3.1Hardness Removal Results

Evaluation of hardness removal could be calculated in part per million (ppm, mg/L,or American degrees) and percentage, ppm is usually equal 1mg/L $CaCO_3$Further information about water hardness is given in table (3) below from the United State Geological Survey. (USGS)

Table (3): Water hardness classification

Hardness,mg$CaCO_3$/l	Hardness
0-60	Soft
61-120	Moderately soft
121-180	Hard
181	Very hard

The results of raw tap water quality are shown in table (4)

Table (4): total hardness of tap water

No of test	Collecting time	Volume of EDTA(cm^3)	Total hardness (ppm)
1	Feb 2011	11.00	220
2	2014	11.80	236
3	Des 2015	09.70	194

The total hardness was a major parameter of industrial water which is average of 216mg\l it is noted that the total hardness as $CaCO_3$ was considered to be very hard water and also was above the suitable allowance according to the United State Geological Survey. The water hardness is above 200mg\l may cause scale deposition in the distribution system. (WHO 2003) the resulting scale builds up can impede water flow in the system. The deposits act as thermal insulation that impede the flow of heat into the water, this is not only reduces heating efficiency, but also increases thermal energy consumption for boiling water.

The determination results of tap water through experiment by West Nile clayis given in table (5)

Table (5): %hardness removal of water by West Nile clay treated by NaOH

NaOH(M)	Hardiness equivalent to EDTA in (cm^3)	Hardness in (ppm)	%hardness removal
0.01	9.00	180	18.18
0.02	7.00	148	32.72
0.05	7.90	158	28.18
0.07	6.40	128	41.81
0.10	2.10	42	80.90
0.20	3.30	66	70.00

Table (6): %hardness of water by West Nile clay treated with KOH

KOH(M)	Hardness equivalent to EDTA in(cm^3)	Hardness in (ppm)	%hardness removal
0.01	10.20	204	7.27
0.02	9.70	192	11.81
0.05	7.20	144	35.45
0.07	6.70	134	39.09
0.10	3.00	60	72.72
0.20	2.00	40	81.81

3.1.1West Nile Clay

From the results one can notice general decreasing in tap water total hardness if clay sample treatment by NaOH or KOH. Also noticed that the total hardness decreases when increasing base concentration by which the samples are treated.

The clay which modified by base have the same properties of Na-zeolites and K-zeolites; zeolites may therefor exhibit to a greater extent the properties of ion exchange and molecular absorption. (Deer et al. 1992) According to the limits of United States Geological Survey that the good concentration of NOH and KOH are within molarities of 0.1M and 0.2M that made the water soft.

The clay used had strong exchange capacity, when stream of hard water had passed through funnel packed with modified clay particles. The process of ion exchange would not continue, indefinite, the modified clay or zeolite contained only limited number of sodium and potassium cations and they are called a cation exchange capacity and after this point the modified clay or zeolite should show some sort of saturation.

Table (7): %removal of hardness by East Nile clay treated with NaOH

NaOH(M)	Hardness equivalent to EDTA in (cm^3)	Hardness in (ppm)	%hardness removal
0.01	9.50	190	13.63
0.02	8.20	164	25.45
0.05	5.20	104	52.72
0.07	4.80	96	57.27
0.10	2.45	49	77.72
0.20	3.30	66	70.00

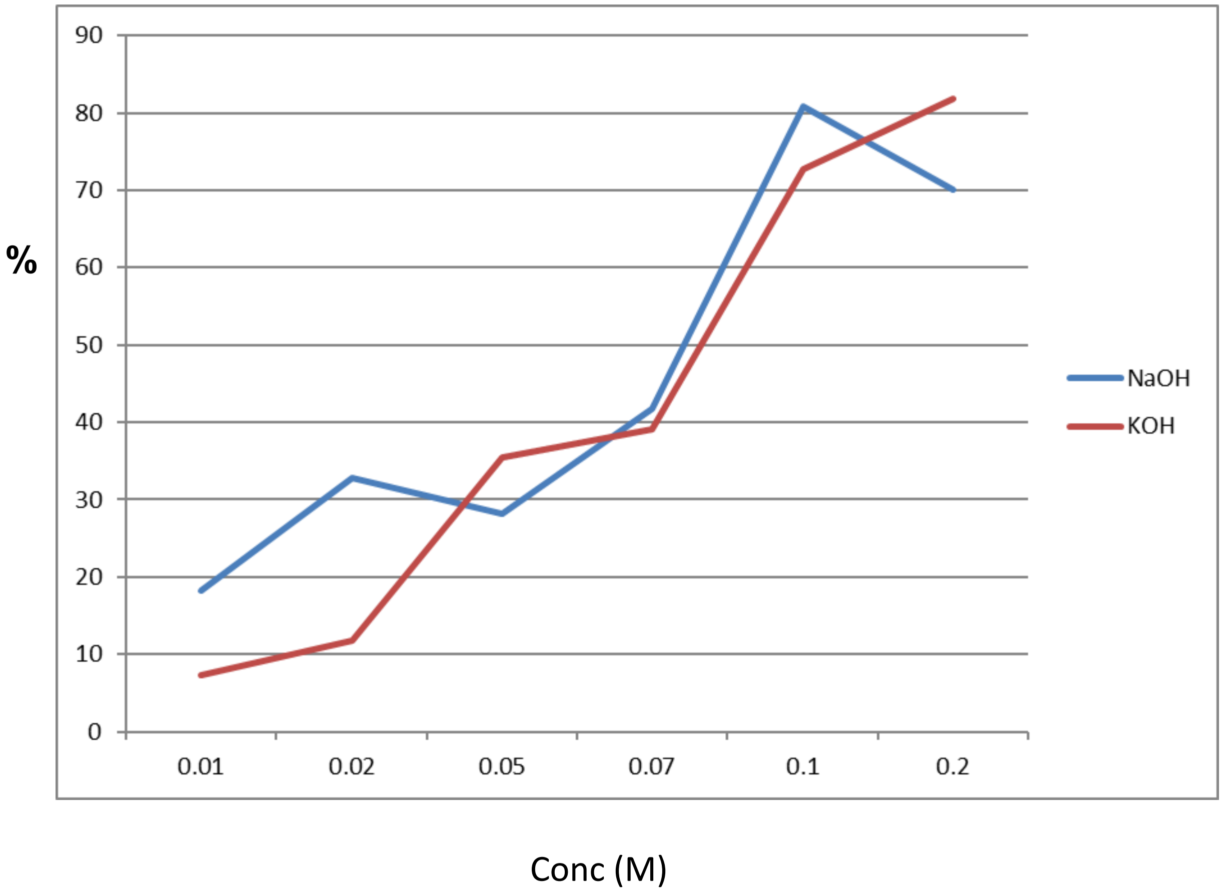


Fig (2)%removal of hardness by West Nile clay treated with NaOH and KOH

Table (8): %removal of hardness by East Nile clay treated with KOH

KOH(M)	Hardness equivalent to EDTA in cm^3	Hardness in ppm	%hardness removal
0.01	10.50	210	04.45
0.02	10.20	204	07.27
0.05	08.80	176	20.00
0.07	05.55	111	49.54
0.10	03.00	60	72.72
0.20	02.00	40	81.8

Table 7 and 8 show that KOH was generally better in hardness removal .

