Impact of Raw Water Characteristics on Aski - Mosul Water Treatment Plant

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(Received 14/12/2011 , Accepted 31/10/2012)

ABSTRACT

It was claimed that the studied plant did not perform as expected. A careful investigation was carried out to troubleshoot any inconveniences. Many visits to plant site and discussion with managers and operators were made. A series of tests on samples taken from different sites in the river for various quality parameters such as pH, total solids TS, total dissolved solids TDS, electrical conductivity EC, Turbidity, nitrates NO_3, phosphates PO_4 , total plate bacterial count TPC, and algae were conducted .

The results revealed that the plant suffered a lot of problems. The plant acted as a passing through units. No significant change could be detected in received and treated water characteristics. Maintenance of various units were rarely practiced, and if it was done it would take long time. Pretreatment by alum was not carried out. This would complicate settling of flocs in subsequent units and might lead to growth of microorganisms.

As the plant located downstream a big impoundment lake, the incoming water characteristics were relatively acceptable and bear a sign of eutrophied water particularly phosphates and nitrates. Patches of algae could be seen adhered to sedimentation tank walls.

Backwashing of filters was done by air scour only through the recent 20 years. This led to loss of fines and cracks in filter bed. Gradation of media grains and the depth of sand layer were not adequate. Acid loss of used media amounted to 6.3% which was excessive and beyond authorized criteria

Removal of algae and bacteria was low as filter medium pores were relatively Large due to loss of fines and due to possible contamination.

Keywords: Impact, Raw Water, Characteristics, Aski – Mosul,

تأثير خصائص الماء الخام على أداء محطة تصفية المياه في أسكي موصل

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الملخص

تعاني محطة أسكي موصل من عدد من المشاكل التشغيلية مما يؤثر على أدائها. وقد تم التحقق من صحة هذه الادعاءات من خلال عدد من الزيارات الميدانية والالتقاء بالمسئولين والمشغلين في هذه المحطة. كما تم إجراء عدد من التجارب للخصائص النوعية ذات الصلة مثل العكورة، المواد الصلبة، المغذيات (الفوسفات والنترات) والكبريتات والتوصيلة الكهربائية والعسرة والرقم الهيدروجيني وغيرها.

أظهرت النتائج صحة الادعاءات حيث بدت المحطة مجرد سلسلة وحدات – مرور – إذ لم تتغير الخصائص النوعية للمياه الداخلة إلى المحطة عن تلك المتعلقة بالمياه المعالجة. كما ظهر أن صيانة الوحدات المختلفة لا يجري بشكل منتظم وفي حال إجراء الصيانة فان الأمر يستغرق فترة طويلة تبقى فيها الوحدات خارج نطاق العمل.

من الأمور المهمة التي تمت ملاحظتها إن إضافة الشب لا تمارس في هذه المحطة بحجة أن المياه الداخلة قليلة العكورة. ومن الطبيعي أن يسبب مثل هذا الإجراء العديد من المشاكل من بينها نمو الكائنات الدقيقة وصعوبة التعامل مع مثل هذه المياه قليلة العكورة.

وحيث أن المحطة قيد الدراسة تقع إلى الجنوب من سد كبير فان مواصفات المياه الداخلة إليها يغلب عليها خصائص ظاهرة الإثراء الغذائي وبخاصة الفوسفات والنترات.

أما المرشحات فقد تمت دراستها بعناية حيث ظهر أن تدرج حبيبات الوسط وسمك طبقة الرمل غير مناسبين. أما غسل هذه المرشحات فقد كان خلال العقدين المنصرمين يجري بواسطة الهواء فقط. وهذا الأمر له مردوداته السلبية في فقدان المواد الناعمة من طبقة الرمل وحصول تكسرات في مادة الوسط وعدم حصول الغسل بالشكل المطلوب والكفوء.

كذلك وجد أن مقدار الفقدان في الحامض لمادة الرمل يبلغ ٦.٣ بالمائة وهذه القيمة تتجاوز بكثير المواصفات المتعلقة بهذه الخاصية.

الكلمات الدالة: تأثير، خصائص، الماء الخام، محطة تصفية المياه، أسكي موصل.

