HARDNESS REMOVAL FROM DRINKING WATER

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ABSTRACT

This study included three trials that were made during December 2003 by using lime, of 98% w/w calcium hydroxide to find the relation between lime doses to be added and the hardness removed .The trials were performed by adding various doses of lime and measuring the hardness, electrical conductivity and pH in water produce by three plants, Nissan in the north of Baghdad, Al-Karama and Al-Wathba water treatment plant in Baghdad center. The objective of this study is to find the optimum lime dose that gives the minimum hardness content.

The results indicate a non linear relation between lime dose added and the hardness removed .

The results represented a 36% removal in hardness when using an optimum dose of lime 200 ppm in Nissan water treatment plant, while a percentage removal of 34% was obtained in both Al-Karama and Wathba water treatment plants with 300 ppm dose of lime.

The low percentage removal indicates the presence of non-carbonate hardness which could not be removed by lime alone.

الخلاصه

تضمنت هذه الدر اسه ثلاث محاولات أجريت خلال كانون الأول 2003باستخدام هيدروكسيد الكالسيوم 98% نسبه وزنيه لإيجاد العلاقة بين جرعة هيدروكسيد الكالسيوم وإزالة العسرة ,المحاولات تمت بإضافة جرع مختلفة من هيدروكسيد الكالسيوم وقياس العسرة والتوصيل الكهربائي وقوة أيون الهيدروجين للماء المسحوب من ثلاث محطات لتصفية ماء الشرب وهي مشروع نيسان شمال مدينة بغداد ,مشروع الكرامة ومشروع الوثبة مركز مدينة بغداد ,الهدف من هذه الدر اسه هو إيجاد الجرعة القصوى من هيدروكسيد الكالسيوم التي تعطي اقل تركيز للعسره .

النتائج أظهرت أن هناك علاقة لا خطيه بين جرع هيدروكسيد الكالسيوم المضافة والعسره المزالة ,النتائج تمثلت بإزالة 36% من العسره عند إضافة أقصى جرعه من هيدروكسيد الكالسيوم 200 ملغم\لتر في مشروع نيسان بينما نسبة أزاله 34% تم الحصول عليها في مشروعي الكرامة والوثبة لجرع 300 ملغم\لتر النسبة القليلة للازاله أشارت إلى وجود عسره لا كاربونيه والتي لا يمكن أزالتها باستخدام هيدروكسيد الكالسيوم لوحده

KEY WARDS
Lime ,hardness, water treatment plant

INTRODUCTION
The publics now demand that the water works operator does more than furnish water which is clear and free of disease-causing organisms. They desire water that is soft, free of taste and odor, and doesn't discolor plumbing fixtures or corrodes metals. Industry also require water that will not interfere with its processes (Steel, 1984). Most natural waters have dissolved matters in them. that may cause such properties

With today's awareness of the many unwanted substances in various water supplies, specialized devices are being marketed to treat small quantities of water just before drinking or for cooking purposes. This awareness has been heightened by the wide media coverage given to chemical spills, toxic waste dumps, and the under-treatment of community waters and improper sewage disposal. All of which seem to cause short or long term effects on potable water sources. Together, these factors tend to create doubts to the quality of water we consume. Bottled water, sold in supermarket as well as home delivery, has met a good deal of need for safer drinking water when doubts persist in mind of the homemaker as to the local water quality. This product is also used for aesthetic quality reasons or to satisfy dietetic needs. (Water facts, 2000)

WATER HARDNESS
Hardness of water is the measure of water capacity to precipitate soaps. Hardness minerals are calcium and magnesium in parts per million. Water hardness may be either carbonate or non carbonate .The carbonate hardness caused by the bicarbonate of calcium and magnesium while non carbonate hardness caused by the sulfate and chlorides of calcium and magnesium. W.H.O, 1984 classified drinking water according to its hardness as in **Table(1)**

Table (1)
Classification of drinking water according to its hardness

Hardness in ppm	*Description of water*
0-60	Soft water
60-120	Medium hard water
120-160	Hard water
>160	Very hard water

SOFTENING METHODS:
One of the main problems in water is the increase in amount of hardness that should be decreased to the desirable concentration There are many methods used in softening of drinking water such as Reveres Osmoses, Ion Exchange, Chemical Precipitation and others.