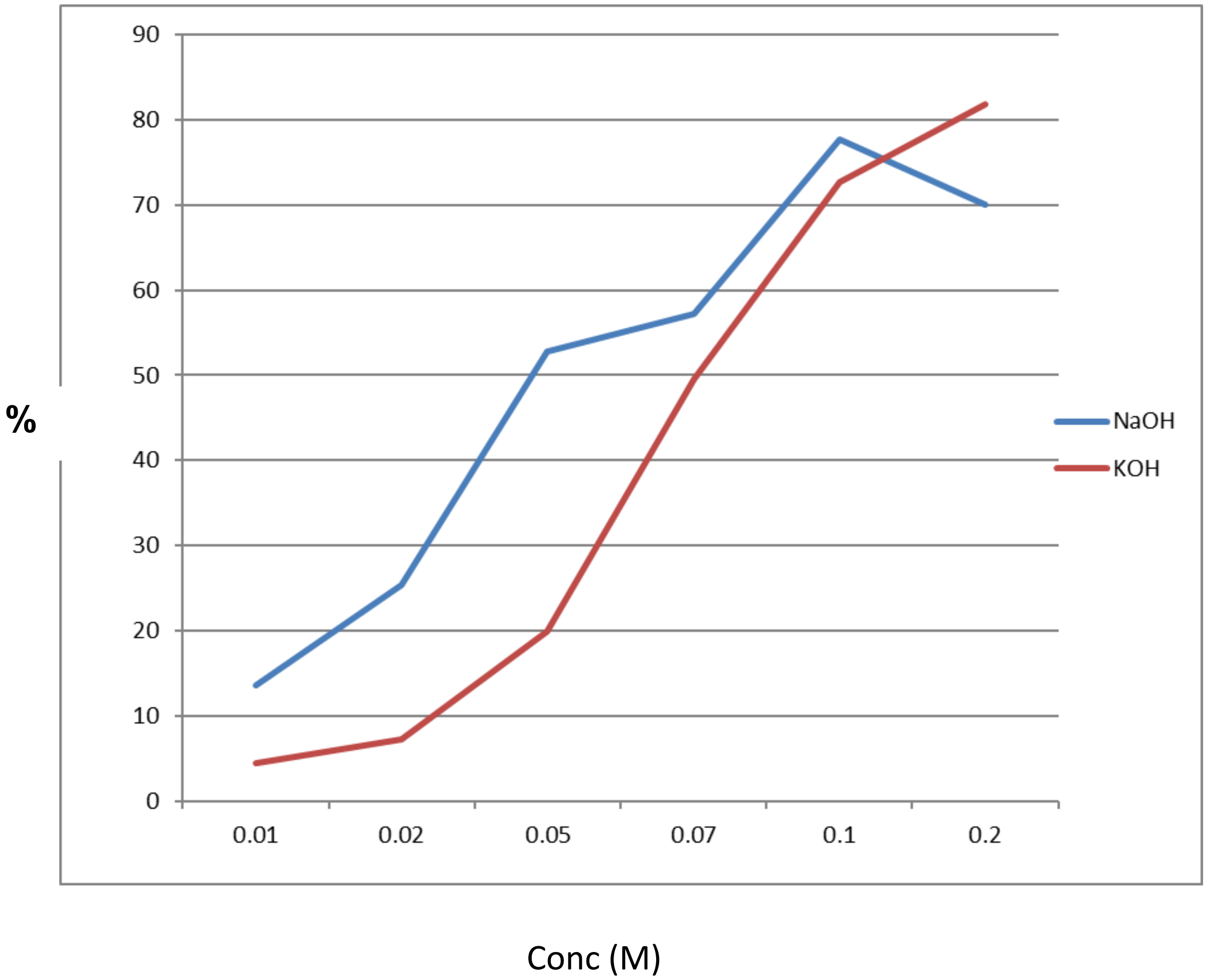


Fig (3)% removal of hardness by East Nile clay treated with NaOH and KOH

3.1.2 East Nile clay

In table (7) the hardness removal by 0.05,0.07,0.1and 0.2MNaOH were 52%,57,77 and 70%,respectively, while in table (8), when the clay treated with KOH, hardness removal were 20,49,72 and 81%.with lower concentration as 0.05 M NaOH was more effective than KOH, which indicated that Na^+ cation were more available for ion exchange process than K^+cation. But in high concentration0.1M,0.2M the results indicated KOH was better than NaOH.

When the clay was used in filtration the process was not continued, the wet clay prevented further filtration by making glutinous mud. Whencompared the hardness removal by 0.1 and 0.2M in table (5)[77%, 70% respectively]. The presence of inert material like sand ,gravel, glass beads and peace of marble prevented accumulation of clay particles, and also increased the surface area of the clay that exposed to stream of hard water, for ion exchange process, and eased and increased the flow rate of hard water in the funnel.

3.1.3Blue Nile clay results

Table (9): %removal of hardness by Blue Nile clay treated with NaOHandKOH

NaOH(M)	%hardness removal	KOH(M)	%hardness removal
0.01	05.90	0.01	8.60
0.02	15.00	0.02	14.09
0.05	32.27	0.05	10.00
0.07	40.00	0.07	41.36
0.10	77.27	0.10	62.72
0.20	65.45	0.20	-----

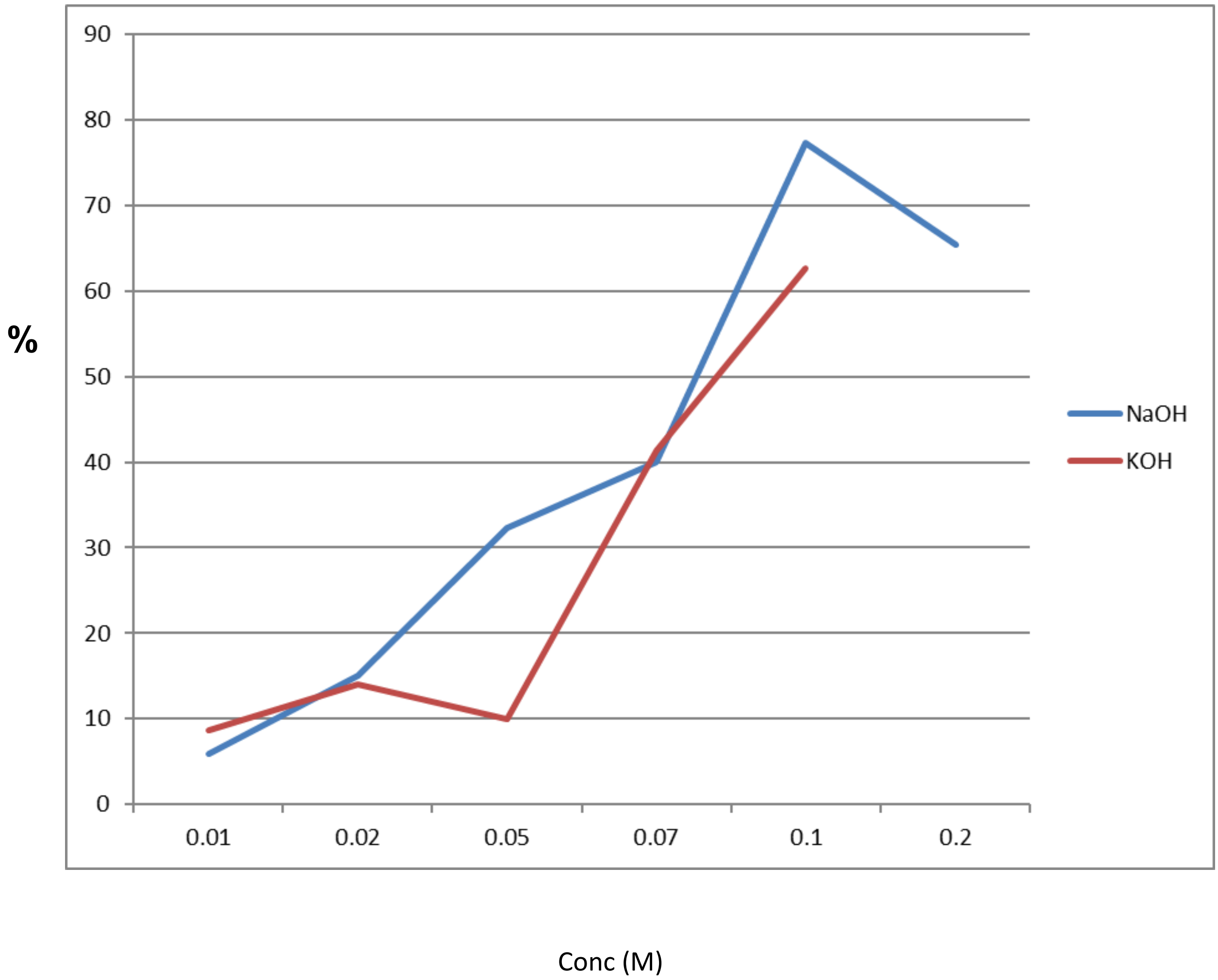


Fig (4)%removal of hardness by blue Nile clay treated with NaOH and KOH

3.1.4West Soba clay Results

Table (10): %removal of hardness by West Soba earth treated with NaOHand KOH solutions

NaOH(M)	%hardness removal	KOH(M)	%hardness removal
0.01	18.18	0.01	18.18
0.02	18.18	0.02	18.18
0.05	27.27	0.05	15.00
0.07	30.00	0.07	13.60
0.10	50.30	0.10	45.45
0.20	60.00	0.20	48.90