INTRODUCTION AND LITERATURES REVIEW

Public water supply users take safe, clean drinking water for granted, however. It is expected that tap water is protected, crystal clear, at sufficient pressure, in abundant supply and cheap. Very few people realize the delicate intricacies of treatment processes that have gone on " behind the scenes" to make such great expectations a consistent reality(Tilman, 2000).

All surface waters require treatment prior to consumption to ensure that they do not pose a health risk to the users. Health risks to consumers from poor quality water can be attributed to microbial, chemical, physical or radioactive contaminations (NRWA, 1992 and Hammer, 2000).

Particulate matter mentioned above cause a decrease in water clarity that is often so - called turbidity. The latter affects adequate disinfection and rarely be achieved by coagulation-sedimentation alone. Consequently, filtration assumes the role of final treatment barrier for removal of undesirable particulate in water treatment (Montgomery, 1985).

In addition, many contaminants such as viruses, heavy metals, or some pesticides may be associated with particulates and thus efficient removal of particulate matter can improve overall water quality (Hammer, 2000).

Most water treatment plants in the city of Mosul were constructed 3 - 4 decades ago and comprised the conventional treatment units. The design of most water treatment plants in the city was based on concepts developed in the early 1960s, when many aspects of the treatment processes were not fully understood (Al-Rawi, 2008).

Filters have been found effective for removing particulate of all sizes as well as colloidal clay and microbial materials provided that proper design parameters are used.

RIVER MORPHOLOGY

The region in which the river going through is covered by deposition consisting of clay, sandstone, and conglomerate. Under these sediments, there exist Fatha Formation that composed mainly from mudstone , limestone, gypsum, and marl. This formation appeared largely on the surface (Al-Hamdani, 1997).

The river movement at present time is restricted by control gates as well as the reduced storage capacity in the lake for technical problems specified by authorized consultants.

The mean monthly sediment transport across Mosul station was 1100 ppm before construction of Mosul dam and reduced to 59 ppm after the construction of the dam (Al-Hamdani, 1997).

Bank erosion was more common in the form of bank collapse in regulating lake while at downstream it changes into normal erosion.

The Plant

Aski-Mosul water treatment plant was claimed to have a low performance in treating Mosul Dam Lake Water. Such water is characterized by reduced turbidity and bears the signs of eutrophied water. It is the purpose of this paper to focuses on the troubleshooting that exist in various units of this plant with a focus on the performance of filtration units in particular.

MATERIALS AND METHODS

The studied water treatment plant had been put into operation in the early 1980s with a total capacity of 66000 m^3/day. The plant is located directly downstream of Mosul dam. It receives high quality raw water due to long retention of the water at dam site. A common flow scheme for municipal water processing incorporates flocculation with a chemical coagulant and sedimentation prior to filtration. After being treated, water is disinfected and distributed to users.

Many visits to the site of the plant were made. All units were investigated to collect information relevant to the study. Discussion with manager and officials had added some extra information.

Water samples from different units were taken for analysis. Tests such as pH, total solids TS, total dissolved solids TDS, suspended solids SS, Turbidity, hardness, nitrates NO_3, phosphates PO_4, total plate bacterial count TPC, and algae were conducted on each sample. These tests were carried out as per standard methods (APHA, AWWA, and WPCF, 1985).

A representative amount of sand media was also taken for determination of characteristics of interest such as acid loss and grain size distribution.

Results of the study were analyzed and interpreted so as to determine treatment plant performance and to reveal any defects that might appear.

RESULTS AND DISCUSSION

Tables (1) shows the analyses of raw water samples received by the treatment plant and after being treated and prior to distribution to consumers. The listed values represent the outcomes of several visits and sampling. The results clearly show that most characteristics of the incoming raw water possesses relatively a good quality characteristics. This is highly attributed to long impoundment of the water in Mosul Dam Lake located to the north of studied plant. Turbidity for example appeared very low due to long impoundment of water in the lake. Further, Mosul lake captures 96% of the sediment transport (Al-Taiee, 1990). This situation is very good from health point of view. At the same time ,this issue has been misunderstood by operators and causes a lot of problems as will be discussed later.

Table 1: Raw Water Characteristics.

