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THE POSSIBILITY OF ELIMINATING METAL IONS FROM INDUSTRIAL SEWAGE BY USING ALUMINUM HYDROXIDE

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ABSTRACT

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THE POSSIBILITY OF ELIMINATING METAL IONS FROM INDUSTRIAL SEWAGE BY USING ALUMINUM HYDROXIDE

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Aluminum hydroxide is an amphoteric hydroxide, and it not only can react with acid and but it's also react with alkali. Aluminum hydroxide can remove suspended solids due to its adsorption characteristics.

Ionization formula of aluminum hydroxide in acidic solution and the alkaline solution is different. Tetrahydroxoaluminate will form in the acidic solution, and ferric ion will be ionized in the alkaline solution

Atomic absorption spectrometer (AAS) is a widely utilized analytical instrument. According to the amount of light be absorbed by atom, the result of the sample solution can be measured.

Solubility of aluminum hydroxide is different in different temperatures and pH.
From pH 4 to pH 6, the solubility of aluminum hydroxide is decrease along with the pH ascending. From pH 6 to pH 12, the solubility is increasing.

Aluminum hydroxide was having significant effect for eliminating the metal ions from industrial sewage. But, in order to reach the highest efficiency, each metal ion has a specific removal condition.

Key words
Aluminium hydroxide, amphoteric hydroxides, metal ions removed, sewage treatment

CONTENTS

1 INTRODUCTION

Sewage treatment is an inevitable process for all the industrial processes in order to discharge wastewater in to the ocean. Whatever which factories, all of them are looking for an economical method that could achieve the goal by spending the least expenditure. This thesis is about examining whether aluminum hydroxide which was produced from waste stream is able to eliminate the most common metal ions from the sewage.

Aluminum hydroxide is an amphoteric hydroxide, because it can react with acid, and is also possible to react with alkali. Aluminum hydroxide is already being utilized in the sewage treatment process in order to remove suspended solids due to its adsorption characteristics. In the experiment, adsorption is one of the characteristics that were utilized. Moreover, other chemical characters can also be utilized in the experiment. For instance, aluminum hydroxide is having a completely different ionization formula for a different pH solution. Therefore, the major reactant would be different, and hydroxyl will be ionized, in the meantime, most hydroxides are precipitated.

The concentration of each metal ion can be measured through AAS. Atomic absorption spectroscopy is a common technique used in many analytical chemistry protocols, as well as applications requiring a high degree of precision and accuracy. Nowadays, there are plenty of types of AAS that be utilizing, and among all of them, flame atomizer's AAS is the most common one that can be utilized for analyzing. There are also several combinations between fuel and oxidant that can create various flam that have different temperatures. Each metal ion has specific light that be utilizing for detection, and different light has a different wavelength. AAS is widely use in the area of food and drug safety, clinical diagnostics and environmental monitoring.

The experiment will initially examine the effect of aluminum hydroxide in room temperature and the original pH of the sewage. Aluminum hydroxide has two forms which are moist and dried. And experiment will examine which property of aluminum hydroxide is the best option for eliminating the metal ions. Then, the experiment will examine the efficiency of wet aluminum hydroxide in different conditions. For instance, which temperature is the best temperature for the eliminating process proceeding? Which pH is the best choice for the eliminating process? Whether the mixing time will influence the result? All of these problems were solved sequentially in this thesis.

The major point of chapter 3 is about the theoretical method that AAS been utilized for achieving result. Especially the importance of calibration line in the process. Due to the scarcity of the volumetric flask, results in each procedure were not achieved relying on the same calibration line. Then, the procedure of the experiment will be introduced. In the experiment, influences what creates by different temperatures and pH that have been concerned. Finally, comparison of each result was conducted in order to obtain the most appropriate condition for eliminating each ion.

This thesis expects to provide references in this area because of the research in this field is very limited. If the effect of aluminum hydroxide can be demonstrated, which is a significant promotion in the pollution treatment, especially can brings benefits to the company which produces aluminum hydroxide or produce it as a side product. Except these, the thesis should able to provide information for further research.

2 CHARACTERISTICS OF ALUMINUM HYDROXIDE

Aluminum hydroxide is also known as alumina hydrate, which chemical formula is $Al(OH)_3$. It's a common odorless white amorphous powder of aluminum compound. It's an ingredient of mineral gibbsite and there are three polymorphs of it, which are bayerite, doyleite and nordstrandite. The melting point of aluminum hydroxide is 300℃ due to its inner structure constructed by two layers of hydroxyl groups with aluminum ions, therefore forms an octahedral model. According to the standard system for identification of the hazards of materials for emergency response released by the National Fire Protection Association (NFPA), the health hazard of aluminum hydroxide is level 1, and level 0 separately for flammability and instability. These numerical levels respectively indicates that aluminum hydroxide could cause irritation but only minor residual injury even if no treatment is given after exposure, normally stable, even exposures under fire conditions, and are not reactive with water and will not combust. (National Fire Protection Association, 2012)

Aluminum hydroxide is non-carcinogenic, low toxic, halogen free and flame retardant. These are the physical properties of aluminum hydroxide. Except those properties, aluminum hydroxide can form gels in the water, which is the ground theory that ensures this experiment can succeed theoretically. In fact, due to the realization of formation of gels, aluminum hydroxide at present is occasionally been utilized for purifying wastewater as the flocculating agent. Because of gel has strong adsorption ability, suspended solids can be adsorbed and precipitated. In the meantime, transition elementary particles can also be precipitated by adding assistant compound which is aluminum potassium disulfate dodecahydrate.

Aluminum hydroxide is insoluble in water but is soluble and will react with either acidic liquid or alkaline liquid due to its properties of amphoteric hydroxides.

Whatever it's in acidic solution or alkaline liquid, ionization is place among both conditions. As the table 1 shows, aluminum ions (+3) was produced in alkaline solution, conversely, in acidic solution which tetrahydroxoaluminate ($[Al(OH)4]^-$) was producing. Therefore, a hypothesis can be suggested that these ionized ions were possible combining and precipitating with ions in sewage, thereby eliminating those ions from sewage. (Chang & Cruickshank, 2003)

Table 1. Ionization of aluminum hydroxide.

Solution property	**Ionization equation**
Alkaline	$\mathrm{Al(OH)_3} \rightarrow Al^{3+} + OH^-$
Acidic	$Al(OH)_3 + H_2O \rightarrow [Al(OH)_4]^- + H^+$

3 Atomic Absorption spectrometer

Atomic absorption spectrometer (AAS) is the equipment that determines the concentration of elements by optical radiation according to specific amount of energy absorbed by gaseous free atoms. No other apparatus was used in the experiment. There are several classifications of AAS, and among of these classification, flame atomizer had been utilized. The oxidant is air with 10 L/min of flow rate, and acetylene is used as fuel with 2.5 L/min. Depend on the temperature required, there are numerous combinations of fuel and oxidant to provide differential range temperature. Table 2 illustrates seven combinations that commonly utilize. Normally, propane, hydrogen or acetylene is be utilized as fuels, and air, nitrous oxide or oxygen be utilized as oxidants.

Table 2. Temperature/temperature range of flame with different combinations (UCDavis chemwiki, Lajunen, L.J.H., 2004).

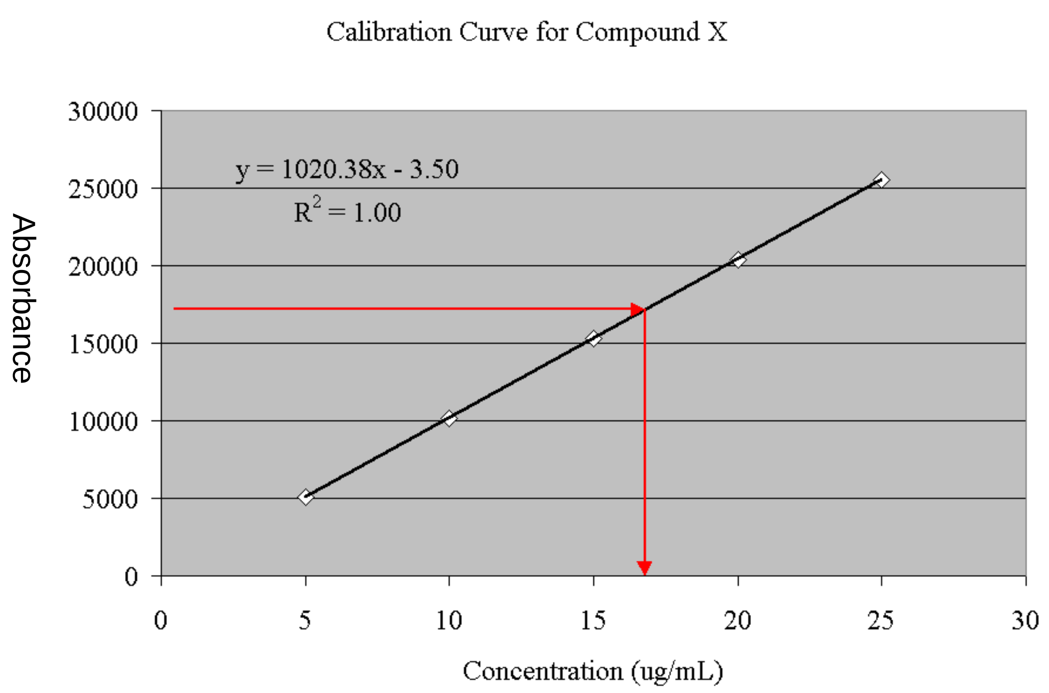
Fuel	Oxidant	Temperature/temperature range (K)
Propane	Air	2200
Acetylene	Air	2450
Hydrogen	Air	2300
Propane	Nitrous oxide	2900
Acetylene	Nitrous oxide	3200
Hydrogen	Nitrous oxide	2900
Acetylene	Oxygen	3320-3420

Sample solution must be atomized firstly in order to be analyzed. Atoms will be elevated by absorbing optical radiation, moreover, each atom has specific light for emitting specific radiation according to a different wavelength. Table 3 illustrates eight particular data of wavelength and limitation of detected concentration for several ions which required to be measured in the experiment. The rest of the radiation which was not absorbed by atoms will pass through an instrument called monochromator. In the monochromator, only selected light is able to leave the instrument.

Table 3. Wavelength and detection limits of measured ions obtained with air-acetylene flame AAS (J. Braz. 2003).

Ion	**Wavelength (nm)**	**LOD ($\mu g/L$)**
Co	240,73	1,8
Cu	324,75	1,2
Fe	248,33	1,8
Mg	285,21	0,15
Mn	279,48	0,6
Ni	232,00	2,5
Zn	213,86	1,4
Ca	422.67	1

Graph 1 is illustrate and explain how is the AAS get achieve result. Before analyzing the sample solution, standard solution of measured ion should be prepared. Standard solution is providing data for constructing a line in an x-y axis graph. Therefore, in order to draw this line, at least two different concentration's solution is required. However, the accuracy is increasing gradually with the quantity of standard solution.



Graph 1 Calibration curve of AAS for an ion (George Mason University, 1998)

Normally, the line is pass through the original point, but is not absolute.

According to the absorbance of sample solution which detected by the detector, thereby, the concentration can be read by finding the corresponding point. The accuracy of the standard solution has the possibility that influences the result of the sample solution, therefore, deviation of the standard solution should to be abated as much as possible.

Standard solution is prepared by dissolving metal into distilled water which contain 2% nitric acid. This method can prevent introducing impurities into the standard solution, and the probable effect could occurs. Nonetheless, in this experiment, compound has been utilized instead of pure metal, and the compound was chosen according to the reference material in the laboratory.

4 EXPERIMENT

Ionic eliminate is a process that removing heavy metal ions from sewage by chemical or physical methods in order to decreasing the damage which could create during the sewage withdrawing. Chemical precipitation method, adsorption method, ion exchange method, modified filtering medium method and extraction method are the most common method nowadays. Chemical precipitation method includes neutralization precipitation, sulfide precipitation, barium salt precipitation and ferrite precipitation. Among them ferrite precipitation is a novel technology, which can remove several metal ions at the same time. Adsorption method is utilized of porous solid materials for adsorbing the contaminants in the sewage. Sepiolite ($Mg_4Si_6O_{15}(OH)_2 \cdot 6H_2O$) is widely uses adsorbent. (Mineralogy database, 2012)

Aluminum hydroxide is the experimental chemical in this experiment, which is not widely used for eliminating metal ions but for removing suspended solids. According to the ionization formula and properties introduced in chapter 2, aluminum hydroxide method can be classified to the chemical precipitation method and adsorption method theoretically. There were not much research was conducted or had conducted about the efficiency of eliminating metal ions by aluminum hydroxide. The reason why chosen aluminum hydroxide as experimental substance that is aluminum hydroxide is a side product of an industrial company. All the emissions are compulsory to be treated before discharging. If the side product can be utilized during the treatment, that is a beneficial method for the company.

Aluminum hydroxide also is contained in the sludge of the water treatment plant. Traditionally, the sludge was directly discharged back to the original river or lake. Sludge banks could occur with regard to accumulation of sludge, and since the removal impurities are moving along with the aluminum sludge, the risk for polluting the environment is ascending. (D.Y.HSU & W.O PIPES, 1972) This experiment cannot describing as a novel technology invention, it's just expected to make up the scarcity of research in this field.

4.1 Experiment procedure

Aluminum hydroxide was directly afforded from one industrial company. Therefore, the procedure for producing aluminum hydroxide can be omitted. And comparing with the aluminum hydroxide which produce in the laboratory, the company's aluminum hydroxide is close to the authentic environment due to the effect which cause by the impurities. Briefly, it can summarized into six major procedures.

4.1.1 Standard solution

Standard solution should be prepared by using elemental metal. That's because the concentration of the solution which made by elemental metal must be more accurate. Due to the AAS's operational theory, the accuracy of the concentration of the standard solution could lead to a huge difference in the result of the sample solution. However, the original chemical that used in the experiment is all according to the reference book, which should be in the reasonable difference range.

This experiment was designed to detect eight elements, which was measured eight elements that AAS could measure in the laboratory. Measured element were Cobalt (Co), Copper (Cu), Iron (Fe), Nickel (Ni), Zinc (Zn), Manganese (Mn), Calcium (Ca), and Magnesium (Mg). 1000 ppm standard solution of every ion were prepared initially. Table 4 provides detail information of the quantities needed to prepare the solutions.

Table 4. Chemical and the quantity that used for preparing the 1000 ppm standard solution.

Ions	Ions' source	Quantity utilized (g)
Co	$CoSO_4 \cdot 7H_2O$	4.7702
Cu	$CuSO_4 \cdot 5H_2O$	3.9455
Fe	$(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$	7.0224
Ni	$Ni(NO_3)_2 \cdot 6H_2O$	4.9560
Zn	$ZnSO_4 \cdot 7H_2O$	4.3960
Mn	$MnSO_4 \cdot H_2O$	3.0755
Ca	$CaCl_2 \cdot 2H_2O$	3.6680
Mg	$MgSO_4 \cdot 7H_2O$	10.1393

Except iron ions, the rest of the elements were diluted to preparing four smaller concentrations' standard solution. Automatic pipe was used to measure 200 mL, 100 mL, 50 mL and 25 mL, after that, liquid was added to the 100 volumetric flask respectively. Volumetric flask was been filled by distilled water up to the scale line, and then tapped the flask and mixed the solution upside down. Thereby, 2 ppm, 1 ppm, 0.5 ppm and 0.25 ppm standard solutions were prepared. Due to the iron's concentration was higher than other elements, therefore, 4 ppm, 3 ppm, 2 ppm and 1 ppm standard solutions had been prepared by using the same method.

4.1.2 Add wet aluminum hydroxide

The aluminum hydroxide from the industrial company is not completely dried, and the proportion of water contained will be measured in the next step. In this procedure, only bakers, filtration apparatus and magnetic rotation device were utilized. Sewage needs to be filtrated before the treatment in order to remove the visible suspended solids. Originally, the experiment was designed with input aluminum hydroxide from one gram to ten grams with one gram as a unit.

However, due to the limitation of the quantity of the volumetric flask, the unit was changed to two grams.

Table 5. Mass of wet aluminum hydroxide added.

Sewage (mL)	Aluminum hydroxide (g)
100	1.0080
100	3.0013
100	5.0050
100	7.0013
100	9.0033

Take 100 mL sewage into a beaker, then measure around one gram of aluminum hydroxide and add into the beaker. Magnetic stirrer was needed in order to provide constant rotating speed. Place the beaker on the magnetic stirrer, allow the solution mix for 10 minutes within the 650 rpm rotating speed. Other quantitative aluminum hydroxide is conduct with same method.

4.1.3 Add dried aluminum hydroxide

This procedure is similar to the last procedure, the mere difference exist that it is convert the wet aluminum hydroxide into dried aluminum hydroxide in order to make a comparison of its efficiency. During the experiment, 42.4509 grams of aluminum hydroxide was measured and placed into a 105℃ oven for dehydrating. After one day, measure the mass of the aluminum hydroxide, it’s only rest 11.0366 grams. Nearly three proportions of the original mass were disappeared, and this disappeared mass is the quantity of the water. Therefore, the moisture content of the aluminum hydroxide is approximately 74%.

Due to the high moisture content, the comparison between wet aluminum hydroxide and dried aluminum hydroxide becomes more valuable. If the efficiency of the dried aluminum hydroxide is equal or higher, then using dried aluminum hydroxide would be a better option.

Table 6. Mass of dried aluminum hydroxide added.

Sewage (mL)	Aluminum hydroxide (g)
100	1.003
100	3.007
100	5.006
100	7.003
100	9.001

4.1.4 Add three grams wet aluminum hydroxide into the sewage with different temperature

The temperature of sewage in the laboratory is 21.3℃, and the experiment was designed to using 10℃ as one increasing unit. But due to the limitation of the volumetric flask, the increasing unit has been changed to 20℃. Thereby, 40℃, 60℃ and 80℃ are the three temperature levels in the experiment. Actually, 100℃ suppose to be included in the experiment. However, 100℃ is the boiling point of water, concern the evaporation of the water could cause possible influence on the result. Moreover, heating the water to the boiling point requiring much energy, that will increase the expenditure of the company.

Concerning that the solubility is ascending with the temperature increases gradually. Add three grams aluminum hydroxide is the best choice, which can prevent that one gram aluminum hydroxide might completely dissolve within

80℃, but also can decreasing the amount that was wasted. This procedure is able to certify at which temperature aluminum hydroxide can exert the highest efficiency. Therefore, able to providing reference information for the utilization in the future.

Measure 100 mL sewage and then put into a beaker, place the beaker on the magnetic stirrer which includes the heating function. Heat sewage until 40℃ before add aluminum hydroxide. After three grams of aluminum hydroxide was added, turned on the stirrer with 650 rpm and mixed the solution for ten minutes.

4.1.5 Add wet aluminum hydroxide into different pH's sewage

Except temperature, pH should also could influence the proceeding of experiment. The original pH of sewage is 2.88, and which is acidic solution. Therefore, merely the performance in neutral solution and alkaline solution needed to be observed. Lime was used during the experiment for controlling the pH. Normally, there are two kinds of lime that be utilized for adjusting pH, one is calcium oxide (CaO), another one is calcium hydroxide (CaOH). When calcium oxide contacts with water, calcium hydroxide will be created. Therefore, calcium hydroxide is the real reacting compound eventually. Dislike add calcium hydroxide directly, massive amount of heat is released when calcium oxide reacts with water. This amount of heat is adequate for reaching the boiling point.

Reaction equation of calcium oxide and water: $\mathrm{CaO}\,(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$ (ΔHr = −63.7 kJ/mol) (Collie, Robert L., 1976)

According to the data collected in the laboratory, only 0.0086 grams of lime was needed to adjust the pH to 7.2. And 0.1039 grams lime was required for increasing the pH to 12.21. After the pH reached the objection point, mix the solution for ten minutes after adding three grams of aluminum hydroxide.

4.1.6 Mix the solution for different times

All previous procedures were mixing the solution for ten minutes. That's because the first solution was mixed for 10 minutes, and the mixing time have to keep constant in the follow procedure. However, ten minutes couldn't guarantee is the best mix time. For example, the result of twenty minutes mixing time could be either better or worse. Therefore, five minutes and twenty minutes were chosen as the representatives of the shorter time and the longer time.

Filtration process must conducts after every mixing process before detecting the concentration of metal ions through AAS. Permeability of the filter paper that use in the filtration process was 11μm, and the thickness was 0.18 mm. Due to the absorption characteristics of aluminum hydroxide, the volume of the filtrated sewage less than the sewage's initial volume.

4.2 Experimental results

All the experiment's results will be published in this sector. All the result detection processes are the same. The explanation of results and the phenomenons will be provided in the next chapter.

4.2.1 Metal ion's concentration in the sewage

Ions were detected by using the light which has specific wavelength for measuring different ions. Five replicates were taken during each ion's measurement, and the calibration line is passing through the original point of the X-Y axis. Details of measured data can checking the Appendix 1.

Table 7. Ion's concentration in the sewage.

Metal ion	Wavelength (nm)	Concentration (mg/L)
Co	240.73	0.017
Cu	324.75	0.032
Zn	213.86	0.117
Mn	279.48	0.161
Ni	232.00	0.272
Fe	248.33	3.194
Mg	285.21	11.735
Ca	422.67	196.924

Table 8. pH diversification.

The amount of added	pH
1g	4.29
3g	4.99
5g	5.34
7g	5.65
9g	5.83

4.2.2 Result after adding wet aluminum hydroxide

Ions were detected by using the light which is the same specific wavelength with the first measurement. Five replicates was taken during each ion's measurement, and the calibration line is passing through the original point of the X-Y axis. Details of measured data can checking the Appendix 2.

Table 9. pH diversification.

The amount of added	pH
1g	4.43
3g	5.09
5g	5.34
7g	5.54
9g	5.76

Table 10. Ion's concentration in the sewage after treating by wet aluminum hydroxide.

Metal ion	Wavelength (nm)	Concentration (mg/L)				
		1g	3g	5g	7g	9g
Co	240.73	0.031	0.017	0.018	0.016	0.014
Cu	324.75	0.024	0.013	-0.016	-0.005	-0.004
Zn	213.86	0.095	0.005	-0.012	-0.018	-0.019
Mn	279.48	0.253	0.423	0.570	0.586	0.721
Ni	232.00	0.224	0.182	0.156	0.108	0.102
Fe	248.33	0.163	0.116	0.069	0.037	0.049
Mg	285.21	11.028	10.438	10.694	10.973	11.340
Ca	422.67	165.233	162.718	159.190	154.312	145.451

4.2.3 Result after adding dried aluminum hydroxide

Ions were detected by using the light which is the same specific wavelength with the first measurement. Five replicates was taken during each ion's measurement, and the calibration linear is passing through the original point of the X-Y axis. Details of measured data can checking the Appendix 3.

Table 11. Ion's concentration in the sewage after adding dried aluminum hydroxide.

Metal ion	Wavelength (nm)	Concentration (mg/L)				
		1g	3g	5g	7g	9g
Co	240.73	0.019	0.018	0.017	0.019	0.020
Cu	324.75	0.031	0.007	-0.012	-0.007	-0.023
Zn	213.86	0.287	0.111	0.041	0.004	-0.002
Mn	279.48	0.149	0.172	0.197	0.235	0.243
Ni	232.00	0.233	0.236	0.232	0.217	0.177
Fe	248.33	1.700	0.172	0.140	0.079	0.067
Mg	285.21	11.727	12.039	12.233	11.154	12.413
Ca	422.67	182.536	176.484	174.590	173.923	170.736

4.2.4 Result under different conditions

Three grams of aluminum hydroxide were been added in each experiment. Ions were detected by using the light which is the same specific wavelength with the first measurement. Five replicates was taken during each ion's measurement, and the calibration linear is passing through the original point of the X-Y axis. Details of measured data can checking the Appendix 4.

