | 0.15| 44.94| 2.31| 1.30| 0.11| 0.2345   |
| 19a  | 22.74  | 0.42| 2.09| 2.29| 1.54 | 0.03| 0.24 | 0.08| 0.39| ND  |          |
| 25s  | 33.94  | 0.30| 1.90| 1.81| 2.50 | 0.17| 5.80 | 0.30| 0.78| ND  | 0.3410   |
| 25a  | 33.44  | 0.34| 1.89| 2.61| 1.93 | 0.13| 5.19 | 0.08| 0.61| ND  |          |

ND-Not Detected
With the amounts recorded for the three metals, it can have an adverse effect on anyone who takes in cocaine contaminated to this level with these metals. Abernathy et al. (1999) indicate that the toxicity of arsenic depends on these factors; exposure dose, frequency and duration, biological species, age and gender as well as on genetic and nutritional factors. Investigations from epidemiological studies have indicated that long-term exposure to arsenic can end up in carcinogenesis (Zhao, Young, Diwan, Coogan, & Waalkes, 1997). All the health hazards attributed to arsenic can be related to chromium and lead and with the high levels of these metals; the end user of the illegal powder can have a serious health consequence on him. Measures should be put in place in order to prevent people from taking in these substances so it will not add up on the small amounts taken through food and water daily.

8. Proposed identification of missing seized cocaine

The aim of the sampling plan for the seized cocaine was to compare two samples from the same cocaine batch with respect to their metal profile. According to Table 7, some of the samples from the same batch showed no significant differences between them. Based on the data gathered there can be two proposed ways of identifying missing cocaine looking at their metal profiles. Firstly, the confirmation test can be done on missing metals and secondly the amount of each metal can be confirmed. This can produce perfect results if there is no adulteration. The metal content analysis can be preceded by an analysis of adulterants. Assuming sample x was first seized, analyzed for metal content as shown in Table 8, then got missing from custody. The metal profile for sample y is representing the found sample x that got missing.
From the earlier hypothesis, the first metal that would be analyzed for on sample y will be the element Zinc. It can be seen from the analysis conducted on the sample x that, Zn was missing from the metal profiling done. Ideally, if nothing was added to the cocaine when it got missing, it is expected that Zinc will also be missing in sample y. Secondly, the amount recorded for each metal in the two samples would also be compared. According to Table 4.4, it can be seen that the two-sample x and y almost look the same compared to the amount of metals. There is only a slight change, which is not significant according to the p-value.

It should also be noted that these theories would only stand if there is no adulteration on the cocaine sample when it goes missing. Addition of adulterants and diluents may introduce some other metals into the ones already in the cocaine sample.

9. Conclusion and recommendations
The study shows that illicit cocaine can be confirmed to contain metals that can be use as a form of identification. The metal profile on the seized cocaine samples using ICP-MS can be used to identify cocaine that comes from the same batch even though they might be from different seizures. Seized illicit cocaine also contains some amount of heavy metals such as Lead, Arsenics and Chromium and they can have serious health implications on the end user. In spite of the data gathered in the study conducted, these are some few recommendations for future studies:

- More metals should be analyzed to aid in less variation between within-batch cocaine samples
- To have a sample from missing and found cocaine to compare the changes in metal profile between the first and second catch.

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