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Full Length Research Paper

Improvement of water treatment plants capacity and effluent quality by introducing "NINIVITE" as new filtration media

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This work compares the performance of four types of filters, three of them are dual media/capping filters and the fourth is a single medium sand filter. The filters were made to operate with the same effective size and the same depth. These filter were subjected to the same operating conditions of filtration rates and influent turbidity. A new locally available filter medium called ninivite (recently discovered rock) was introduced to act as an upper layer of one of the selected dual media filters. To verify the goals of this work a pilot plant similar to the classical water treatment plant was constructed. Filtration system consisted of four glass column filters, acting parallel and simultaneously. The first three columns contained 20 cm of granular ninivite rock GNR, granular activated carbon GAC, and anthracite coal respectively over 40 cm of sand. The fourth column was kept with 60 cm sand to act as a single –medium filter. The effective size of each media grains was 0.82 mm with a uniformity coefficient 1.6. A total of 18 runs for natural raw water turbidity were conducted. Run times of these experiments amounted to 12-27 h. The filters were operated at rates of 4.9, 7.3, and 9.8 m/h; which were 1, 1.5 and 2 times the current rate at treatment plants. The results were encouraging .Using filters consisting of GNR and sand operated at mentioned rates appeared to have the best performance for the studied parameters. Efficiency of turbidity removal amounted to 91.31% for sample having 9.9 NTU at filtration rate 4.9 m/h. Such performances were also recorded for other dual – media filters for the considered rates. GNR filter also showed considerable efficiency in bacterial removal.

Key words: Water treatment, dual- media filters, capping filtration, ninivite/porcelanite, drinking water filtration.

INTRODUCTION AND REVIEW OF LITERATURE

Municipal water treatment plants in Iraq adopt the rapid sand filtration technique for clarification of water for drinking and other uses. Filters of such kind operate at rates 1-2 gpm/sq.ft amounting to 2.5-5.0 m/h. Most of Iraqi plants are employed at 4 m/h as an average and employ a sand layer supported by gravel as a porous medium (Al-Rawi, 1995).

These filters suffer some problems that may affect its performance. Examples are: removal of suspended matter occurs in the top 1-4 inches (2.5-10 cm) and the whole remaining depth of the filter is not utilized. Besides, these filters are incapable of satisfying growing per capita demand and consumption. Furthermore, a deficiency of such filters to produce high quality furnished water is often noted.

The construction of upstream impoundment has greatly affected raw water quality received by treatment plants leaving the existing plants act merely as a passing through units.

Dual-media beds have gradually replaced sand alone in filters of many water treatment plants all over the world. Dual-media filters possess several distinct advantages compared to those of conventional rapid sand filters.
Higher filtration rates, longer runtimes, flexibility to tackle variable turbidity loading and better performance are some examples (Amirtharaga, 1988; Al- Rawi, 1987; Degremont, 1991; Al- Ani et al., 1988; Twort et al., 2001; Peavey et al., 1987; Montgomery, 1985)

Usually the depth of upper lighter layers equals twice that of the bottom heavier layers. However, from view of cost, the developing countries –and Iraq is no exception-have used sand filter capping. Here the depth of the up-

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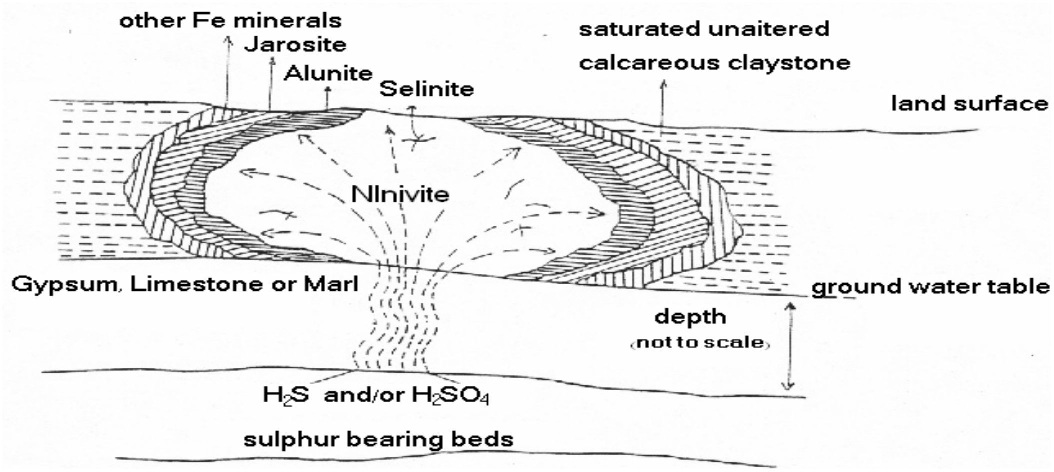

Figure 1. Model for the genesis of ninivite.

