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Determination of manganese, iron, calcium and potassium in soil samples

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Abstract

The purpose of this work is to determine manganese (Mn), iron (Fe), calcium (Ca) and potassium (K) concentration in four unknown samples of soil by two techniques: Atomic Absorption Spectrometry (AAS) and Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES). Then by comparing the results, a verification of the most accurate technique is reached. Since soil analysis is essential in many fields, it is, therefore, useful to know which is the most efficient and accurate technique. In this experiment, unknown soil samples were compared to standard soil samples and their metal content was determined by the two instruments. The results verify that the Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) is by far the most accurate technique.

Keywords: Soil samples, Iron, soil, unknown samples, standard soil samples

Introduction

Soil analysis is important in many fields. Soil needs to be analysed and perhaps its nature modified so that it will be optimal for certain plants in a specific area and climate. Soil analysis is also important for many forensic reasons. There are many methods used for identification of soil samples. These can be physical and chemical. Examples include microscopy, PH, thermal analysis, spectroscopy and fluorescence (*1*).

Atomic absorption spectrometry (AAS) is a spectra analytical procedure for the qualitative and quantitative determination of chemical elements employing the absorption of optical radiation (light) by free atoms in the gaseous state. In analytical chemistry the technique is used for determining the concentration of a particular element in a sample to be analysed. AAS can be used to determine over thirty different elements in solution (*2*). Atomic absorption units have four basic parts, interchangeable lamps that emit light with element-specific wavelengths, a sample aspirator, a flame or furnace apparatus for volatilizing the sample, and a photon detector. In order to analyse for any given element, a lamp is chosen that produces a wavelength of light that is absorbed by that element. Sample solutions are aspirated into the flame. If any ions of the given element are present in the flame, they will absorb light produced by the lamp before it reaches the detector (*2*). The amount of light absorbed depends on the amount of the element present in the sample. Absorbance values for unknown samples are compared to calibration curves prepared by running known samples (*2*).

Inductively Coupled Plasma - Optical Emission Spectrometry (ICP-OES) is a method of optical emission spectrometry where plasma energy is given from an outside to the sample so that its atoms are excited and then return to their low energy position to emit spectrum rays where those which correspond to the photon wavelength are measured (*3*). The element type is then identified based on the position and the content based on the intensity of the photon rays. ICP-Optical Emission Spectrometry (ICP-OES) is one of the most commonly used methods in organic analysis for almost three decades now. The exciting temperature of argon ICP-OES is 5000-7000 K which is capable of exciting many elements (*3*).

OES equipment is the light source unit, a spectrometer, a detector and a data processing unit. The differences among various equipments are present due to the differences in the spectrometers and the detectors. The equipment is mainly of 2 types, the sequential and the simultaneous. The former is good for high matrix samples measurements and the latter for its fast measurements i.e., one or two minutes for 72 measurable elements. ICP-OES has many applications which include steel analysis, bastnasite analysis and hair analysis (*3*). ICP-OES is a multipurpose analysis technique. It is an important environmental measurement technique which has a very wide worldwide use which is also foreseen to expand even further.

The aim of this study is to verify the most accurate technique and instrument that used to analyse soil metal concentration. The two instruments and techniques tested in this study are: Atomic Absorption Spectrometry (AAS) and Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES). In this experiment identification of four unknown soil samples using one known standard soil sample was performed

Materials and Methods

This procedure is to prepare soil samples for both the AAS and ICP-OES instruments

Standard preparation Procedure

This is the standard preparation method, which aims to identify the best instrument to analyse the four components in the soil (*4*):

1. Six known soil samples of 0.50 g each are prepared.
2. Thirty mL of Nitric acid (HNO_3) is added to 10 mL of Nitric/Hydrochloric acid (HCL), i.e., 3:1 ratio in a 50 mL beaker to form M solution.
3. The six soil samples are divided into two groups. The first group consists of three samples with 10 mL of solution nitric acid added to each sample and the second group consists of the other three samples with 10 mL of solution Nitric/Hydrochloric added to each sample.
4. Two blank samples are added so the total number of the soil samples is eight.

The first three samples represent the Nitric acid and the fourth is blank:

1. Samples are put on the hotplate for heating for 30 minutes so that the mixture is homogeneous.
2. They are then taken away for 5 minutes for cooling.
3. The whole four samples are then filtered in a 50 mL flask.
4. After filtration, distilled water is added to top up the mixture to 50 mL.
5. The samples are shaken to assure homogeneity of the solution.

For the other four samples, the same methods are done as above and the samples were put in the tubes of the instrument after it has been put on and calibrated. This process took one hour.

Methods of preparation of the four unknown samples

1. Four unknown soil samples at 0.50 g for each sample and was put in the Microwave.
2. Solution M was prepared by adding 30 mL of Nitric acid to 10 mL of Nitric/Hydrochloric acid, i.e., 3:1 ratio in a 50 mL baker.

3. 10 mL of solution M was added to the Microwave tubes.
4. A blank sample is added to the five samples so that there are 6samples.
5. The Microwave is put on for almost 1 hour.
6. Filtration for the four samples in a 50 mL flask.
7. Distilled water is added to the flask to top it up to 50 mL.
8. The four samples are well shaken so that the solution is homogeneous.