Table 12. Ion's concentration in the sewage after treatment under different temperatures and pH.

Metal ion	**Wavelength (nm)**	**Concentration (mg/L)**				
		40℃	**60℃**	**80℃**	**pH 7**	**pH12**
Co	240.73	0.019	0.017	0.012	0.020	0.020
Cu	324.75	-0.034	-0.029	-0.026	-0.027	-0.028
Zn	213.86	0.084	0.087	0.101	0.060	0.036
Mn	279.48	0.184	0.208	0.221	0.137	0.045
Ni	232.00	0.168	0.110	0.045	0.019	0.025
Fe	248.33	0.062	0.069	0.059	0.069	0.079
Mg	285.21	10.596	10.780	11.644	9.722	0.797
Ca	422.67	148.351	148.915	161.144	177.501	342.678

Table 13. Ion's concentration in the sewage after treatment under different mixing times.

Metal ion	**Wavelength (nm)**	**5 min**	**20 min**
Co	240.73	0.031	0.029
Cu	324.75	-0.021	-0.027
Zn	213.86	0.068	0.089
Mn	279.48	0.176	0.204
Ni	232.00	0.227	0.222
Fe	248.33	0.139	0.094
Mg	285.21	10.584	10.471
Ca	422.67	143.230	153.999

Table 14. pH diversification.

Condition	pH
40℃	5.2
60℃	5.35
80℃	5.37
pH 7	5.52
pH 12	8.43
5 min	5.02
20 min	5.13

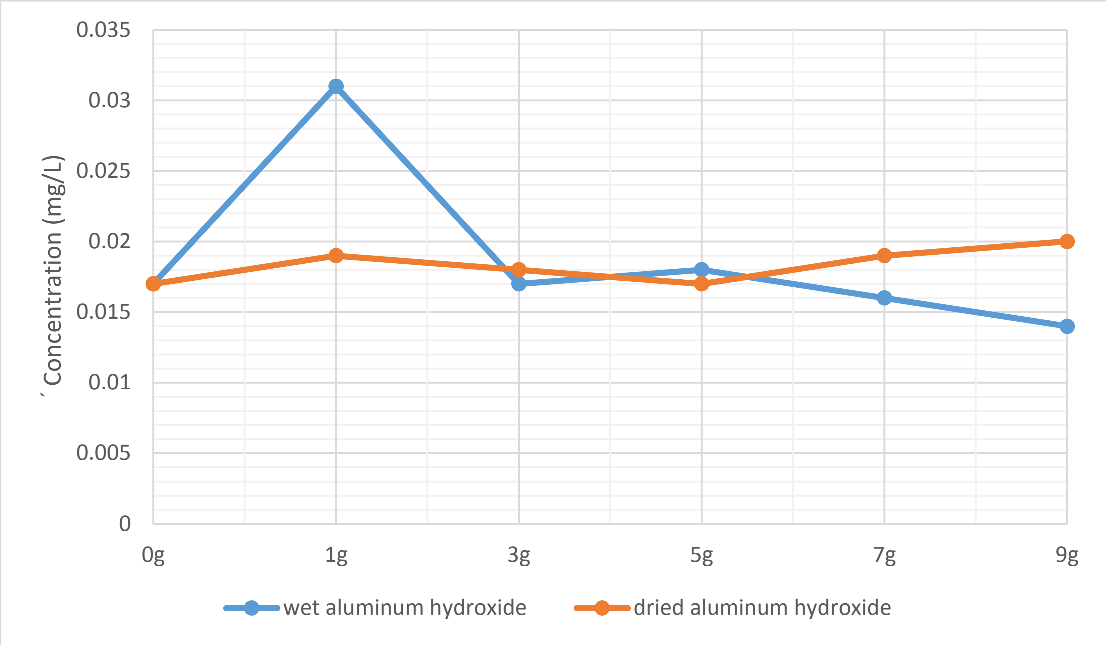
5 DISCUSSION

Adding aluminum hydroxide to sewage is supposed to be similar with the chemical treatment of sewage by adding alum because of both of chemicals are flocculants. This chapter is providing a comprehensive comparison between wet and dried aluminum hydroxide, also the different results among several conditions. The most ideal result that is the concentration of each ion decreases gradually with the quantity of aluminum hydroxide increase.

Due to the result is not achieved through the same line which construct with standard solution. That's meaning the line used in the first procedure is different with the second procedure due to its different slope and correlation coefficient. Actually, achieving results from the same line is more accurate, but because of the limitation of the volumetric flask, it's has to conducting in separate time. This little error could yield a slight deviation, however, the trend can be known through the curve's movement. In the third procedure, all the data were achieved from the same line in order to ensure accuracy.

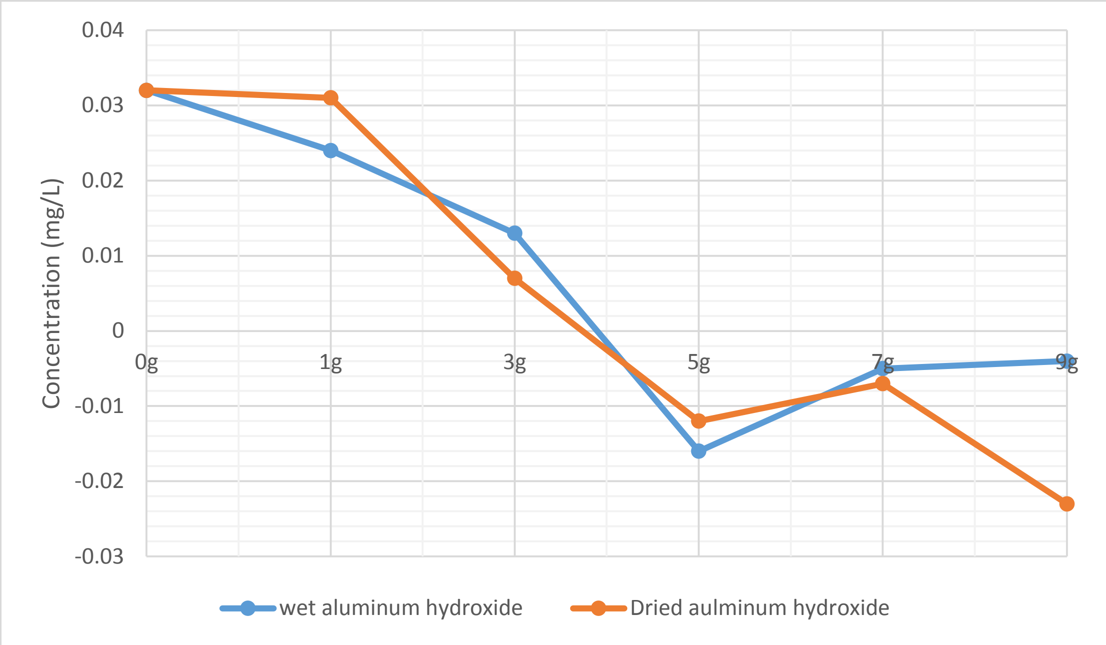
5.1 Compare the result between dry and wet aluminum hydroxide

Different from the wet aluminum hydroxide, dried aluminum hydroxide is losing about 74% weight, which can illustrate that dried aluminum hydroxide should contain more sufficient substances within the same quantity. Therefore, the result of dried aluminum hydroxide must is better.



Graph 1. The comparison of the concentration of cobalt

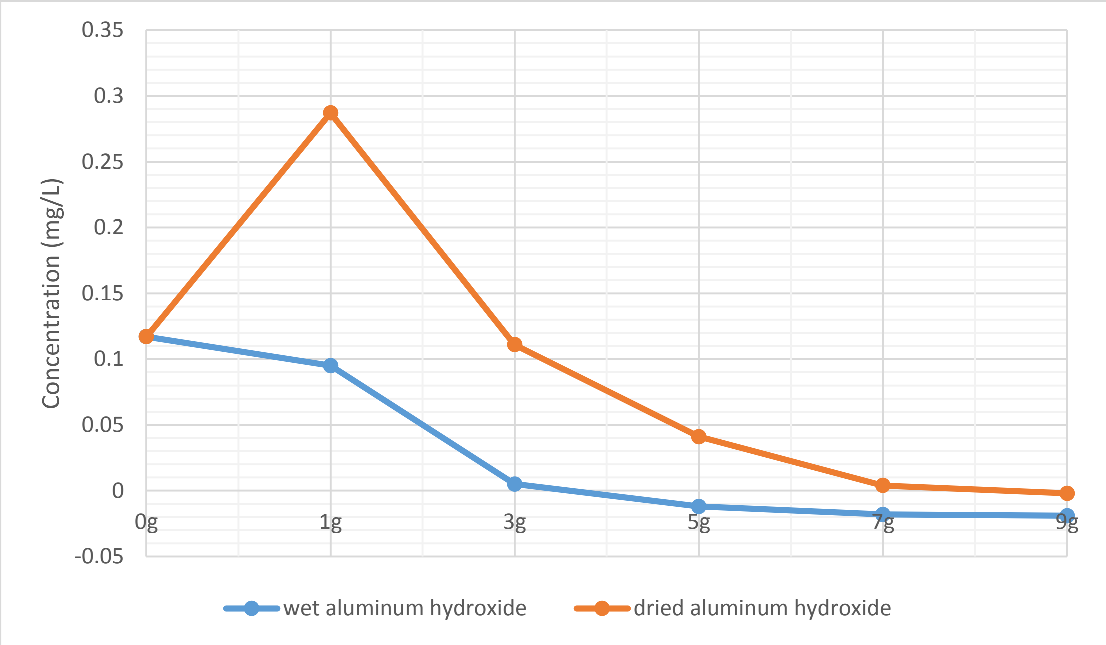
From the curve in Graph 1, the result of each method is similar, except the result of one gram. The original concentration is 0.017 mg/L, and no matter how much aluminum hydroxide was added, the quantity of cobalt is not had a big difference. If direct neglect the deviation which caused by different line, then these two curves can be seem as the same line. After adding one gram wet aluminum hydroxide, the concentration was increased sharply and reaches around 0.03 mg/L. However, a clear result could not be explained by this graph, and there are two factors that could cause this phenomenon. Aluminum hydroxide either basically cannot remove cobalt from the sewage or the original concentration is too small that aluminum hydroxide is rarely react with cobalt. If a trusted result is needed, the experiment of adding aluminum hydroxide into a liquid with high cobalt concentration should be conducted.



Graph 2. The comparison of the concentration of copper.

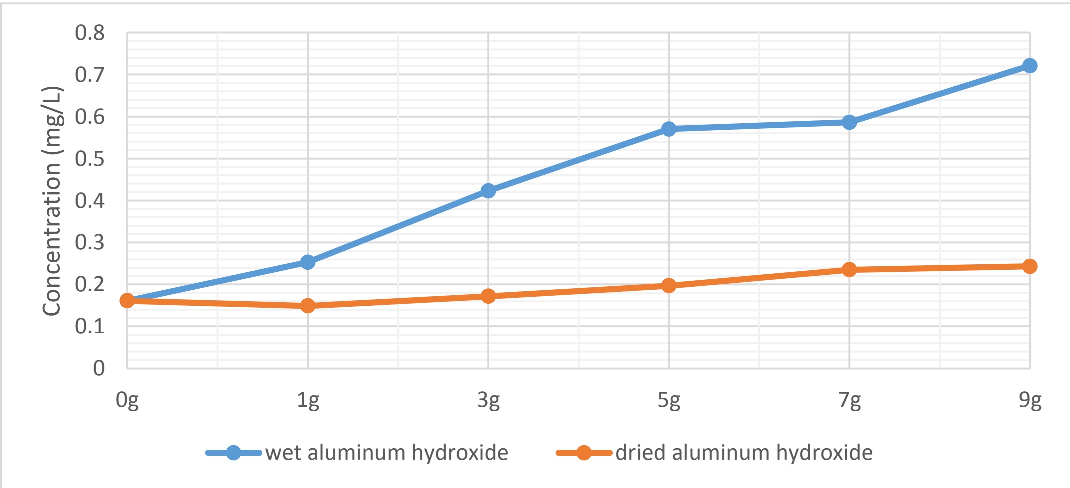
Graph 2 is clearly illustrating that the concentration is decreasing along with the aluminum hydroxide increasing. And around input four grams, the concentration of cooper was very limited. The real zero concentration point is not illustrated in this graph due to the data were predicted. But the point is around four grams. AAS also has limitation for detecting, therefore, the concentration of the last three data was negative. Under these circumstances, an extraction technique developed by Sachdev and West can be used for treating the sample before sending to the AAS (Sachdev, S.L. and West, P.W., 1970). Through this method, the copper concentration can be concentrated in the filtrate.

Graph 2 shows when adding one gram aluminum hydroxide, wet aluminum hydroxide is more efficient, conversely, the concentration of copper in dried aluminum hydroxide was unchanged. However, until three grams of dried aluminum hydroxide, the efficiency of wet aluminum hydroxide was be exceeded.



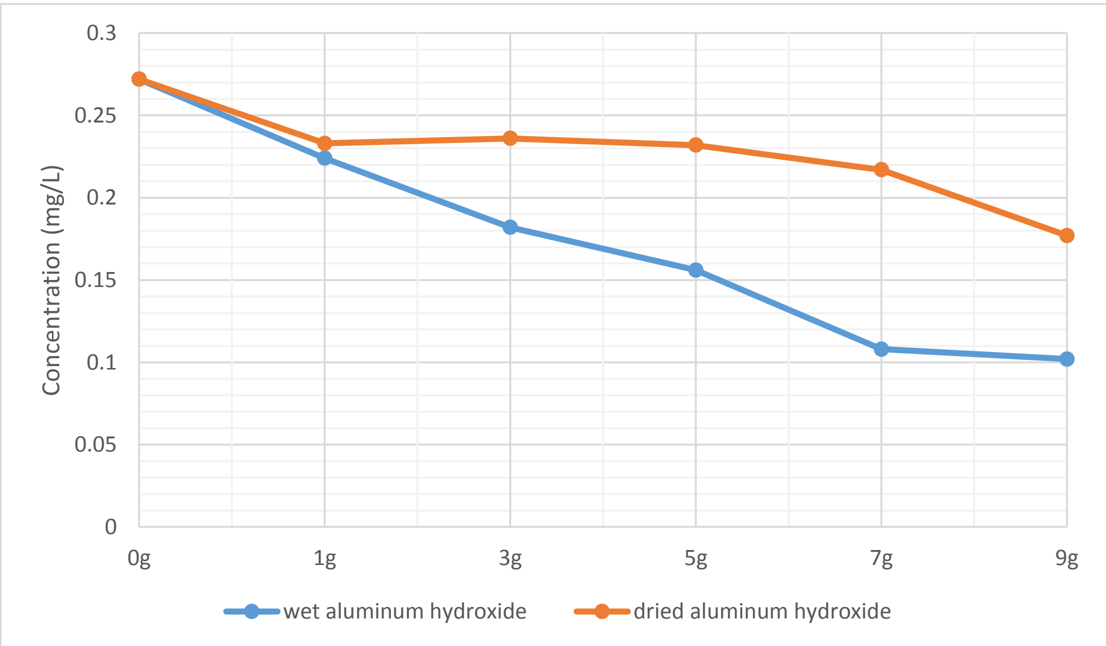
Graph 3. The comparison of the concentration of zinc.

Graph 3 clearly shows that wet aluminum hydroxide is more efficient in the elimination of zinc. The trend of wet aluminum hydroxide is continuously decreasing. After adding one gram aluminum hydroxide, there is an apparent ascending, and three grams of dried aluminum hydroxide seems doesn't have many influences if compares with the wet aluminum hydroxide.



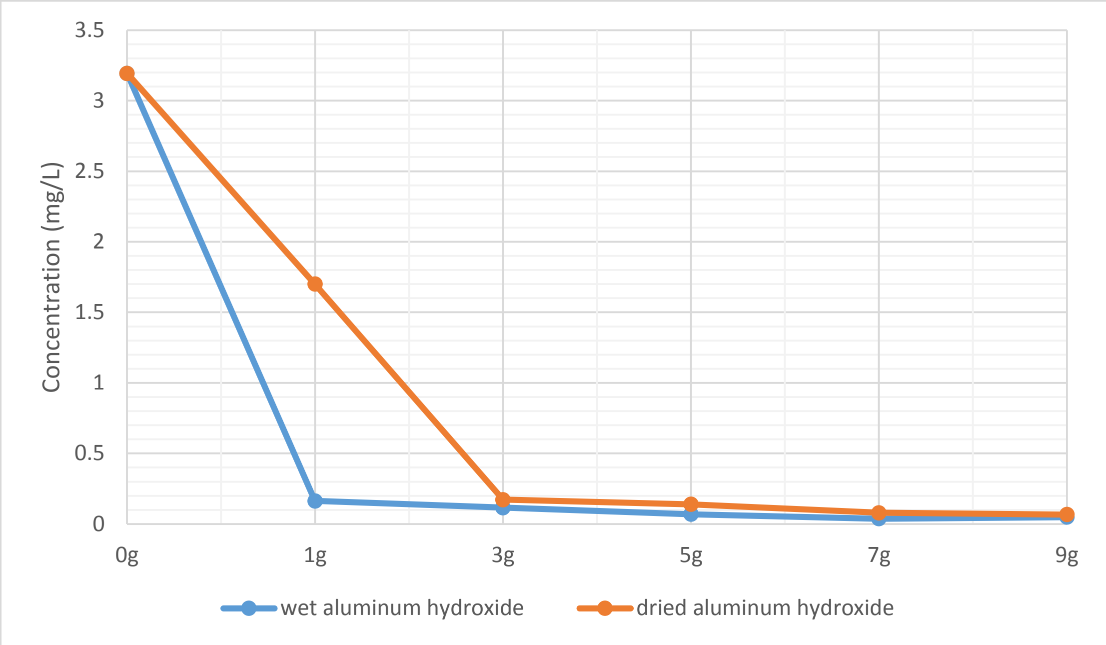
Graph 4. The comparison of the concentration of manganese.

Dislike the other element's curves, curves in Graph 4 are significantly different. Both of the curves are ascending and it's demonstrate that the aluminum hydroxide is not suitable for eliminating the manganese from the sewage. Dried aluminum hydroxide has a slow rise and wouldn't cause much effect in the sewage. If wet aluminum hydroxide has been used, one more step is needed for eliminating the manganese specially. Moreover, the quantity of aluminum hydroxide that be inputted in the sewage should be monitored strictly in order to prevent overdose of manganese is produce, hereby causes additional damage.



Graph 5. The comparison of the concentration of nickel.

Graph 5 shows the efficiency of adding one gram aluminum hydroxide whatever wet or dried are closing with each other. After one gram, the advantage of wet aluminum hydroxide was appearing along with the quantity increasing. On the other hand, dried aluminum hydroxide seems to keep stable, and the amount of removal of nickel is limited.



Graph 6. The comparison of the concentration of iron.

The result of wet and dried aluminum hydroxide in Graph 6 were getting a great consequent for removing iron ions. Around 95% of ions can be removed by just adding three grams aluminum hydroxide, however, wet aluminum hydroxide is more better than dried aluminum hydroxide due to only one gram of wet aluminum hydroxide can reach the effect of three grams' dried aluminum hydroxide.

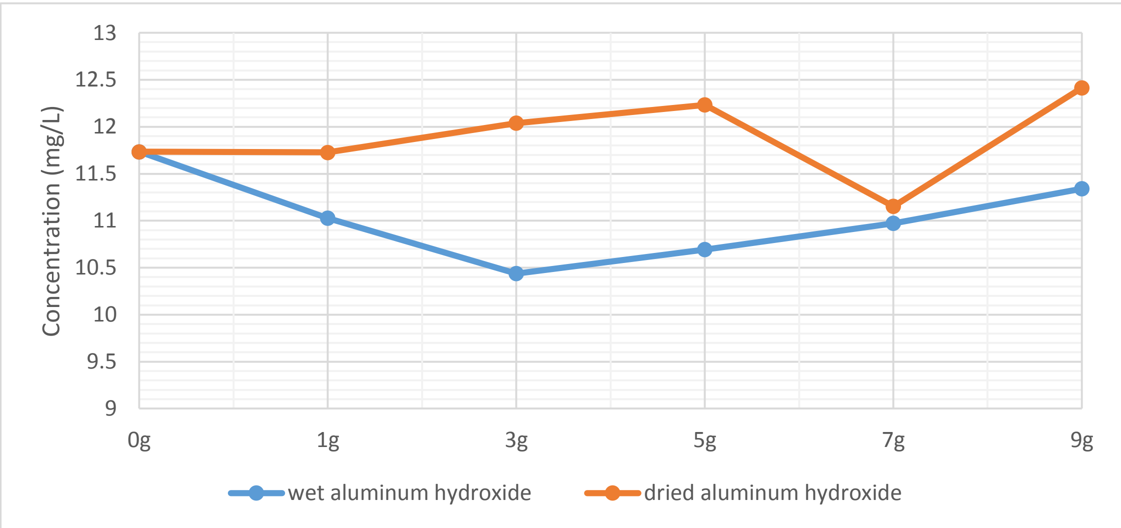
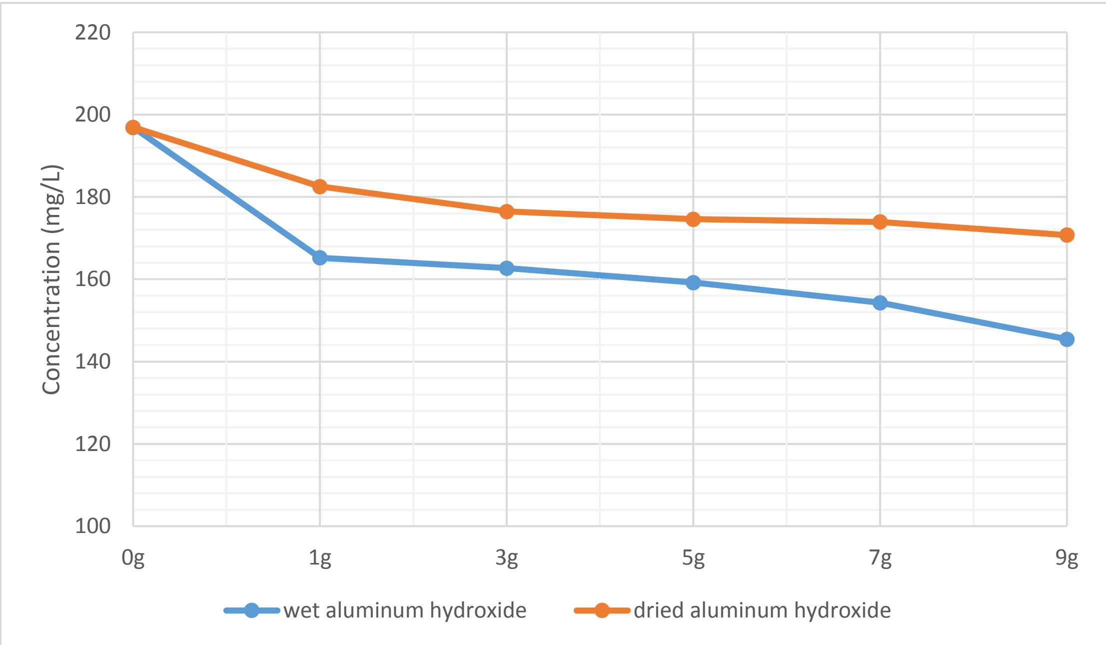


Figure 7. The comparison of the concentration of magnesium.