Table 1. Some physical characteristics of ninivite.

Sample No.	Porosity %	Density(gm/cm^3)	Absorption ratio %
1	72.0	0.787	91.43
2	72.7	0.743	97.82
3	68.0	0.753	89.51
4	76.2	0.720	104.5
5	72.2	0.740	96.37
6	71.1	0.750	95.17
7	70.5	0.726	97.20
8	69.6	0.745	93.46
9	62.1	0.760	81.60
10	70.3	0.670	104.70

Permeability = $6.9x10^{-5}$ cm/s. Surface area = 739-765.5 m^2/gm, Acid loss = zero color: white-grey, white when dry, grey when wet.

Table 2. some chemical constituents of ninivite

Oxides	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	TiO_2	L.O.I
%	95.7	0.22	0.08	0.98	0.02	0.07	0.59	2.2

per layers is often half that of the sand layer.

This work aims at improving the performance of existing water treatment filters through capping sand layers with GNR (granular ninivite rock, newly introduced filter medium), GAC(granular activated carbon), and anthracite coal, thus acting as a dual media/capping filters. Besides, filter with sand and the introduced ninivite is to be compared with different types of filters that employs sand alone (single layer filter) and sand with activated carbon and sand with anthracite (as dual media/capping filters).

The comparison will be based on using different levels of influent turbidity, and variable filtration rates and intends to add another savings to water treatment processes.

Background of ninivite

Ninivite is not widely known to researchers. It was discovered in 1987 during detailed geological mapping of some areas in Mosul suburbs. Ninivite was then defined as a new form of Porecelanite (Al- Naqib and Al-Dabbagh, 1990).

Ninivite is derived from the name of “Nineveh“, the ancient capital of Assyrian civilization. Mosul, a city in the north of Iraq, now embraces the site. Figure 1 illustrates ninivite composition (Aswad et al., 1995).

This ninivite possesses the following physical and chemical process that enable this rock – as thought- to act as the upper layer of dual/capping media filters Tables 1 and 2 (Al- Naqib and Al- Dabbagh, 1990).

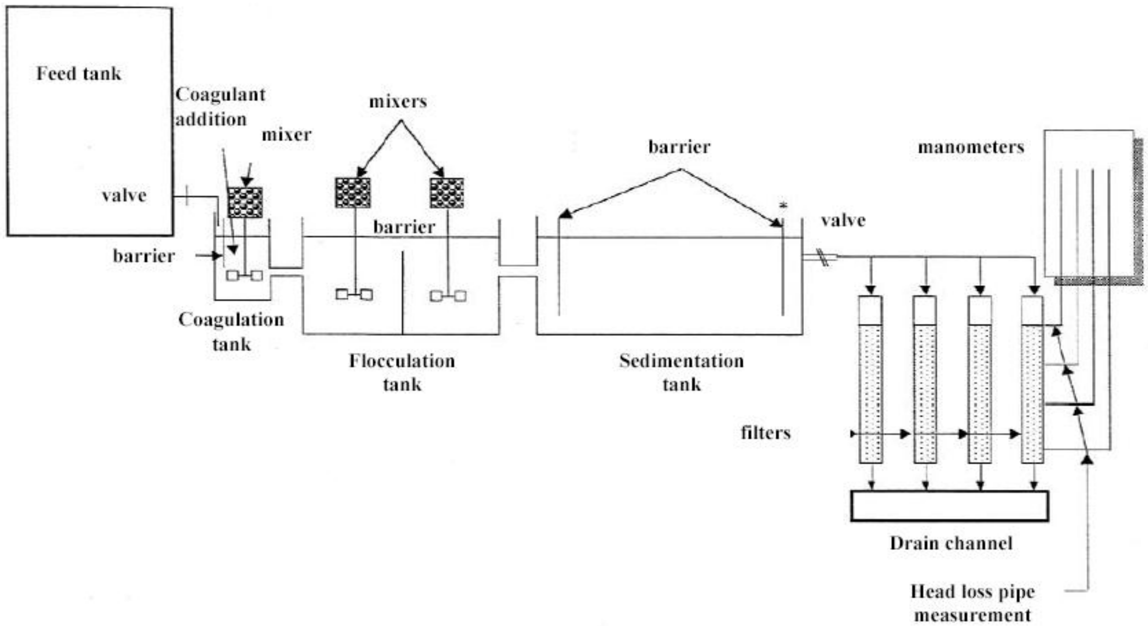

Figure 2. Pilot plant components.