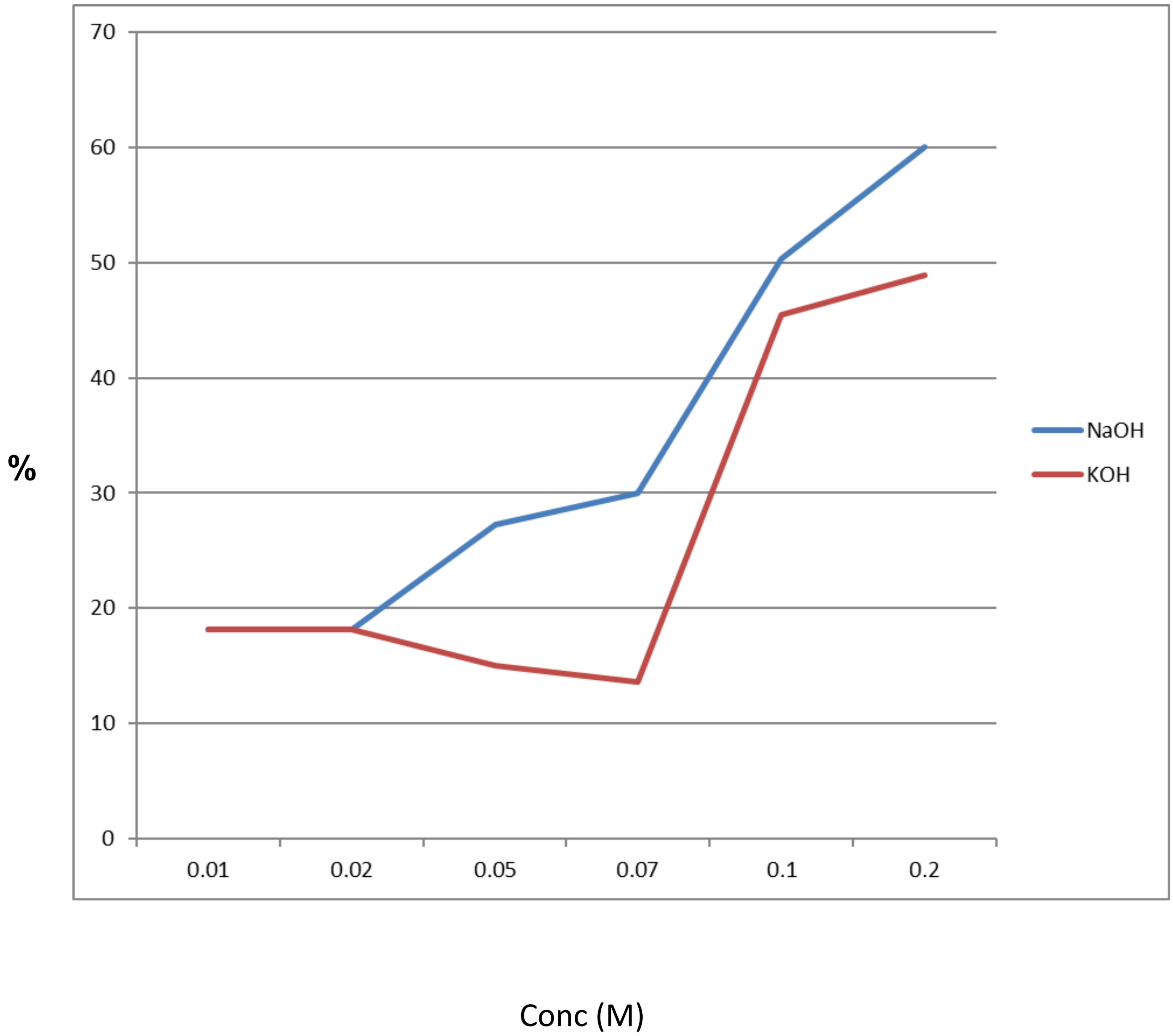
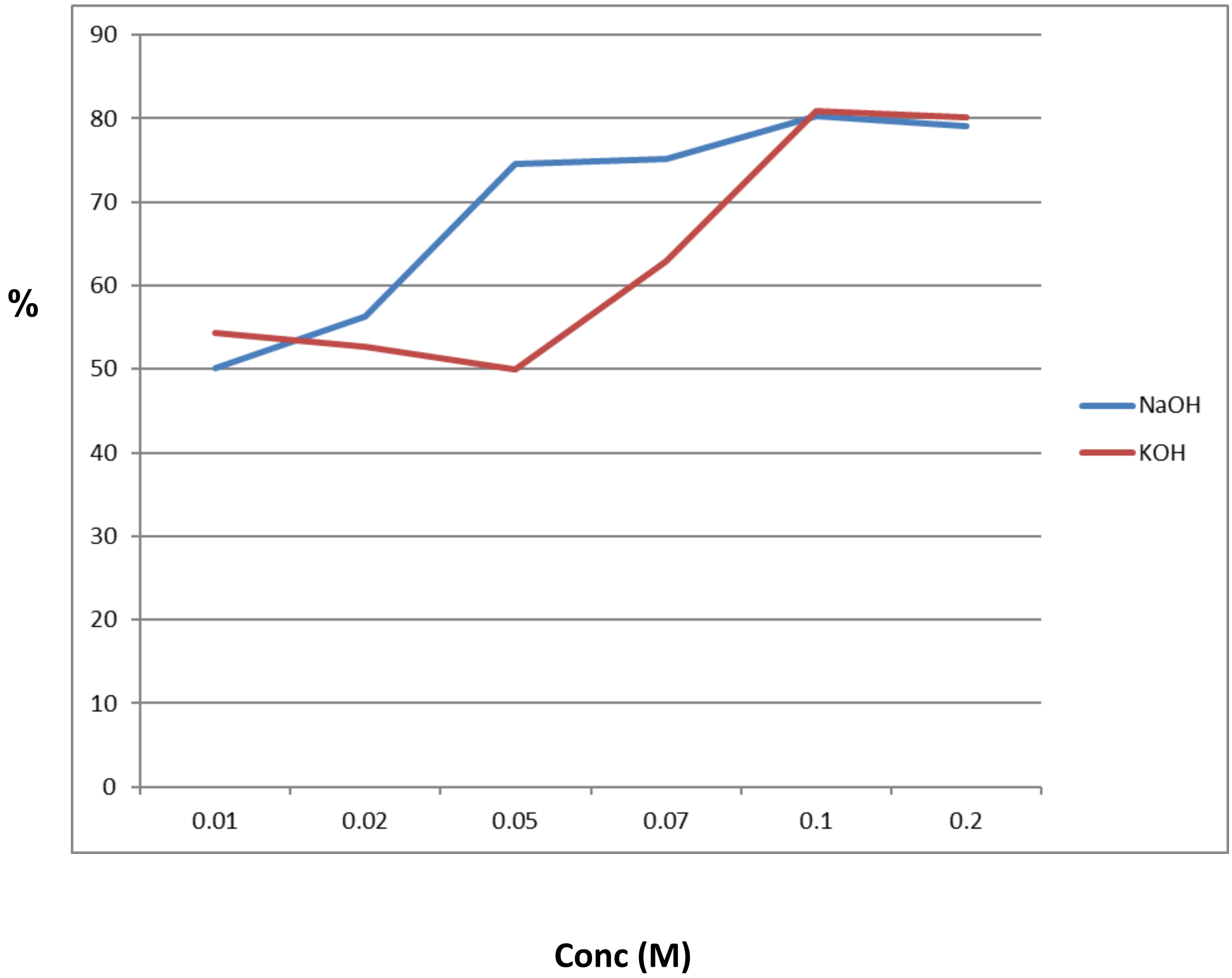


Fig (5) %removal of hardness by West Soba earths treated with NaOH and KOH

3.1.5Jurdiga clay results:

Table (11): %removal of hardness by Jurdiga treated with NaOH and KOH solution

NaOH(M)	%hardness removal	KOH(M)	%hardness removal
0.01	50.18	0.01	45.30
0.02	56.36	0.02	52.72
0.05	74.54	0.05	50.00
0.07	75.20	0.07	63.00
0.10	80.30	0.10	80.90
0.20	79.09	0.20	80.20



<u>Fig (6) %removal of hardness by Jurdiga treated with NaOH and KOH</u>

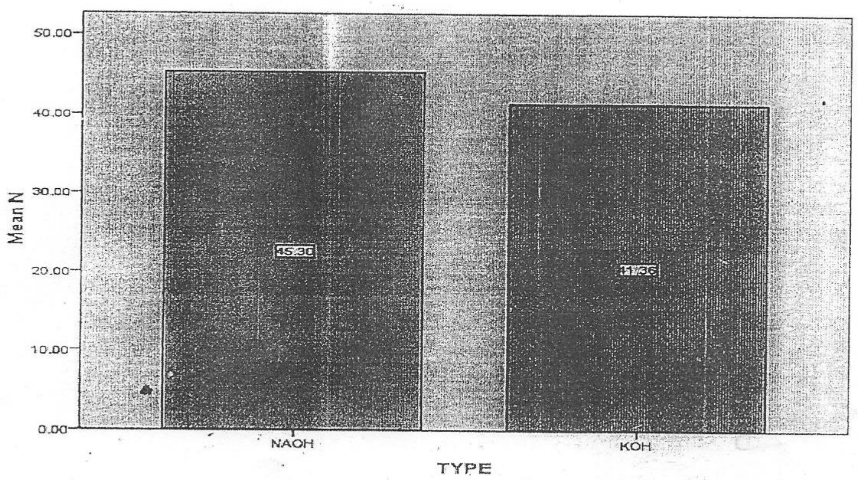
Table (12) rating of the clays beginning with the best type in hardness removal of industrial water

Origin of the clay	Concentration of base(M)	%hardness removal
1-Jurdiga	A-0.1M NaOH B-0.1 M KOH	A-80.30 B-80.90
2-West Nile clay	A- 0.1MNaOH B-0.1MKOH	A-77.72 B-72.72
3-East Nile clay	A- 0.1MNaOH B - 0.1MKOH	A-77.27 B-72.72
4-Blue Nile clay	A- 0.1MNaOH B-0.1MKOH	A-77.27 B-62.72
5-West Soba	A - 0.1M NaOH B-0.1M KOH	A-50.30 B-45.45

The statistical studies results by independent sample test for the purpose of comparison of the results when using NaOH or KOH revealed that there was no immaterial difference between the two ingredient means of all samples fig 6,7,8,9, and 10