The ICP-OES instrument was chosen to analyse the four components in the four unknown samples. The AAS instrument was used to confirm accuracy.

Results

Atomic Absorption Spectroscopy (AAS)

This instrument is used to determine the concentration of manganese and iron in both the standard soil samples and the unknown soil samples. Samples were prepared by microwave then they have been run by using the AAS instrument after they were diluted in a different range of 50 mL flasks. The calculated results for samples that have been run-in the microwave instrument are closer to the readings that are provided. For example, the concentration for iron (Fe) in the sample digested by microwave is 26,790 ppm while the iron concentration in the certificate is 29,167.

Standard soil

Manganese

For manganese concentration in the standard soil sample N with absorbance reading (y) of 0.04 ppm were illustrated in (Table 1). Results are calculated as follows (Table 2, Figure.1):

$y = 0.058\,x + 0.003$

$x = 0.645$ ppm × 10 = 6.4 ppm

$x = (6.4 \times 50) = 320 \times 2 =$ **640 ppm**

For sample M:

$y = 0.058\,x + 0.003$, when $y = 0.055$ ppm

$x = 0.89$ ppm × 10 = 8.9 ppm

$x = (8.9 \times 50) = 445 \times 2 =$ **890 ppm**

Iron

For Iron concentration in the standard soil, sample N with absorbance (y) reading of 0.1 ppm (Table 1). Results are calculated as follows (Table 2, Figure. 2):

$y = 0.015\,x + 0$

$x = 6.7$ ppm × 10 = 67 ppm

x = (67 × 50) = 3350 × 2 = **6,700 ppm**
For Sample M:
y = 0.015 x + 0, when y = 0.134
x = 8.93 × 30 = 267
x = (267 × 50) = 13350× 2 = **26,790 ppm**

Table 1: Absorbance values of manganese and iron in soil samples N and M

Analysis Sample	Absorbance of Mn (ppm)	Absorbance of Fe (ppm)
Sample (N)	0.040	0.100
Sample (M)	0.055	0.134

Table 2: Concentration and absorbance of manganese and iron in standard soil samples

Concentration (ppm)	Absorbance of Mn standard (ppm)	Absorbance of Fe standard (ppm)
0.2	0.017	0.032
0.5	0.033	0.059
0.1	0.064	0.094
1.5	0.076	0.15
2	0.119	

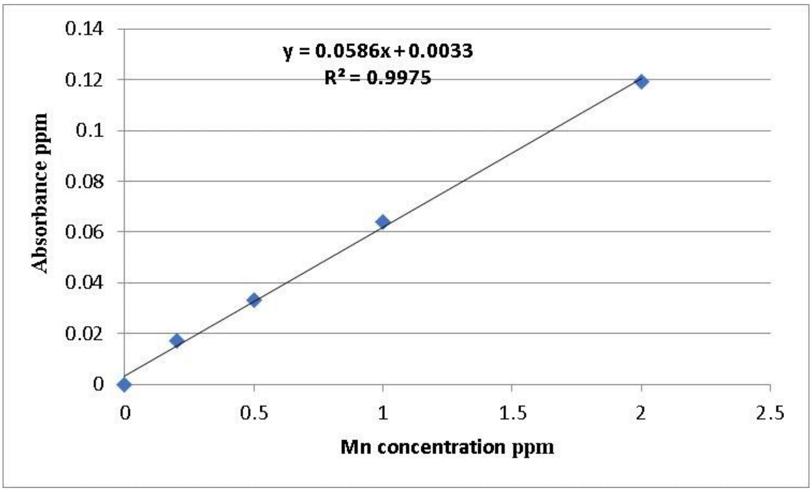

Figure. 1: Manganese (Mn) calibration curve of absorbance against concentration in standard soil samples

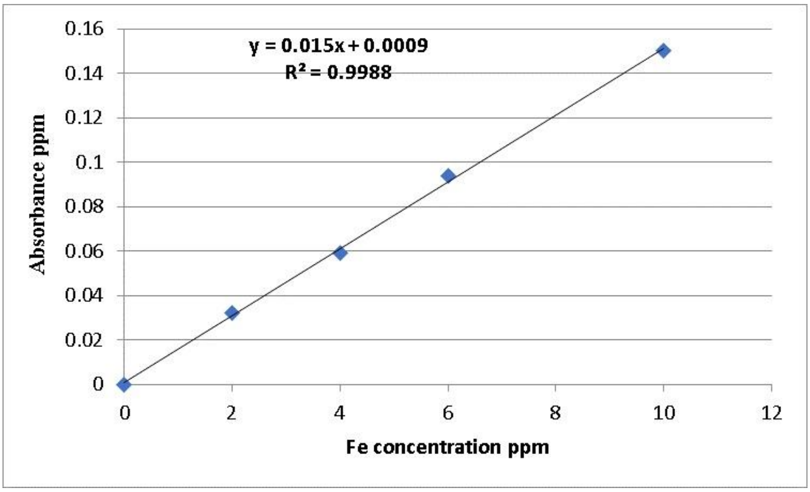

Figure. 2: Iron (Fe) calibration curve of absorbance against concentration in standard soil samples