The Chemical Precipitation which is most suitable in Iraq because of the availability of lime locally produced and its low cost.

That precipitate most commonly used in water treatment are those calcium carbonate and metallic hydroxides. Such as lime.

Chemical precipitation-lime softening
The aim of this process is to remove the carbonate hardness (temporary hardness) attributed to calcium and magnesium. The non-carbonate hardness (permanent hardness) is not affected.

The assessment of lime softening equipment should be primarily based on its ability to produce a homogenous mixture of raw water reagent and $CaCO_3$ nuclei, in a reaction zone of a suitable size. In order to increase the settling velocity, an organic flocculants may be injected following the growing phase of the crystals. When the aim is to obtain particularly clear carbonate-free water, lime softening should always be followed by filtration. (Degremont, 1991).

Basic Reactions

The chemical reactions for lime softening are as follows: -

$$Ca(OH)_2+Ca(HCO_3)_2 \longrightarrow 2CaCO_3\downarrow +2H_2O \quad (1)$$

$$Ca(OH)_2+Mg(HCO_3)_2 \longrightarrow CaCO_3\downarrow +MgCO_3+2H_2O \quad (2)$$

As magnesium carbonate is relatively soluble (solubility about 70mg/l), an excess of lime will bring about the following reaction: -

$$Ca(OH)_2+MgCO_3 \longrightarrow CaCO_3\downarrow +Mg\ (OH)_2 \quad (3)$$

PROPERTIES OF LIME

A very fine powder, which is usually white. The form used is hydrated lime, which varies from source to source. For example (limbux) lime from UK has 98%w/w calcium hydroxide, and Iraqi lime from Kerbala has been analyzed as having about 95%w/w

Initially the lime will be delivered in bags stacked on pallets, provision has been made for possible future bulk delivery by special rod vehicles which can be pneumatically discharged direct into lime silos also in (big bags) of one ton capacity.

Being a caustic alkali, lime requires careful handling but is not corrosive to iron, steel, most metals or general construction materials. The dust will however roughen glass over a period of time.

Storage areas must be kept dry and free from draught and if the lime is not contaminated or caked, any recently damaged or split bags must be used immediately.

Long exposure to the atmosphere may cause carbonated lime that should be rejected

Stocks should be used in rotation and care must be taken to keep them separated from other chemicals.

Careful handling is required to minimize dust formation at all dry lime handling stages and the dust extractors provided at key points must be used and be properly maintained.

Hydrated lime doesn't produce heat on mixing with water or when subsequently diluted. However, as its solubility is very low, the slurry, must be continually agitated otherwise it will settle. The mixing tanks must have stirrers, which run continuously while containing lime slurry.

When lime is first mixed with hard water, local softening occurs with a precipitation of calcium carbonate and magnesium hydroxide. This reaction initially takes place in the slurry mixing tanks and later in mixers where further water is added.

Beyond the need to clean out the mixing tanks and mixers, from time to time, no operational problems are expected from such reactions. (Operation Instruction, 1986)

EXPERIMENTAL WORK AND DISCUSSION

Three trials were made during Dec. 2003 by using lime, of 98%w/w calcium hydroxide to find the relation between the doses added and hardness removal in three plants, Nissan WTP, Al-Karama WTP and Wathba WTP as discussed below: -

Calculation of Lime Required for Optimum Precipitation

Notation:-

CaH:- Calcium hardness in French degrees representing the total calcium salts content.

MgH:- Magnesium hardness in French degrees representing the total magnesium salts content.