The situation of the result shows in Graph 7 is a little bit complicate, due to the osculation curves. Therefore, the trending of the curves has to describe respectively. The result of adding seven grams is the best among the five sample solutions, and it's the only one that eliminate the magnesium from the sewage even though the effect is not excellent. The effect of the dosage of one gram, three grams, five grams and nine grams seem has the converse consequent with the initial hypothesis.

Dissimilar curve of wet aluminum hydroxide was drawn in the Graph, even also was merely one dosage has the best effect among five examples. Among these five examples, all of the dosage was removing specific amount of magnesium from the sewage. Among them, adding three grams of wet aluminum hydroxide can reach the best efficiency. A conclusion can be drown from graph 7 that the removal amount of magnesium is not promote with the quantity of the aluminum hydroxide increasing. The best additional dosage is at a particular amount. When the input dosage is more than nine grams, the result is either better or worse should be examined through further experiment.



Graph 8. The comparison of the concentration of calcium.

Graph 8 is demonstrating that eliminating calcium ions from sewage is also work by adding aluminum hydroxide. Above graph gives a clear information that wet aluminum hydroxide is better. 26% of copper has been removed after treating by nine grams wet aluminum hydroxide. In the same quantity of aluminum hydroxide added, the concentration of copper ions in the sewage after treating by wet aluminum hydroxide is always smaller. The trend of the curves are both going down, and the concentration of the copper should abate continuously.

Because of the original pH of the sewage is lower than seven, therefore, aluminum is in the form of $[Al(OH)_4]^-$in the water. Because it's negatively charged and all the metal ions are positively charged. Thereby, they will abstract and combine with each other. It can be said is one kind of the combination reactions. The solubility of the substance which produce after the combination is deciding whether the substance can be eliminated from the sewage. Mass of ions could combine with it and stay in the sewage due to its soluble characteristic.

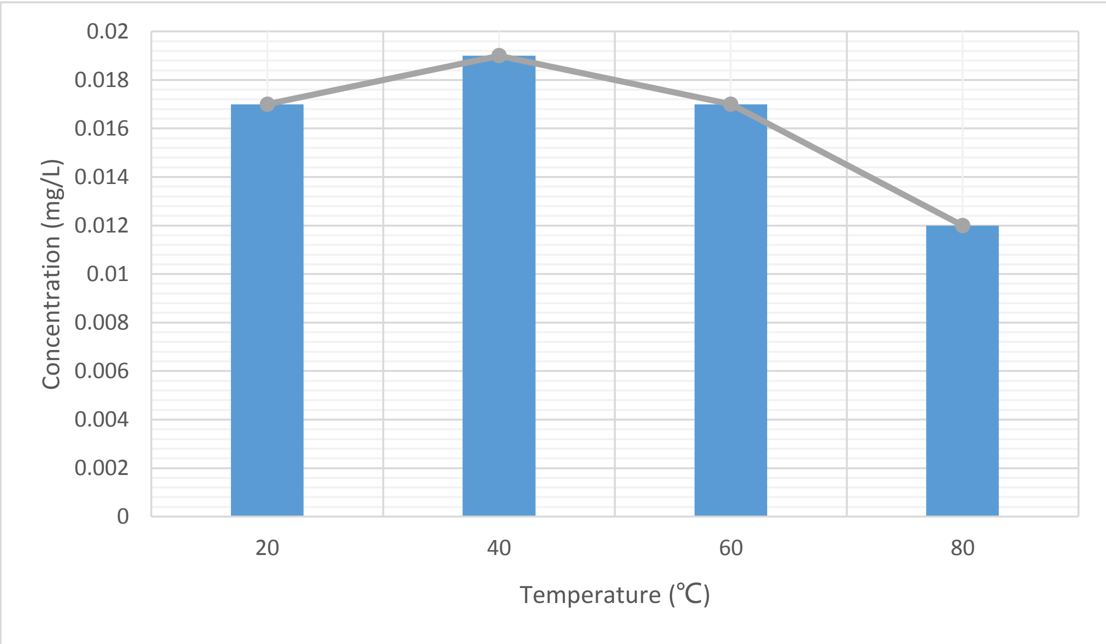
Except cobalt, manganese and magnesium, the other ions can be eliminated smoothly and efficiently. Especially for removing the iron ions, the result is outstanding and extraordinary. Among those three examples which not able to removing ions, cobalt is unproven. The most probable reason for explaining the ascending of the concentration of manganese that is the compound which combine by manganese and tetrahydroxoaluminate is soluble in water.

5.2 Comparison of the results in different conditions

All the previous data were collected from the experiments conducted under normal temperature and acidic liquid. If under some special circumstance. For instance high temperature or neutral and acidic pH. In these kinds of circumstances, the characteristics of the aluminum hydroxide would change, hereby the result would be influenced or changed to completely different consequent. Under particular situation, the result might towards to a better development, and parts might create converse effect. All the experiments were conducted by adding three grams of wet aluminum hydroxide.

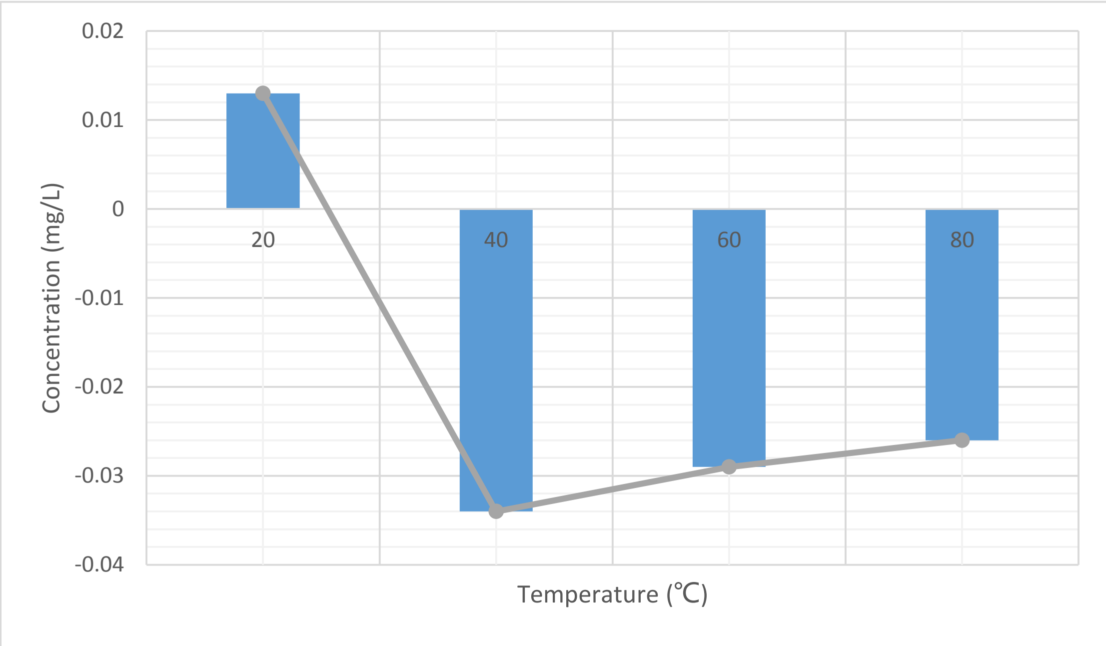
5.2.1 Results in different temperatures

Aluminum hydroxide is theoretically not soluble in water, but it is soluble in acids. In fact, there is nothing totally insoluble in water, there are always very tiny amounts of it that will dissolve. Increasing temperature not only can increase the quantity of dissolved aluminum hydroxide, but will also promote the production of $[Al(OH)_4]^-$. Theoretically, the removed amount would grow along with the reactant increasing.

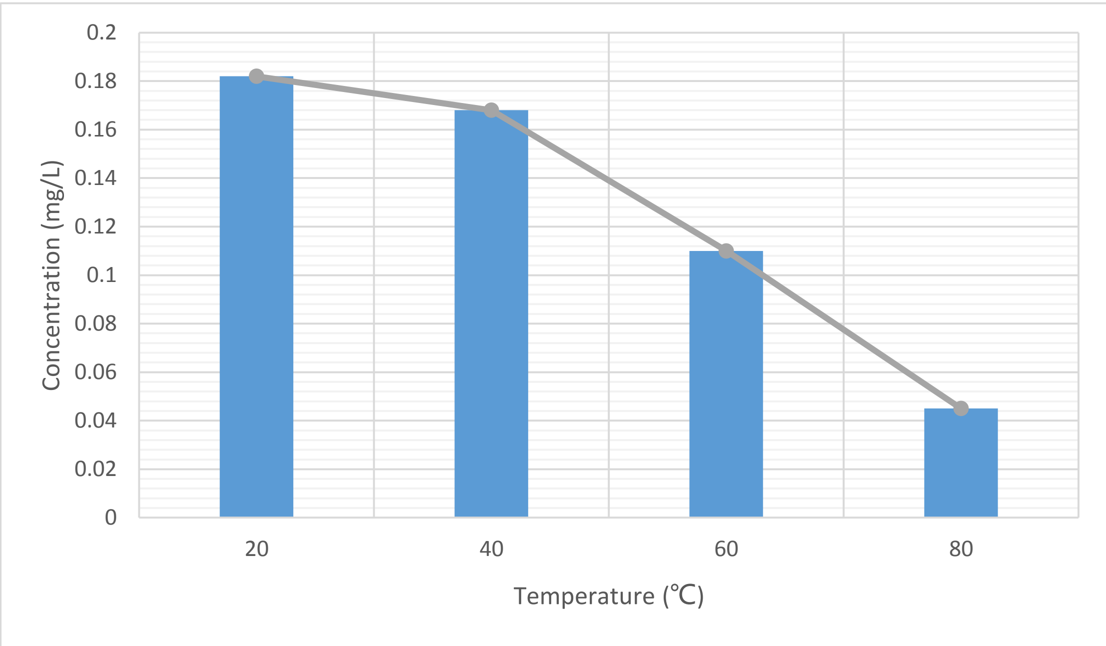


Graph 9. The concentration of cobalt in different temperatures.

Apparently, when the temperature is between 40℃ and 60℃ that the results are equal or even worse than the results at room temperature. If the temperature continuously increase until reaching 80℃, 30% more cobalt ions are removed from the sewage. Until now, a new conclusion can be testified, which is that the cobalt can be removed by adding aluminum hydroxide. Moreover, the results of cobalt which illustrating in the last chapter can also be proved that are not due the small concentration, but is not in a suitable condition.

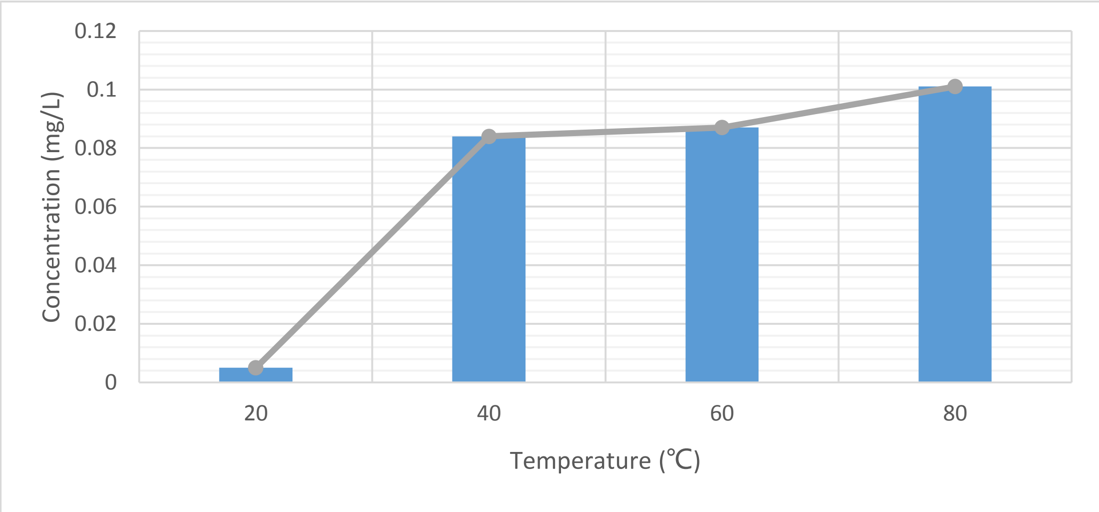


Graph 10. The concentration of copper in different temperatures.



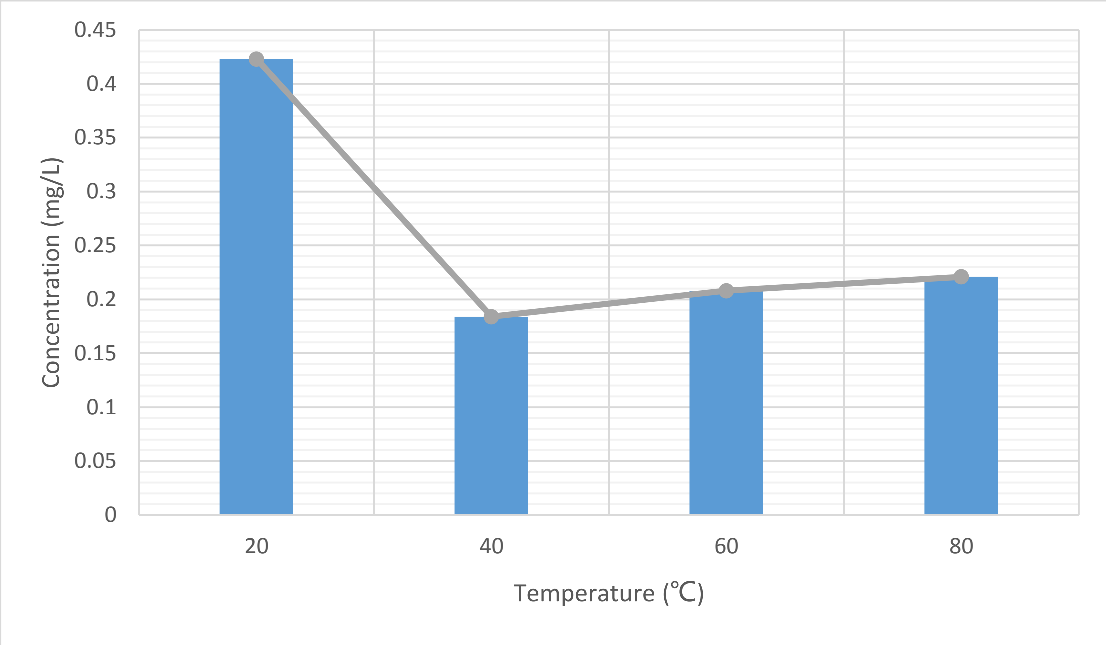
Graph 11. The concentration of nickel in different temperatures.

The Graphs 10 and 11 of copper and nickel is both having an obvious decreasing curve. The data at higher temperature were already turned to negative, that's demonstrating that the concentration of copper in the sewage is difficult to detect due to its tiny concentration. Increased the temperature has greatly enhanced the aluminum hydroxide ability to eliminating the nickel ions. More than 75% nickel ions were be removed under 80℃ comparing to room temperature.



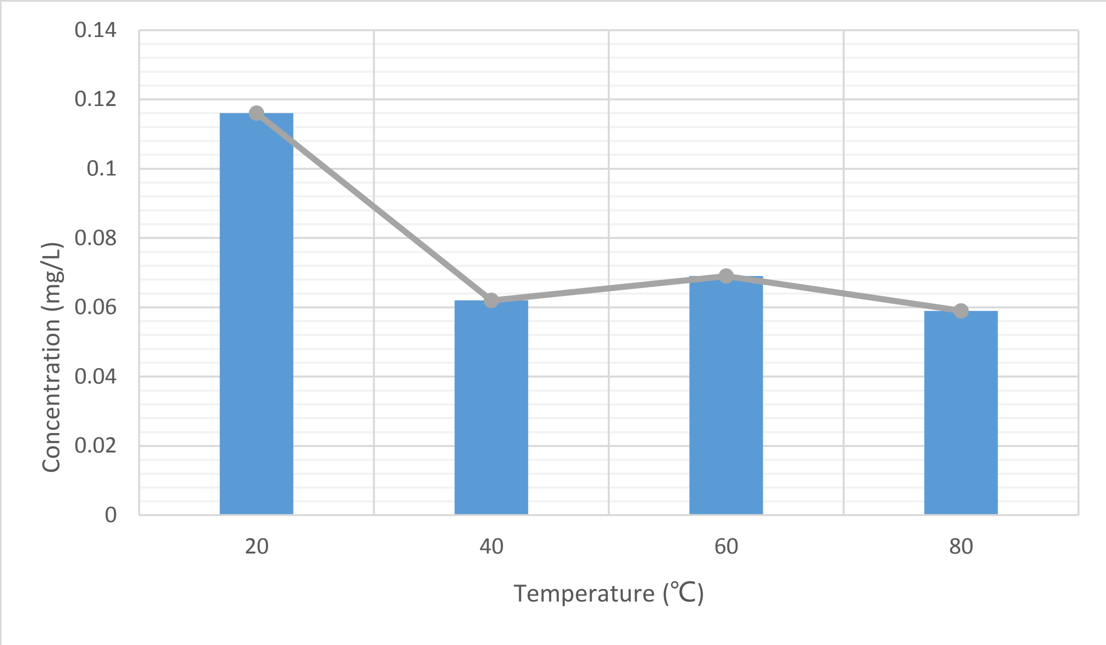
Graph 12. The concentration of zinc in different temperature.

However, the results which bring with increasing temperature had created completely different consequent to zinc. Along with the temperature increasing, the removed quantity of zinc decreases sharply. 70% less of zinc doesn't be removed in the higher temperature of the sewage. A reasonable ground that can explain this phenomenon is that zinc oxide was produced. Thereby, resist the reaction between the zinc and $[Al(OH)_4]^-$. This is a serious problem that need be concerned when design the whole process.



Graph 13. The concentration of manganese in different temperature.

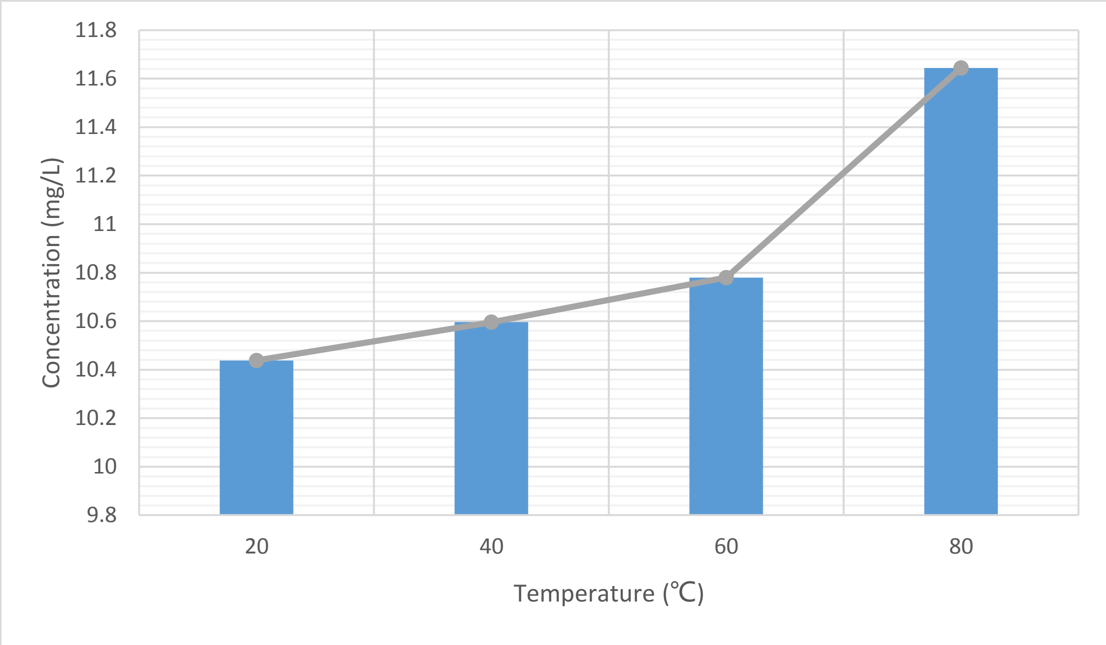
Graph 13 shows a very interesting result if compares with Graph 4. In graph 4, the curve was ascending sharply along with the quantity of the wet aluminum hydroxide. Even the concentration increases almost five times than the original concentration in the last sample. When the sewage's temperature was increased, the increase rate of the concentration of manganese has been restricted perfectly. The result is similar with the result of dried aluminum hydroxide. Abate the quantity of the manganese produced as much as possible is better for conducting after the treatment. And moreover, 40℃ is a reachable temperature without requiring much energy.



Graph 14. The concentration of iron in different temperatures.

Actually, the result in room temperature is also a nice consequent, about 95% iron ions were removed in room temperature. However, the result could be better if the temperature increasing to 40℃, and the effect of 40℃ is similar with the result of adding five grams aluminum hydroxide. Therefore, either to improve the temperature or input additional aluminum hydroxide is both working. The details of the implementation should be considered under the specific circumstances. The temperature after 40℃ is unnecessary be considered, because the effects are not better than 40℃, but are require much more energy.

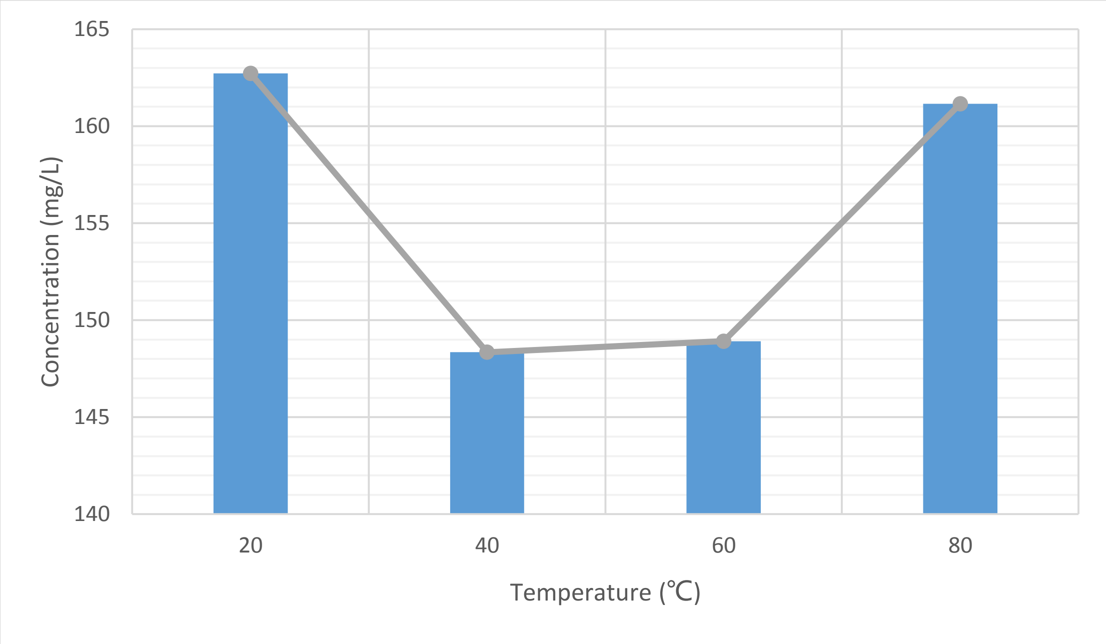
There is an interesting phenomenon if make a contrast between graph 13 and 14, which the graphs are almost the same with each other. Increasing the temperature has bring the benefits for the process of removing manganese and iron.



