Experimental evaluation of filter conditioning on the ripening of conventional rapid sand filter

Mr. Manoj H Mota, Dr. P S Patil

Abstract- The use of filter conditioning, by means of filter aid is relatively new concept to improve filtrate quality of conventional media filters. Different advantages claimed by such use of filter aid includes reduction in ripening period, higher turbidity removal as well as relatively stable effluent quality. Research explained in the paper focuses on the use of alum as filter conditioner. The study was carried out using a pilot plant installed at Ichalkaranji municipal water treatment plant. Different doses of alum were used and the comparison was made with the performance of conventional filter without filter aid. The parameters for evaluation were turbidity removal and head loss observed. The surface removal was dramatically improved because of the filter conditioning resulting in early maturation of the media. The effect of zeta (ζp) potential change was observed to be one of the major reasons of the performance improvement.

Index terms: Alum dose, Filter conditioning, rapid sand filter, ripening period, turbidity removal, head loss, zeta (ζp) potential.

1. INTRODUCTION

Filtration is a unit process which physically removes suspended materials. The particles able to escape through the process of clarification are removed by the process of filtration. The filtration using rapid sand filter is the polishing stage of the water treatment process.1 A typical filter run can be divided into three different phases as filter ripening or maturation of bed, effective filtration and break-through. During the ripening the quality of filtrate is very poor. It is a phase characterized by comparatively high effluent turbidity. It is the consequence of flushing of left over backwash water and remnant particles from the filter media (Amirtharajah and Wetstein, 1980). It may last from only some minutes to more than a few hours (O’Leary et al. 2003; Amburgey and Amirtharajah 2005). For more than few decades filter ripening has been studied as a result of its weakness of increased passage of particles and microorganisms into the distribution system. Unfortunately in developing countries this part is not at all been seems to be addressed at conventional water treatment plants. The major reason of such ignorance may be the reliance upon the use of chlorination to deal with pathogens escaped and relatively less stringent norms in regard with turbidity as compared to the norms followed in developed countries. How-ever the standards in India was revised in 2015 and has upgraded the requirement of turbidity of potable water from 5NTU to 1 NTU. This change has forced the improvement of performance during ripening of bed as one of the important objective in filtration studies. In India sand is used as a filter medium as native anthracite coal or appropriate substitute media is not available. Nevertheless, sand media may not be efficient in removing fine or submicron particles including colloids, bacteria, and viruses because of electrostatic repulsion arising from the fact that both the particles and the sand media are negatively charged at pH ranging from 6 to 8, which is typical of surface waters. Small particles close to 1 μm also have very poor transport, impairing their removal (Yao et al. 1971). This is also a fact that few microorganisms like C.parvum Oocysts are usually resistant to traditional disinfectants like chlorine and chloramines (Finch et al. 1993, Owens et. Al, 1994), thus protection of municipal potable water supply often relies on granular bed filtration as on robust, simple and inexpensive method to prevent penetration of disinfectant resistant pathogenic microorganism (Logstone et.al, 1981, US EPA 2000).

Most of the water treatment plants in India rely depend on the surface water sources, mainly river. Natural organic matter (NOM) concentration in surface water generally

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ranges from 0.1mg/lit to 20mg/lit and is mainly composed of humic substances. (Alexandrina Rodrigues et al. 2008). Dissolved aquatic humic substances are net negatively charged macro-molecules can adsorb onto the surface of clay and other natural particles, further increasing their negative charge (Pernitsky and Edzwald 2006) and reported to reduce particle capture by porous medium filters (Franchi and O’Melia 2003). All these circumstances are affecting the overall performance of filter including ripening behavior adversely.