Malk:- Alkalinity Measurement due to adding Methyl Orange

C:- Free CO_2 content in French degrees is calculated as: -

$$C = \frac{\text{Free } CO_2 \text{ (mg/l)}}{4.4} \qquad (4)$$

Amount of lime: -
The theoretical amount of lime required for optimum precipitation of calcium carbonate alone is: -
$Ca(OH)_2$= 7.4(Malk + C) g/m^3 (5)

To precipitate calcium carbonate and magnesium oxide simultaneously: -

$$Ca(OH)_2 = 7.4(2Malk - CaH + C) \text{ g/m}^3 \qquad (6)$$

$$CO_2 \text{ (mg/l)} = \frac{\text{ml of titration} * N * 44000}{\text{ml of sample}} \qquad (7)$$

First Trial

In Nissan WTP which is in the north of Baghdad its intake is an upstream disposal area of many industries on the Tigris River, this region is considered a good quality source.
CO_2 =34.32 mg/l from the experimental work.
C= 7.8 mg/l from equation 4.
Malk = 13.6 F.D. from the experimental work.
CaH =8.3 F.D from the experimental work.
The amount of lime required to precipitate calcium carbonate and magnesium oxide simultaneously is 197.58mg/l ≅ 200 mg/l from equation 6.
The results of this trial was as follows:-

Table (2)
The Result of the First Trial of Lime Softening.

Lime dose(ppm)	*Ha(ppm)*	*Ha removal(ppm)*	*% removal*	*PH*	*Ec*
0	352	0	0	7.75	960
50	341	11	3	8.5	920
100	328	24	7	9	800
150	270	82	23	9.1	756
200	226	126	36	10.25	659
250	245	107	30	10.5	700
300	276	76	22	10.6	727
350	279	73	21	10.7	776
400	280	72	20	10.75	796
450	285	67	19	11	799
500	296	56	16	11.2	801

Second Trial

In Al-Karama WTP at Baghdad center on Al-Karkh side which is the region of poor water quality because of the disposal of industrial effluents.
CO_2 =98 mg/l from the experimental work.
C= 22.27 mg/l from equation 4.
Malk=15.7 F.D. from the experimental work.
CaH =13.3 F.D. from the experimental work.
The lime dose =298.7mg/l ≅ 300 mg/l for optimum precipitation from equation 6.
The results of the second trial were as follows:-

Table (3)
The Result of the Second Trial of Lime Softening

Lime(ppm)	Ha(ppm)	Ha removal (ppm)	% removal	PH	Ec
0	507	0	0	7.8	1089
50	497	10	2	7.83	1084
100	453	54	11	7.85	1080
150	437	70	14	7.88	1077
200	404	103	20	7.9	1036
250	365	142	28	8.2	1010
300	334	173	34	9.3	1022
350	357	150	30	9.5	1050
400	384	123	24	9.8	1075
450	390	117	23	9.85	1090
500	396	111	22	9.9	1122

Third Trial

In Al-Wathba WTP at Baghdad center on Al-Rasafa side about 3.0 km south Al-Karama WTP with water of poor quality also.

CO_2 =64 mg/l
C= 14.5 mg/l
Malk=16.1 F.D.
CaH=12.4 F.D.
The lime dose=254.1mg/l $\cong$ 300 mg/l for optimum precipitation.
The results of the third trial was as follows:-

Table (4)
The Result of the Third Trial of Lime Softening

Lime(ppm)	Ha(ppm)	Ha removal (ppm)	% removal	PH	Ec
0	488	0	0	7.2	1250
50	465	23	5	7.5	1240
100	440	48	10	7.8	1200
150	425	63	13	8	1170
200	400	88	18	8.58	1100
250	350	138	28	9.7	1095
300	322	166	34	9.8	1190
350	358	130	27	10	1160
400	400	88	18	10.35	1200
450	407	81	17	10.5	1280
500	412	76	16	10.65	1310

From **Tables (2),(3) and (4)** the hardness values began with high value and decreased on adding lime ,reaching the minimum value at the optimum dose, the pH value increased as the lime dose increased.