Graph 15. The concentration of magnesium in different temperatures.

At room temperature, adding three grams of wet aluminum hydroxide is the best option for eliminating the magnesium from the sewage. Along with the temperature increasing, it might still be the suitable point, but the effect would take a huge discount. Graph 16 is the concentration of calcium in different temperatures. From the graph, 40℃ and 60℃ are the two best temperature options that can be chosen. At these two temperatures, merely three grams of aluminum hydroxide can reach the effect of nine grams of aluminum hydroxide in the temperature. The amount of aluminum hydroxide is saved on a certain extent. However, increasing temperature is require energy. Therefore, which choice is better are needing a detail calculation depends on the particular situation.

Concluded from the previous data, and 40℃ can be said is a good temperature for the whole process. But, 40℃ can't be set as the first choice of temperature. The real conducting temperature is recommend design according to the major ions in the sewage. For instance, if eliminating zinc is the main purpose, then increasing the temperature apparently is not a brilliant decision.

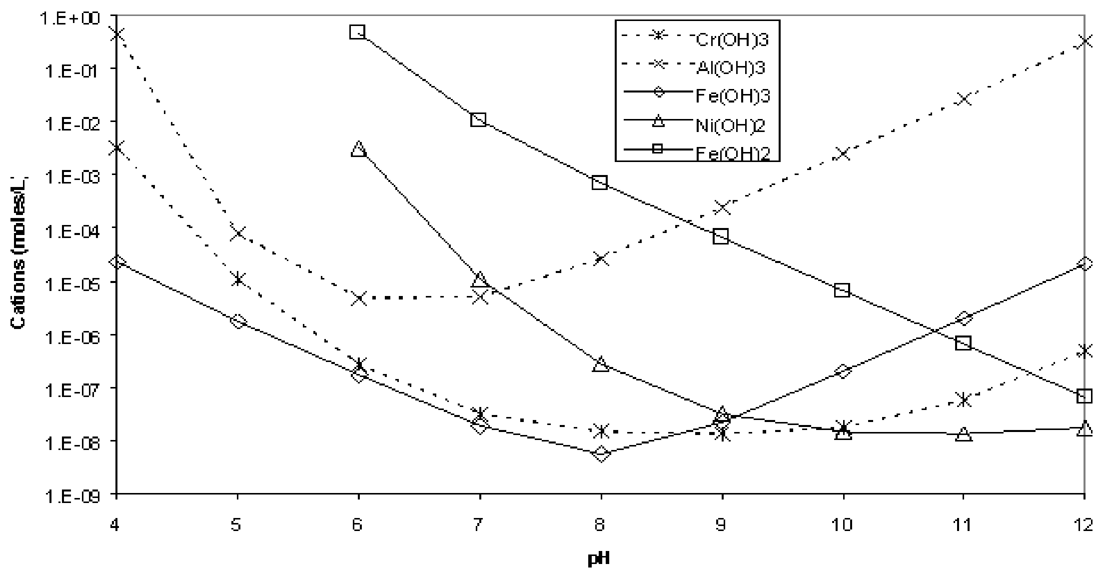


Graph 16. The concentration of calcium in different temperatures.

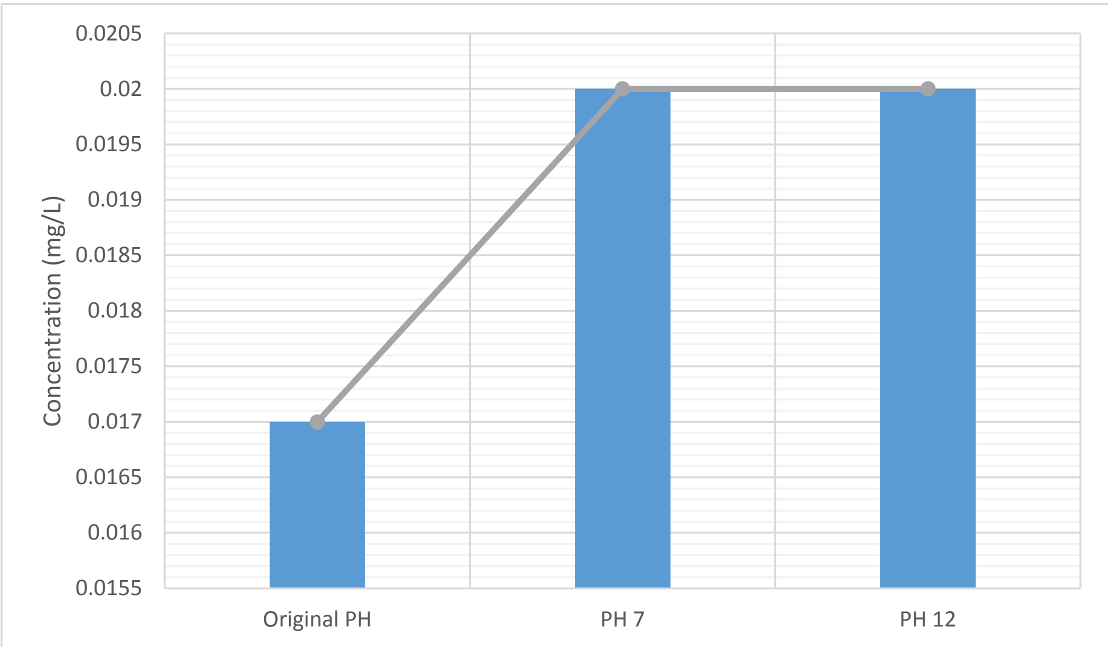
5.2.2 Results in different pHs

Similar with the effect caused by different temperatures, different pH also could promote or inhibit the reaction. The major effect is from two factors which are the different reactants and solubility. As introduced in chapter two, the main reactant in the alkaline solution is Al^{3+}, unlike in the acidic solution. Al^{3+} is positively charged metal ions, and will inevitably have a difference with the reaction with $[Al(OH)_4]^-$, at least the reaction in the alkaline solution should be the substitution reaction rather than the combination reaction.

According to Graph 17, the solubility graph of the aluminum hydroxide is a curve. From pH 4 to pH 6, the solubility of aluminum hydroxide is decreasing sharply, and pH 6 is the lowest solubility point of aluminum hydroxide. From pH 6 until pH 12, the curve is changing back and growing steadily. All the experiments were conducted by adding three grams of wet aluminum hydroxide.

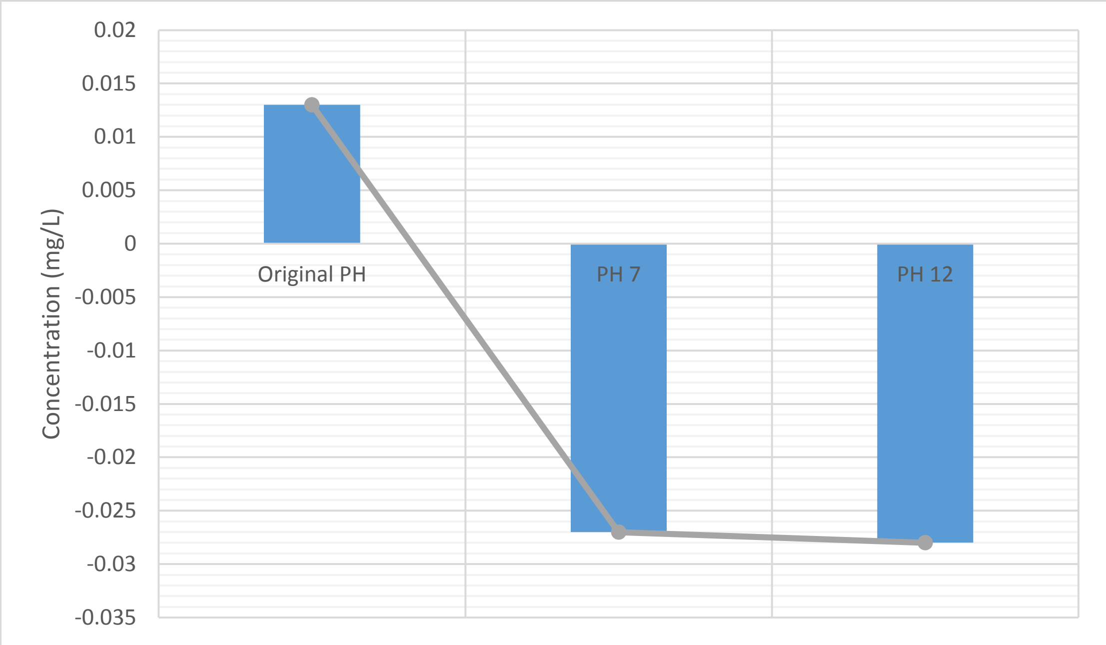


Graph 17. The solubility diagram of aluminum hydroxide (Phifer, M.A., 2000).

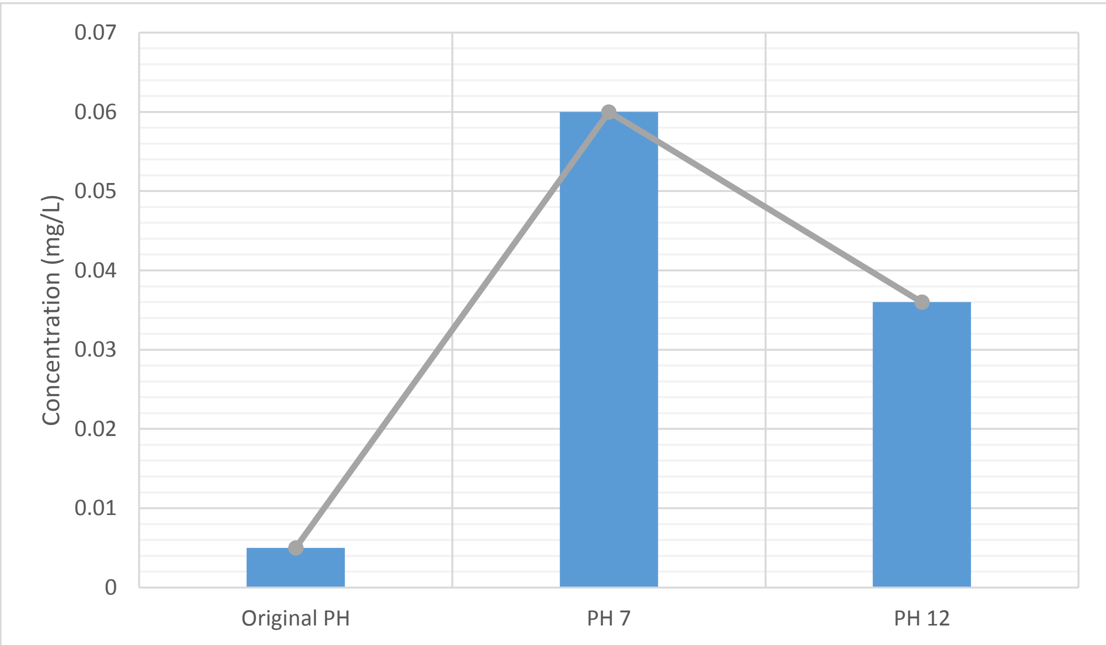


Graph 18. The concentration of cobalt in different pHs.

Though the results between the original pH, pH 7 and pH 12 involve a little different. However, due the results of pH 7 and pH 12 were very close, because these two data were achieved from the same line. Therefore, the differences between the original pH and changed pH can belong to the error which cause by achieving the data from a different line.

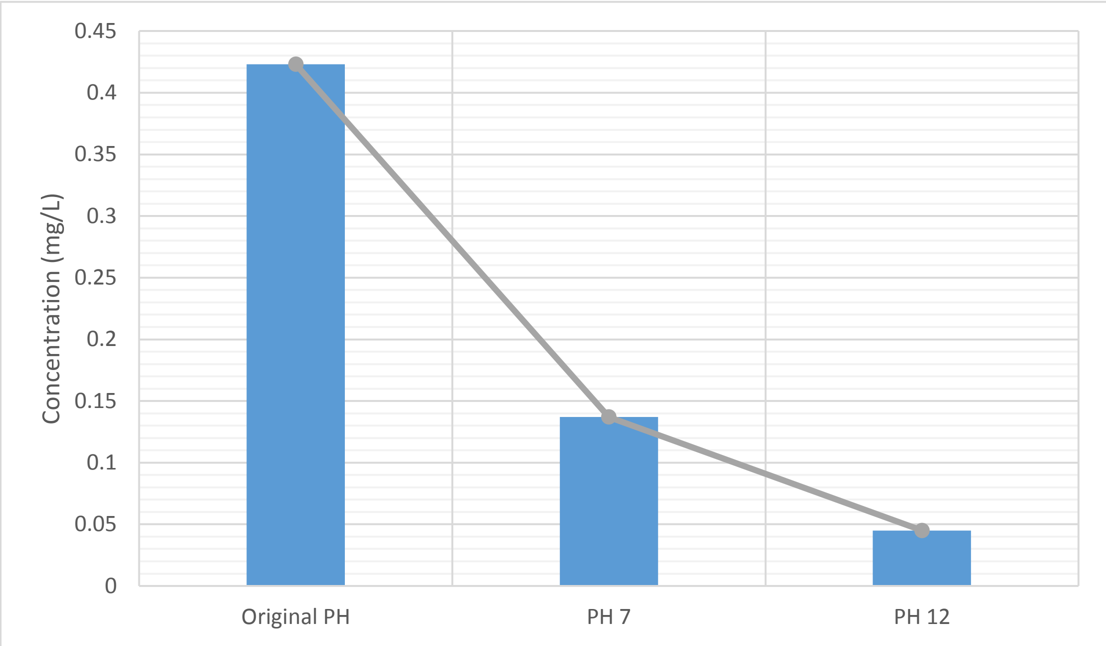


Graph 19. The concentration of copper in different pHs.



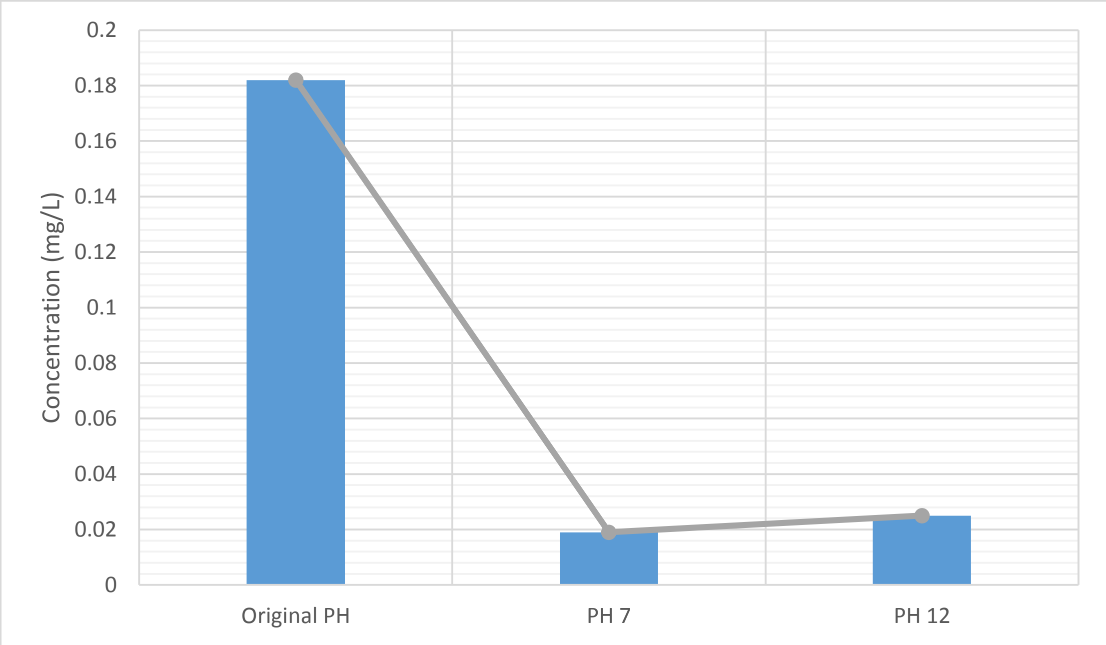
Graph 20. The concentration of zinc in different pHs.

The influence occur in copper and zinc is similar with the influence caused by temperature. For the copper, whatever is pH 7 or pH 12, the concentration can be reduced beyond the detecting limitation. That's illustrating most of the copper has been removed out of the sewage. For zinc, any variation occur could abate the effect of be eliminated. If the pH of the sewage increasing to 7, the amount of zinc that be removed would reducing 90%. And continues increasing to pH 12, the quantity that be removed could increase, but is still not as good as the result of the original pH.



Graph 21. The concentration of manganese in different pHs.

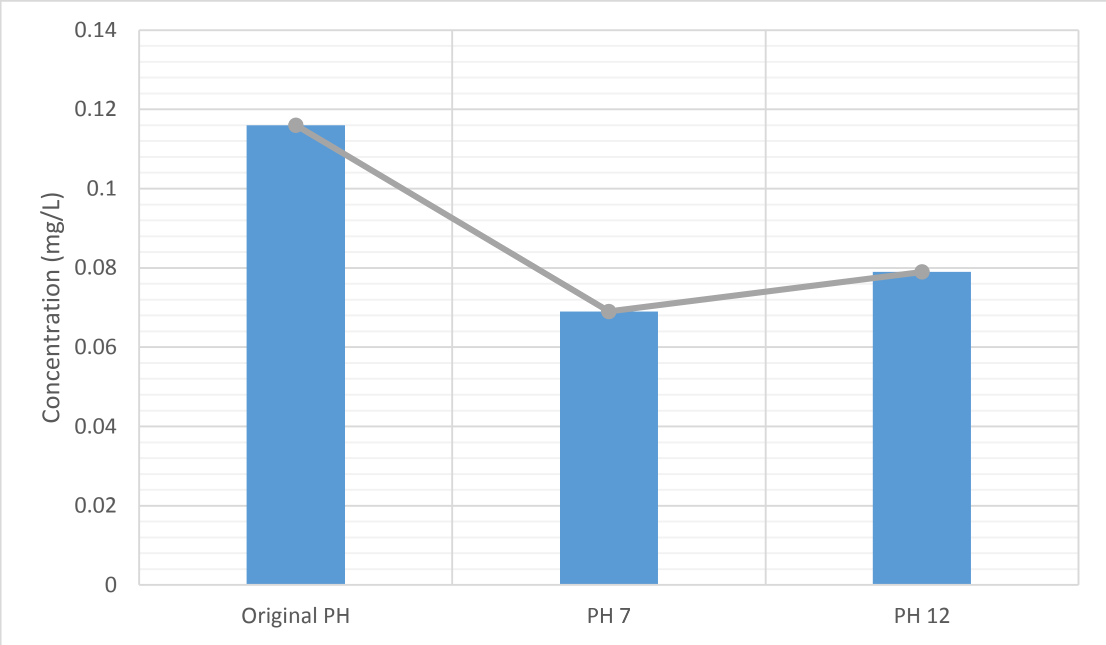
Surprisingly, manganese’s concentration in different pHs gives an unexpected result. Among all the previous experiments, this is the first time that the concentration of manganese was abated. Utilizing the same amount of aluminum hydroxide, 72% of manganese would be eliminated from the sewage. In the solution which the pH is 7, aluminum hydroxide could also eliminating the manganese from the sewage rather than increase its concentration. However, the quantity that was removed is not considerable. Anyway, a conclusion can be made that if manganese is needed to be eliminated by aluminum hydroxide from the sewage, the alkaline solution would be the optional environment.



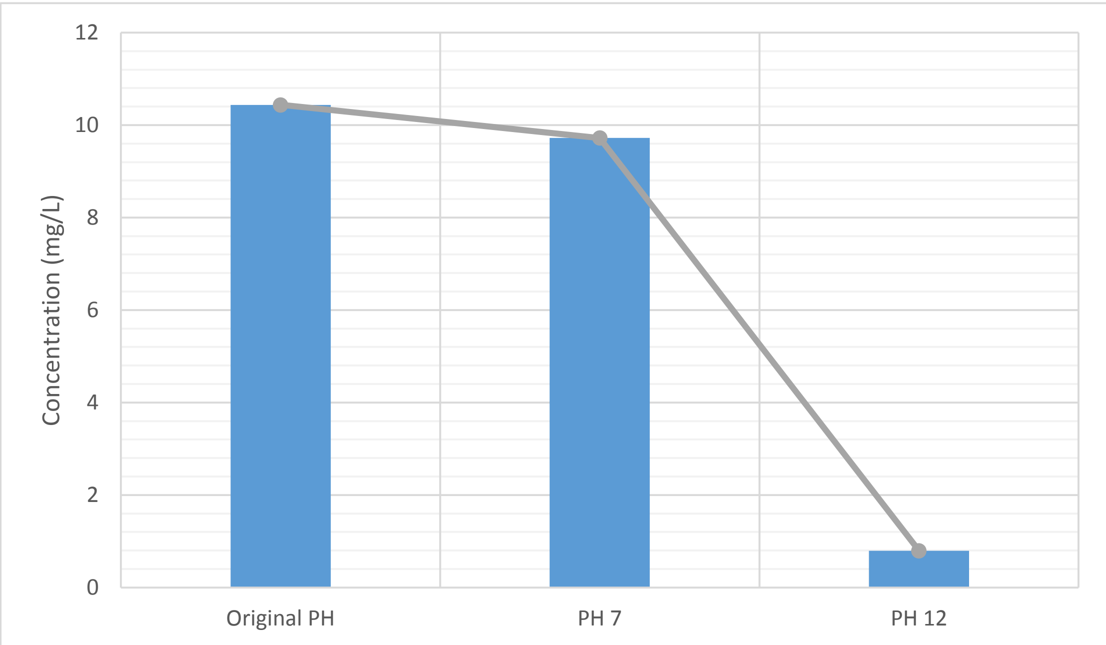
Graph 22. The concentration of nickel in different pHs.

Like manganese, the performance of nickel and iron in the higher pHs also has promotion. Especially the nickel ions, approximately 90% more ions can be eliminated from the sewage in the neutral solution, which is an enormous reduction. Alkaline environment also improved the performance of aluminum hydroxide, but just 3% fewer ions that was removed in the neutral solution. A considerable amount of aluminum hydroxide can be saved if the sewage is treated in the neutral or alkaline environment.

Iron also has a great promotion, even though the original process's result is already extraordinary. The result showing in graph 22 is similar with the graph 22of the nickel in different pHs. The best pH environment for the iron ions eliminating process is also the neutral pH among three different pH values.