Table 3. Components of pilot plant.

Item	Remarks
Feed tank	Three tanks 1 x 1 x 1 m each are used to provide a continuous supply of raw water .
Rapid mix	10.5 x 10.5 x 10.5 cm. Detention time is 1 min.
Flocculation	50 x 30 x 22 cm. Detention time is 30 min.
Sedimentation	Two tanks, 54 x 34 x 28 cm each. Detention time is 2 h.
Filter unit	4 Glass columns 5.3 cm diameter each connected to piezometers as shown in Figure 3

Table 4. Process variables and conditions

Parameters	Remarks
Raw water	River water having raw turbidity ranging from 16 56- NTU.
Temperature	11 – 19 ^{o}C
Coagulant	Alum is dosed as complied by raw water turbidity.
Filter media	Three dual/capping media filters consisting of 20 cm of ninivite, or anthracite, or activated carbon over 40 cm of sand .the 4th filter is kept 60 cm of sand as a single layer filter.
Treatment	Conventional processes.
Filtration rate	4.9, 7.3, and 9.8 m/h.
pH	It ranges from 7.3 to 8.6
Headloss	It is measured through water levels in 4 tubes connected at different heights. Filter cycle terminates when head loss reaches 80 cm.

MATERIALS AND METHODS

A pilot plant constructed similarly to the conventional water treatment plant is employed for the purposes of this work. Figure 2 illustrates the units of the used pilot plant. Tables 3 and 4 explain the units and process variables (Al-Najjar, 2000).

Ninivite is tested at ministry of health laboratories to check its suitability from health point of view as a filter medium. Besides, tests required to verify it as a filter medium such as acid loss, effective size and uniformity ... are also carried out.

Filtration system consists of four glass column filters, acting parallel and simultaneously. The first three columns contain 20 cm of granular ninivite rock GNR, granular activated carbon GAC, and anthracite coal respectively over 40 cm of sand. The fourth column is kept with 60 cm sand to act as a single -medium filter. The effective size of each medium grains is 0.82 mm (the current

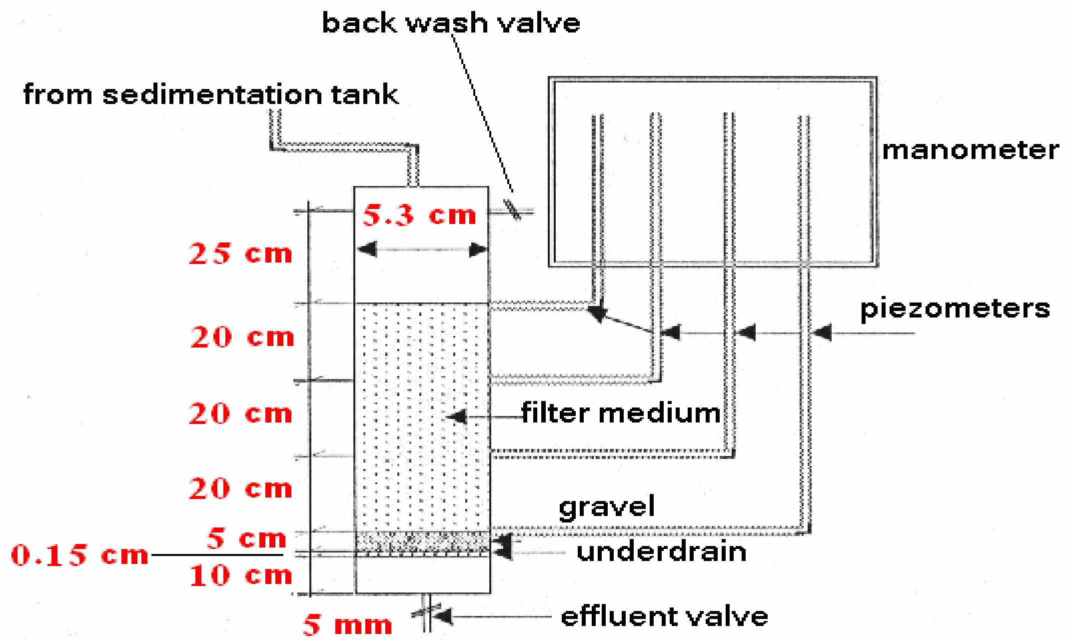

Figure 3. Filter column design.

Table 5. Achieved effluent turbidity under variable raw turbidity and variable filtration rates.

Average effluent turbidity NTU types of filters				Filtration rate m/h	Influent turbidity NTU
Sand alone	Sand + anthracite	Sand + Activated carbon	Sand + Ninivite		
1.10	0.93	0.87	0.86	4.9	9.9
0.91	0.82	0.76	0.75		5.8
1.10	0.93	0.88	0.86		9.8
0.91	0.83	0.75	0.73		5.6
0.59	0.53	0.47	0.47		3.6
0.60	0.52	0.46	0.46		3.3
1.13	0.94	0.89	0.87	7.3	9.8
0.94	0.84	0.76	0.74		5.6
1.14	0.95	0.88	0.87		9.8
0.95	0.83	0.77	0.75		5.5
0.62	0.55	0.50	0.48		3.5
0.63	0.55	0.51	0.49		3.2
1.25	0.97	0.94	0.92	9.8	9.9
0.98	0.85	0.77	0.76		5.7
1.24	0.97	0.94	0.93		9.8
0.99	0.85	0.77	0.76		5.5
0.68	0.55	0.52	0.51		3.6
0.66	0.56	0.52	0.50		3.5

medium size in the city treatment plants) with a uniformity coefficient 1.6. Figure 3 shows the details of filter unit.

A total of 18 runs for natural raw water turbidity are conducted. The filters were operated at rates of 4.9, 7.3, and 9.8 m/h; which is to 1.8 and 2.5 times the current prevailing filtration rate in the city water treatment plants. This practice may add to the economy of water treatment processes.

RESULTS AND DISCUSSION

Table 5 summarizes influent raw turbidity levels received by all filters. It also shows effluent turbidity for the employed filtration rates .It is worthy to note here that none of the resulting effluent turbidity for used dual/capping fil-

Table 6. Filter performance as filtration rate varies.

Influent turbidity NTU	Filtration rate m/h	Turbidity removal %			
		Sand + ninivite	Sand + activated carbon	Sand + anthracite	Sand alone
	4.9	100	100	100	100
3.6	7.3	95.92	92.16	94.44	93.65
	9.8	92.16	90.39	92.86	86.77
	4.9	100	100	100	100
5.6	7.3	97.3	97.40	97.62	95.79
	9.8	96.05	97.40	96.47	91.92
	4.9	100	100	100	100
9.9	7.3	98.85	97.75	97.90	94.93
	9.8	92.47	92.55	95.88	88.00

ters exceeds (1) NTU. This highly confirms the excellent performance of the used filters.

In practice and for single medium filters in treatment plant works, the listed results might not be achieved due- mainly- to improper alum doses, improper operation of units etc. Generally, as far as this work is concerned, effluent turbidity complies well with the WHO (1984), EPA (Hendricks, 2006), and Iraqi specifications (Ministry of health, 1988).

As shown, –for example- the influent turbidity for filtration rate of 4.9 m/h was 9.9 NTU. The resulting effluent turbidity for the used filters was 0.86, 0.87, 0.93 and 1.1. This means that removal achieved was 91.3, 91.1, 90.6, and 88.8% respectively.

Also, it is seen that filter consisting of 20 cm of ninivite over 40 cm of sand is superior in removal of turbidity compared to other filters.

It is worthy to display the role of porosity in achieving good filter performance. The porosity of ninivite, activated carbon, anthracite and sand were 0.77, 0.74, 0.62 and 0.40 respectively. This means that as porosity increases, the spaces among grains increase. Consequently a more ability for accumulation of flocs to be removed by various removal mechanisms. This ultimately will reduce the breakthrough of impurities inside the filters which may come out in the effluent and degrades filtrate quality.

From the other hand, the used filtration rates were 4.9, 7.3 and 9.9 m/h. This is equivalent to 1:1.5:2 times the current rates in country treatment works. This is very important from economic point of view. Authorities need not to construct a new plant to satisfy the demands on water. Water output in this case will be doubled with minimum cost and minor plant modifications.