Group Statistics

	TYPE	N	Mean	Std. Deviation
N	NAOH	6	45.2983	24.80514
	KOH	6	41.3583	30.64331



Fig(7) comparison of bases by independent sample T-test of West Nile clay

Group Statistics

	TYPE	N	Mean	Std. Deviation
N2	NAOH	6	49.4650	25.10941
	KOH	6	44.4317	31.91961

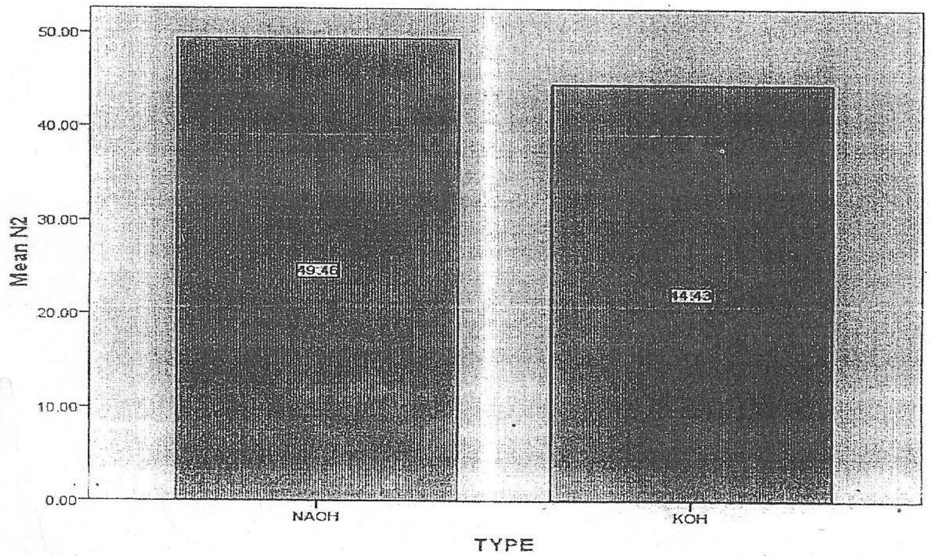
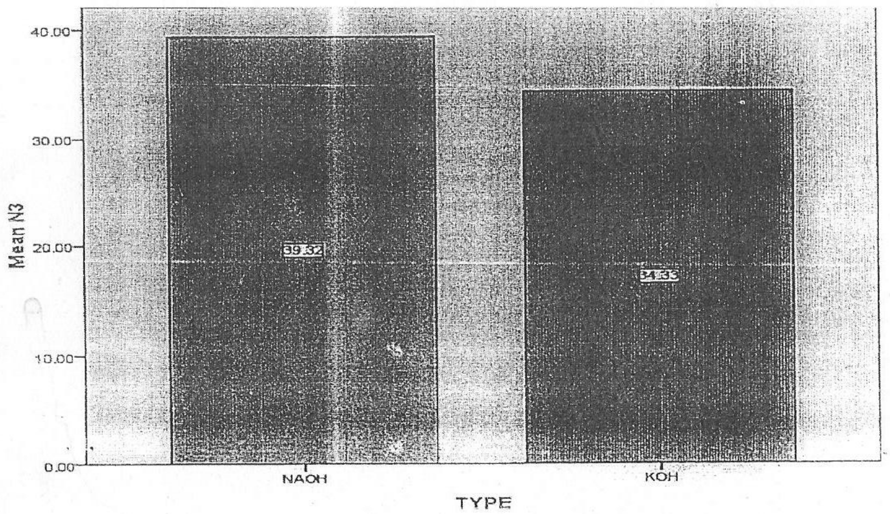


Fig (8)comparison of bases by independent sample T-test of East Nile clay

Group Statistics

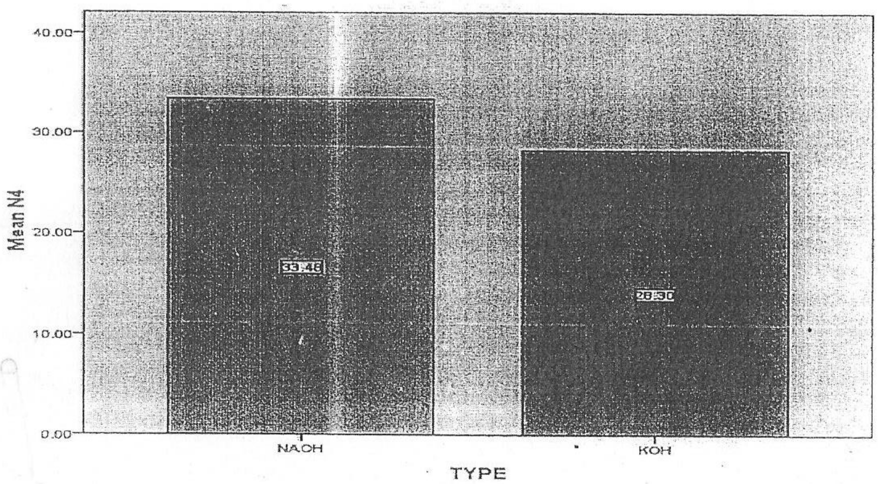
	TYPE	N	Mean	Std. Deviation
N3	NAOH	6	39.3150	27.86217
	KOH	6	34.3333	27.32554



Fig(9)comparison of bases by independent sample T-test of Blue Nile

Group Statistics

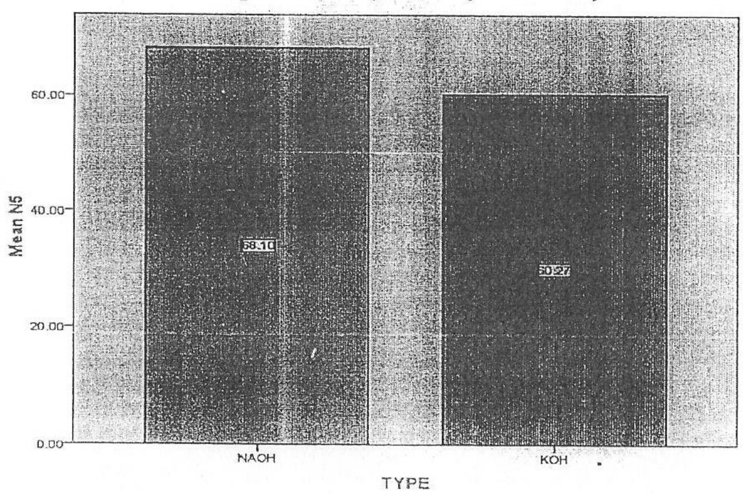
	TYPE	N	Mean	Std. Deviation
N4	NAOH	6	33.4800	19.11480
	KOH	6	28.3033	17.86048



Fig(10)comparison of bases by independent sample T-test of WestSoba

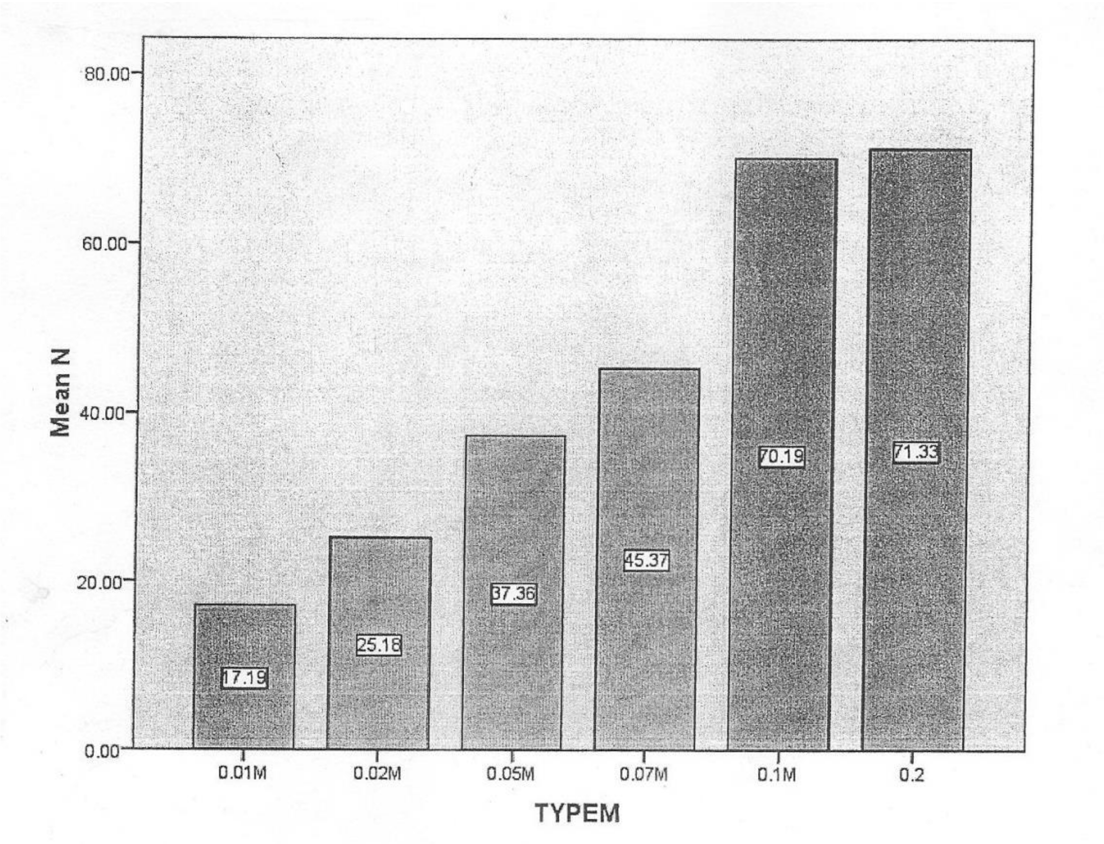
Group Statistics

	TYPE	N	Mean	Std. Deviation
N5	NAOH	6	68.0967	14.90653
	KOH	6	60.2667	17.27851



Fig(11)comparison of bases by independent sample T-test of Jurdiga

As for the knowledge of the results obtained when using different concentrations for each ingredient separately, the results were statistically treated by ANOVA program.



Fig(12) histogram by ANOVA

one noticed some differences when using concentrations to find out that the concentration by which one can obtain high percentage of hardness removing was 0.1Mand 0.2M. However from economical aspect one can find that the percentage of competency of removing the total hardness was by using concentration 0.1M through NaOH only.

3.2Pilot plant experiment studyresults:

The results of tap water quality through designed bed are given in table (13)

Table (13): % hardness removal by West Nile clay treated with 0.1MNaOH before and after calcination at 400^0C

No of liters	%hardness removal before calcination	%hardness removal after calcination
1	74.58	55.67
2	58.05	54.63
3	36.86	40.20
4	32.20	64.43 2L
5	32.20	------
6	30.51	60.82
7	41.10	38.65
8	33.89	31.44
9	22.88	10.82
10	30.93	46.39
11	43.64	36.08
12	-	31.95
13	-	38.14
14	-	43.81
15	-	32.98
16	-	30.98
17	-	30.92

Table (14):%hardness removal by East Nile clay treated with 0.05MNaOH before and after calcination

No of liters	%Hardness removal before calcination	%Hardness removal after calcination
1	65.25	65.46
2	35.75	65.46
3	-	55.67
4	57.20	55.67
5	38.98	48.45
6	49.15	48.45
7	44.49	47.42
8	11.86	47.42
9	53.39	10.82
10	50.00	10.82
11	48.31	14.43
12	43.22	10.82
13	54.24	28.86
14	53.39	22.68
15	30.93	21.64
16	53.39	17.52
17	44.91	-

Table (15): %hardness removal by Blue Nile treated with o.1MNaOH before andafter calcination at 400^0C

No of liters	%harness removal before calcination	%hardness removal after calcination
1	51.27	63.91
2	32.63	50.51
3	61.06	30.41
4	44.92	29.89
5	59.75	63.91
6	51.27	34.02
7	44.92	26.28
8	58.05	22.68
9	43.22	-
10	49.15	-
11	38.14	-
12	8.47	-
13	34.75	-
14	40.68	-
15	38.13	-
16	45.76	-
17	49.92	-
18	44.92	-
19	35.17	-
20	42.79	-
21	29.66	-

Table (16): % hardness removal by West Soba treated with 0.1MNaOH before and after calcination at 400^0C

No of liters filtered	%hardness removal before calcination	%hardness removal after calcination
1	73.19	65.97
2	87.62	64.94
3	73.19	38.14
4	72.85	27.83
5	56.70	26.28
6	38.14	25.25
7	65.97	27.83
8	53.60	25.25
9	37.11	-
10	32.89	-
11	25.77	-
12	27.38	-

3.3Characterization of clay:

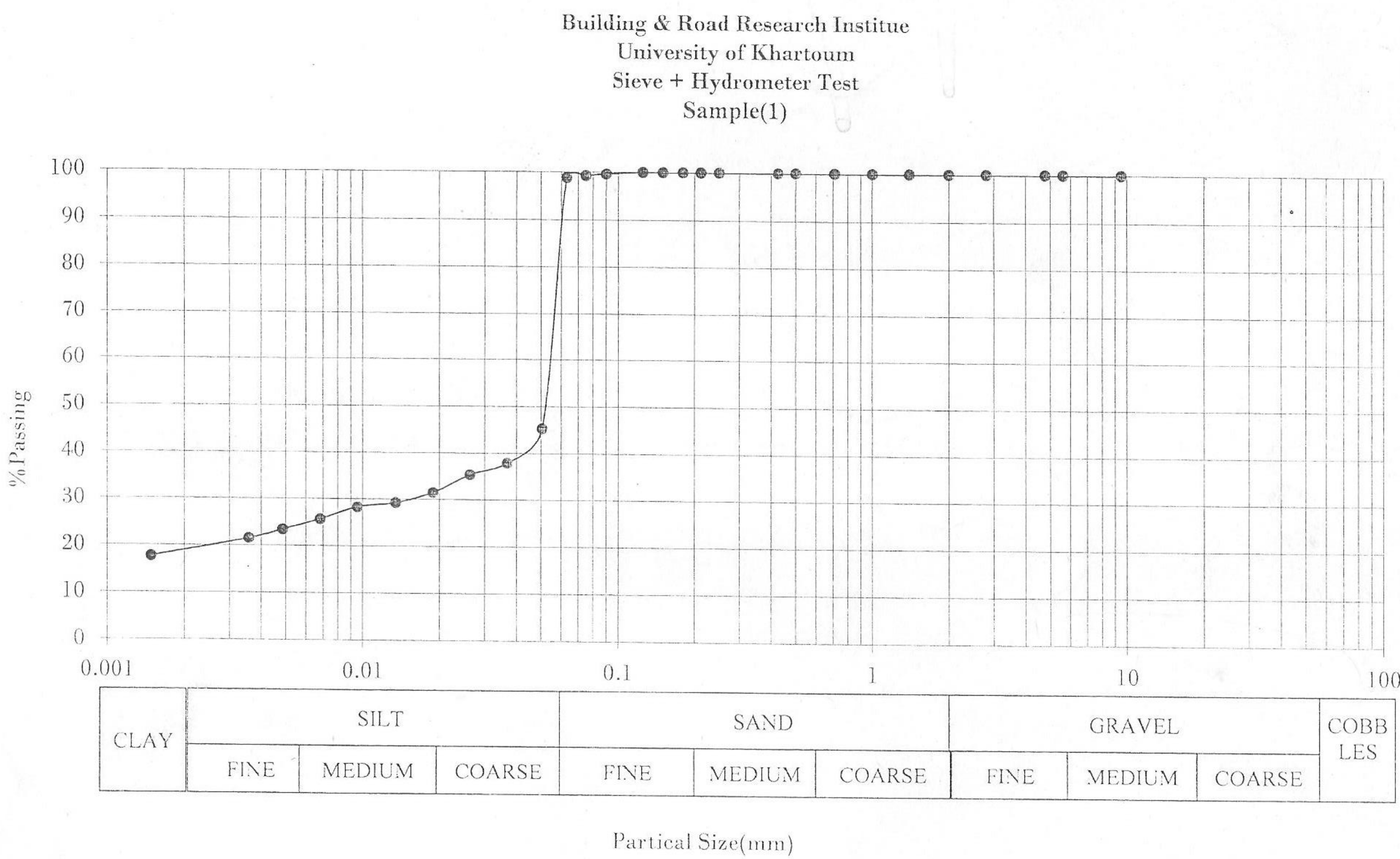
3.3.1grain size distribution:

The use of the grain size helps in soil characterization. Clay must carry at least 35% of the clay separate and in most cases not less than 40% (Zhang et al. 2004) in the results sample 1, 2, 3 are silty clays but sample 4 is 5o% silt and 50% fine sands.

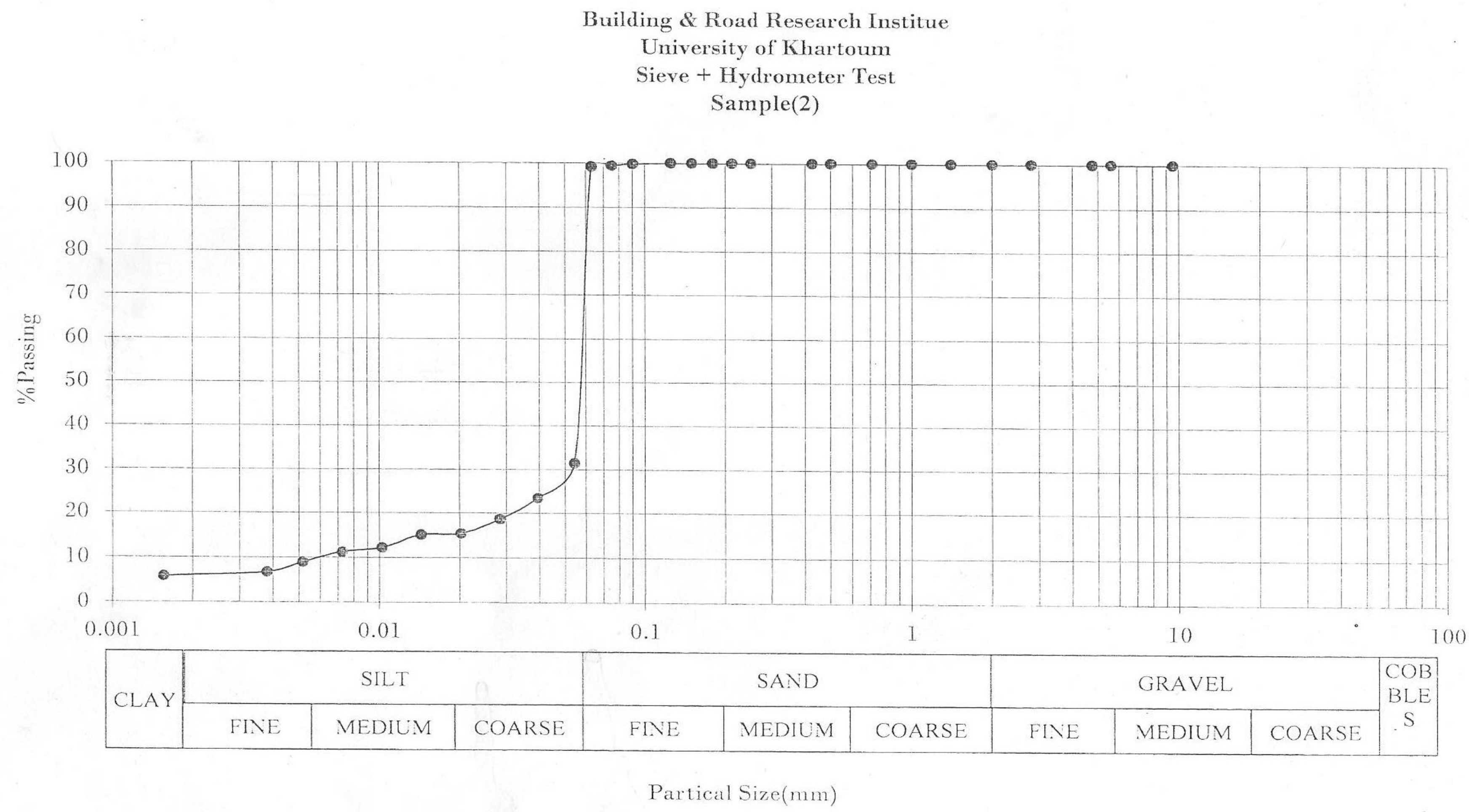
Table(17): grain size distribution types

Type %		1	2	3	4
Clay		17	5	9	0
Silt	Fine	28	25	41	50
	Medium				
	Coarse				
Sand	Fine	45	70	50	50
	Medium				
	Coarse				

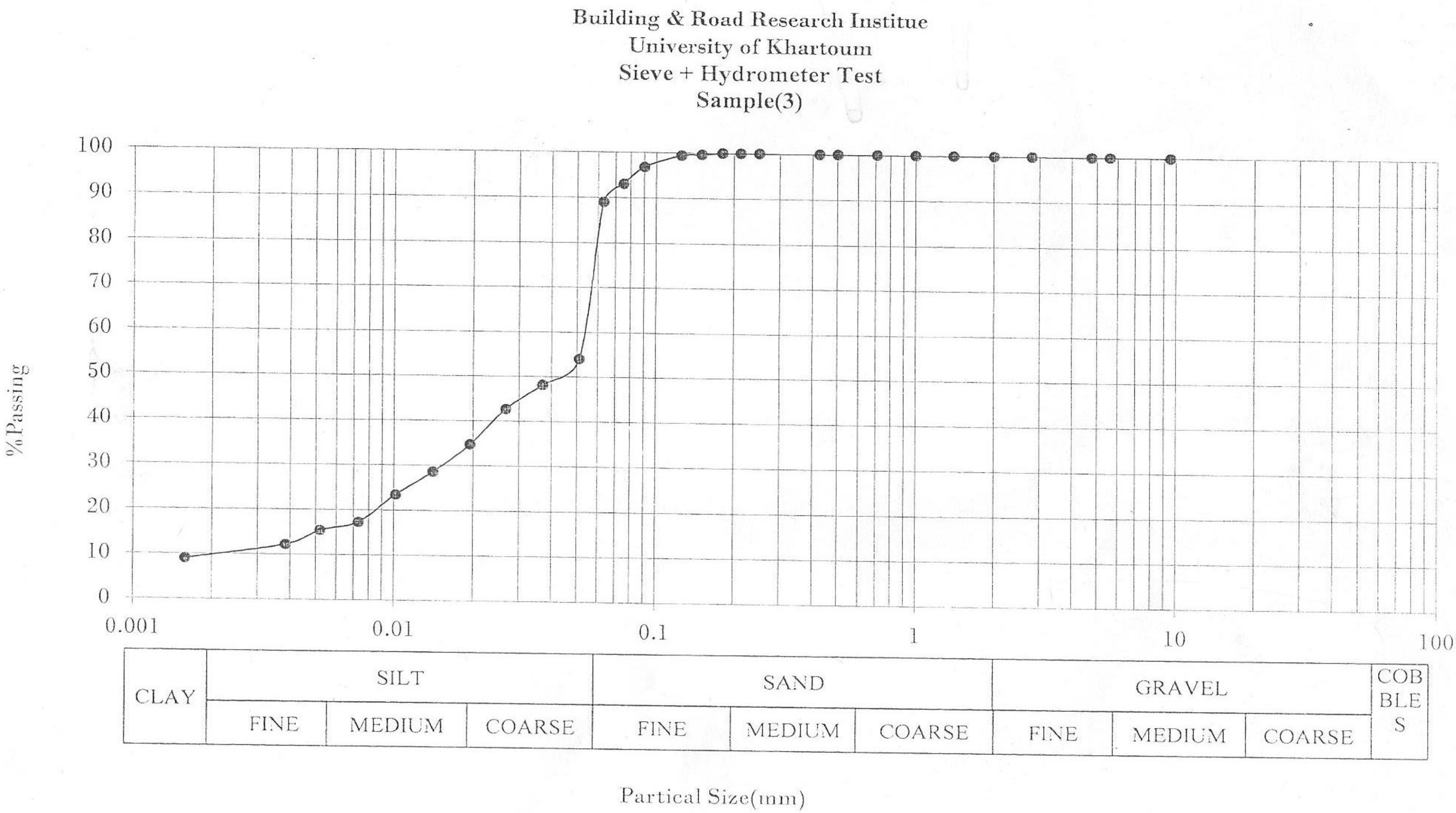
It appears from the table the percentage clay is small to no clay as in sample 4 the samples are silt soils together with fine sands.



Fig(13) grain size distribution of sample (1)



Fig(14) grain size distribution of sample (2)



Fig(15) grain size distribution of sample (3)

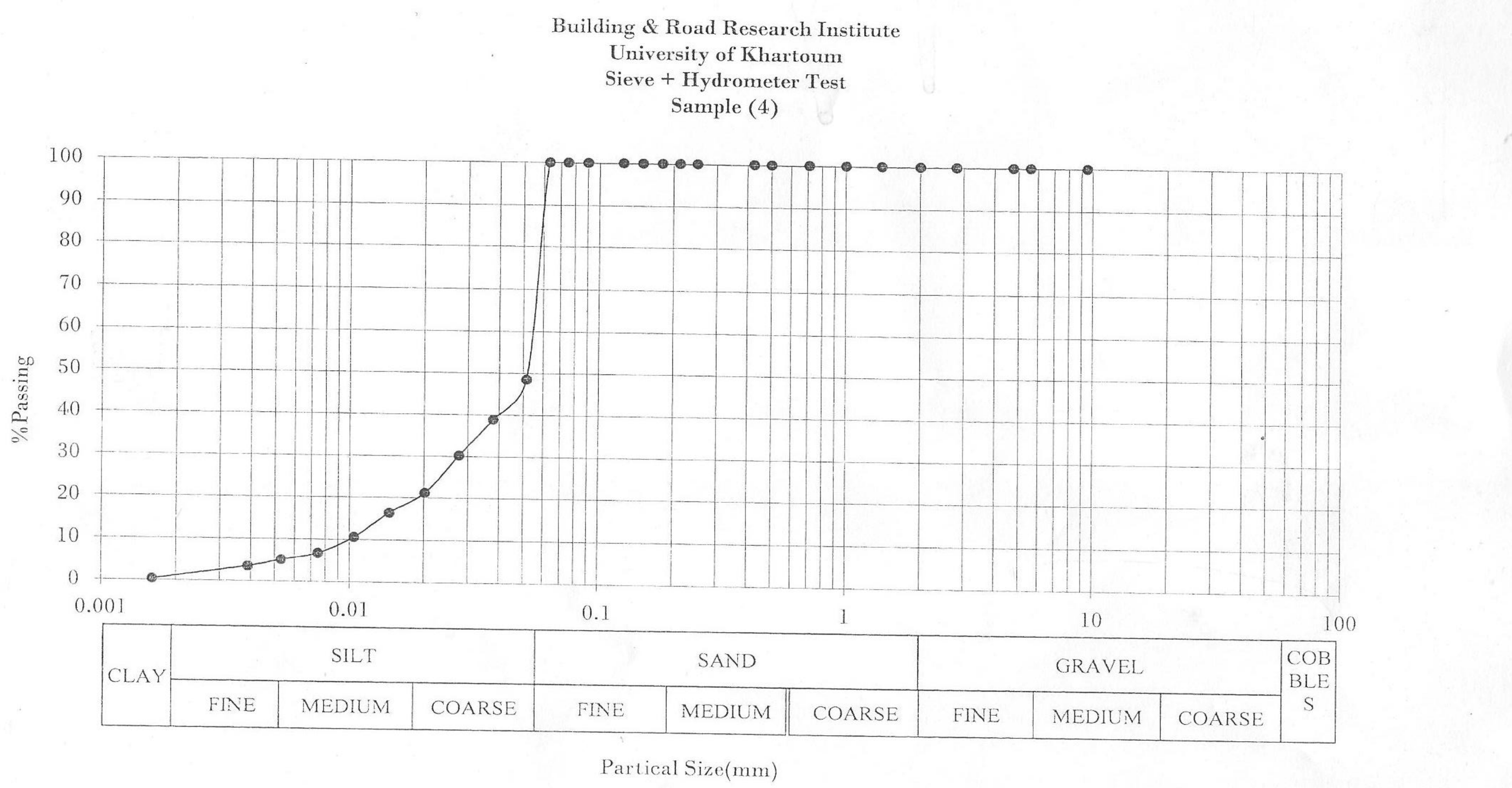


Fig (16) grain size distribution of sample(4)

3.3.2 Chemical analysis

Five types of clays were analyzed by gravimetric and titrimetric analysis and flame photometric to determine the elements of clay as oxides. The results are given in table (18) andtable (19)

Table (18): gravimetric and titrimetric results

Sample / Test	Results, %by mass				
	1	2	3	4	5
Loss on ignition	11.52	9.36	12.14	11.99	11.69
Silica, as SiO_2	47.94	49.76	48.49	49.35	48.65
Ferric oxide, asFe_2O_3	4.78	5.17	3.17	2.79	4.00
Aluminum oxide, as Al_2O_3	24.14	26.64	28.50	26.45	23.76
Calcium oxide, as CaO	9.42	8.10	6.41	6.88	7.80
Magnesium oxide, asMgO	0.61	0.77	0.12	0.34	0.05
Sulphate SO_3	-	-	-	0.83	3.19

It is clear from the table that the chemical analysis of the clay contains silica, alumina, calcium in major quantities and the others elements are in minor quantities. The loss on ignition value indicates that clay has lower carbonaceous matter and higher mineral matter contents.