In developed countries different procedures have been reported to be very significant in controlling ripening. Such procedures includes filter to waste strategy, filter resting, slow start, extended terminal sub-fluidization wash, addition of polymer or coagulant in wash water or use of filter aid in influent etc. (Cranston and amirthrajah,1987, Colten et al. 2003,Amburgy,2005, Logstone et al. 2003). One very effective way to reduce the ripening period is the use of filter aid. The coagulant like alum of poly-aluminum chloride can be used effectively as filter aid. These aids can be used as continuous dose during the filter, as slug dose or during the back-washing. (Nick Pizzy,2000,Gary et al.2005, Suthakar et al.2008, Po-Hus Lin et al.2011, 2012,2013). Such conditioning is also effective in case of slow sand filtration too. (Kwok et al. 2005) Very little work in this regard is done in developing country like India. This research unfolds the study made to improve the performance of rapid sand filter during the ripening period using the filter conditioning. The alum is used as the filter aid. Unlike other researchers who have used the filter aid as continuous dose during the filter or during the backwashing, the slug dose of alum is used to condition the filter media. Different doses of alum as filter aid were tested and the comparison was made with the performance of conventional filter without filter aid during the ripening. The parameters for evaluation were turbidity removal and head loss observed. Enhanced surface removal because of less negative zeta potential of the sand surface as a result of the filter conditioning was observed to be the key reason behind the improvement in ripening behavior. The comparatively faster head-loss development was also observed, which was an obvious outcome of high particulate removal in early stage.

The study was carried out by installing a pilot plant at Ichalkaranji municipal water treatment plant. The capacity of the plant is 26MLD. The source of the water is river Panchganga.

2. MATERIAL AND METHODS:

The pilot model was installed at Ichalkaranji water treatment plant, where the clarified water was used for the performance evaluation of filter media conditioning during the ripening. The filters were challenged by the water having turbidity in the range of 7.1 to 7.5 NTU. The feeding tank of 300 liter was kept to achieve uninterrupted supply during the study.

A pilot scale model of filter was constructed using square glass columns of inside dimension of 0.15m along with associated piping and valves for appropriate control on filtration rate. The pump of 0.5 HP was used to facilitate back washing. The backwashing rate was kept as around 0.7m/min.

The sand utilized for the filter media was obtained from the stock sand available at Ichalkaranji WTP. The required sand was initially washed and sun dried. The sand of required specification was prepared by sieving and mixing in appropriate proportions. The fines from sand were removed by washing out. The effective size was 0.5mm and coefficient of uniformity of sand used was 1.7. Because of wall effects, porosity (ε) is dependent on the ratio of particle diameter (d) to container dimension (D), as well as the ratio of particle diameter to medium depth of the medium (H). The effective sand particle diameter and filter column dimension were 0.5 and 150 mm, respectively (i.e., d:D, 1:300), and depth of sand medium was 750 mm (i.e., d:H, 1:1550). At these ratios the porosity for both loose and dense packing is almost the same as the original porosity (Zou and Yu 1995). Thus, wall and thickness effects did not significantly affect porosity in the filtration studies. This was helpful in maintaining expected porosity. These parameters were helpful in modeling the realistic conditions.

The alum was added in the form of solution after backwashing as a slug dose, just before challenging the filter column to settled water. Different alum doses tried during the study were as follows. The turbidity inlet as well as outlet and associated head loss of filter was measured at an interval of 1min. The Hach turbidity meter-2100P was
used to measure the turbidity. As per the BIS (IS 10500:2012 revision 2) the acceptable range of turbidity was assumed to be 1NTU for ripening. The filters were run and backwashed several times before the actual observations were recorded. This step was helpful to achieve the stratification of media and to model the realistic condition of filter bed. Filters were run for declining rate of filtration. Initial rate of filtration was kept around 6000lit/hr/m² (i.e. approach velocity around 6m/hr). Filtration rates were monitored by pre-calibrated rotameters. Three runs for each dose of alum were conducted. Although the finest run is being considered for the discussion in the current paper. Zeta meter 4.0 (Zeta-meter, Inc. USA) was used to measure the zeta potential. The zeta potential of influent particles and conditioned media was measured.

3. RESULTS AND DISCUSSIONS:
Following are the observations recorded during the pilot plant study. The prominent observations are summarized in table 1 and table 2.

3.1 Filter ripening behavior:
The characteristic curve of initial effluent quality is referred as filter ripening sequence, (FRS) (Cranston and Amirthrajah, 1987). Simultaneous filter run were conducted to understand the FRS. FRS observed during the various dosages used to condition the filter media are demonstrated in fig.2. The FRS observed is quite consistent with the definition sketch proposed by various researchers. Initial low turbidity water passage can be attributed to the passage of clean water present in lower part of media and gravel bed. As a common fact, the lower part of media is not efficiently utilized for the removal of turbidity due to stratification; the pores in this part of media are occupied by the clean backwash water immediately after the backwashing. On other hand because of application of filter conditioner dose, the particles which are present in the upper part of media (i.e. remnant particles, those which are dislodged during the backwashing from media but not been escaped from filter box during the course of backwashing,) are pushed in to the lower part which may get comparatively early escape through the media.