Item	**Range**	**Average effluent**
Hydrogen Ion Concentration pH	8.09- 8.13	8.3
Electrical conductivity EC	394 – 443	445
Total Hardness TH	136 -170	176
Alkalinity ALK.	86-128	126
Chlorides Cl	9.3 -13.9	9.9
Phosphates PO_4	0.07 -0.23	0.54
Nitrates NO_3	.0.07- 0.12	0.147
Sulfates SO_4	45 -55	55
Total Solids T.S	168 -203	198
Total Dissolved solids T.D.S	147-197	195
Turbidity (NTU)	١.٨-٢.٢	١.٥-٢.٣

All concentrations are in mg/l except pH and EC

However, some results also indicate that the treated water approximately appears to have the same characteristics as that of influent water. In other words, the studied plant units did not show the expected removal efficiency of impurities. This emphasizes the fact that the various units do not perform well enough when dealing with high - quality raw water (Al-Rawi, 2000). According to this fact, this plant is merely acting as a series of passing - through units.
As such ,a careful investigation has been made to disclose the reasons behind such inconveniences. This investigation follows the same sequences of employed treatment units.

PRETREATMENT

Reduction of solids going to filters is usually accomplished by using chemical coagulants (coagulation) and mechanical pretreatment (flocculation) designed to improve the settling of the suspended solids. Addition of coagulant provides floc size large enough to settle, and settling out most of the original suspended solids. An effluent is produced which will contain less of the original suspended solids but which will contain some of different kind (residual floc). The net effect is to reduce the rate of head loss development. The effect of the reduction of head loss will appear in longer filter runs .

As previously stated the operators usually think that addition of alum or any other coagulant is not needed as the amount of turbidity is highly reduced due to water impoundment. Such decision is not scientifically acceptable. Low turbidity causes water to becomes “tough” and hardly can be tackled in subsequent units of water treatment plants. Besides, Giardia Cyst can grow in such water and lead to many health disturbances(Al-Rawi, 2000).

Addition of chemicals however, is not practiced in this plant due to misunderstanding of the mechanism and the importance of chemical coagulation.

The absence of pretreatment by alum in the treatment plant under study may increase the filtration resistance of suspended solids. In other word it decreases the ability of the filter to remove and retain suspended solids.

It is well known that natural impurity such as algae, clay, and biological cells…etc. removed by filtration are compressible. Thus as head loss builds up across the solids retained on a filter, these solids become increasingly compressed due to higher hydraulic gradient. As the solids compress, the void space available for passage of water is reduced and the permeability of the solids decreases. Consequently a degradation of effluent quality does occur.

Coagulant carryover is essential in removing microscopic particulate matter that would otherwise pass through the bed. If an excessive quantity of large floc overflows the settling basin, a heavy mat forms on the filter surface by straining action and clogs the bed. However, the impurities in an improperly coagulated water may penetrate too far into the bed and can be flushed through before being trapped causing a turbid effluent.

Clariflocculators tanks on the other hand are left without maintenance for long time. During the she period of study ,one of the two main clariflocculators was left out of operation while the other one act as a feeder to filtration units. This gives chance to considerable patches of algae to accumulate and adhere to tank surface and reach to subsequent units. The effects of algae patches appear in increased concentration of nutrients such as phosphates in the influent water to the filters.

This is confirmed by the increase of phosphate concentration in the treated water. Algae can not be removed in filters as no chemical coagulation is practiced. Algae then can pass through the voids of sand media and emerge in the effluent.

Such actions is probably and partially attributed to lack of pretreatment by alum or the doses are not adequate.

FILTERS

The granular–media gravity type filter is adopted in the studied water treatment plant. A total of 16 filters of 40 m^2 surface area each are used. These filters aid in removing non - settleable floc remaining after clariflocculation. Each filter is placed in a concrete box with a depth of about 3.0 m.

The performance of filtration process depends on many factors. Gradation of media grains, media acid loss, filtration rate, raw water turbidity, ease of backwash, and media depth are few examples. During filtration, water passes downward through the filter bed by a combination of water pressure from above and suction from the bottom. Filters are cleaned by backwashing (reversing the flow) upward through the bed. Wash troughs suspended above the filter surfaces collect the backwash water and carry it out of the filter box.

On the other hand, visual test of filter media shows that the filter sand is almost absent particularly the fines, and what is there is a thin layer of coarse sand embedded into gravel layer of the under drain system. It is worthy to mention that original drawings of the plant amount to 75 cms whereas the existing depth does not exceed 50cms.

BACKWASH

Filters are washed to restore their capacity when the effluent quality becomes unacceptable, or when the pressure drop through the filter reaches a predetermined value. Those two conditions are not followed in the studied filters. Lack of instrumentation for quality determination, and absence of headloss measurements have led to this situation. Back washing is practiced in the plant as a rule of thumb, each 3 days. Besides backwash is practiced for the past 20 years by air scouring only. This inevitably will lead to a lot of problems.

Filters may suffer poor cleaning during hydraulic backwash. Higher backwash rates may also result in disturbance of the graded gravel underdrain, or in carryover of sand in the wash water.

On the other hand, poor washing may lead to cracks. These cracks form an easy flow-path that provides little opportunity for filtration.

Mounds or holes suggest a lack of uniformity in the gravel and underdrain such as displaced gravel or blocked or broken nozzles.

Mud balls are clumps of sand grain cemented together by deposits. Mud ball and other heavy impurities formed during filtration would drop down to the gravel under layer when the bed was expanded rather than being washed out in the overflow. They are indicators of poor backwash. These problems can easily be detected in the studied filters. plate 1 and 2 display this fact.

MEDIA SIZE

The ideal filter possesses the following characteristics: coarse enough for the large pore openings to retain the large quantities of floc yet sufficiently fine to prevent passage of suspended solids.

Granular media are specified by effective size and uniformity coefficient. Effective size is the 10-percentile diameter, which means that 10 percent of the filter grains by weight are smaller than this diameter. Uniformity coefficient is the ratio of the 60 percentile diameter to the 10 percentile diameter. Common ranges in effective size and uniformity coefficient for single media sand filters are 0.40 to 0.55 mm and 1.3 to .7, respectively (Al-Rawi, 1987 and Twort, 2000).
As shown in fig.1 , it is impossible to determine the value of d_{10} as most or all the fines had been washed out due to backwash by air scour.

Besides, an important factor of suitability of sand material to ac as a filtration medium is its acid loss in a strong acid. The determined value for the used sand was 6.3% compared to 2.% required by specification (Degremont, 1991).

Accordingly, the existing system of sand layers and underdrains should be substituted by a new one conforming to authorized recommendations. The new system is preferably assumes the following size and thickness (tables 2 and 3) (WHO, 1969) .

Plate 1: Mounds and Holes in the Filter Bed Suggest Probability of Problems in the Gravel and Under Drains.

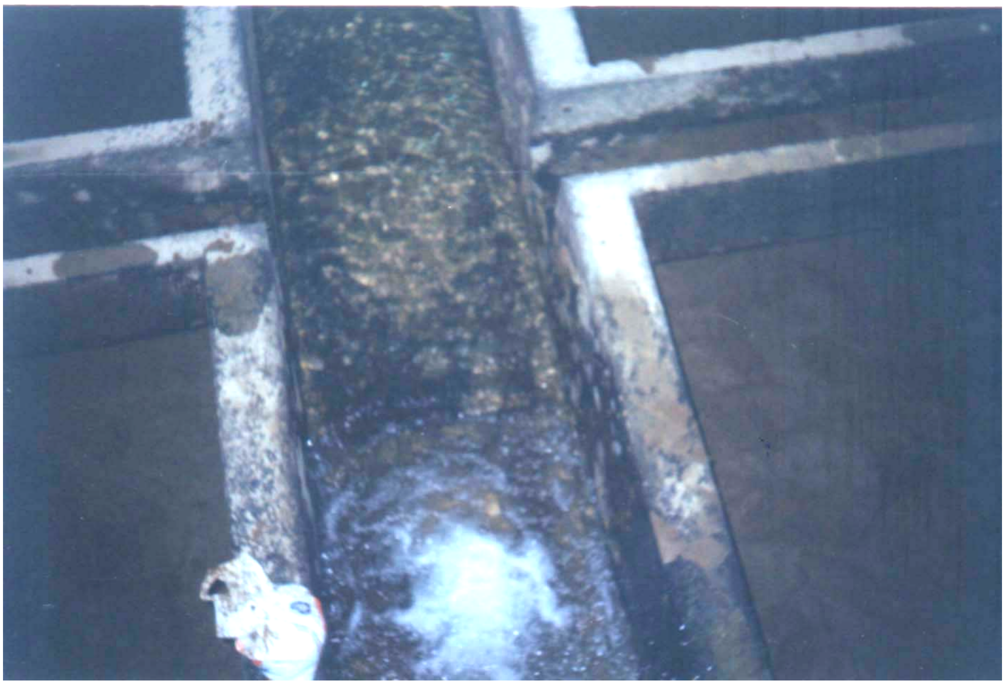

Plate 2: Sand in the Wash Water Trough is an Indication of the Escape of this Material Due to Excessive Air Scour.

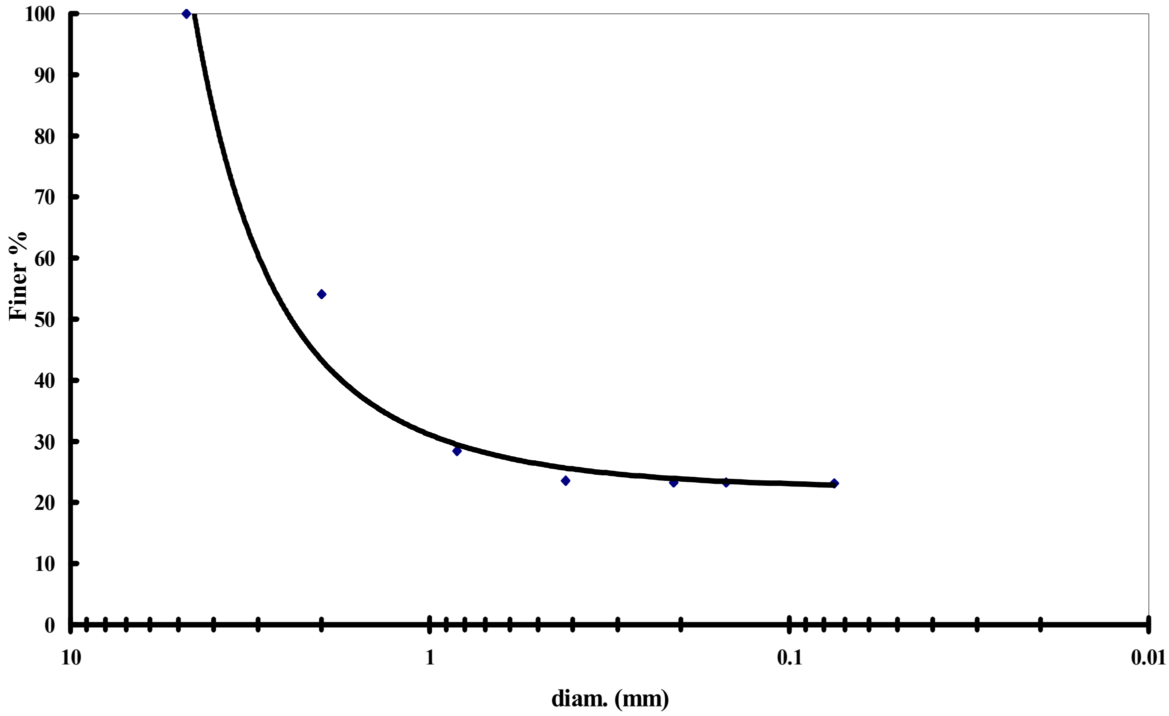

Fig. 1: Gradation of Sand Medium Used in the Studied WTP.

Table 2: Recommended Sand Media Sizes.