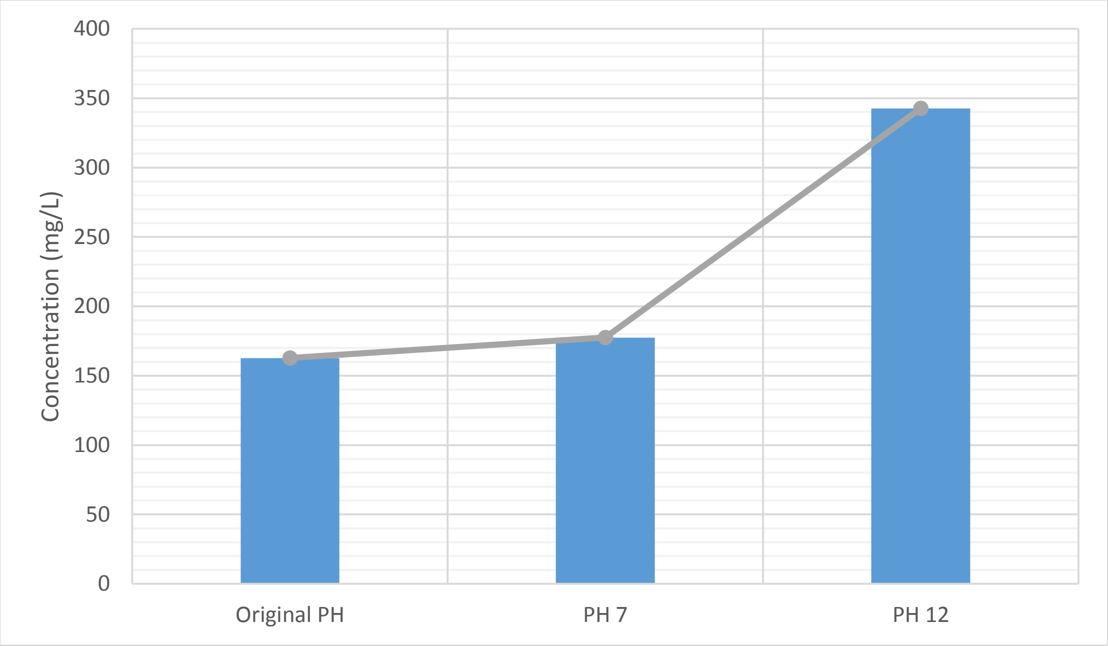


Graph 23. The concentration of iron in different pHs.



Graph 24. The concentration of magnesium in different pHs.

Aluminum hydroxide is having a very good performance for eliminating magnesium in the alkaline solution. Nine tenths more magnesium ions was eliminated than in the original pH. And the performance in alkaline solution is also greater than the effect of the neutral solution. Comparing with the osculation result in the original temperature and pH. This result is much better and more acceptable. In the original pH (acid), whatever how much wet aluminum hydroxide was be added, the lowest concentration that can reach is more than 10 mg/L. However, in the alkaline solution, merely needs three grams of aluminum hydroxide that can abate the concentration of magnesium below 1 mg/L, which is one tenth of the original value.



Graph 25. The concentration of calcium in different pHs.

The result of the concentration of calcium in pH 7 and pH 12 is unexpected. The concentration was increasing along with the pH ascending, particularly when pH reache 12, which the concentration is nearly doubled. Therefore, calcium ions apparently is not suit eliminating by aluminum hydroxide in the alkaline solution. If the treatment conducting in the high pH environment is inevitable, then additional process is necessary in order to eliminate the calcium ions afterwards.

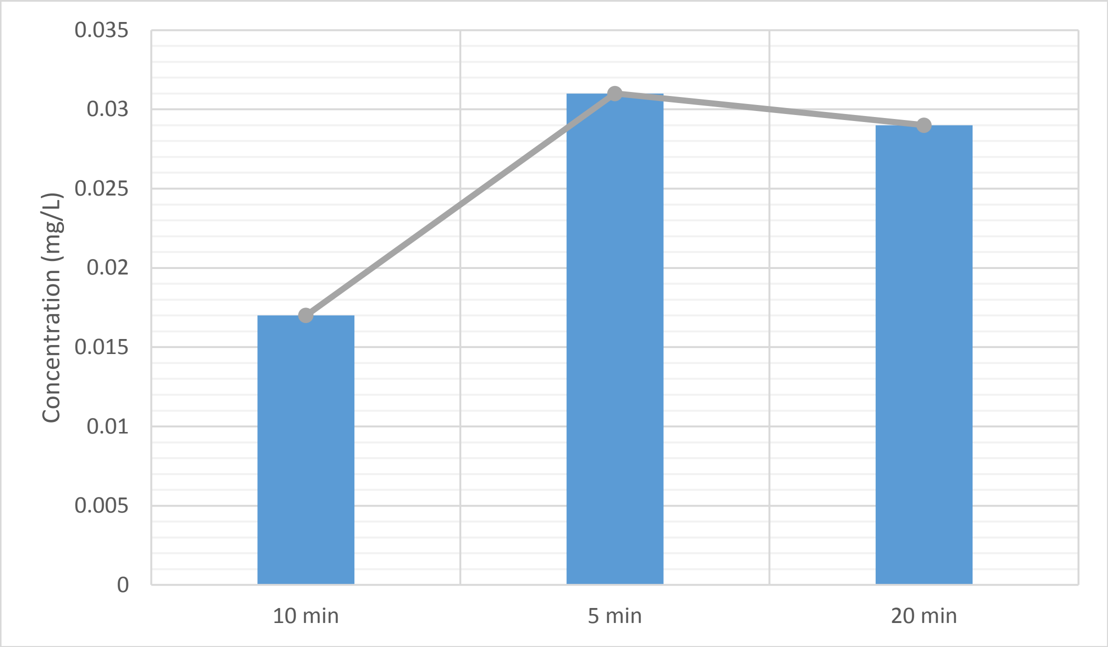
Each ions' performance in different pH is different, some results is better and some are worse, but all phenomenon seem has an intensive relationship with element reactivity and in-separate from it, which is the infrastructure knowledge of the exchange reaction. Though the results are not absolutely follow the element reactivity series, due to there are other factors can influencing the results, and the products' solubility can be an instance, and the results is also logistically.

Table 15. Element activity table (activity increasing from bottom to top) (France & Colin, 2008).

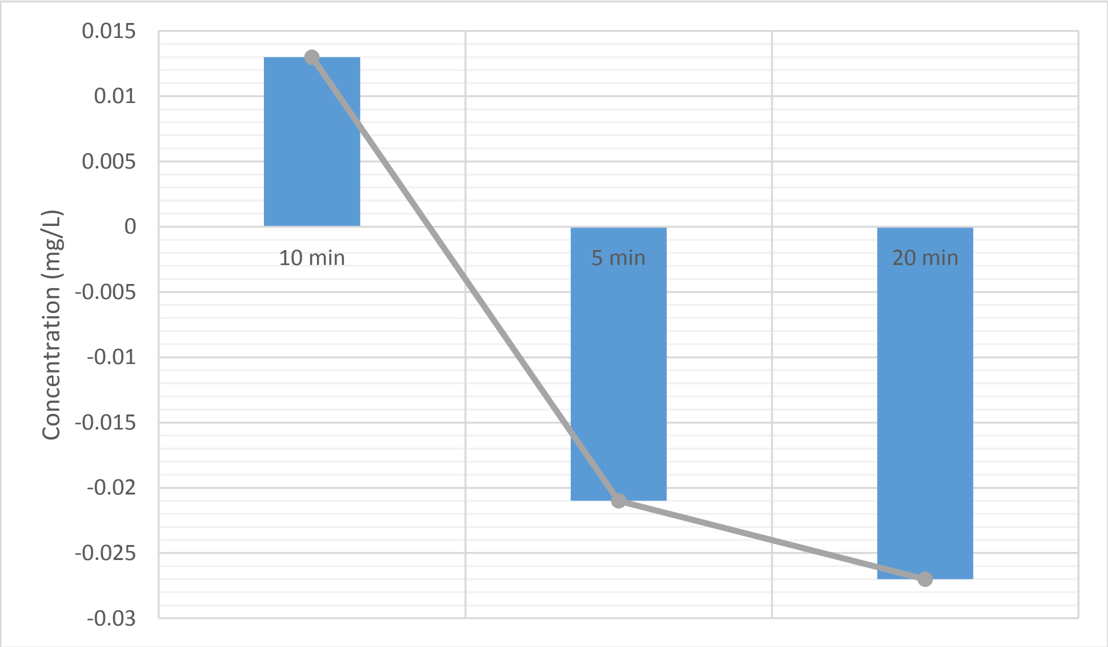
Metal	Ion
K	K^{+}
Na	Na^{2+}
Ca	Ca^{2+}
Mg	Mg^{2+}
Al	Al^{3+}
Mn	Mn^{2+}
Zn	Zn^{2+}
Fe	Fe^{2+}
Co	Co^{2+}
Ni	Ni^{2+}
H_2	--
Cu	Cu^{2+}

5.2.3 Different mixing time periods

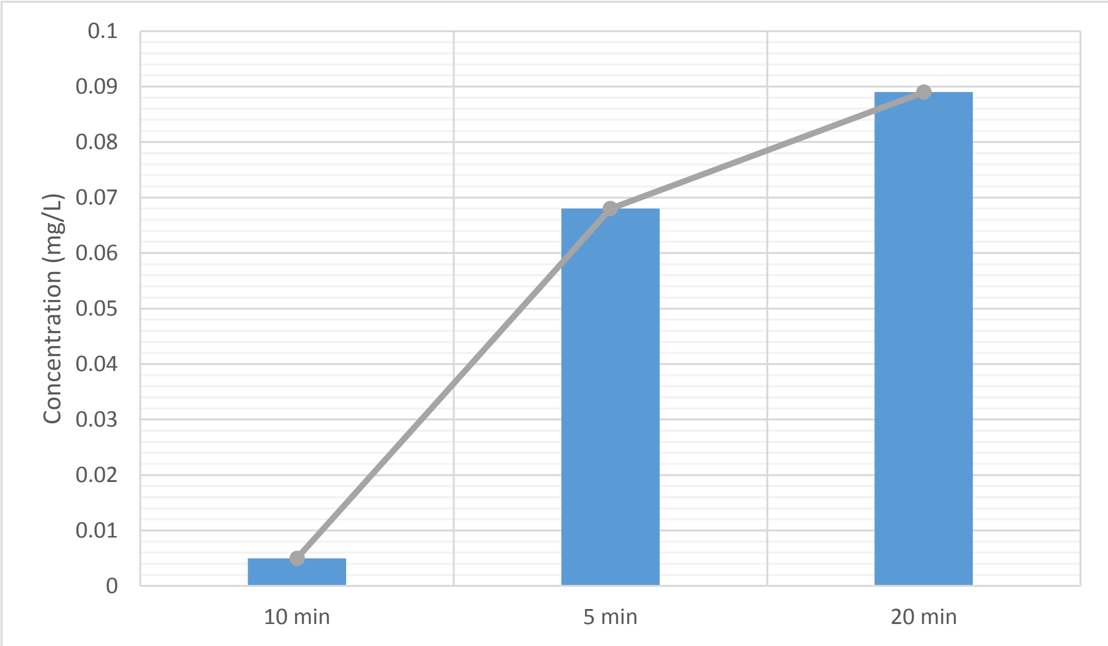
This section is research whether the mixing time can affect the results. Long mixing time might could slightly increase the soluble quantity of aluminum hydroxide. It also might could promote the effect due to the longer contact time between the aluminum hydroxide and ions. Conversely, cut the mixing time might cause negative effect. Therefore, this section will conduct an experiment for extending or shortening the mixing time.



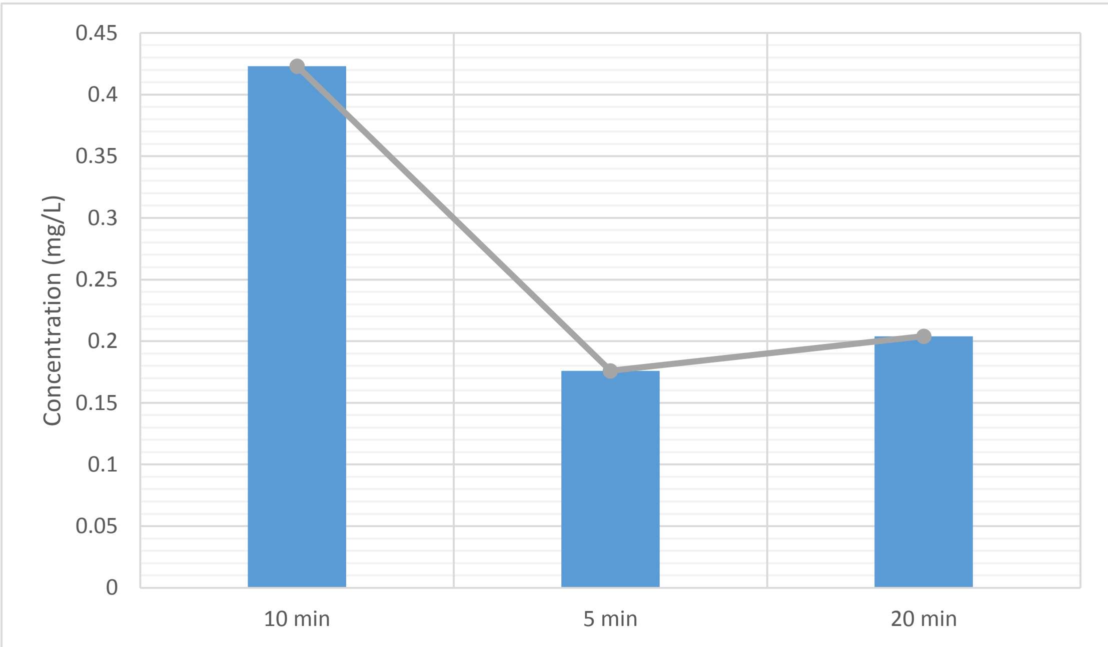
Graph 26. The concentration of cobalt under treatment in different mixing times.



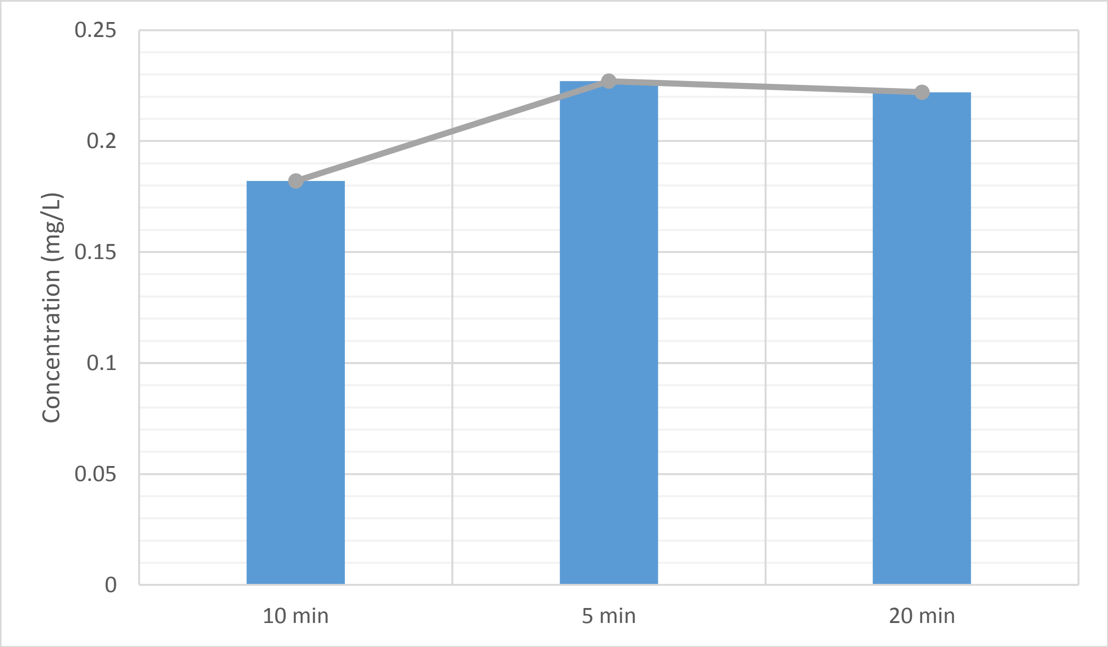
Graph 27. The concentration of copper under treatment in different mixing times.



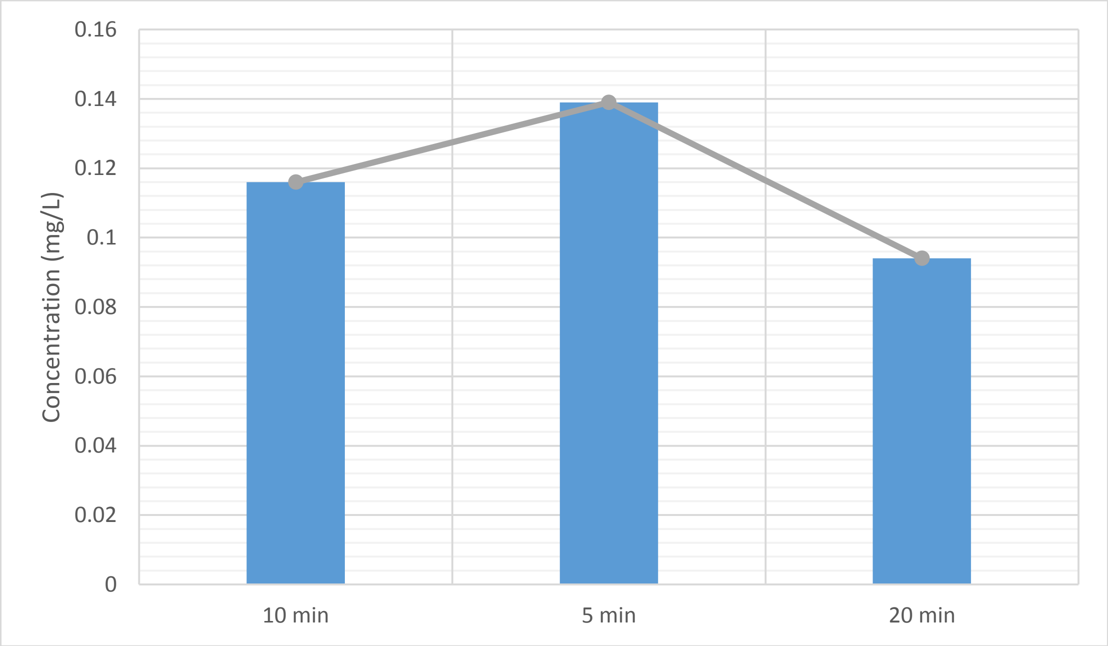
Graph 28. The concentration of zinc under treatment in different mixing times.



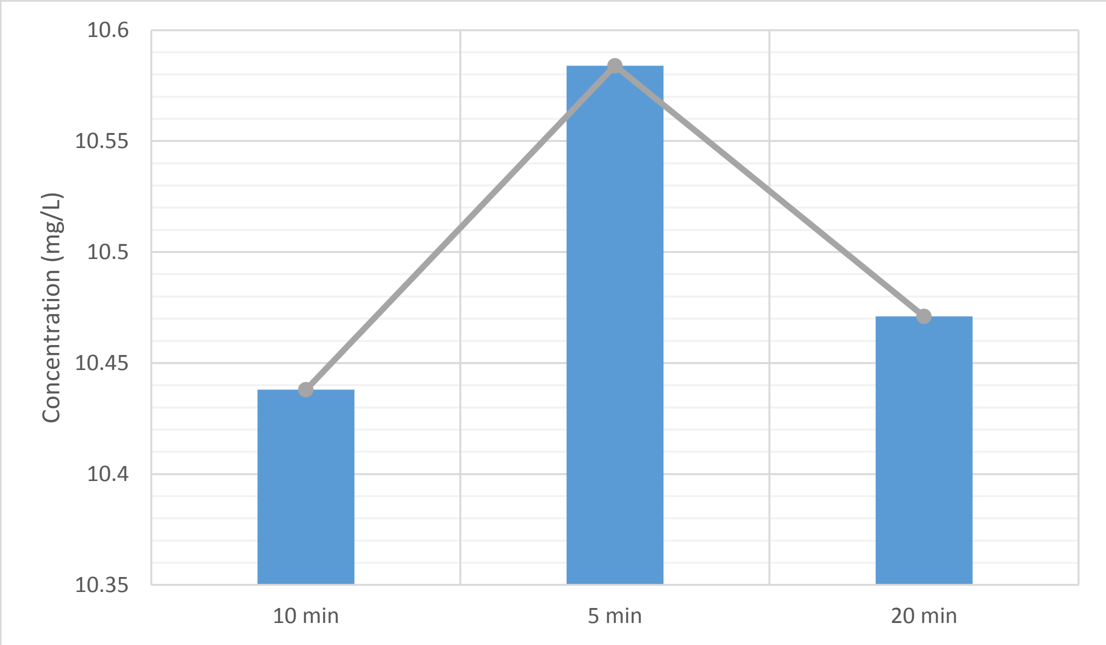
Graph 29. The concentration of manganese under treatment in different mixing times.



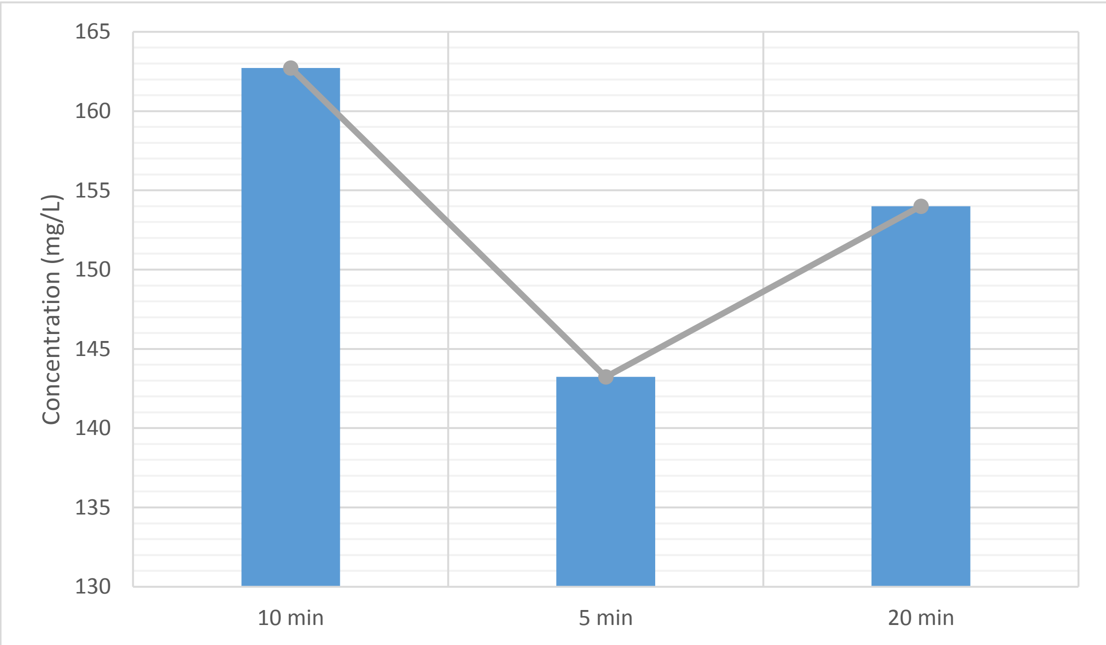
Graph 30. The concentration of nickel under treatment in different mixing times.



Graph 31. The concentration of iron under treatment in different mixing times.



Graph 32. The concentration of magnesium under treatment in different mixing times.



Graph 33. The concentration of calcium under treatment in different mixing times.

All the data are have some differences among three mixing times. Especially zinc, manganese and calcium are the most variation's ions. Other metal ions also have different, but due to the error yield of different calibration line, these tiny differences can be neglected.