![Fig.1 Photograph of installed pilot plant at Ichalkaranji WTP](image)

![Fig. 2. Definition sketch, FRS](image)

(Source: Experimental evaluation of ripening behavior; V.D Salkar and A R Tembhurkar, 2015)

The next phase is characterized by reduction in the turbidity with sporadic small turbidity spikes. The reason of these spikes is escape of remnant along with the particles present in influent as the filter is not ripened. Similar kind of behavior is observed in both cases. This is followed by the sharp reduction in turbidity of filtrate, which is an indication of ripening because of media conditioning. Application of media conditioner has resulted in dramatic acceleration in filter ripening. The ripening period in case of conventional filter media was found in between 51 to 57 minutes, while significant reduction in the same was observed after the filter conditioning. The ripening was reduced as the dose of conditioner is increased. The reduction in ripening period was observed in the range of 63 to 77 %.)
Another noteworthy thing to mention is the leaching of alum solution in case of first two dosages at the beginning of the filter cycle which can be assumed to be the wastage of the dose. Even the smaller dose of alum as slug dose is quite enough as conditioner. The dose of 2.222 kg/m² of filter area is also sufficient to achieve the significant reduction in ripening period which is in the range of 70%.

3.2 Effect of zeta (ζp) potential:
One of the requirements for removing particulate contaminants as well as pathogens is to enhance the water quality. These impurities are primarily negatively charged. The bacteria and viruses also carry negative charge. Such elements are always undesirable as they are difficult to separate because of such charge. These particles can be removed by oppositely charged additives by reducing their charge close to zero. Zeta (ζp) potential is nothing but the measure of such potential. Higher zeta (ζp) potential indicates more repulsion of the particles. The addition of coagulant like alum destabilizes the particles by reducing the negative zeta (ζp) potential (Bean et.al.1964).

On other hand the sand media is also negatively charge resulting in less efficiency because of repulsing the particles. Influent particles with negative zeta (ζp) potential are less likely to adhere to negatively charged sand grains unless their zeta (ζp) potential is modified. Exess doses of coagulant are required for reversing the surface charge to positive or less negative. So the attempt is made to modify the surface charge of media by conditioning it with alum. Also the formation of the coat of liquid alum around the sand grains, resulted in suppression of repulsive forces of media and particles present in the influent.

The zeta(ζp) potential of influent was measured and found in the range of -17.8 to -20.1 mV, while the zeta(ζp) potential of effluent passed through the conditioned media was found in the range of +3 to -6.8 mV depending on the dose of alum. Higher zeta(ζp) potential is observed in case of high alum dose as conditioner. The zeta(ζp) potential is decreased as the dose of alum is decreased. Still for various dosages examined the reduction in zeta(ζp) potential was proved to be significant. This is a fair indication of excellent surface removal of particles after the conditioning because of destabilization. Additionally because of contact of influent particles with the alum solution present in the pores may resulting in the destabilization of the particles at less negative zeta(ζp) potential, improves their settling within the filter media which are acting as a tiny settling basins. Better attachment of particles may even result in increased stress on back-washing process.

Table 1: Relation between stability behavior and zeta(ζp) potential values

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Stability Characteristics</th>
<th>zeta(ζp) potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>01.</td>
<td>Maximum agglomeration</td>
<td>+3 to 0 mV</td>
</tr>
<tr>
<td>02.</td>
<td>Excellent agglomeration</td>
<td>-1 to -4 mV</td>
</tr>
<tr>
<td>03.</td>
<td>Fair agglomeration</td>
<td>-5 to -10 mV</td>
</tr>
</tbody>
</table>

(Source: Zeta meter system 4.0 operating Instructions)

3.3 Effect on the head-loss:
As mentioned in table no.3 and shown in fig.5, the development of head-loss observed in case of conditioned media was higher . The clean bed head-loss observed was also higher. The prime cause of the rapid head loss development in early stage was the aggravated surface removal due to reduced zeta(ζp) potential. This may result in significant reduction in the total filter run. This incremental increase in head-loss can be attributed to the excessive surface removal. The extent of development of head loss is found increasing as increase in alum dose. Steady buildup of collector efficiency is also responsible for incremental increase in the head loss.