Table 6 also shows the effect of changing filtration rates upon effluent turbidity. This effect appears to be minor when changing the rate from 4.9 to 7.3 m/h. This bears an economic point of view. Such change encourages the operation of the existing Iraqi water treatment filters at higher rates above the current rate of 3-5 m/h. Consequently, more furnished water will be produced, and a thinking of future extension of water works can be done at minimum costs.

However, when filtration rate becomes 9.8 m/h, some decrease in performance is noted, and water quality declines for all used filters. The reasons behind water deterioration can be accounted as follows:

Increasing filtration rates means an increase of collisions between suspended matter and the media. At the same time, it increases the hydraulic shear force. The latter tends to push the particulate matter deeper into the filter, where ultimately it emerges in the effluent and thus deteriorates its quality (Al-Najjar, 2000). However, the turbidity of the effluent for all rates remained below 1.0 NTU (except for sand filter).

Generally speaking, the competition among tried dual filters is so great, however, from an economical point of view, the focus will be made on GNR filter as it is locally available.

Runtimes

The elapsed time after backwash to the termination of a filter cycle is called length of run of that filter, or simply runtime. This parameter is dependent on many factors such as size and depth of the media, raw water characteristics, filtration rates, and other factors. Since this paper keeps the size and depth of the media constant for all runs, the effect of filtration rate on runtime will be discussed.

The fluctuation of filter runtimes at various rates is listed in Table 7. It is clearly evident that the lengths of filter runs are almost inversely proportional to filtration rates. This does not mean that doubling the rate from 4.9 to 9.8 m/h will necessarily reduce the runtime of filter cycle to half its original length of run. This is clearly shown in Figure 3. It is important to mention here that this runtimes are achieved after termination of filter cycles. The latter occurs as the head loss attains 80 cm, which is considered maximum value due to the used filter column.

Here GNR filter shoes longer runtime compared to other filters.

Table 7. Role of influent turbidity and filtration rate on filter runtimes.

Filtration rate m/h	Influent turbidity NTU	Filter runtime(h)			
		Sand + ninivite	Sand + activated carbon	Sand + anthracite	Sand alone
4.9	3.6	27	27	25	22
	5.6	26	26	24	20
	9.9	24	24	22	18
7.3	3.6	27	26	24	21
	5.6	26	24	22	19
	9.9	23	23	21	17
9.8	3.6	26	25	23	17
	5.6	24	23	20	15
	9.9	20	19	17	12

Table 8. Bacterial count of treated water*.

Filtration rate m/h	Bacterial count In the Filtrate influent (no/ml)	Bacterial count in the effluent and its percentage removal			
		Sand + ninivite	Sand +activated carbon	Sand +anthracite	Sand only
4.9	1300	60(95.4%)	50(96.2%)	70(94.6%)	120(90.8%)
7.3	1600	80(95%)	80(95%)	100(93.8%)	170(89.4%)
9.8	1400	90(92.6%)	80(94.3%)	120(91.4%)	170(87.9%)

* ( ): denotes percentage removal.

Bacterial removal

Table 8 lists bacterial count estimated at influent and effluent of the filter at different filtration rates. The removal efficiency ranges from 92 to 95.4% which is fairly high. Production of such water will provide complete satisfaction related to the biological quality of the treated water.

Conclusions

This work comes out with the following findings:

1. Ninivite - a locally available introduced material - has acquired good characteristics that enable it to be used as an upper layer in dual media filter in water treatment works.
2. A very clear furnished effluent that is palatable to consumers is produced. This is very vital from health point of view.
3. Great savings can be achieved represented by avoiding construction of new plants to meet increasing demands on water. Use of higher rates of filtration can yield greater plant output of water.
4. Further considerable economic consequences are expected when using ninivite. This includes avoiding importing upper coal or carbon layer material, as well as duplicating plant water productivity (compared to current city water treatment plants) and producing high quality water.
5. Turbidity as low as 0.50 NTU or less can be obtained, and a performance efficiency as high as 92 % can be achieved using ninivite.
6. Ninivite considerably minimizes bacterial count in the effluent water.
7. Dual - media filters consisting of 20 cm of ninivite over 40 cm of sand appear to fairly work under various conditions of turbidity loadings, runtime length, and filtration rates.
8. The study highly recommends using this Ninivite in water treatment works for its many merits.

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