Among these three particular ions, zinc is the most special ions comparing with other element ions. Either shorten or extend the mixing time, the effect of the treatment seems had a big influence. The concentration of zinc that was treated for 5 minutes and 20 minutes are seven times and nine times of the concentration of zinc be treated for 10 minutes.

Dislike zinc, extending or shortening the mixing time for eliminating the manganese ions will bring the advantage promotion. At least half of the manganese can be removed from the sewage. Shorter mixing period seems is benefit for eliminating the manganese ions.

Shorter mixing period also has a significant effect for eliminating calcium ions. If the mixing time lasts 5 minutes, 12% more calcium ions can be eliminated from the sewage. 12% seems not like a remarkable number. However, if check back the result of calcium treated in the normal pH and temperature, reached this 12% amount reduction is needed additional six grams of aluminum hydroxide.

6 CONCLUSION

There are several factors that could influence the results of the experiment. Two of them will be described in this chapter. These two factors are theoretically able to create considerable effects on the experimental results. However, these two factors were be controlled strictly during the experiment, and abate the negative effect as much as possible. Therefore, the result of each experiment is reliable and acceptable.

The first factor has been mentioned several times through the whole thesis, which is the differences between each calibration line. AAS is depend on the calibration line, therefore achieving the result according to the corresponding point. Due to the scarcity of the volumetric flask, the concentration of one metal ion in each experiment can't be measured in the same time by utilizing the same calibration line. Different calibration line must has different corresponding number for the same point. During the experiment, all the calibration lines were adjusted close to each other according to the slope comparison. All the slopes' differences were controlled in the third number after the decimal.

The second factor that could impact the results are the particle size of the aluminum hydroxide. The particle size of the aluminum hydroxide is not the same and each time the size of the particle was added are have a considerable difference. Because of the aluminum hydroxide is moist and every tiny particle was adhered with each other to form a bigger particle, therefore, this is difficult for separating.

Dried aluminum hydroxide are also not grinded in order to get smaller particles. The particle size could influence the contact area, reaction velocity and the quantity of the reactant. Tiny particle size was had much more contact area due to the enormous quantity. And because of the large contact area, reacting velocity was had significantly improved. Even detect the same ion concentration from the same solution several times, the calibration line's slope also has a little bit different.

Even though these factors had the possibility to influence the results. However, the above collected data, which can prove that aluminum hydroxide is certainly have significant effect for eliminating the ions from the sewage. All the metal ions are have quantitative reduction during the experiment, and these huge amounts of reduction are not possible due to the effect of the error. All the metal ions can be eliminated by aluminum hydroxide, but the process might have to conduct in the specific environment.

Eliminating each metal ions has its suitable environment for exerting the efficiency of aluminum hydroxide as much as possible. Table 14 shows the best condition for eliminating the metal ions by aluminum hydroxide.

Table 15. Particular conditions for eliminating each metal ions.

Metal	**Property**	**Temperature (℃)**	**pH**	**Mixing time (min)**
Co	wet	80	acidic	10
Cu	dried	40	uncertain	uncertain
Zn	wet	20	acidic	10
Mn	dried	40	alkaline	5
Ni	wet	80	neutral	10
Fe	wet	80	neutral	20
Mg	wet	20	alkaline	10
Ca	wet	40	acidic	5

The above table could illustrate that each metal ion has the specific condition for eliminating the metal ions. Therefore, major eliminating ions must be ensured when drafting the process. Moreover, all the metal ions can't be eliminated at one time. Therefore, the concentration of ions that might increasing must be monitored and controlled carefully. After the eliminating process, the metal ions' concentration must be measured. Additional eliminating process is necessary if the concentration is exceeding the maximum allowable discharge value.

It can be therefore concluded that if all expenditure such as the energy needed for heating, pH adjusting substance and sludge processing, is lower than the original treatment method, then eliminating the metal ions in the sewage by utilizing aluminum hydroxide is encouraged. Aluminum hydroxide has been proven that is can be utilized for eliminating the metal ions. However, plenty of novel technologies were be or being invented. Moreover, every single technology has advantages. Therefore, aluminum hydroxide is just a chemical that used in the treatment process. Unstop to enrich the technologies that can be utilized in the treatment process, the factory hence could have several options and turn the process be more convenient.

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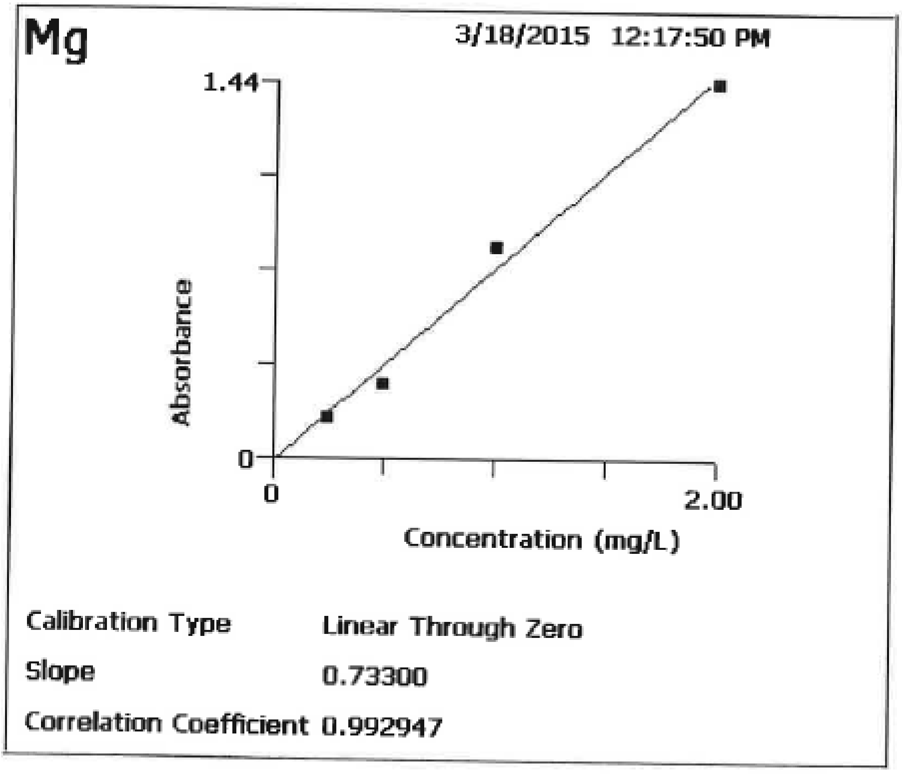
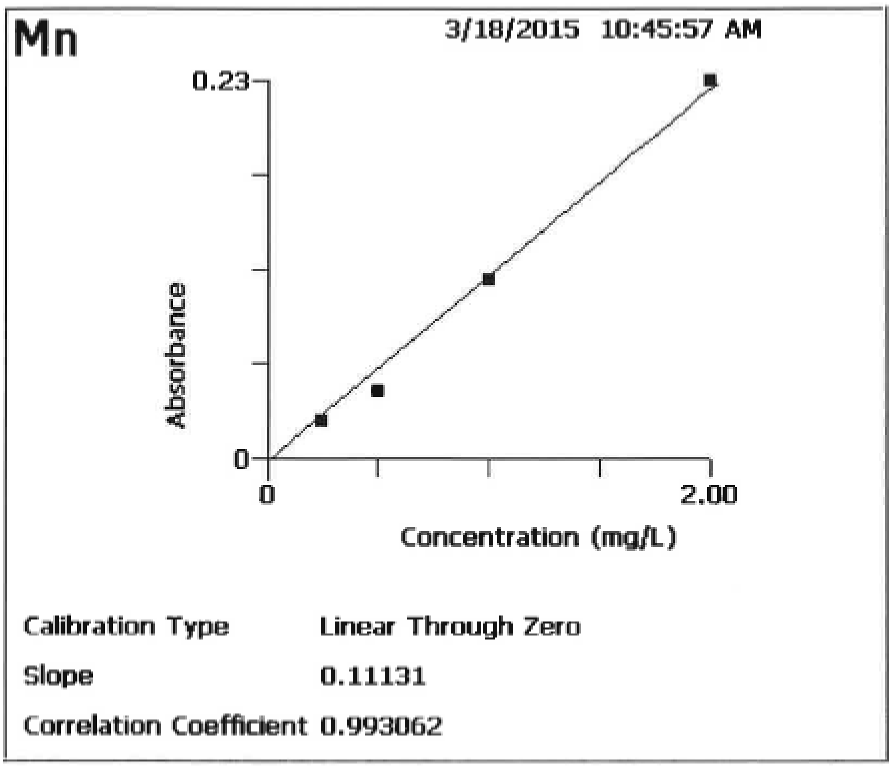

Mg
3/18/2015 12:17:50 PM
1.44
0
Absorbance
0
2.00
Concentration (mg/L)
Calibration Type Linear Through Zero
Slope 0.73300
Correlation Coefficient 0.992947


Mn
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Absorbance
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2.00
Concentration (mg/L)
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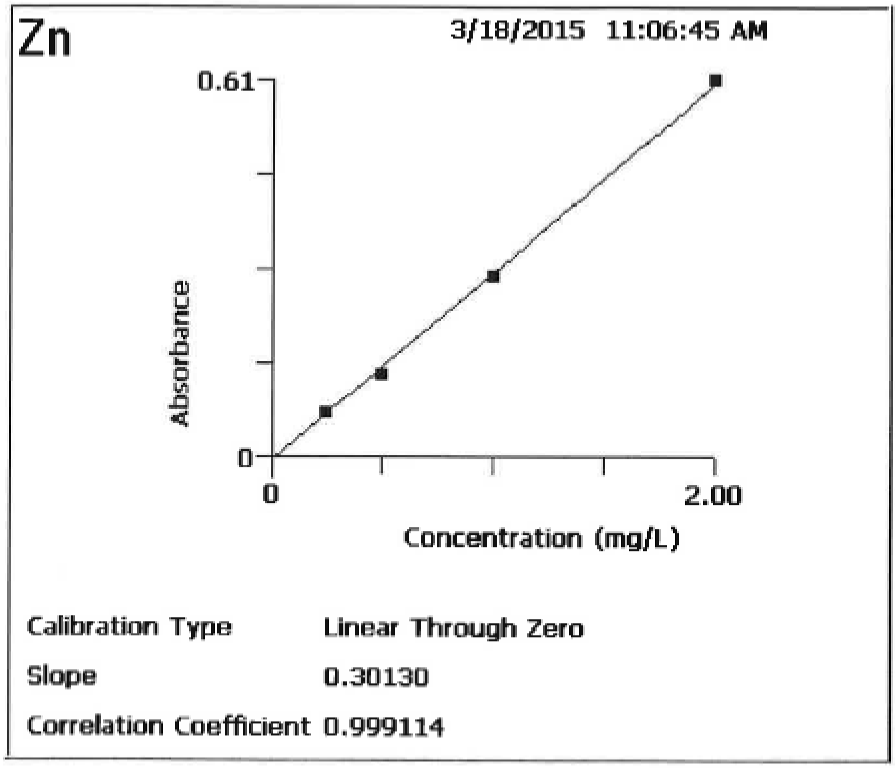
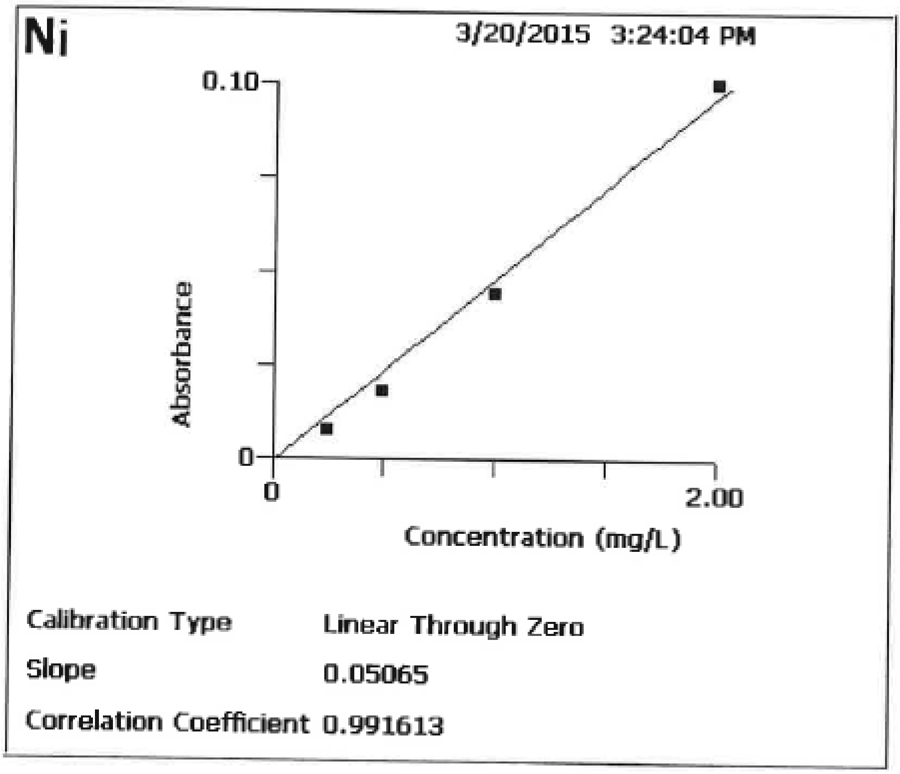

Zn
3/18/2015 11:06:45 AM
0.61
0
Absorbance
0
2.00
Concentration (mg/L)
Calibration Type
Linear Through Zero
Slope
0.30130
Correlation Coefficient 0.999114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Concentration (mg/L)
Calibration Type
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Slope
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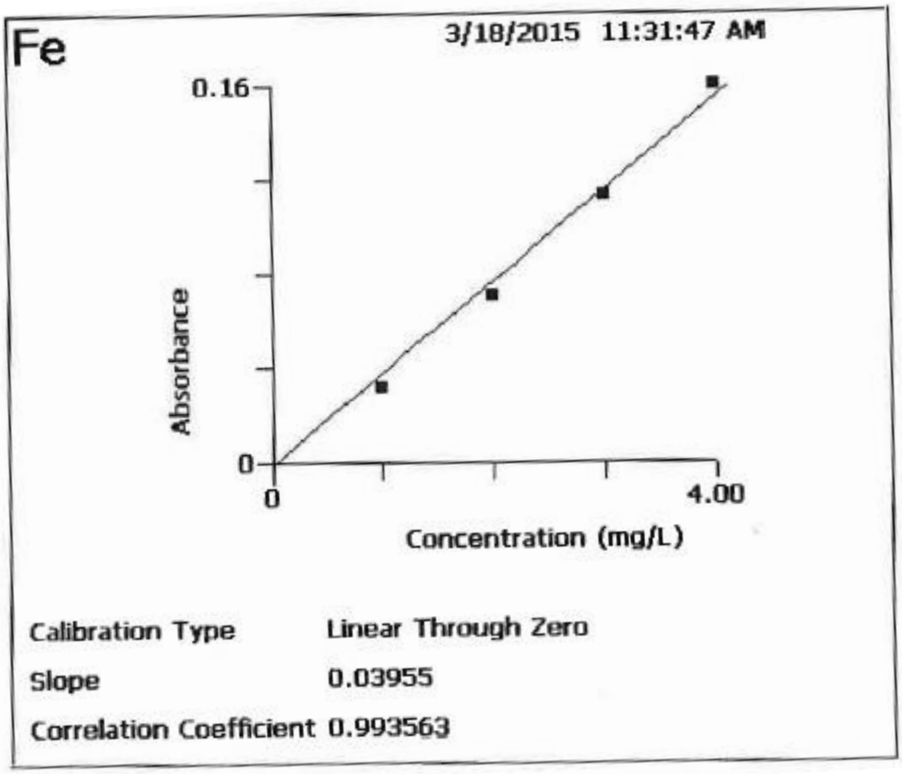
Correlation Coefficient 0.991613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Concentration (mg/L)
Calibration Type
Linear Through Zero
Slope
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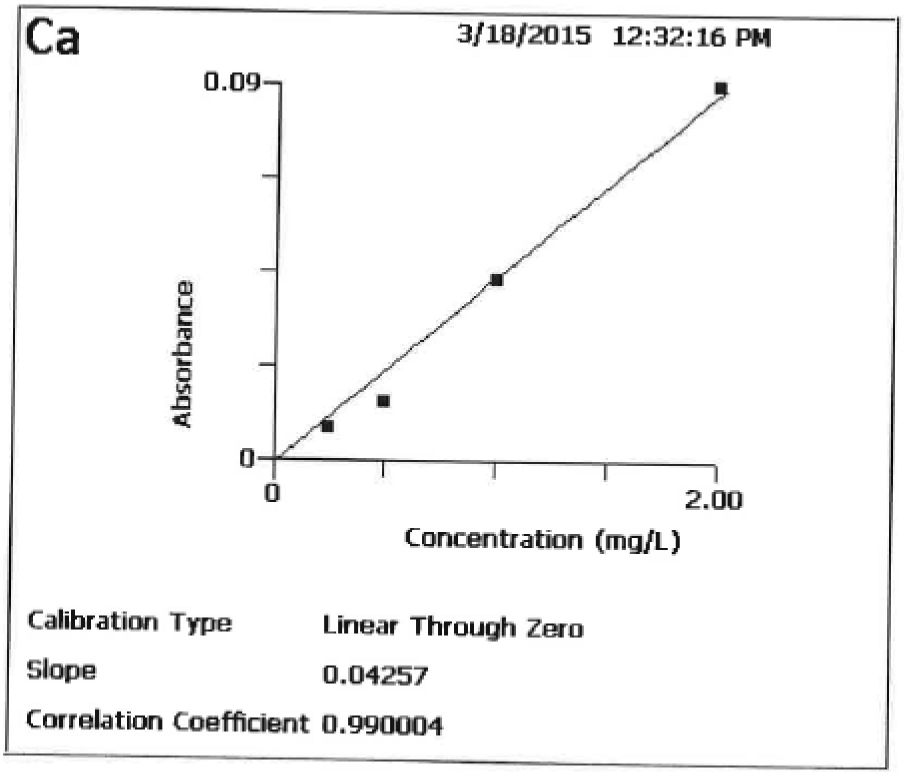
Correlation Coefficient
0.993563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Calibration Type
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Slope
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Correlation Coefficient
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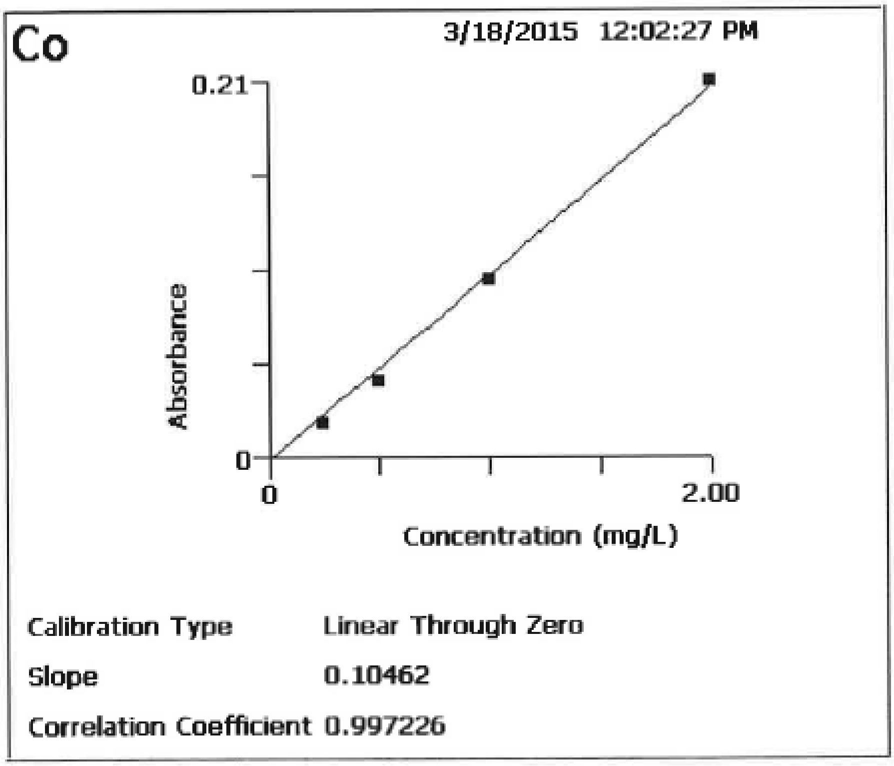
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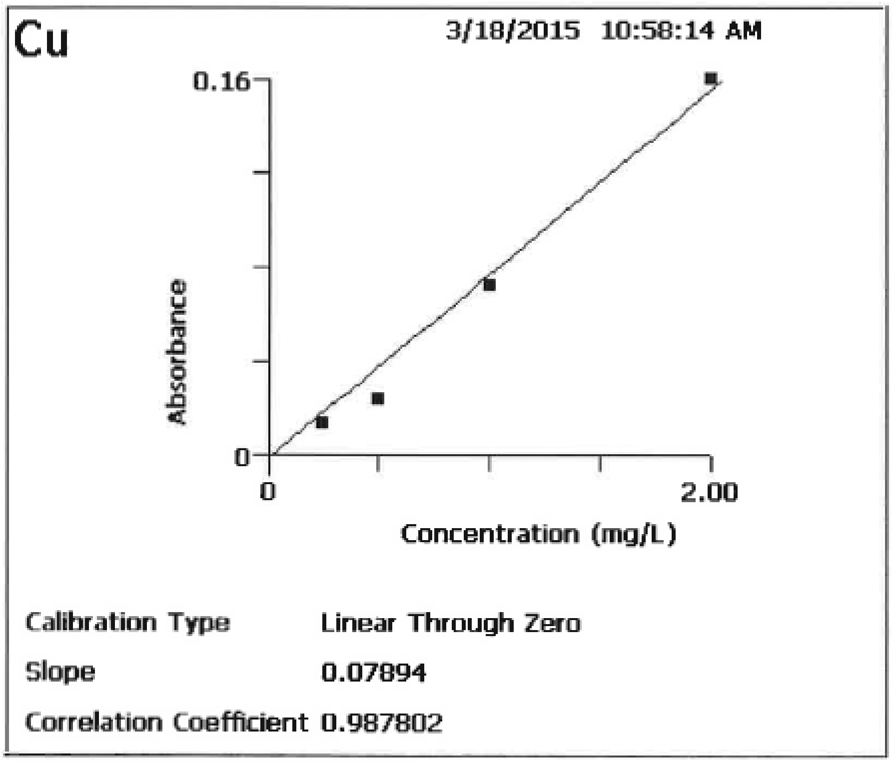
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Calibration Type Linear Through Zero
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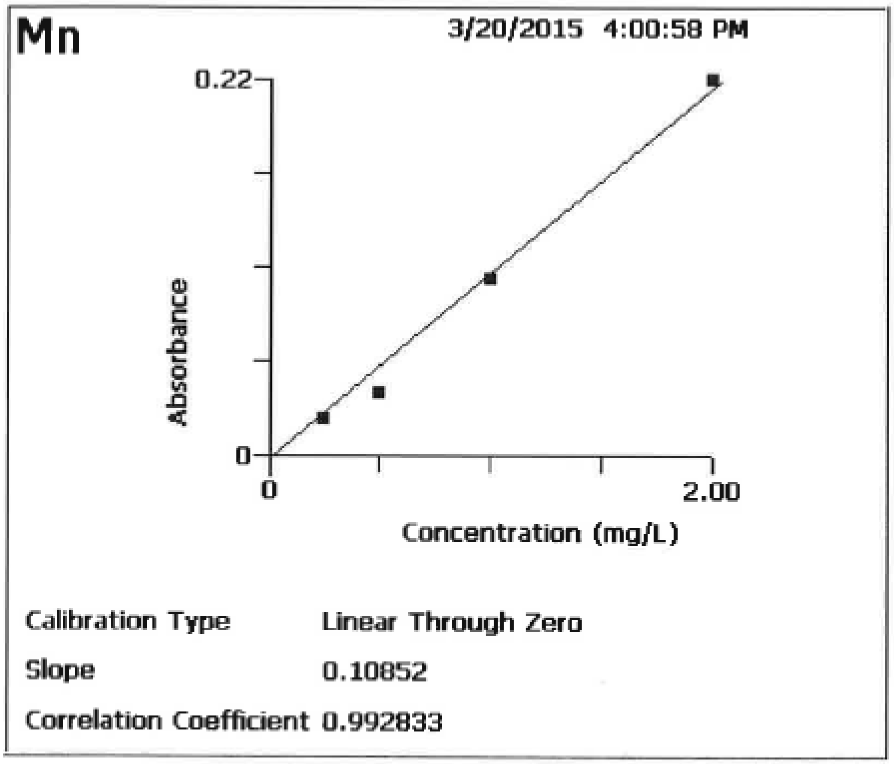
Correlation Coefficient 0.987802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Concentration (mg/L)
Calibration Type
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Slope
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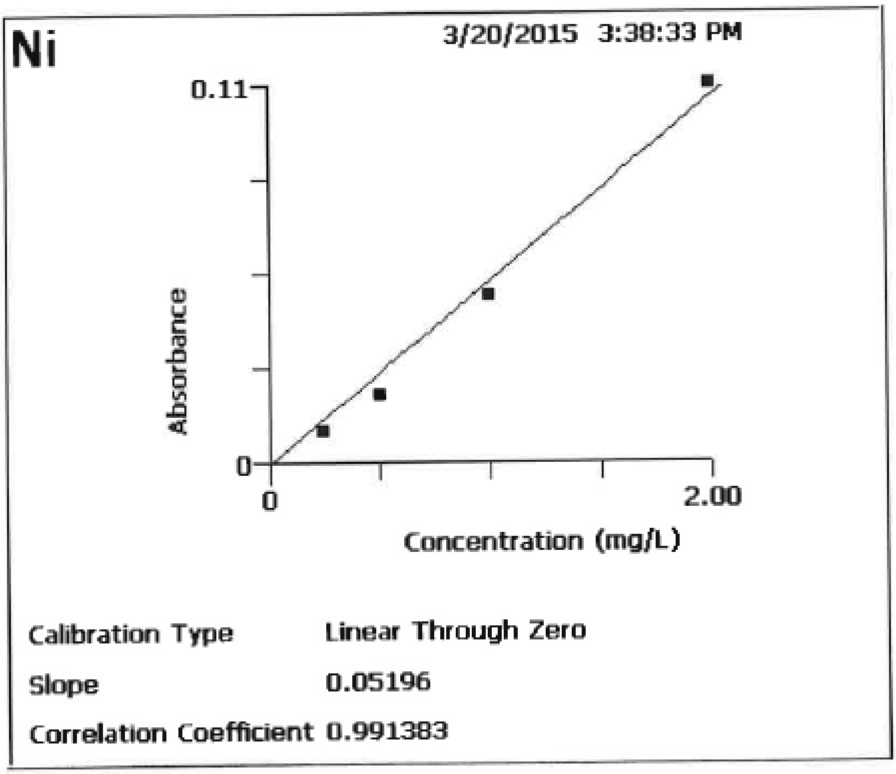
Correlation Coefficient
0.992833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Calibration Type
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Slope
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Correlation Coefficient
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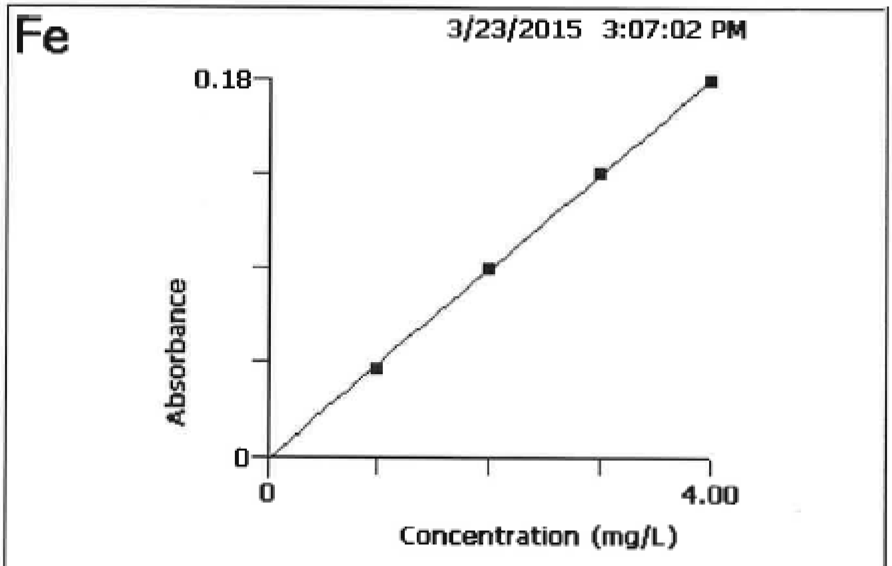
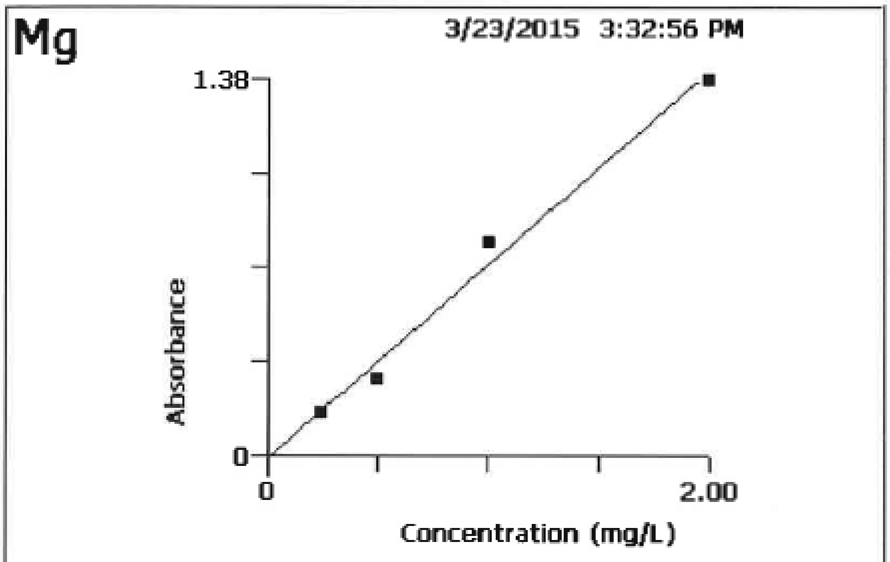
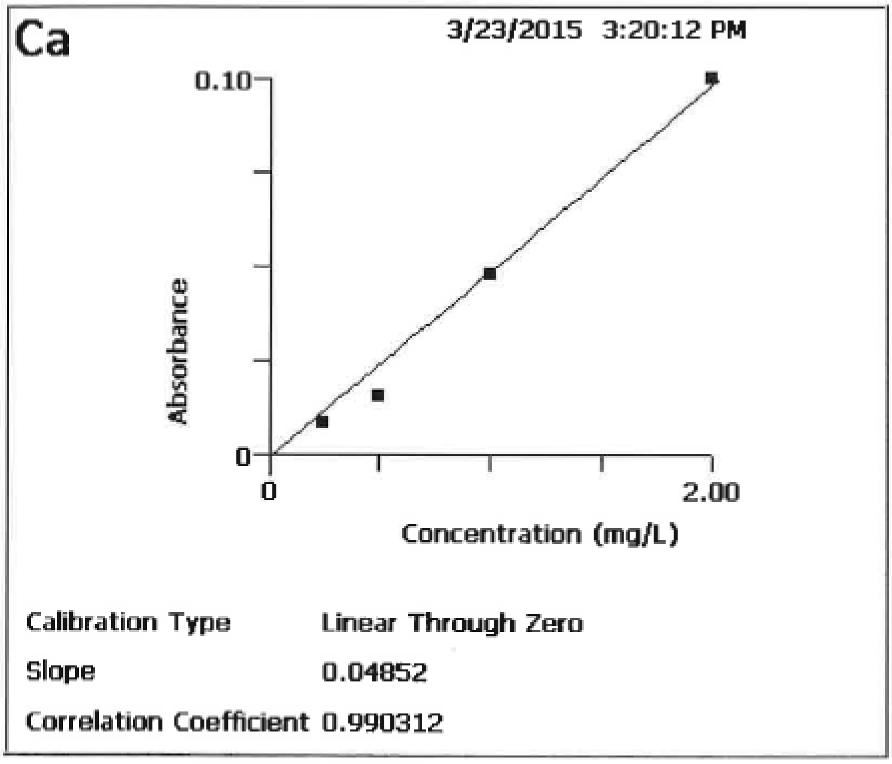


Calibration Type	Linear Through Zero
Slope	0.04563
Correlation Coefficient	0.999617



Calibration Type	Linear Through Zero
Slope	0.70640
Correlation Coefficient	0.993519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Calibration Type Linear Through Zero
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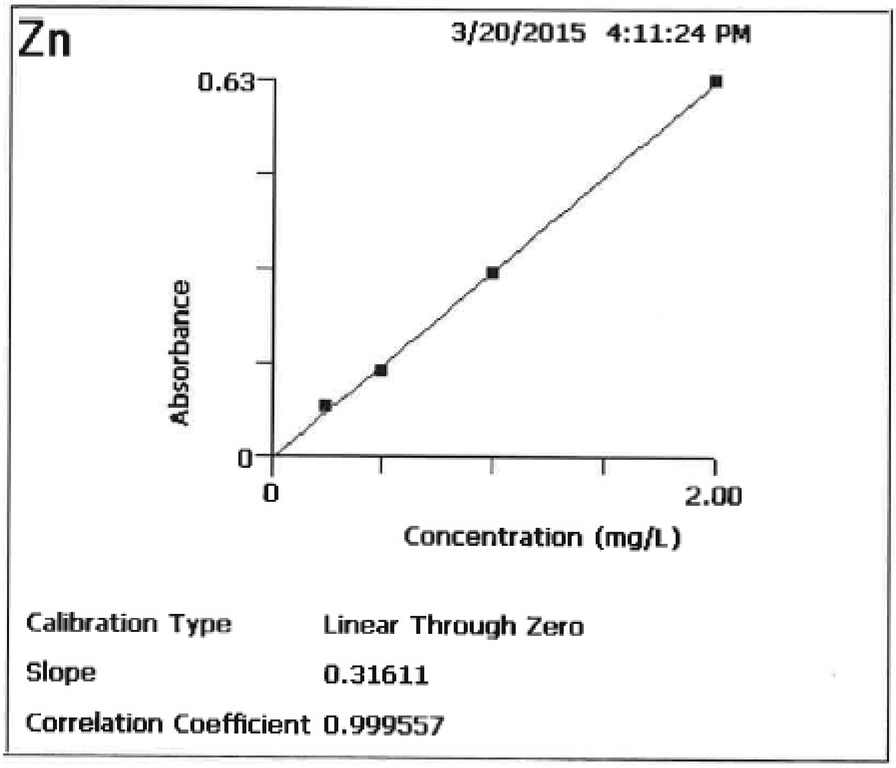
Correlation Coefficient 0.990312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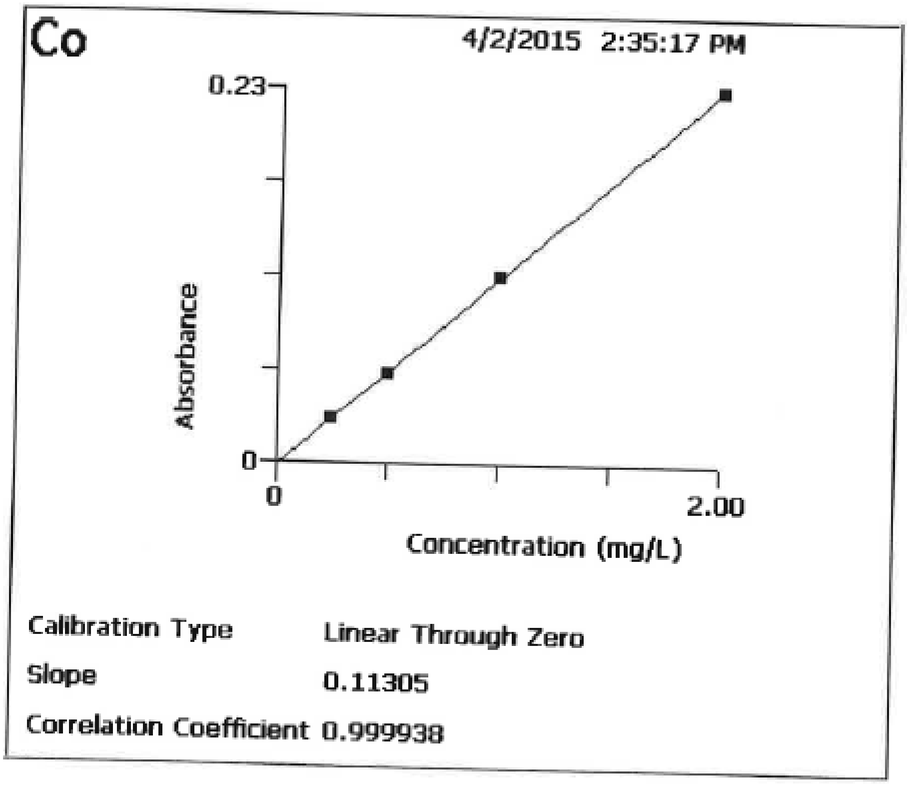
Concentration (mg/L)
Calibration Type Linear Through Zero
Slope 0.31611
Correlation Coefficient 0.999557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Absorbance
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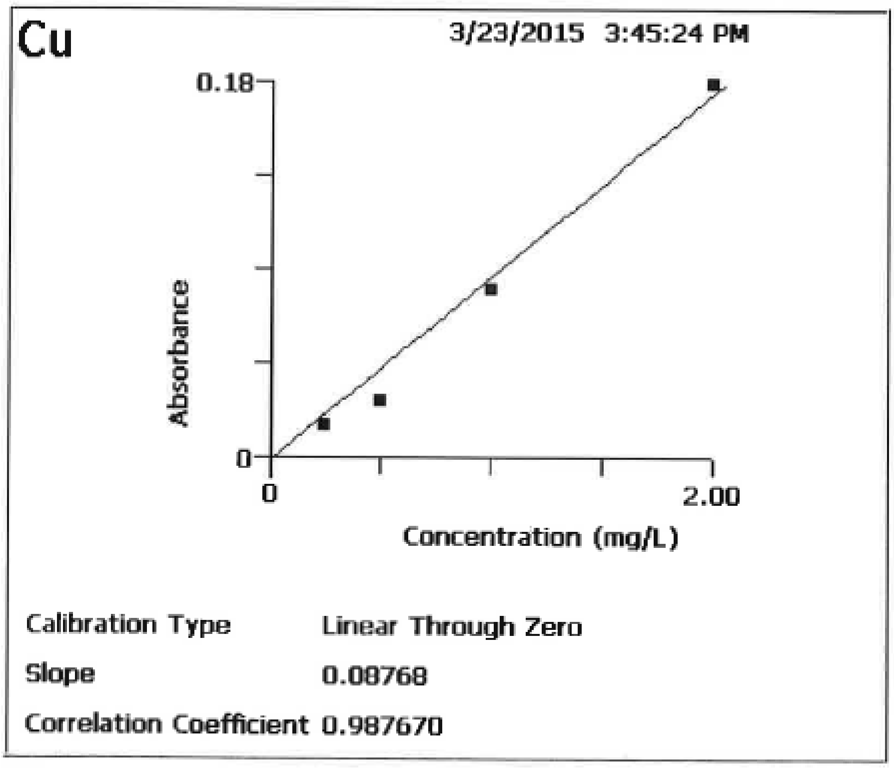
2.00
Concentration (mg/L)
Calibration Type Linear Through Zero
Slope 0.11305
Correlation Coefficient 0.999938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Concentration (mg/L)
Calibration Type Linear Through Zero
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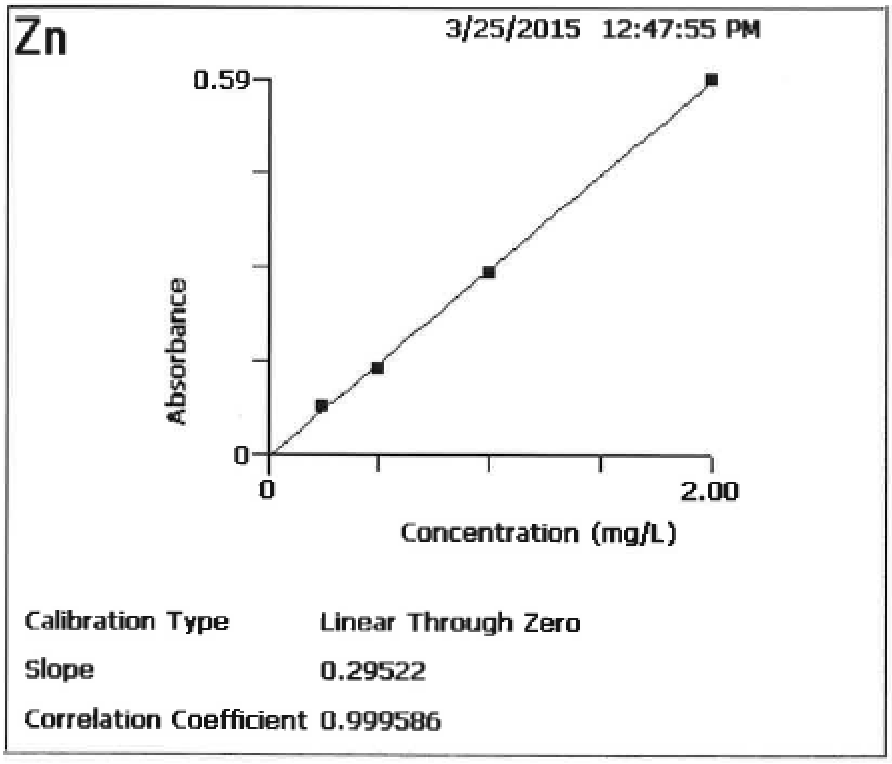
Correlation Coefficient 0.987670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Absorbance
Concentration (mg/L)
Calibration Type Linear Through Zero
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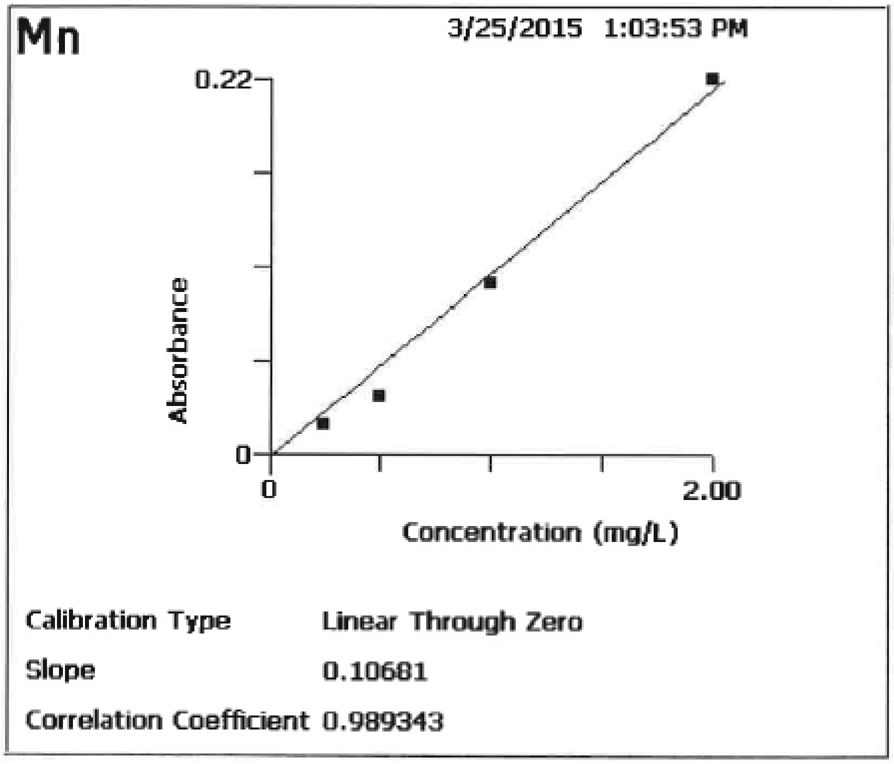
Correlation Coefficient 0.999586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Absorbance
Concentration (mg/L)
Calibration Type Linear Through Zero
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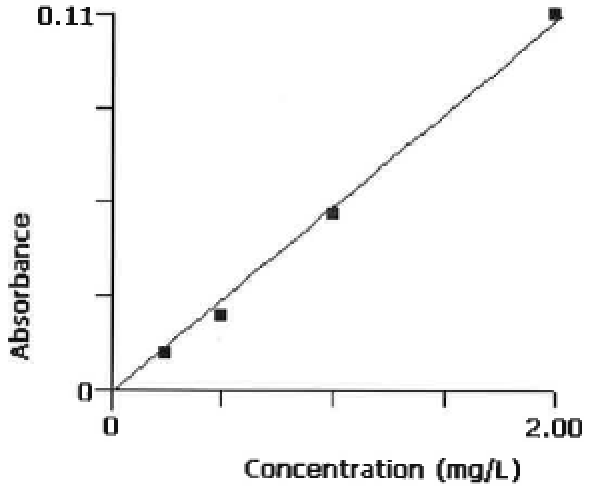
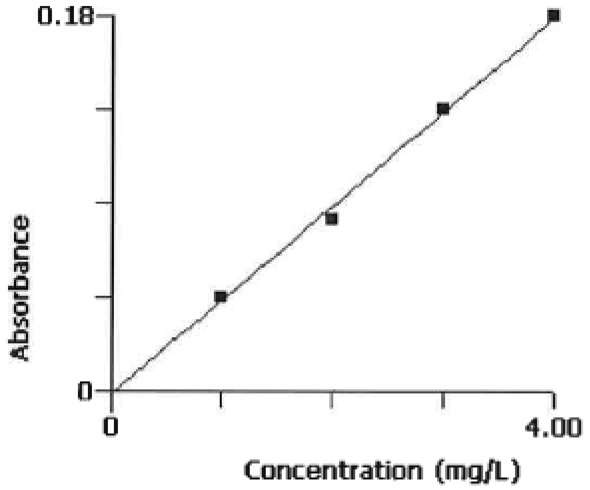
Correlation Coefficient 0.989343

Ni 3/25/2015 1:27:33 PM



Calibration Type	Linear Through Zero
Slope	0.05338
Correlation Coefficient	0.996722