Sieve No.	**Sieve opening**	**EFFECTIVE SIZE % PASSING SIEVE**		
		0.35- 0.45 mm	0.45 – 0.55 mm	0.55 0 0.65 mm
16	1.19	94 –100	84 –99	66 – 94
20	0.84	71 –97	49 – 84	30 – 71
30	o.59	31 –73	14 –39	6 –31
40	0.42	6 –25	2 –6	0 –1
50	0.30	0 –3	0 –1	0.0

Table 3: Recommended Gravel Sizes

Layer	**Depth**	**Size**
Top most layer	7.5 – 10 cms	3 – 6 mm
Intermediate	7.5 – 10 cms	6 –10 mm
Intermediate	12 –15 cms	10 –20 mm
Bottom	12 – 15 cms	20 –40 mm
Bottom most	15 –20 cms	40 – 64 mm
Total	54 – 70 cms	

BACTERIOLOGY AND ALGAE

Table (4) shows the performance of the plant in removing harmful microorganisms. The plate count may be considered as an indicator of pollution. Actually there is no definite standards can be set for plate count, but usually it should be less than 500 per milliliter (Al-Singery, 2001). The results show considerably higher values. This means possible contamination with surface drains or sewage. The higher counts in the filtered water may indicate passage of bacteria through the filters or bacterial growth in the filters.

Similarly the presence of algae in the influent may lessen filtration run length. Patches of algae had been noticed on filter's surface. The relative high concentration of PO_4 in the filtered water compared to influent confirms this fact.

Table (4) lists the values of selected parameters concerning the biological performance of the plant.

Table 4: Selected Physical and Bbiological Tests*

Source	Turbidity (NTU)	Total plate count No./ml	Algae No./ml
Raw	1.8	8700	21000
Sed.T	2.0	5200	10500
F.7**	2.2	2800	5000
F.10	1.5	2310	6250
F.13	2.2	4100	5500
F.5	2.0	2340	4500
Storage tank	2.4	2400	4000

*listed values represent the average value of stages 1 and 2

** indicates filter number in the treatment plant.

CONCLUSIONS

1- Units of the studied WTP did not perform as expected. This may be attributed to poor design, age of the plant.

2- Sand media or grain size distributions do not conform to the specifications Majority of fines are already lost.

3- Acid loss of sand grains amounts to 6.3 % which is excessive and urpasses the recommended 2 % .

4- The depth of sand media is insufficient for proper operation and affects filter run length.

5- Filters are backwashed by air scour only. This practice was followed for the recent 20 years.

6- Bacterial count and algae exceed the usual recommended value and a fear of contamination is expected.

7- Mudballs, cracks, mounds, and holes can easily be detected in the filters.

8- Plant units do not perform well in removing impurities. They are merely acting as a passing through units.

9- Absence of instrumentation and measuring devices add to plant problems.

10- Limited experience of the working staff in the plant needs to strengthen.

11- New system of sand layer and under drain should replace the existing system.

REFERENCES

Al-Hamdani, A. 1997. Development of Tigris River Reach between Sadam dam and Mosul city" Ph. D. thesis, Baghdad University, College of Science.

Al- Rawi, S. M. 1987. Turbidity Removal of Drinking Water by Dual Media Filtration". MSc. thesis, Mosul University, Iraq.

Al-Rawi, S. M. 2000.Treating Low Turbidity of Tigris River by Unconventional Filtration Methods, J. Res. on Envir. And Sustaiable Development, Vol. 3, No. 1, Iraq.

Al-Rawi, S. M. 2008. Troubleshooting, Rehabilitation and Improvement of Water Treatment Plants in Mosul City, A preliminary report for ASTF, Unpublished.

Al-Singery, M. N. 2001. An Ecological Study of The Tigris within Mosul City M.Sc., Thesis, College of Science, Mosul University, Iraq.

Al-Taiee, T. M. 1990. The Influence of Dam on the Degradation of Downstream River Bed, Proc. Of the Inter. Conference of hydrology in Mountainous Regions Swaziland,.

APHA, AWWA, and WPCF, 1985. Standard Methods for the Examination of Water and Wastewater. 14th edition, USA.

Degremont, 1991. Water Treatment Handbook, 6th edition, France.

Hammer, M. J. and M. J. Hammer Jr, 2000. Water and Wastewater Technology 6th ed. USA.

Montgomery, J. Consulting Engineers, 1985. Water Treatment Principles and Design. John Wiley and Sons, USA.

NRWA, National Rural Water Association, 1992. Filters and Filtration, USA.

Tilman, G. M. 2000. Water Treatment, Troubleshooting and Problem Solving Lewis Publisher, USA.

Twort, A. C., D. D. Ratnayaka and M. J. Brandt, 2000. Water Supply: Butterworth, UK.

WHO, 1969. Operation and Control of Water Treatment Processes, Geneva.