Unknown soil samples

Manganese

For manganese concentration in the unknown soil samples, sample one which was diluted 1:20 and with absorbance (y) of 0.043 ppm was used (Table 3). Results are then calculated (Table 4, Figure. 3):

y = 0.073 x + 0.013
x = 0.4109 ppm × 20
x = (8.21 × 50) = 410.5 × 2 = **821 ppm**
Sample two diluted 1:20 absorbance (y) of 0.041 ppm:
y = 0.073 x + 0.013
x = 0.383 ppm × 20
x = (7.7 × 50) = 385 × 2 = **770 ppm**
Sample three diluted 1:20 absorbance(y) of 0.042 ppm:
y = 0.073 x + 0.013
x = 0.4 ppm × 20
x = (8 × 50) = 400 × 2 = **800 ppm**
Sample four diluted 1:30 absorbance (y) of 0.035 ppm

y = 0.073 x + 0.013
x =0.3 × 30
x = (9 × 50) = 450 × 2 = **900 ppm**

Iron

Iron concentration in Sample one diluted 1:30 with absorbance (y) of 0.09 ppm (Table 3). Results are then calculated (Table 5, Figure. 4):
y = 0.014x + 0
x = 6.42 ppm ×30
x = (192.6 × 50) = 9630 × 2= **19,260 ppm**
Iron concentration in Sample two diluted 1:30 with absorbance (y) of 0.1 ppm:
y = 0.014 x + 0
x = 7.14 ppm × 30
x = (214.2 × 50) = 10710 × 2 = **21,420 ppm**
Iron concentration in Sample three diluted 1:30 with absorbance (y) of 0.094 ppm:
y = 0.014 x + 0
x = 6.71 ppm × 30
x = (201.3 × 50) = 10065 × 2 = **20,130 ppm**
Iron concentration in Sample four diluted 1:50 with absorbance (y) of 0.065 ppm:
y = 0.014 x + 0
x = 4.6 ppm × 50

x = (230 × 50) = 11500 × 2 = **23,000 ppm**

Table 3: Absorbance values of manganese in unknown soil samples

Analysis Sample	Absorbance of Mn in samples (ppm)	Absorbance of Fe in samples (ppm)
Sample 1	0.043	0.090
Sample 2	0.041	0.100
Sample 3	0.042	0.094
Sample 4	0.035	0.065

Table 4: Concentration and absorbance of manganese in unknown soil samples

Concentration (ppm)	Absorbance of Mn standard (ppm)
0.2	0.031
0.5	0.059
1	0.089

1.5	0.134
2	0.149

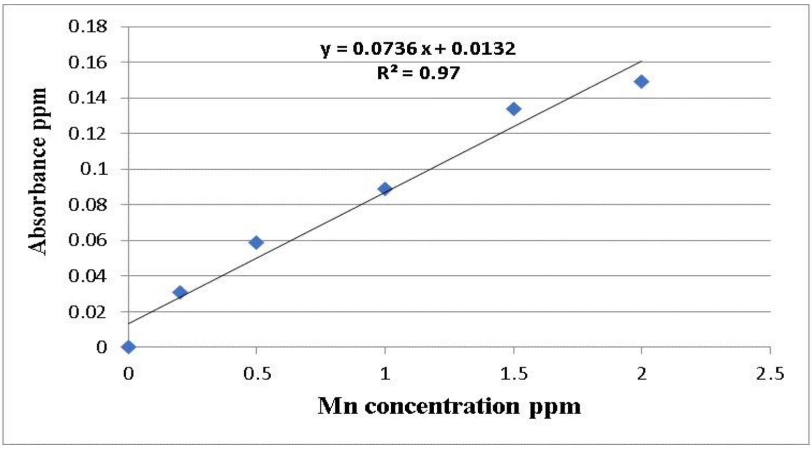

Figure. 3: Manganese (Mn) calibration curve of absorbance against concentration in unknown soil samples

Table 5: Concentration and absorbance of iron in unknown soil samples

Concentration (ppm)	Absorbance of Fe standard (ppm)
1	0.031
2	0.059
3	0.089
4	0.134
5	0.149

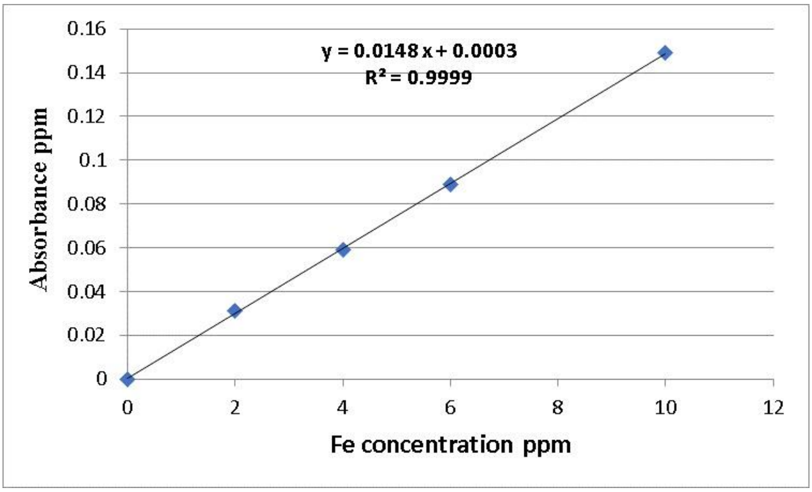

Figure. 4: Iron (Fe) calibration curve of absorbance against concentration in unknown soil samples

Unknown soil samples were prepared by microwave and then they have been run by using the AAS instrument after they were diluted in different ranges in 50 ml flask. The concentration of manganese sample two is 770 ppm and sample three is 800 ppm. As we can see from the data, sample four contained a much higher concentration of Fe than the other samples and because of that it was diluted 1 to 30 and it is the closer one of samples to the standard. For iron concentrations in the four samples, samples two and three have a slightly smaller amount of iron concentration 21,420 ppm and 20,130 ppm respectively. However, the concentration of iron in sample four which was diluted 1:50 is 23,000 ppm and that was more than others and that means it is a closer sample to the standard from the other samples.

Inductively Coupled Plasma ICP-OES

The ICP-OES instrument is used to determine the concentration of manganese, iron, calcium, and potassium in both the standard soil samples and the unknown soil samples.

Standard soil

Manganese

- For manganese concentration in the standard soil, diluted 1:50 sample N is as follows (Table 6, Figure. 5):

$y = 12{,}333\ x + 664.2$

$3{,}982.76 = 12{,}333\ x + 664.2$

$x = 0.269$ ppm $\times 50 = 13.45 \times 50 = 672.7 \times 2 =$ **1,345.4 ppm**

- For Sample M diluted 1:50 manganese concentration:

$y = 12{,}333\ x + 664.2$

$3{,}106.62 = 12{,}333\ x + 664.2$

$x = 0.1980$ ppm $\times 50 = 9.902 \times 50 = 495.1 \times 2 =$ **990.2 ppm**

Table 6: Concentration and absorbance of manganese in standard soil samples

Concentration (µg/g)	Absorbance of Mn standard (nm)
0.2	2,885
0.5	6,629
1	13,930
1.5	18,790
2	25,220

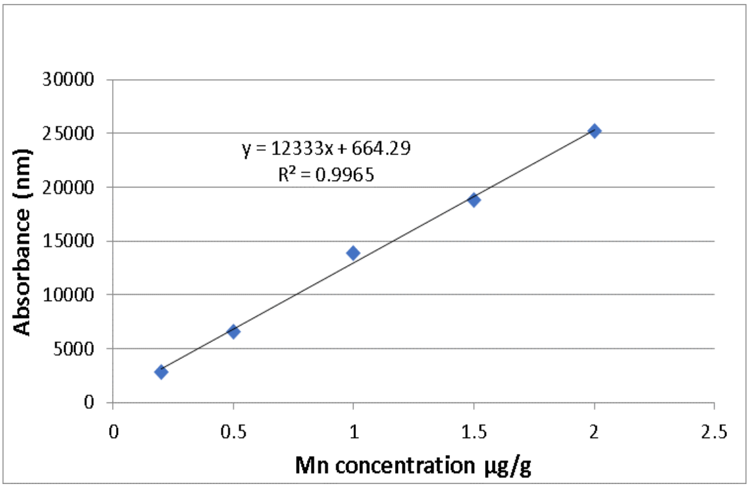

Figure. 5: Manganese (Mn) calibration curve of absorbance against concentration for Standard soil samples

Iron

Both N and M samples are diluted 1:100.

- For iron concentration in the standard soil sample N is as follows (Table 10, Figure. 6):

$y = 1{,}633\,x + 126.6$

$4405.06 = 1633\,x + 126.6$

$x = 2.62$ ppm × 100 = 262.51 × 50 = 13,125.5 × 2 = **26,251 ppm**

- For Sample M manganese concentration:

$y = 1{,}633\,x + 126.6$

$4{,}731.66 = 1{,}633.x + 126.6$

$x = 2.82$ ppm × 100 = 282.62 × 50 = 14,131 × 2 = **28,262 ppm**

Calcium

Both N and M samples are diluted 1:50.

- For calcium concentration in the standard soil sample N is as follows (Table 7, Figure. 7):

$y = 29{,}811\,x + 20{,}052$

$1{,}123{,}148.433 = 29{,}811\,x + 20{,}052$

$x = 37.003$ × 50 = 1,850.15× 2 = **3,700.3 ppm**

- For Sample M calcium concentration:

$y = 29{,}811\,x + 20{,}052$

$1{,}249{,}845.1 = 29{,}811\,x + 20{,}052$

$x = 41.253$ × 50 = 2,062.65× 2 = **4,125.3 ppm**

Table 7: concentration and absorbance of iron and Ca in standard soil samples

Concentration (µg/g)	Absorbance of Fe standard (nm)	Absorbance of Ca standard (nm)
0	4.282	80,5900
2	3,213	1,333,000
4	7,056	2,091,000
6	9,779	2,525,000
8	13,650	3,191,000
10	16,070	

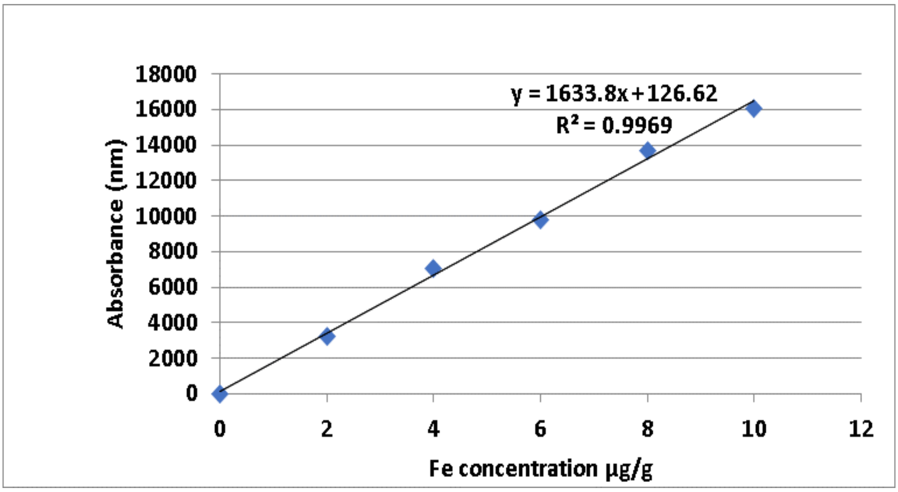

Figure. 6: Iron (Fe) calibration curve of absorbance vs. concentration for Standard soil samples

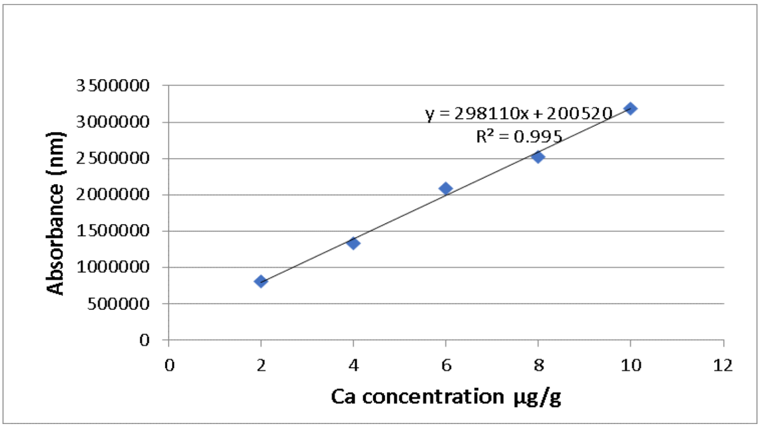

Figure. 7: Calcium (Ca) calibration curve of absorbance vs. concentration for Standard soil samples

Potassium

Both N and M samples are diluted 1:50.

For potassium concentration in the standard soil sample N is as follows (Table 8, Figure. 8):

y = 970.3 x - 49.3

252.57 = 970.3 x - 49.3

x = 0.311 ppm × 50 = 15.556 × 50 = 777.8 × 2 = **1,555.6 ppm**

- For Sample M potassium concentration:

y = 970.3 x - 49.3

157.50 = 970.3 x - 49.3

x = 0.213 ppm × 50 = 10.657 × 50 = 532.85 × 2 = **1,065.7 ppm**

Table 8: Concentration and absorbance of potassium in standard soil samples

Concentration (µg/g)	Absorbance of K standard (nm)
0.2	150.7
0.5	478.2
1	841.6
1.5	1,327
2	1,977

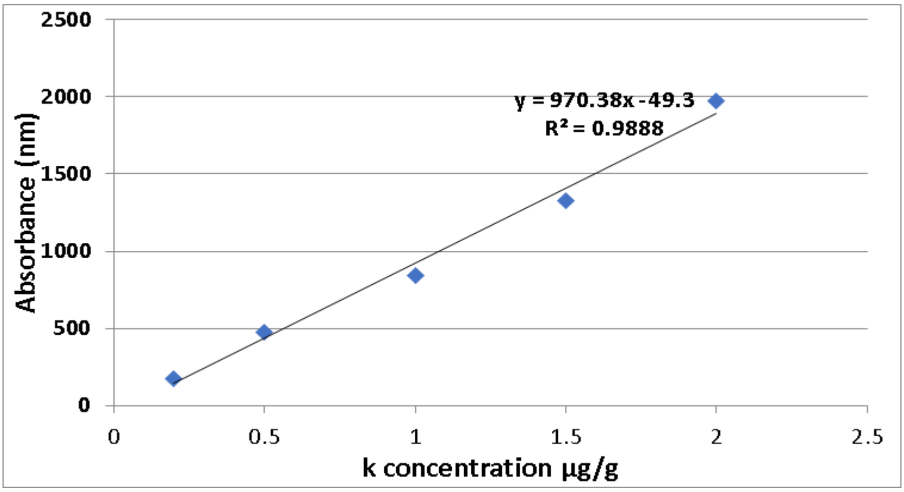

Figure. 8: Potassium (K) calibration curve of absorbance against concentration for Standard soil samples

Unknown soil samples

Manganese

All four samples are diluted 1:50.

For Sample one manganese concentration is as follows (Table 9, Figure. 9):

$y = 15{,}375\ x + 280.7$

$1{,}018.7 = 15{,}375\ x + 280.7$

$x = 0.048 \times 200 = 9.6 \times 50 = 480 \times 2 =$ **960 ppm**

For Sample two Mn concentration:

$y = 15{,}375\ x + 280.7$

$3{,}063.5 = 15{,}375\ x + 280.7$

$x = 0.181 \times 50 = 9.05 \times 50 = 452.5 \times 2 =$ **905 ppm**

For Sample three Mn concentration:

$y = 15{,}375\ x + 280.7$

$3{,}109.7 = 15{,}375\ x + 280.7$

$x = 0.184 \times 50 = 9.2 \times 50 = 460 \times 2=$ **920 ppm**

For Sample four Mn concentration:

$y = 15375\ x + 280.7$

$3324.95 = 15375\ x + 280.7$

$x = 0.198 \times 50 = 9.9 \times 50 = 495 \times 2 =$ **990 ppm**

Table 9: Concentration and absorbance of manganese in unknown soil samples

Concentration (ppm)	**Absorbance of Mn standard (nm)**
0	102.4
0.2	3,773
0.5	8,181
1	15,230
1.5	22,770
2	31,580

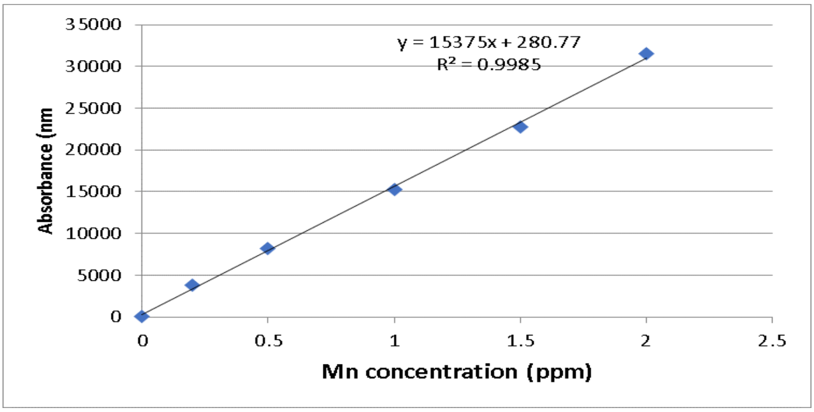

Figure. 9: Manganese (Mn) calibration curve of absorbance vs. concentration for unknown soil samples

Iron

All four samples are diluted 1:100.

- For Sample one Iron concentration is as follows (Table 10, Figure. 10):

$y = 1770\ x - 137.9$

$3458.91 = 1770\ x - 137.9$

x = 2.032 ppm × 100 = 203.21 × 50 = 10160.5 × 2 = **20,321 ppm**

- For Sample two Iron concentrations:

$y = 1770\ x - 137.9$

$3836.10 = 1770\ x - 137.9$

x = 2.245 × 100 = 224.52 × 50 = 11226 × 2 = **2,2452 ppm**

- For Sample three Iron concentrations:

$y = 1770\ x - 137.9$

$7664.29 = 1770x - 137.9$

$7526.39= 3541\ x$

x = 2.12 × 100 = 212.55 × 50 = 10627.5 × 2 = **21.255 ppm**

- For Sample four Iron concentrations:

$y = 1770\ x - 137.9$

$4703.9 = 1770\ x - 137.9$

x = 2.73 ppm × 100 = 273.55 × 50 = 13677.5 × 2 = **27.355 ppm**

Table 10: concentration and absorbance of iron in unknown soil samples

Concentration (ppm)	Absorbance of Fe standard (nm)
0	78.84
2	3,021
4	6,983
6	10,650
8	16,680
10	17,530

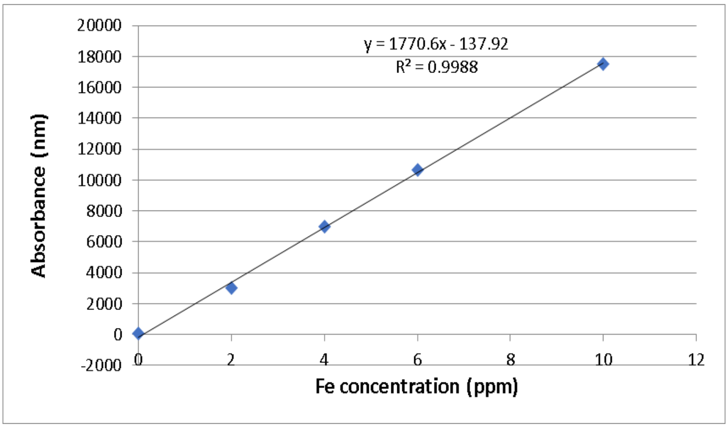

Figure. 10: Iron (Fe) calibration curve of absorbance vs. concentration for unknown soil samples

Calcium

Sample one is diluted 1:200 while the other samples are diluted 1:20.

- For Sample one calcium concentration is as follows (Table 11, Figure. 11):

$y = 34718\ x + 47486$

$1471618.3 = 34718\ x + 47486$

$x = 41.02 \times 50 = 2051 \times 2 =$ **4.102ppm**

- For Sample two calcium concentration:

$y = 34718\ x + 47486$

$788600 = 34718\ x + 47486$

$x = 21.3 \times 50 = 1067 \times 2 =$ **2.134ppm**

- For Sample three calcium concentrations:

$y = 34718\ x + 47486$

$815000 = 34718\ x + 47486$

$x = 22.10 \times 50 = 1105 \times 2 =$ **2.210 ppm**

- For Sample four calcium concentrations:

$y = 34718\ x + 47486$

1477867.6 = 34718 x + 47486
x = 41.2 × 50 = 2060 × 2 = **4120 ppm**

Table 11: Concentration and absorbance of calcium in unknown soil samples

Concentration (ppm)	Absorbance of Ca standard (nm)
0	18,000
2	746,400
4	1,446,000
6	2,174,000
8	2,838,000
10	3,478,000

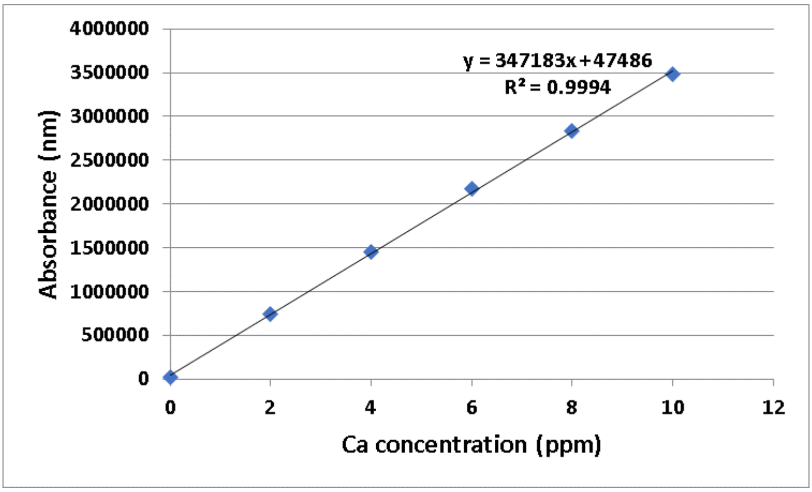

Figure. 11: Calcium (Ca) calibration curve of absorbance vs. concentration for unknown soil samples

Potassium

All four samples are diluted 1:50 except sample 3 which is diluted 1: 20.

- For Sample one potassium concentration is as follows (Table 12, Figure. 12):

y = 1421 x + 4626
4918.72 = 1421 x + 4626
x = 0.206× 50 = 10.3 × 50 = 515× 2 = **1. 030ppm**

- For Sample two potassium concentrations:

y = 1421 x + 4626
4895.99 = 1421 x + 4626
x = 0.19 × 50 = 9.5 × 50 = 475 × 2 = **950 ppm**

- For Sample three potassium concentration:
y = 1421x + 4626
5343.6 = 1421 x + 4626
x = 0.505 × 20 = 10.1 × 50 = 505 × = **1.010 ppm**
- For Sample four potassium concentration:
y = 1421x + 4626
4938.62 = 1421 x + 4626
312.62 = 1421 x

x = 0.22 × 50 = 11 × 50 = 550 × 2 = **1.100ppm**

Table 12: Concentration and absorbance of potassium in unknown soil samples

Concentration (ppm)	Absorbance of K standard (nm)
0	4,558
0.2	4,910
0.5	5,452
1	6,028
1.5	6,734

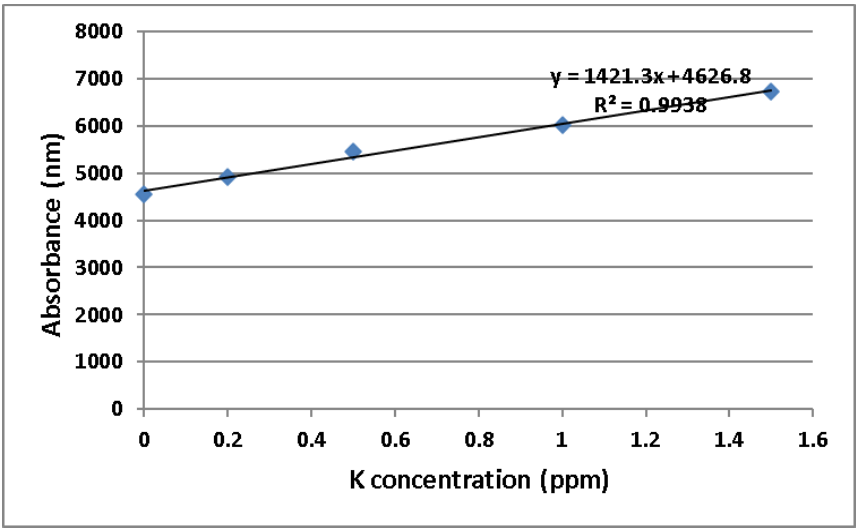

Figure. 12: Potassium (K) calibration graph of absorbance vs. concentration for unknown soil sample

Table 13: Comparison of the soil samples analysis results to the certificate's using both methods

Method	AAS		ICP-OES			
Element	Mn (ppm)	Fe (ppm)	Mn (ppm)	Fe (ppm)	K (ppm)	Ca (ppm)
Sample 1	821 ± 37	19260 ± 925	960 ± 45	20321 ± 1007	1030 ± 56	4102 ± 210
Sample 2	770 ± 40	21420 ±1050	905 ± 40	22452 ± 1128	950 ± 75	2134 ± 100
Sample3	800 ± 42	20130 ±1000	920 ± 43	21255 ± 1050	1010 ± 60	2210 ± 99
Sample4	900 ± 23	23000± 1190	990 ± 40	27355 ± 1390	1100 ± 53	4120 ± 200
Standard	890 ± 36	26790± 1430	990.2 ± 52	28262 ± 1425	1065.7 ± 56	4125.3 ± 205
Certificate	1060	29167	1060	29167	1188	4145

Discussion

Based on these results, when we look at the standard concentrations 1 to 5, which constitute the iron, we observe that the coefficient of determination (R^2) equals 0.998, takes into consideration the fourth point in the standard because it is out of the range of the other samples (*5*). This was done to improve the results. Looking at the standard representing the manganese, we observe that the results are better than the one for the iron element as all points' plots in a straight line without omitting any point and R^2 is 0.998, which is considered to be good. If we look at the standard representing the potassium, results were less accurate compared to manganese and iron where R^2 is 0.997 was slightly more, which represents the results for the calcium was one of the best results as all the 5 concentrations 1 to 5 were good and R^2 was small representing 0.999 (*5*). In the upper part, analysis of the four samples was done and now analysis of the results of the unknown samples using ICP-OES. Sample one contained the highest manganese concentration compared to all samples including the standard and the certificate samples. Sample four contained the highest iron, calcium and potassium concentrations; a feature that is also observed in the standard sample. Furthermore, the actual concentrations of these three elements and also the manganese were the closest to the standard sample. This is also observed using the other technique but to a lesser degree. Samples two and three are close to each other. However, sample one is clearly different from all other samples. It is therefore concluded that sample four is the closest to the standard and the one that is identified (Table 13).

Conclusion

The ICP-OES has the advantage of its capability to measure many elements in the given sample, in this experiment the calcium, potassium, iron and manganese. It has also shown evidence of accuracy, as all the four elements' concentrations in the standard sample were very close to the certificate sample as shown in the table. The AAS methods produced results that are not as close comparing the standard and the certificate samples. Comparing the standard with the certificate samples, it is clear that the ICP-OES technique has produced readings comparable to each other for all the four elements namely, iron, manganese, calcium and potassium compared to the AAS technique. The percentage amount of manganese and iron in the soil as determined by the ASS instrument are 16% and 8% respectively whereas results obtained by the ICP-OES are 6% and 3% respectively. ICP-OES technique is therefore superior to the AAS technique. This is added to its superiority in its capability of multiple elements analysis. Using the two techniques, it is obvious that the highest element concentration was that of the iron followed by calcium and then manganese and potassium. This is also the case for both the standard and the certificate samples using both techniques. There may be an error due to lack of accuracy in the additions or an error in the used instruments for the process was not complete which may have affected the results. Possible contaminations during the experiment are also a possible source for an error. It is observed that the use of instrument ICP-OES is considered to the best for results accuracy as well as the high speed it has and its simple application.

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تحديد كميات المنغنيز والحديد والكالسيوم والبوتاسيوم في عينات التربة

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الغرض من هذا العمل هو تحديد تركيز المنغنيز (Mn) والحديد (Fe) والكالسيوم (Ca) والبوتاسيوم (K) في أربع عينات غير معروفة من التربة من خلال تقنيتين: قياس طيف الامتصاص الذري (AAS) وقياس البلازما المرتبط بالحث- قياس طيف الانبعاث (ICP–OES)، ثم بمقارنة النتائج، يتم الوصول إلى التحقق من التقنية الأكثر دقة. نظراً لأن تحليل التربة مهم في العديد من المجالات، فمن المفيد معرفة الطريقة الأكثر كفاءة ودقة، وفي هذه التجربة تمت مقارنة عينات التربة غير المعروفة مع عينات التربة القياسية وتم تحديد محتواها المعدني باستخدام الأداتين، وتحققت نتائج التجربة من أن قياس البلازما المرتبط بالحث- قياس طيف الانبعاث (ICP–OES) هو إلى حد بعيد التقنية الأكثر دقة.

الكلمات المفتاحية : عينات تربة, حديد, مغنيسيوم. بوتاسيوم,وكالسيوم