Table (19): flame photometric results for determination of Na^+ and K^+

No of sample	Na^+ mg/l	K^+ mg/l
1	0.10	0.13
2	0.07	0.13
3	0.10	0.22
4	0.15	0.25
5	0.14	0.22

3.3.3XRF Results

X-ray analysis can be used for the determination of major elements; however it is also very sensitive to accurate determinations of some trace elements components.

Four clay samples are reported in table 20and 21, the same samples were analyzed by previous chemical analysis.

Table (20): XRF result

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المختبر الكيميائي
الخرطوم – شارع النيل . ص . ب 410

METHODS: XRF

ENTERY DATE0: 20/ 01/ 2016

RECIPE : AXIOS

RPORT NO : 43

CLAIBATION : OMNIAN

Lab NO	708	709	710	711	UNIT
Sender No	1	2	3	4	%
Na2O	1.027	1.197	1.129	0.909	%
MgO	3.114	2.977	2.875	2.617	%
Al2O3	19.646	18.078	19.691	20.458	%
SiO2	53.597	54.944	54.224	54.331	%
P2O5	0.329	0.314	0.343	0.320	%
SO3	0.058	0.047	0.055	0.062	%
Cl	0.013	0.015	0.014	0.012	%
K2O	1.018	1.026	0.990	0.977	%
CaO	5.023	5.486	4.955	4.456	%
TiO2	2.518	2.678	2.433	2.489	%
Cr2O3	0.031	0.025	0.023	0.023	%
MnO	0.185	0.160	0.194	0.180	%
Fe2O3	13.188	12.799	12.815	12.907	%
Co3O4	0.027	0.021	0.023	0.021	%
NiO	0.017	0.011	0.015	0.013	%
CuO	0.012	0.008	0.013	0.015	%
ZnO	0.016	0.014	0.015	0.014	%
Ga2O3	0.003	0.003	0.004	0.004	%
Rb2O	0.005	0.005	0.005	0.005	%

REFRENCE SEN: عائشة عباس عبدالله

Chief Chemist
DATE:21/01/2016

Table (21): XRF result

Table (21) XRF result

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المختبر الكيميائي
الخرطوم – شارع النيل . ص . ب 410

Lab NO	708	709	710	711	UNIT
Sender No	1	2	3	4	%
SrO	0.037	0.041	0.038	0.032	%
Y2O3	0.005	0.005	0.005	0.005	%
ZrO2	0.050	0.056	0.053	0.051	%
Nb2O5	0.006	0.006	0.006	0.005	%
BaO	0.044	0.049	0.048	0.050	%
CeO2	0.033	0.033	0.032	0.044	%
PbO	----	0.003	----	----	%

REFRENCE SEN: عائشة عباس عبدالله

Chief Chemist
DATE:21/01/2016

the gravimetric results in table 18 compared to the XRF results in table 20 show that the chemical analysis gave lower values of SiO_2 , But alumina gave higher values in chemical analysis, Fe_2O_3 showed higher values by XRF than those in chemical analysis. CaO, %by mass gave higher values in chemical analysis. In contrast to MgO that showed higher percentage in XRF.

The chemical analyses are more adopted and give reliable results since the XRF depends upon the nature of the crystal neighboring atoms i. e. crystal structure and bonds energies.

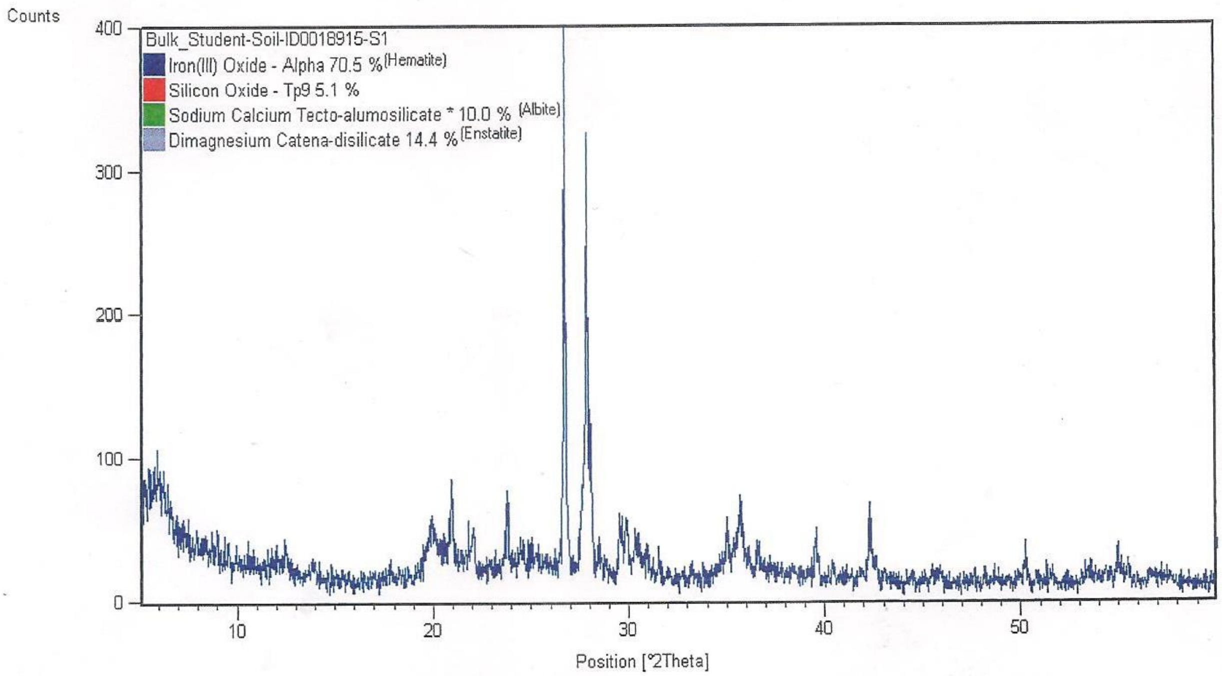
3. 3. 3XRD results

Viewing sample results through diffraction of X – ray one found that sample (1) is Hematite (70%) with existence of Albite and Enstatite. However sample (2) contains Enstatite and Albite of percentages of 59.8% and 29.2%consecutively. Sample (3) contains labrodorite of (52.4%) and enstatite of 44%.

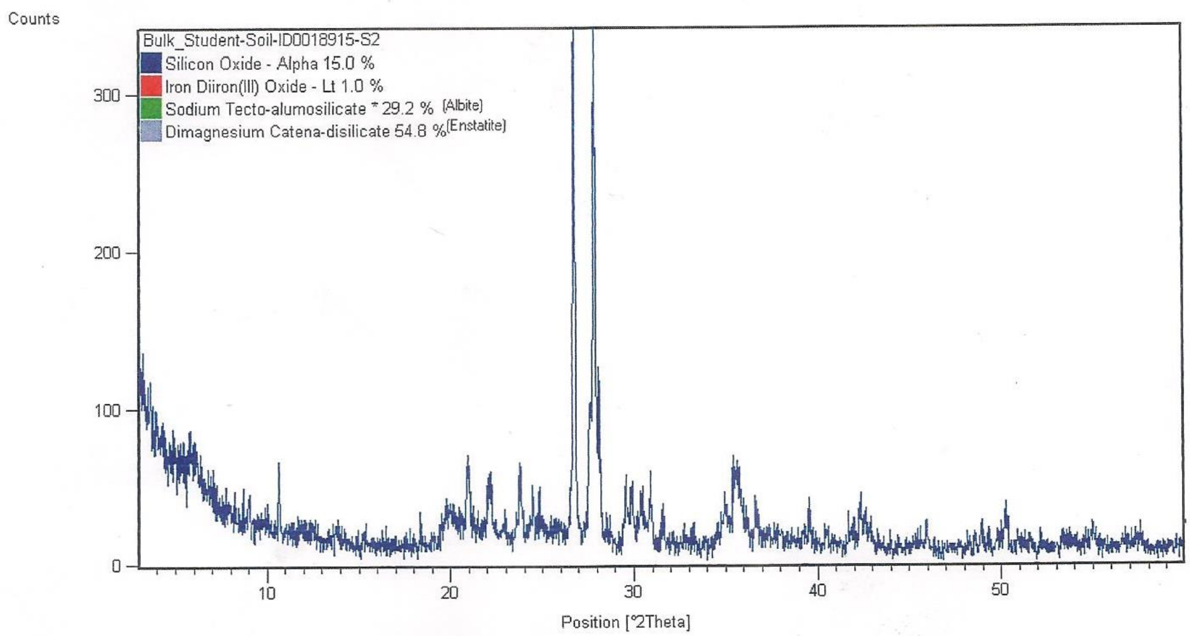
But sample (4) showed a new mineral other than feldspar ingredients which is diopside of 36.9% with existence of microcline (33.6%) , the first is Ca Mg SiO and the second is K AlSiO (feldspar potassium). It is possible that diopside is the big effect as the sample is found at the bottom of the list of removing water total hardness. One should not forget the non- existence of clay in this sample.

However sample (5) contains labrolonite (53.1%) and anothonite (43.9%) which are plagioclase feldspar. From these results one noticed that all samples are feldspar with different concentration except sample 4 contain diopside mineral which is not among feldspar lineage. One noticed the lineage start from albite, labrodrite then anithorite.

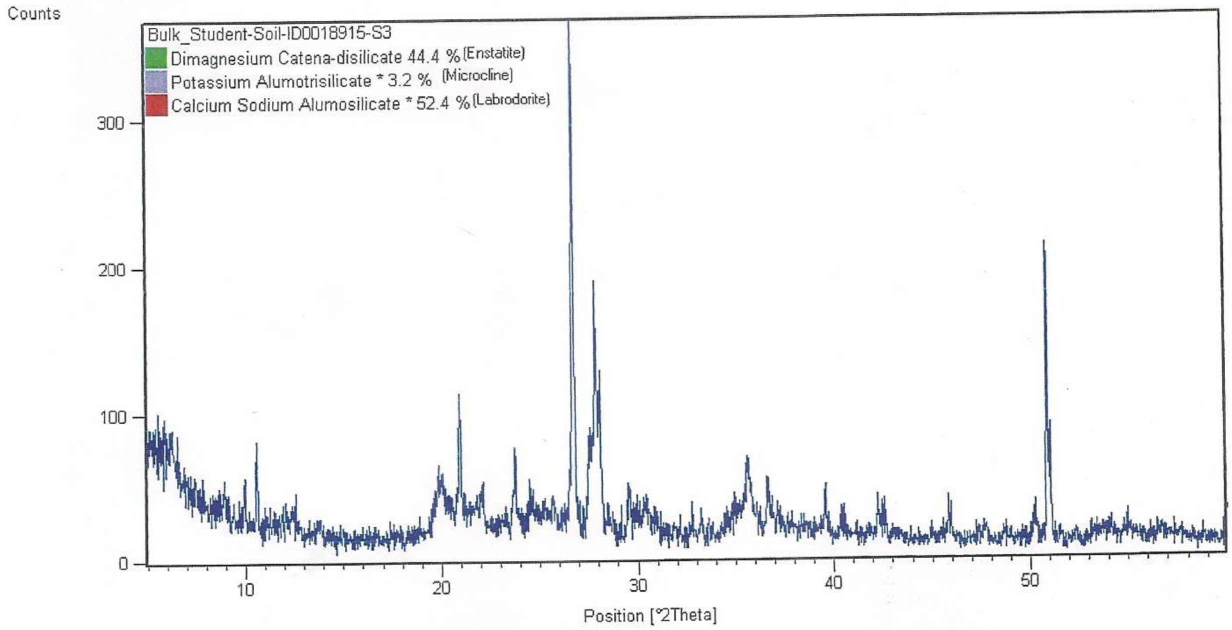
Soil type, mineralogy, and soil particle size have been shown to affect soil lead bioavailability. (Alkan et al. 2004)There also is evidence to suggest that smaller soil particles (e. g. ,< 100- 250µm) are more likely to be incidentally ingested than larger particles because the particles adhere more readily to the skin . Also the adsorption capabilities result from a net negative charge on the structure of minerals. This negative charge gives clay the capability to adsorb positively charged species. Their sorption properties also come from their high surface area and high porosity. (Duggen and Inskip 1985), that means, the sample which contains a high percentage of clays is always the best for removing water total hardness, one noticed this in sample 1 of the results of grain size distribution with clays percentage of 17%. But from the results of removing total harness one that sample 5 is the best among the otherswithout high percentage of clay due to that the sample contains a high percentage of Feldspar. We found that the feldspar works in removing natural zeolites to remove total hardness. A study proved that feldspar is useful in refining oils. (Ibrahim 2014) One noticed from results of removing water total hardness that sample 4 is the worst in removing hardness as the percentage was between (60%) due to the reason that this sample is free from clays and the existence of big grains which are fine silt and fine sand from the results of (grain size distribution).



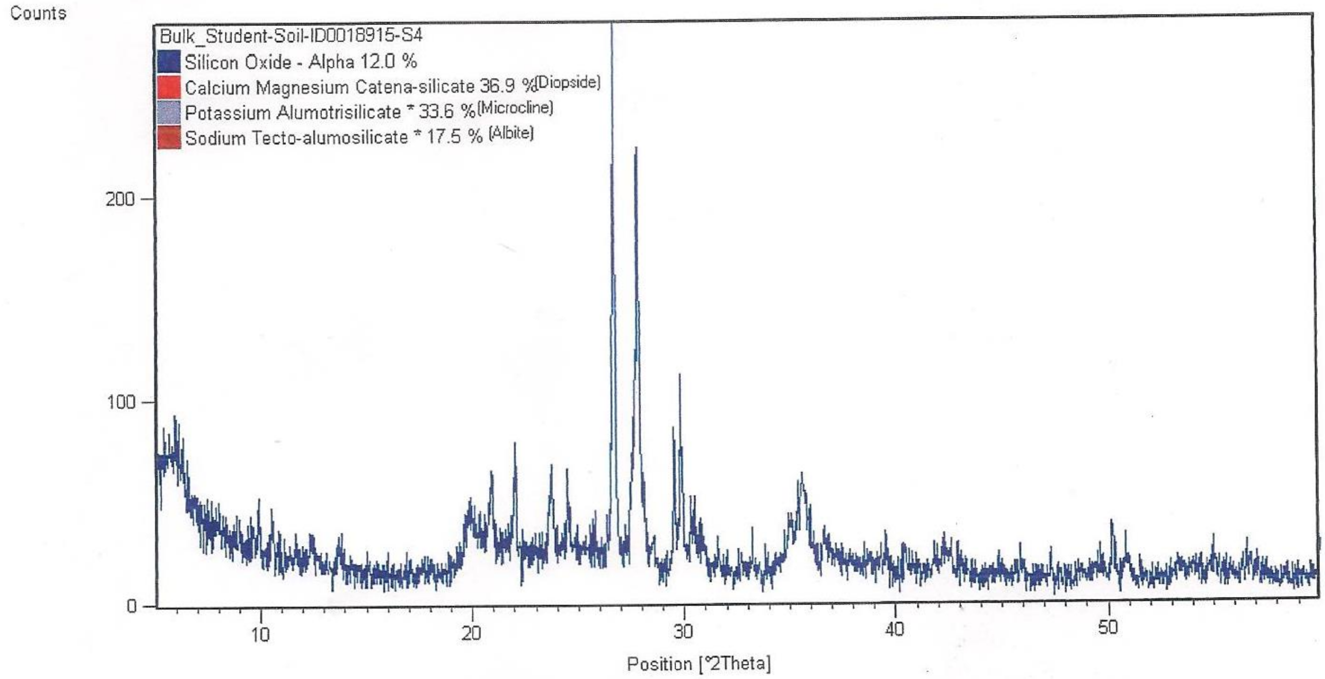
Fig(16) XRD Curve of West Nile clay



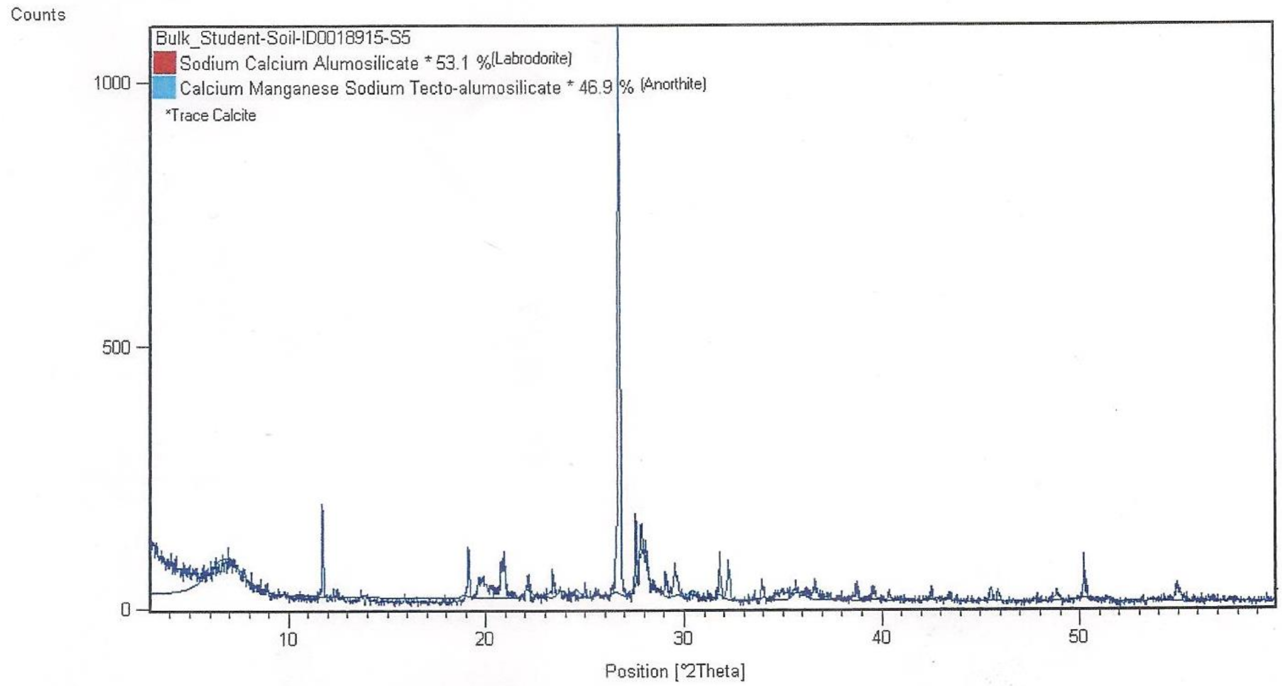
Fig(17) XRD Curve of East Nile clay



Fig(18) XRD Curve of Blue Nile clay



Fig(19) XRD Curve of West Soba earth



Fig(20) XRD Curve of Jurdiga