The removal of hardness began with low values then increased to a maximum value at the optimum dose of lime then decreased when lime dose increased as shown in Fig. **(1-a), (1-b) and (1-c).**

The regression equations of the relation between lime dose and hardness removal was to be of a non-linear form as follows:-

The best regression was:

$Y=ax^b \exp(cx)$ (8)

1- In Nissan WTP:-

$Y=2.31 * 10^{-4} x^{2.892} e^{-0.0117x}$ (9)
R=0.888

2- In Al-Karama WTP:-

$Y=1.61 * 10^{-4} x^{2.897} e^{-0.00922x}$ (10)
R=0.961

3- In Al-Wathba WTP:-

$Y=2.19 * 10^{-4} x^{2.862} e^{-0.010x}$ (11)
R=0.905

Fig.(2) shows the best fit curve for the mean data of the three plants with regression equation as follow:-

$Y=1.81 * 10^{-4} x^{2.896} e^{-0.0102x}$ (12)
R=0.988

The best regression equation in Al-Karama WTP with a correlation coefficient of 0.961.**Fig. (3)** shows the percentage removal of hardness versus lime dose in the three plants Nissan WTP north of Baghdad and Al-Karama WTP, Al-Wathba WTP in Baghdad center. The figure represent high percentage removal in Nissan WTP for low doses but high percentage removal in Al-Karama then Al-Wathba for high lime doses, also the percentage removal 36% when optimum dose of lime in Nissan WTP, while the percentage removal of 34% when optimum lime dose in both Al-Karama and Al-Wathba WTP

The low percentage removal indicates the presence of non - carbonate hardness which can not be removed by lime only.

CONCLUSION

1- The relation between lime dose and % removal of hardness is of a non-linear form with the best regression equation in Al-Karama WTP with a correlation coefficient of 0.961 . this correlation is of 0.988 for the mean data for the three plants.
2- The maximum decrease of carbonate hardness was at the optimal lime dose with percentage removal of 36% in Nissan WTP and 34% in both Al-Karama and Al-Wathba WTP.
3- Softening with Lime need to adjust the pH of the treated water, also ferric chloride is the clarifying reagent to be used because Aluminum Sulfate would solubilize the Alumina, which might subsequently reflocculate.
4- The principle difficulty with using lime for carbonate hardness removal is the large amounts of sludge generated which has to be disposed, although this sludge is easily dried.

RECOMMENDATION AND SUGGESTION

1- To make use of lime plant which is present at Al-Karkh project, which is out of work for the time being, to use it in another project when needed.
2- Studies should be conducted to improve hardness removal by using the combination of Lime and Sodium Carbonate for removing carbonate and non-carbonate hardness.

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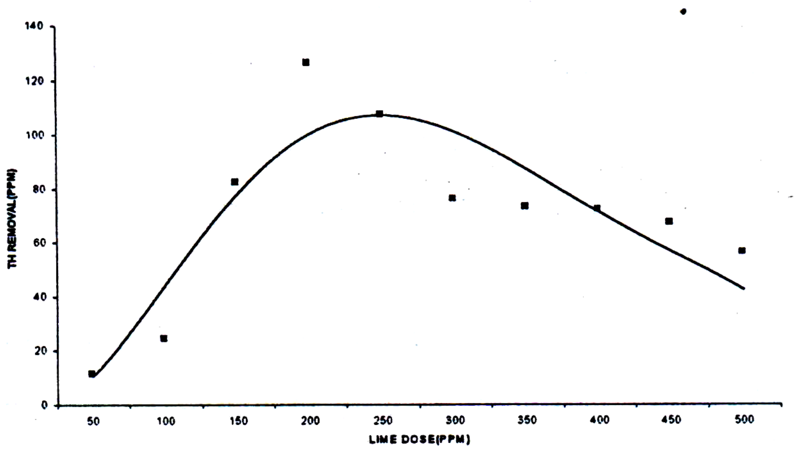
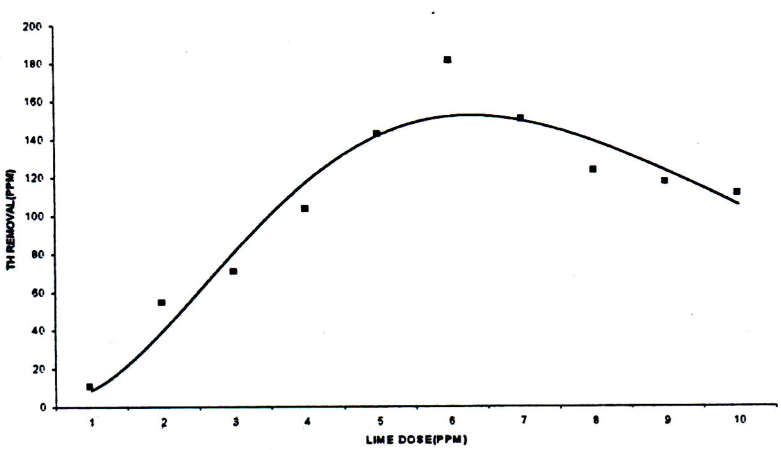


a. In 7-Nissan WTP



b. In Al-Karama TWP

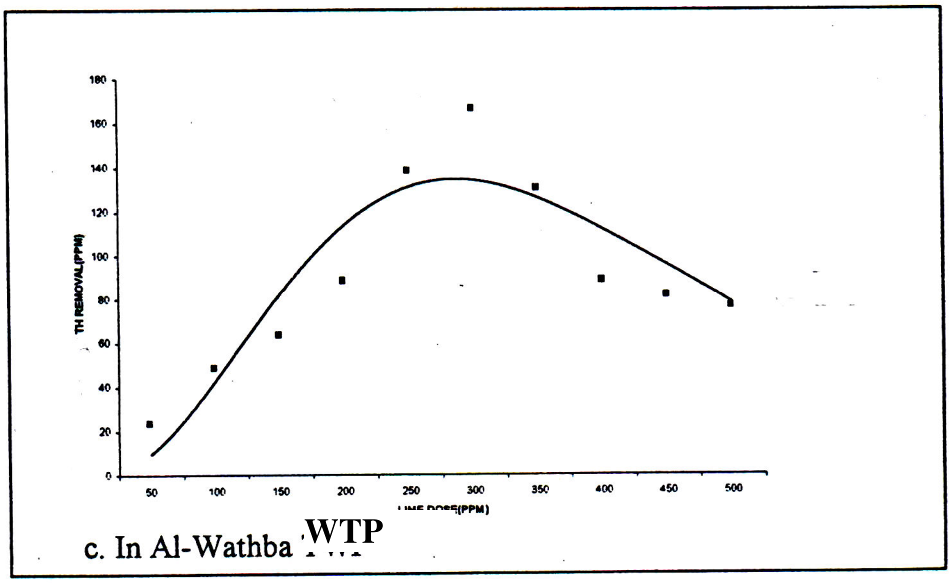


Fig. (1)
The Relationship Between the Hardness Removal and Lime Doses

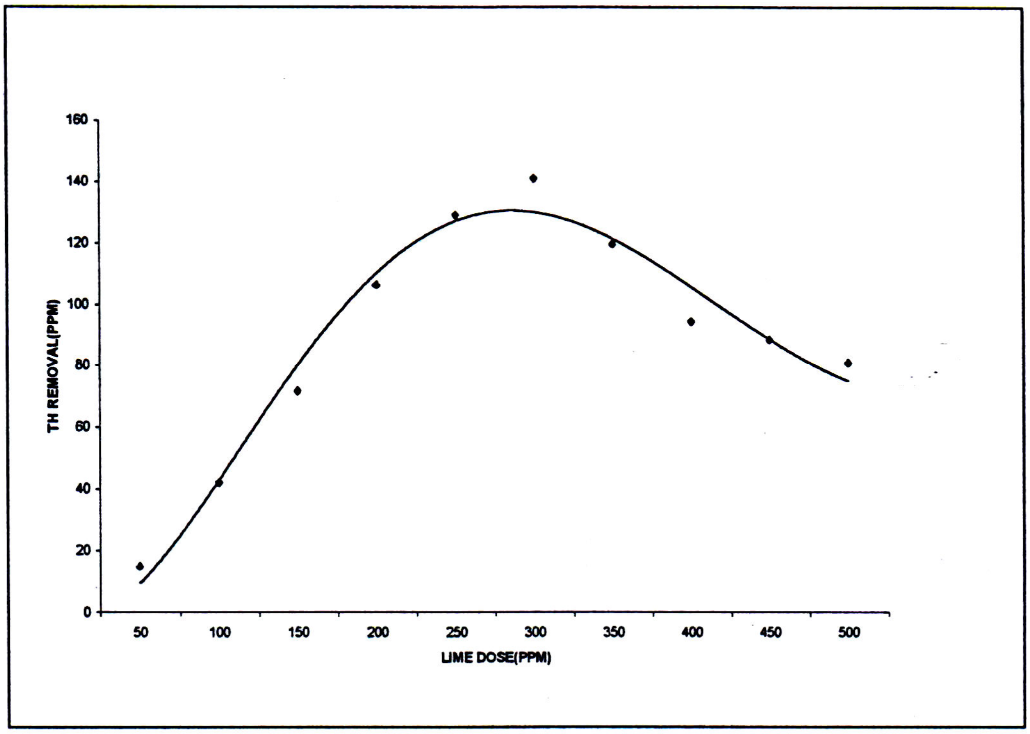


Fig. (2)
The Relationship Between the Hardness Removal and Lime Doses for the Mean Data of the Three Plants

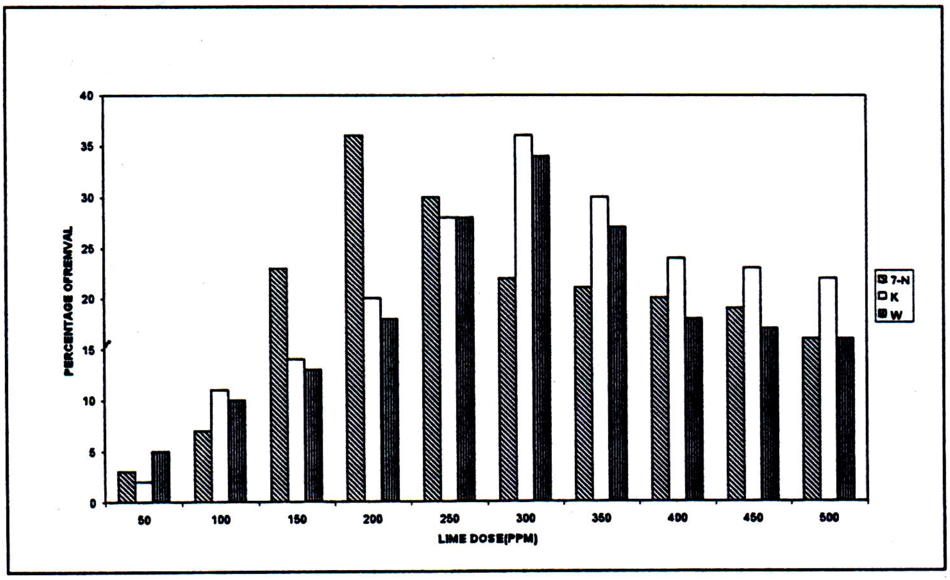


Fig. (3)
The Percentage Removal of Hardness Versus Lime Doses in the Three Plants