Fe 3/25/2015 1:41:18 PM



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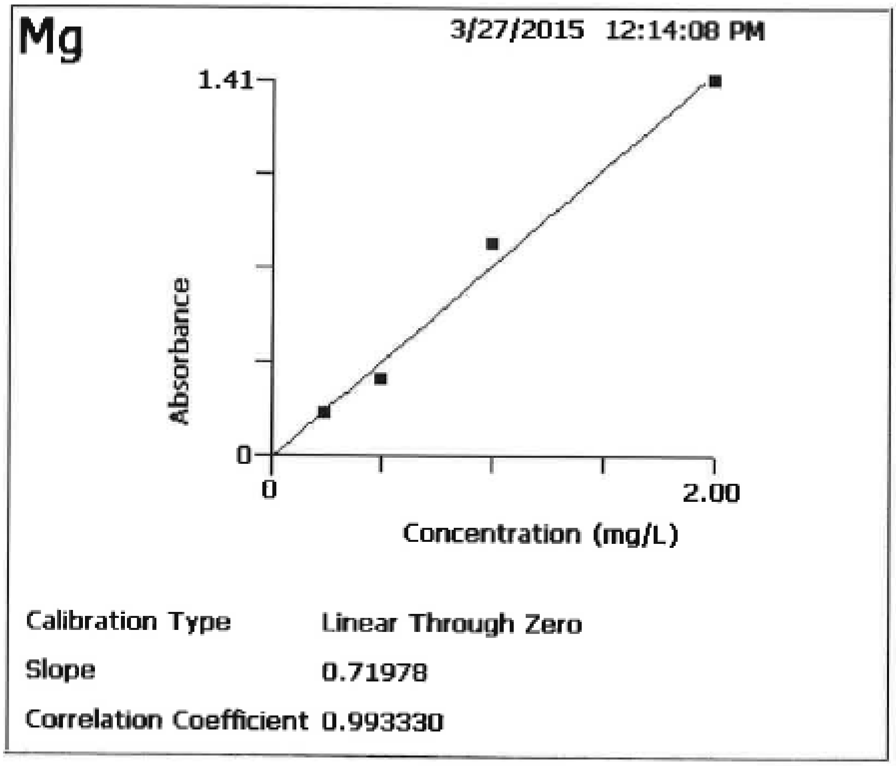
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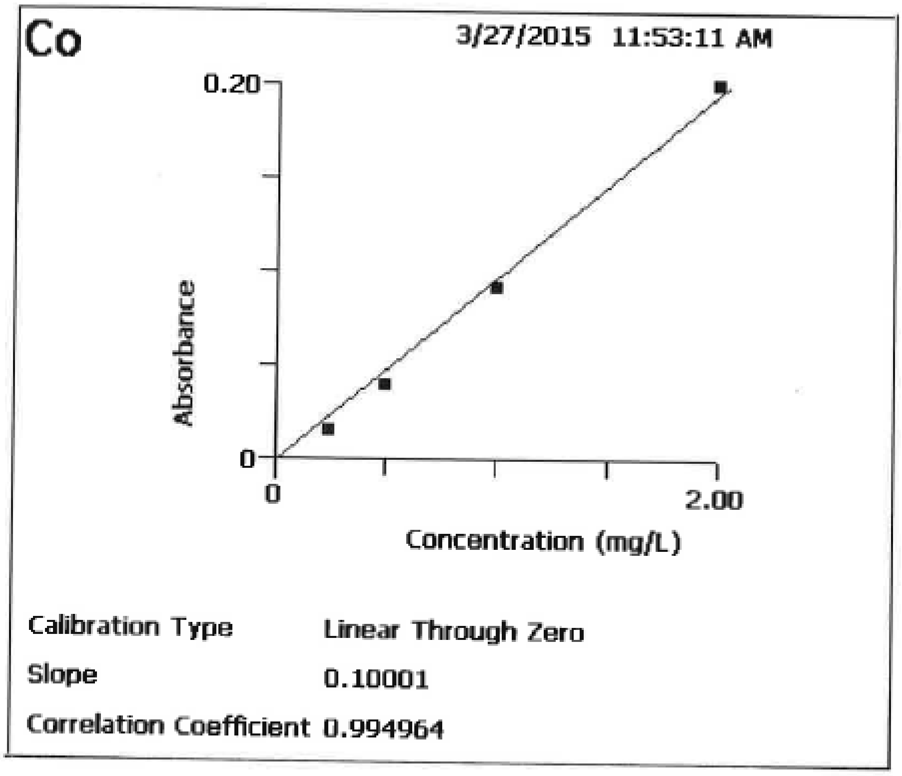
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Correlation Coefficient
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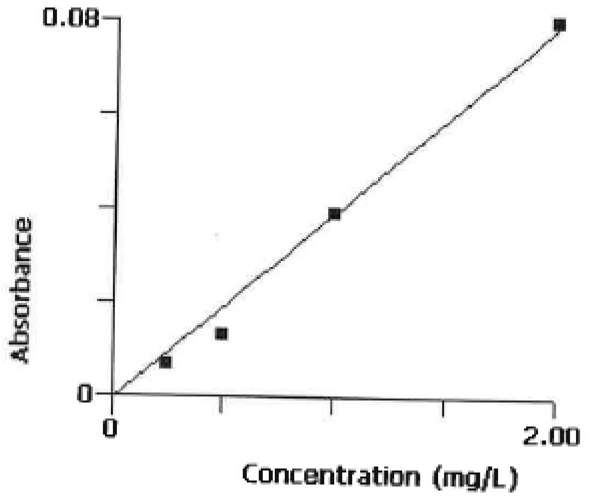
Ca 3/27/2015 12:24:35 PM



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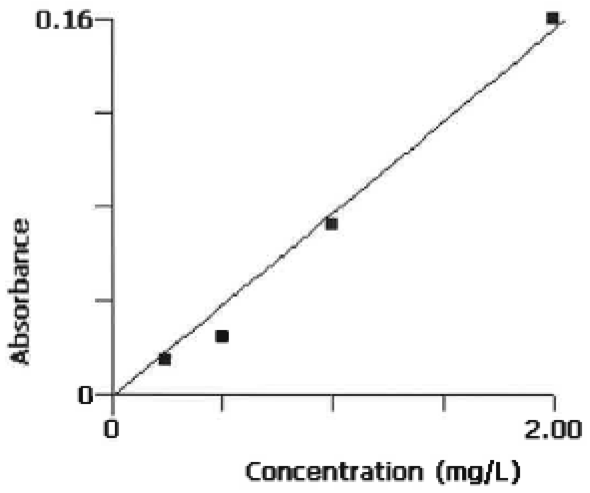
Correlation Coefficient	0.992094

Cu 3/25/2015 1:15:59 PM



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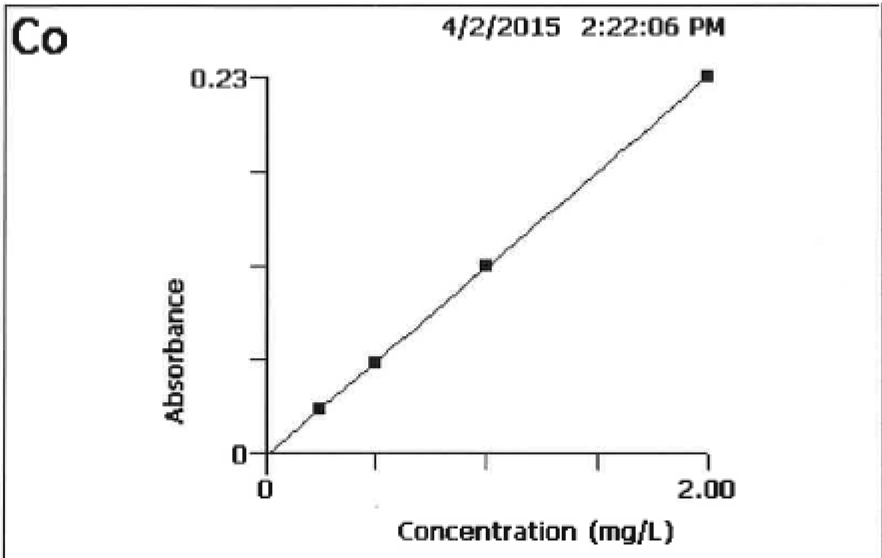
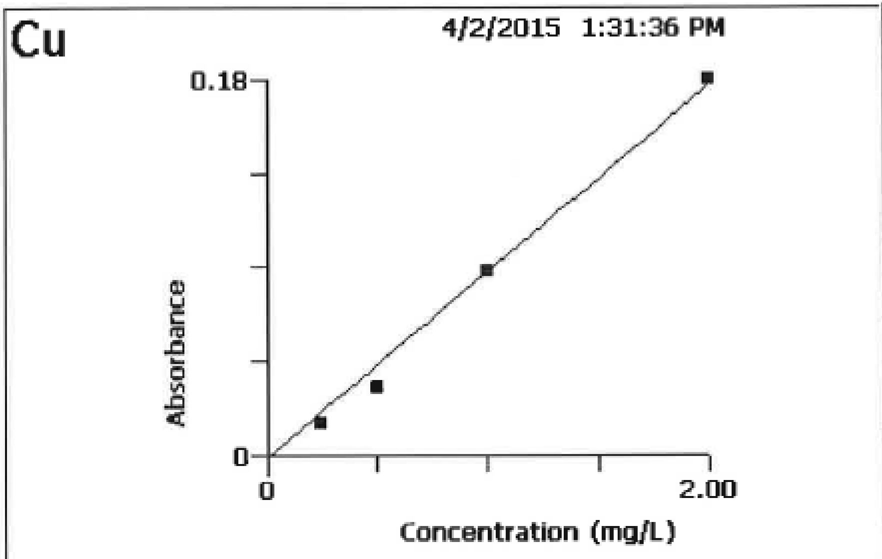
Correlation Coefficient	0.988193



Calibration Type Linear Through Zero

Slope 0.11305

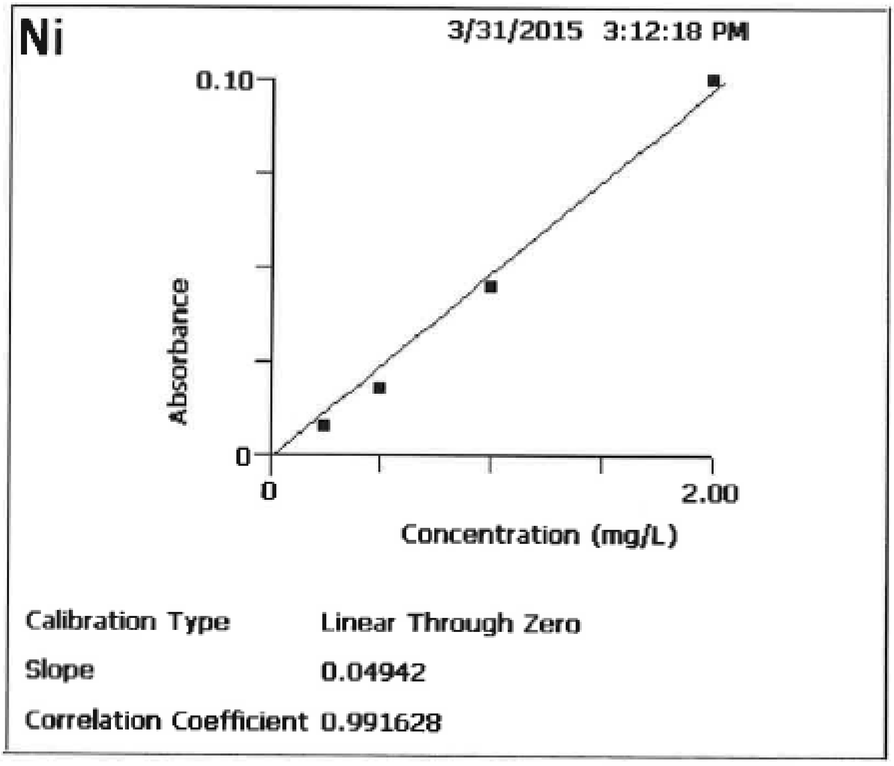
Correlation Coefficient 0.999938



Calibration Type Linear Through Zero

Slope 0.09017

Correlation Coefficient 0.994495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Calibration Type Linear Through Zero
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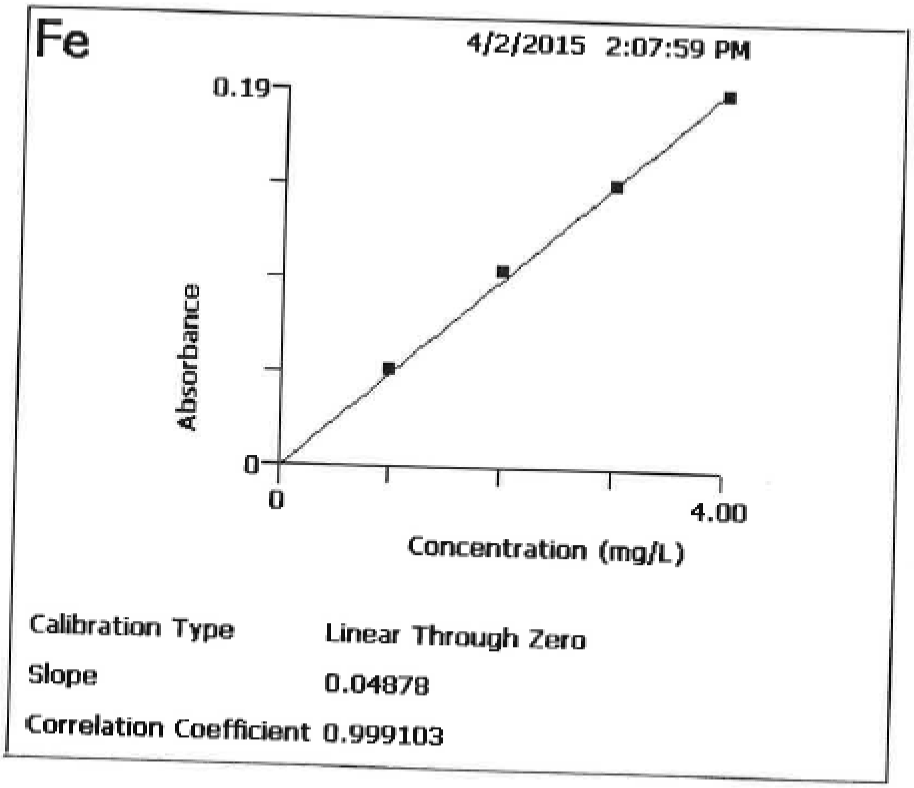
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Calibration Type Linear Through Zero
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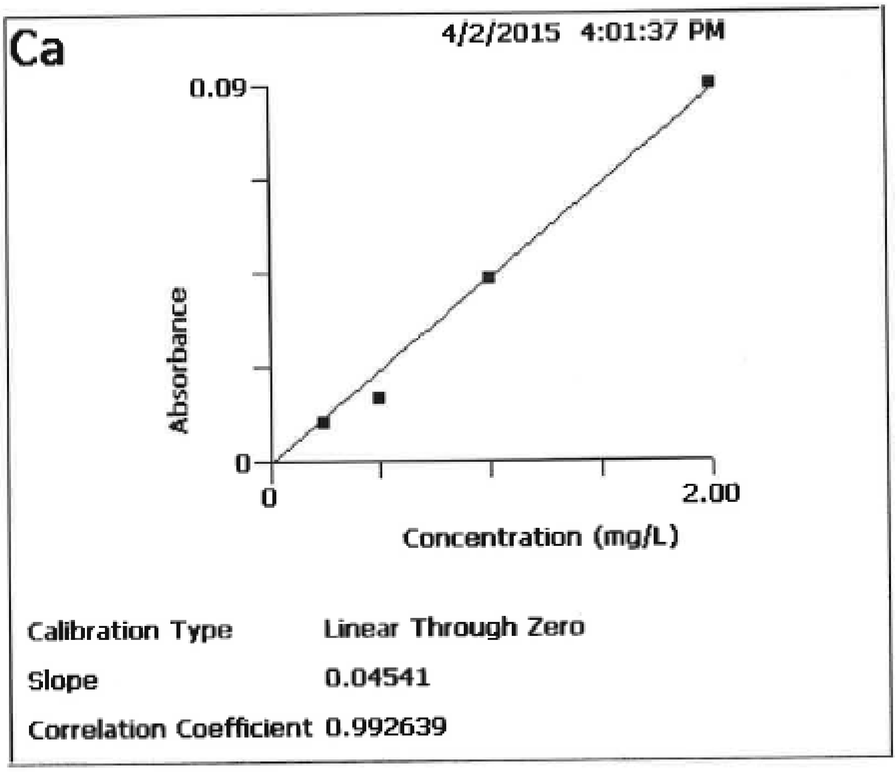
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Concentration (mg/L)
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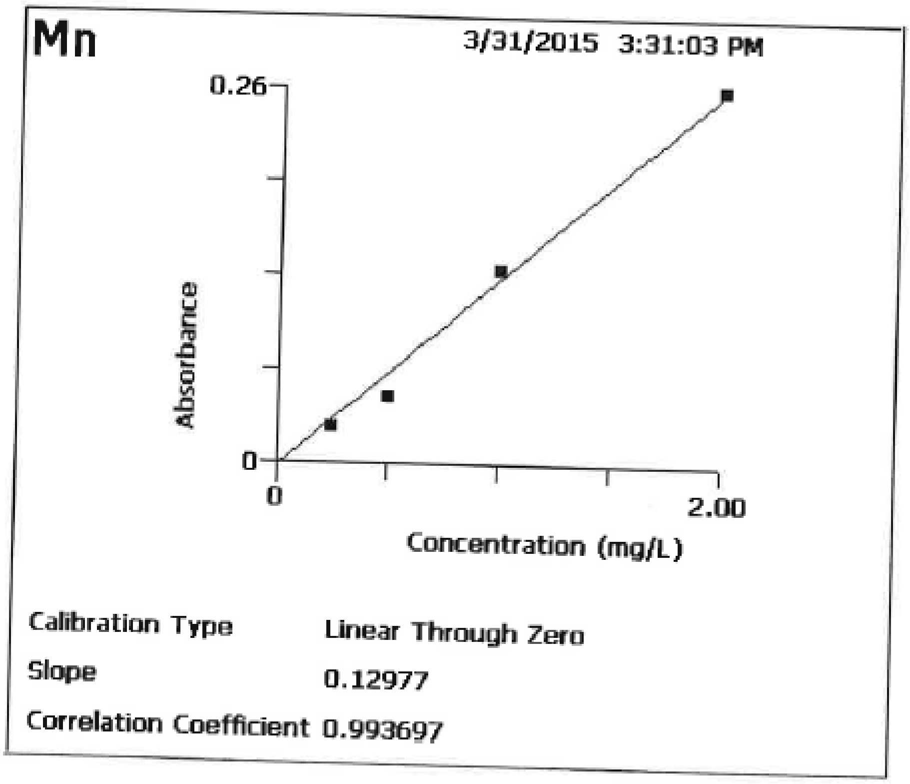
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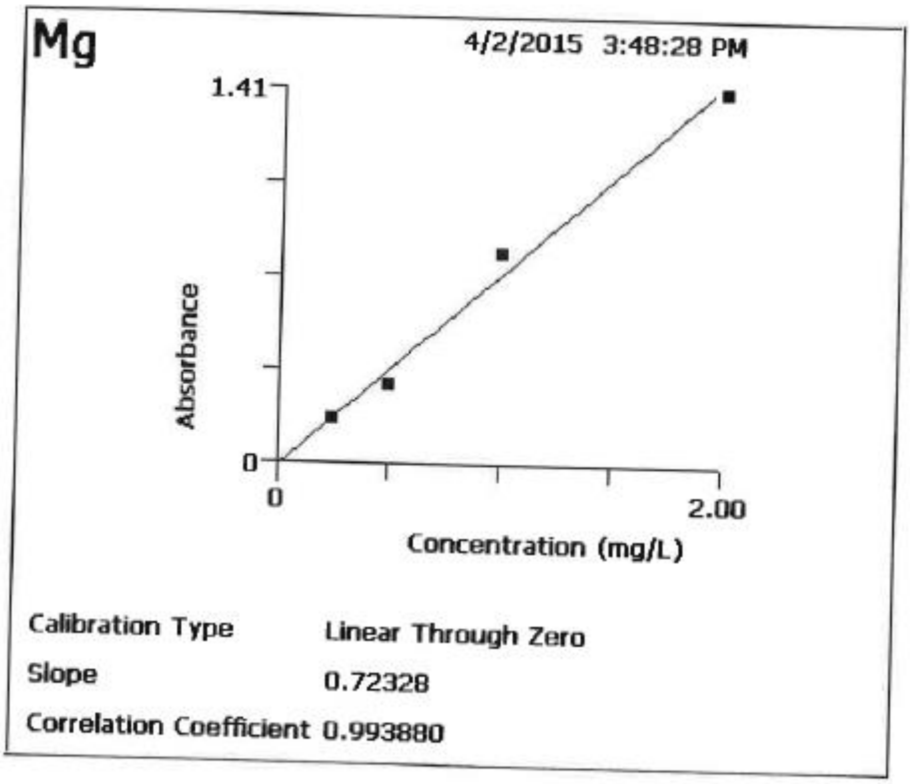
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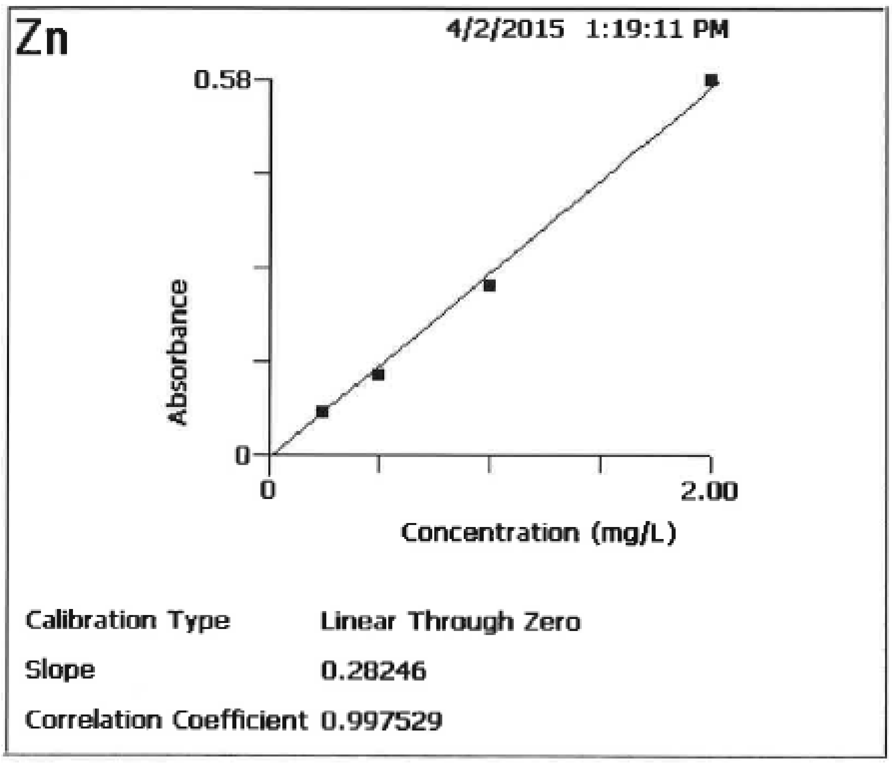
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2.00
Concentration (mg/L)
Calibration Type
Linear Through Zero
Slope
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Correlation Coefficient
0.997529