Table 1: Different Alum dosages tried:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Alum dose provided to pilot filter column</th>
<th>Rate of alum addition per m² of filter area</th>
<th>Dose in terms of moles per m² of filter area</th>
</tr>
</thead>
<tbody>
<tr>
<td>01.</td>
<td>10% alum solution…6 lit</td>
<td>26.667 kg/m²</td>
<td>40.76</td>
</tr>
<tr>
<td>02.</td>
<td>10% alum solution…3 lit</td>
<td>13.333 kg/m²</td>
<td>20.38</td>
</tr>
<tr>
<td>03.</td>
<td>5% alum solution…1 lit</td>
<td>2.222 kg/m²</td>
<td>3.4</td>
</tr>
<tr>
<td>04.</td>
<td>2.5% alum solution…0.5 lit</td>
<td>0.555 kg/m²</td>
<td>0.85</td>
</tr>
</tbody>
</table>

* Rate of alum addition (kg/m²) = Strength X Quantity of solution / (0.15 X 0.15)
Table 3: Different dosages and corresponding ripening period observed

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Alum Dose (kg/m²)</th>
<th>Ripening period (min)</th>
<th>Reduction in ripening period (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Conditioned filter</td>
<td>Conventional filter</td>
</tr>
<tr>
<td>01.</td>
<td>26.667</td>
<td>15</td>
<td>52</td>
</tr>
<tr>
<td>02.</td>
<td>13.333</td>
<td>18</td>
<td>51</td>
</tr>
<tr>
<td>03.</td>
<td>2.222</td>
<td>25</td>
<td>57</td>
</tr>
<tr>
<td>04.</td>
<td>0.555</td>
<td>32</td>
<td>57</td>
</tr>
</tbody>
</table>

Table 4: Different dosages and corresponding head-loss observed

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Alum Dose (kg/m²)</th>
<th>Clean-bed head-loss (m)</th>
<th>Head loss at the end of ripening period (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Conditioned filter</td>
<td>Conventional filter</td>
</tr>
<tr>
<td>01</td>
<td>26.667 kg/m²</td>
<td>0.29</td>
<td>0.40</td>
</tr>
<tr>
<td>02</td>
<td>13.333 kg/m²</td>
<td>0.28</td>
<td>0.38</td>
</tr>
<tr>
<td>03</td>
<td>2.222 kg/m²</td>
<td>0.27</td>
<td>0.34</td>
</tr>
<tr>
<td>04</td>
<td>0.555 kg/m²</td>
<td>0.27</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Fig. 3. Ripening of filter media
4. CONCLUSION:
An alum pre-treated conditioned filter media achieved reduction in ripening period. Results of the pilot study showed that even a small amount of alum dose in the range of 0.555 kg/m² to 2.222 kg/m² of filter area can lower the ripening period by 60-70%. Higher conditioning dose results in leaching of conditioner. Higher dose may not be much significant in achieving the suppression of ripening period. The filter conditioning can be a very easy to implement along with its dramatic improved performance to remove the particles in early stage. It can demand very negligible change in the form of provisions to be made in conventional water treatment plant filter box with no change in existing physical dimensions of filter box.
Reduction in zeta potential of effluent is an indication of excellent surface removal in initial stages. It indicates the adsorption of turbidity causing particles on conditioned granular media. The introduction of such media conditioning is also resulting in the higher head-loss development. This may also result in lower filter run and higher stress on back-washing.
These problems can be addressed by modifying the media configuration and back-washing process. But discussion on those is a topic of separate research and is beyond the scope of this paper.

5. ACKNOWLEDGMENT:
The authors want to acknowledge the support provided by the Hydraulic engineer, Ichalkaranji Municipal Corporation for permitting the study to carry out in their premise of water treatment plant and Walchand college of Engineering for providing laboratory facility required to complete this research. The authors thank their parent institutes namely Sharad institute of technology, college of Engineering and Rajarambapu Institute of Technology, Rajararamnnagar, Islampur without whose support this study would not have been possible.

6. REFERENCES:


