PRACTICAL MEANS OF SOLVING MUD BALL PROBLEMS IN SAND FILTER MEDIA

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ABSTRACT

Sand filter media used in rapid gravity filters must be cleaned properly after each filter cycle to remove all deposited matter. Inadequate cleaning leads to the accumulation of material within the filter bed in any form. “Mud balls”, as one such form, are agglomerates of grains of filter material, fine silt or clay, and flocculated material that are held together with adhesive matter that may be of chemical or biological origin. Mud balls start forming when gelatinous solids accumulate on the exterior of media grains. Normally this deposit is removed through effective backwash procedures. However, if the deposits are not removed the individual dirty grains will form small, pea sized, collective masses which can rapidly grow to clumps some 50 mm or more in diameter. The presence of mud balls can result in an increased headloss, localised increases in filtration rates, the development of cracks and a decline in the filtrate quality. One of the most popular solutions to mud ball problems is to replace the filter media. However, this is an expensive and time consuming solution. In this study, physical and chemical remediation procedures to address mud ball problems were investigated. Physical remediation involved turning the filter media and scraping mud balls from the filter bed. Chemical remediation involved the in situ application of chlorine, and hydrogen peroxide onto the filter media. The efficiency of these remediation procedures were evaluated based on a number of sand filter media characterisation methodologies. It was found that the physical remediation process was very labour intensive and had limited success in terms of improved filter media quality. Chemical remediation processes demonstrated longer lasting mud ball remediation effects. Hydrogen peroxide showed the most potential as a suitable solution to the mud ball problem and showed an improvement in the aesthetic aspects of the filter media, a reduction in the total suspended solids and total organic carbon concentrations on the filter media, and an observed benefit in terms of increased bed expansion. Chlorine showed a reduction in the total suspended solids, but at a lower efficiency compared to that of hydrogen peroxide.

INTRODUCTION

Filtration acts as the final step in the removal of suspended matter in the water treatment. Backwash is the cleaning process of removing these deposited particles from the filter media. (1) If filters are inadequately cleaned then the deposited material tends to accumulate, which could lead to filter media deterioration in the form of mud balls. Mud balls are aggregates of dirt, solids, flocculated material, coagulants, and filter media which accumulate together to form clumps. (2) Mud balls start forming when gelatinous solids accumulate on the exterior of media grains. (1) If these deposits are not removed, the individual dirty grains will form small, pea sized, collective masses which can rapidly grow to 50 mm or more in diameter. (3) Smaller mud balls of low density will normally occur on the surface of the filter bed, but eventually as the mud balls grow in size they may sink, further into the filter bed, making them increasingly difficult to remove. Sub-surface accumulation of mud balls, lead to inactive areas in the filter bed, thus increasing the filtration rates in the remainder of the filter bed, which could have a detrimental effect by decreasing the filtrate water quality and decreasing the filter run time. (3)

Mud balls are formed as a result of one or more of the following:

- Inadequate backwashing of a filter, thus allowing for accumulation of solids and dirt particles (1, 3, 4), i.e. too little air used to break the filter bed, the backwash rate is too slow, and an inappropriate cleaning cycle.
- Too long filter runs resulting in very dirty filter media and compacted filter beds.
- Gradual deterioration of infrastructure i.e. leaking backwash water valves that result in only a portion of the wash water being delivered to the filter being cleaned.
- Inappropriate selection and application of water treatment chemicals used for coagulation and flocculation, i.e. use of polymers which form robust attachments between filter media grains and solid particles. (3)

The formation of mud balls in filter media at water purification plants is a universal problem that should be avoided at all costs, or if already present, be immediately addressed to restore filter efficiency. One of the most popular solutions to mud ball problems is to replace the filter media. However, this is an expensive and time consuming solution. In this study, physical and chemical remediation procedures for mud ball problems were investigated.

METHODOLOGY

Two categories of remediation procedures, i.e. physical remediation procedures and chemical cleaning procedures were tested on mud ball filter media from a filter house at Rand Water’s Zuikerbosch treatment plant. For many years the plant has mainly been using polyelectrolyte as a coagulant.

Physical remediation procedures are highly labour intensive, and involve mechanical work in the filter bed. It is the simplest of remediation procedures, but is time consuming. The physical remediation procedure involved turning the filter media and scraping mud balls from the filter bed. This procedure was repeated as often as needed to remove the mud balls from the filter beds. The concentrations of mud balls present in the filter media were determined in various filters before and after turning.

Chemical procedures are not as labour intensive as the physical remediation procedures; however it seems as though the effects are more rigorous. These procedures do however make use of potentially dangerous chemicals. Chemical remediation involved the application of chlorine, *in situ*, and hydrogen peroxide onto the filter media.

Chlorine was applied directly to the filter bed in the form of calcium hypochlorite granules. The filter was taken out of commission, backwashed and drained. Calcium hypochlorite granules was applied onto the filter bed at a concentration of $100 g/m^2$, the filter bed was then submerged in water to just below the overflow weir, and air scour was applied for 3 minutes to allow for efficient mixing. The filter was left to soak for 4 hours and was then rigorously backwashed before being put back into commission. Filter media was sampled before and after the application of chlorine and analysed for specific deposits and mud ball concentrations.

Hydrogen peroxide is a strong oxidising agent and was applied to the filter media to produce a 10% concentration based on a void volume of 40% in the filter media. The filter media was left to soak overnight. The effect of peroxide on the physical structure of the mud balls, the physical appearance and properties of the media, and the presence of accumulative specific deposits as well as the TOC were determined. The specific deposits on treated and untreated filter media were determined after the media was washed for 7 minutes at an up flow rate of 35 m/h in an experimental filter.

The efficiency of the physical and chemical remediation procedures were evaluated based on the listed methodologies.

<u>Mud ball volume</u>

The mud ball volume was determined by screening 25 litres of filter media through a sieve with an aperture size of 6 mm. The mass and the volume of mud balls that was retained on the sieve were determined. The volume of the mud ball was then expressed as the volume/volume percentage of the original sample. Brouckaert, *et al*, (2) have characterised the percentage volume of the filter occupied by mud balls as follows:

- Less than 0.1% - Clean bed.
- 0.1 - 0.5% - Media in a good condition.
- 0.5 – 1.0% - Fairly clean media.
- 1 – 5% - Media in a bad condition.
- Greater than 5% - Media should be replaced.

<u>Specific deposits (SD)</u>

Specific deposits is a measure of the material that remains on filter media after the cleaning process and it provides an indication of the effectiveness of the backwash cycle, i.e. how well the filter has been cleaned. SD is a direct measure of the amount of dry solids that are deposited on 1 g of clean filter media. The revised South African Guidelines for specific deposit measured as total suspended solids (TSS) present on filter media after a single backwash is given below (5). A value of above 6 mg/g usually indicates a dirty bed. (6)

- Less than 3mg/g - Class I - Clean filter and ripened bed
- 3 – 6mg/g – Class II - Slightly dirty, less than ideal bed, but not yet a concern
- 6 – 10mg/g – Class III - Dirty bed with a need for evaluating the filter washing system and backwash procedure
- >10mg/g – Class IV - Could indicate a mud ball problem

The specific deposits (SD) were determined by the inversion method, and characterised in terms of:

- total suspended solids (TSS) on the sand,
- non-soluble, non-volatile solids (NSNV) on the sand, is the fraction that is not soluble in acid and does not ignite or burn when heated at 550°C and corresponds to the inorganic particles present in the raw water,
- soluble, non-volatile solids (SNV) on the sand, is the fraction that is soluble in acid, but does not ignite or burn when heated at 550°C and originates from the carry-over of chemical precipitates, and
- volatile solids (V) on the sand, which is the fraction of the specific deposit that ignites and burns when heated to 550°C in an oxygen containing atmosphere, representing the loss on ignition of bacterial and algal biomass, i.e. organic matter, as well as losses due to the decomposition or volatilisation of some mineral salts.

From the distribution of the different specific deposits, conclusions about the quality of the media and also the best treatment methods can be made. Van Staden, *et al,* (5), suggested the following rehabilitation strategies after stripping the specific deposit from the media grains:

- If the stripped deposits are mostly biological (volatile solids, V), the media could be treated *in situ* with an oxidant such as chlorine (Cl_2),
- If the stripped deposits are mostly chemical precipitates (soluble non-volatile solids, SNV), the media could be treated *in situ* with an acid such as hydrochloric acid (HCl),
- If the stripped deposits are mostly natural silts (Non-soluble, non-volatile, NSNV), mechanical cleaning methods should be employed to clean the media.

Total organic carbon (TOC)

Total Organic Carbon (TOC) is defined as the measure of the concentration of organic carbon. (1) Filter media samples of dirty filter media and filter media after being treated with hydrogen peroxide were analysed for TOC.

RESULTS AND DISCUSSION

Physical remediation – Turning the sand

a. Mud ball volume

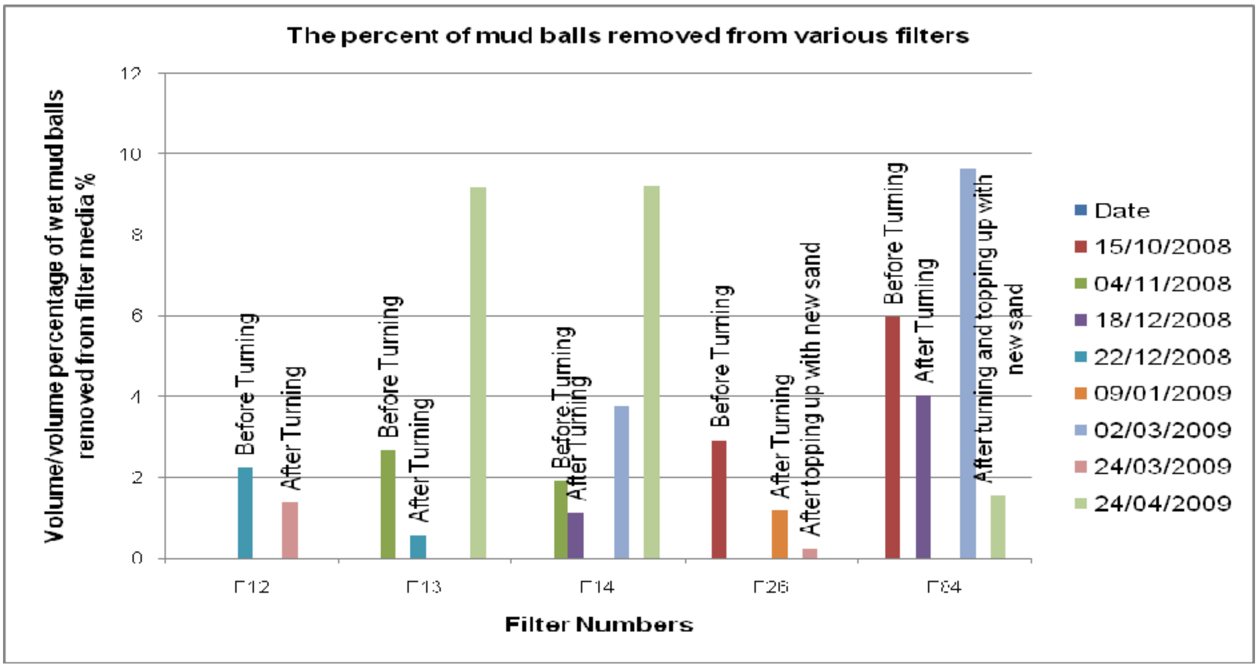

Figure 1: The effect that turning the sand has on the volume/volume percentage of mud balls in the filter media of various filters.

In figure 1, it is clear that there is a smaller volume of mud balls in the filter media after it had been turned.

- For filter 12 the volume/volume percent of mud balls decreased from 2.22% to 1.37%.
- For filter 13 the volume/volume percent of mud balls decreased from 2.66% before turning to 0.57% after turning.
- For filter 14 the volume/volume percent decreased from 1.90% to 1.10%.
- For filter 26 the volume/volume percent decreased from 2.90% to 1.17%.

- For F84 the volume/volume percent of mud balls decreased from 5.96% before turning to 4.03% after turning.

However turning the filter sand is not very effective as the volume/volume percentage after turning is still more than 1% (except filter 13), which according to Brouckaert (2) indicates that the media is in a bad condition. Turning the sand also does not offer a lasting solution to the mud ball problem. It was found that the mud ball volumes had increased after the sand had been turned.

- For filter 14 the mud ball volume increased from 1.10% after turning to 3.75% three months later, and then to 9.21% a month after that.
- For filter 13 the mud ball volume increased from 0.57% after turning to 9.18%. A similar pattern is seen for filter 84.

Thus turning of the filter media can be used as a non aggressive, cheap but labour intensive solution to remove mud balls from filter media; however it is not an effective or long lasting solution, and will have to be applied on a regular basis to make sure that the mud ball problem does not persist.

Chemical cleaning procedures – Chlorine application

a. Specific deposits

Soaking in chlorine is beneficial as it decreases the specific deposits (SD) on the sand. (Table 1) In the filter media before backwash the TSS value was 8.86mg/g. This value can be expected in a filter before backwashing. After backwash the TSS value decreased to 4.76mg/g, which indicates how important correct backwashing is in maintaining the filter media quality. This value however falls into Class II based on the South African guidelines (5), and would indicate a slightly dirty filter bed. A more significant decrease in the value of the TSS is seen after soaking the filter media with a chlorine solution. The TSS value is then 2.51mg/g, which falls into a Class I in terms of the South African guidelines (5), which indicates a clean filter bed that is well ripened. This indicates the effectiveness of the application of chlorine. Also to be noted is the distribution of the different characterisation proportions of SD, where the major fraction is that of the NSNV solids in the dirty media before backwash, the clean media after backwash and the clean media after soaking in chlorine. This is a clear indication that soaking in chlorine does not affect or change the distribution of the specific deposits on the filter media.

Table 1: Characterisation of the composition of deposits for dirty media, clean media and clean media soaked in chlorine from a filter at Rand Water's Zuikerbosch treatment plant.

Filter media Samples		Composition per fraction characterisation					
	TSS	NSNV		SNV		V	
	mg/g	mg/g	%	mg/g	%	mg/g	%
Before backwash	8.86	4.02	45	3.39	38	1.44	17
After backwash	4.76	2.44	51	1.42	30	0.91	19
After backwash, after soaking in chlorine solution	2.51	1.16	46	0.71	28	0.65	26

Chemical cleaning procedures – Hydrogen peroxide application

a. Visual inspection

The filter media that was treated with hydrogen peroxide appeared cleaner, and did not have the sticky texture that was visible in the filter bed while sampling, due to the mud balls. Figure 2 shows magnified microscopic images of the filter media to highlight the aesthetic effects of peroxide application on the filter media. Clean, virgin filter media is included as reference.

The clean filter media represents the ideal situation (figure 2A). This filter media is transparent, and the shape of the filter media is very jagged. The dirty sample from filter media that contained mud balls (figure 2B) is clearly browner than the virgin media, and the edges of the filter media are more rounded. This indicates the particulate build up on the filter media during use. The dirty filter media, after it was treated with peroxide (figure 2C) is clearly of a lighter colour than the dirty media. Also the shape of the filter media is slightly jagged than that of the dirty media. This visually shows the affects of the application of hydrogen peroxide.

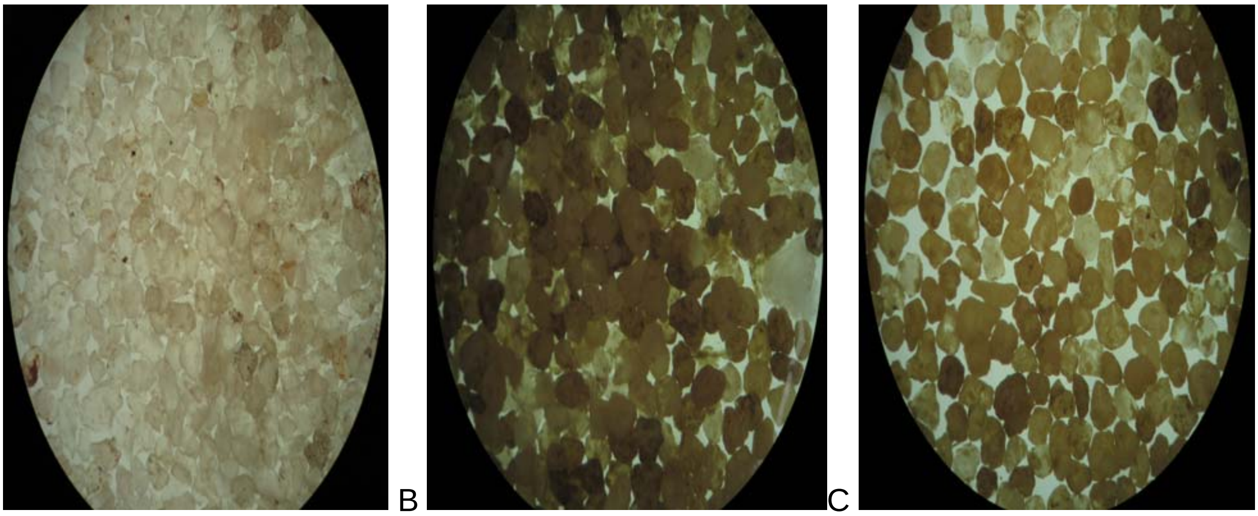
A B C

Figure 2: A comparison of pictures of filter media taken under the microscope.
A) Clean, virgin filter media,
B) Dirty filter media from media with mud balls, and
C) Dirty filter media from media with mud balls, after the application of hydrogen peroxide to a final concentration of 10%.

b. Specific deposits

The specific deposits (SD) are reduced by the application of peroxide (table 2 and figure 3). After peroxide treatment all the filter media samples fall into Class I of the South African guidelines (5). Also all the TSS values are less than 1.5mg/g, which shows the superiority of hydrogen peroxide over that of chlorine application. The major SD fraction present in all filter media samples after the application of hydrogen peroxide is that of SNV solids. That is specific deposits (SD) comprising mainly of chemical precipitates. Also to be noted is that the volatile fractions increased on all filter media samples after being treated with peroxide. The benefit of the application of hydrogen peroxide is clear in terms of the reduction of TSS values on the filter media.

Table 2: Characterisation of the composition of deposits on filter media from various filters before and after being soaked in hydrogen peroxide on the laboratory scale.

Filter media Samples	TSS	Composition per fraction characterisation					
		NSNV		SNV		V	
	mg/g	mg/g	%	mg/g	%	mg/g	%
F12 Dirty	2.89	1.24	43	0.9	31	0.75	26
F12 Soaked in peroxide	1.28	0.17	14	0.74	58	0.37	29
F13 Dirty	7.09	4.09	58	1.54	22	1.46	21

F13 Soaked in peroxide	1.06	0.35	33	0.42	39	0.3	28
F14 Dirty	4.84	1.12	23	3.09	64	0.63	14
F14 Soaked in peroxide	0.99	0.03	3	0.53	54	0.43	44
F26 Dirty	0.86	0.17	20	0.38	44	0.31	36
F26 Soaked in Peroxide	0.58	0.02	4	0.41	70	0.15	26
F84 Dirty	4.84	0.42	9	3.45	71	0.97	20
F84 Soaked in peroxide	1.46	0.39	27	0.55	38	0.52	36

These results are further depicted in Figure 3.

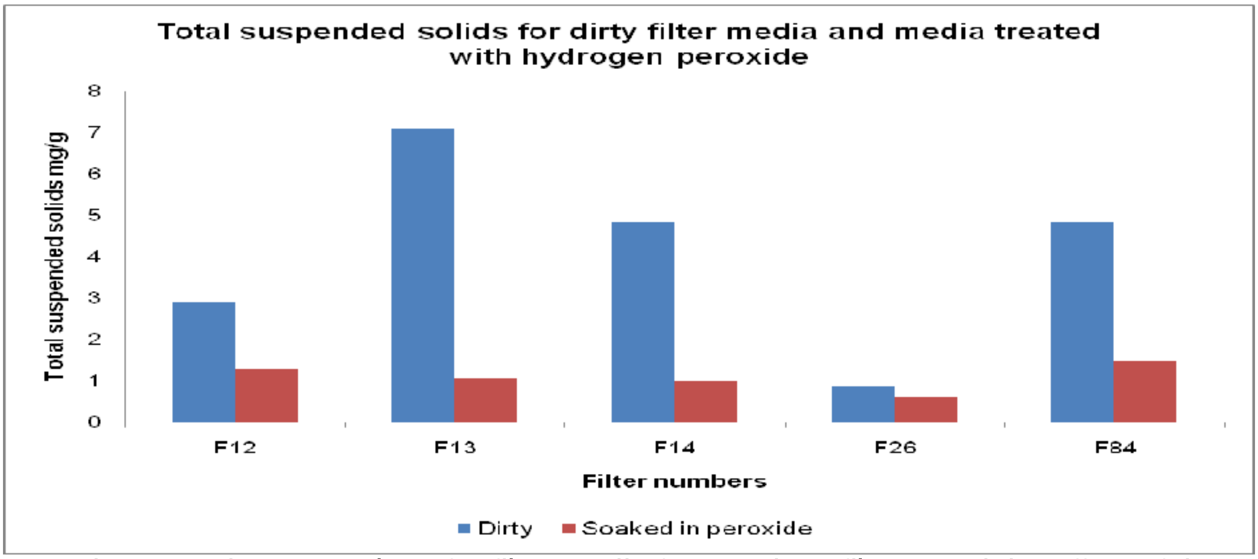

Figure 3: The TSS values for filter media from various filters, and the effect of the application of hydrogen peroxide.

c. Total organic carbon

The concentration of total organic matter extracted from the filter media decreased after it has been treated with hydrogen peroxide (Table 3). For filter 12 the TOC value of the extracted fluid decreased from 15 mg/l to 9.1 mg/l after the application of hydrogen peroxide. For filter 14 this value decreased from 40 mg/l to 9.9 mg/l. The benefits of the application of hydrogen peroxide in the treatment of dirty filter media that also contained mud balls is further highlighted by the decrease in extractable organic matter within the sand.

Table 3: Total organic carbon concentrations extracted from filter media from various filters before and after the application of hydrogen peroxide.

Sand Sample	TOC mg/l
F12 Dirty	15
F12 Soaked in peroxide	9.1
F13 Dirty	21
F13 Soaked in peroxide	11
F14 Dirty	40
F14 Soaked in peroxide	9.9
F26 Dirty	2
F26 Soaked in peroxide	1.8
F84 Dirty	73
F84 Soaked in peroxide	12

CONCLUSIONS

From the results above the following conclusions can be made:

- Physical remediation processes are labour intensive, and time consuming. Turning the sand has shown slight improved filter media quality in the reduction of the presence of mud ball volumes; however this remediation option are not very efficient and do not have long lasting effects. This remediation process will have to be performed regularly, to maintain a good filter media quality.
- Chemical remediation processes show longer lasting effects, however since hazardous compounds are used it must be applied with caution.
- It was shown that the application of chlorine *in situ*, in the form of calcium hypochlorite, decreased the amount of SD on the filter media.
- Hydrogen peroxide has shown the most potential to be a long lasting solution to the mud ball problem. After application there was an improvement in the aesthetic appearance of the filter media, the SD and total extractable organic carbon content on the filter media.

FUTURE WORK

Study the *in situ* application of hydrogen peroxide on filter beds to determine the short and long term benefits regarding the quality of the filter media as well as the economic benefits that could be obtained.

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REFERENCES

1. JM Symons, LC Bradley Jr., TC Cleveland, The Drinking Water Dictionary, pub American Water Works Association, Colorado (2000)
2. BM Brouckaert, A Amirtharajah, R Rajagopaul, P Thompson, “Filter backwash options for rural treatment plants”, Water Institute of South Africa Biennial Conference, Durban (2006)
3. AWWA (American Water Works Association), “Water Quality and Treatment: A Handbook of Community Water Supplies”, 5th edition, pub McGraw-Hill Inc, New York (ed. R.D. Letterman) p. 8.68 (1999)
4. BM Brouckaert, A Amirtharajah, CJ Brouckaert, JE Amburgey, “Predicting the efficiency of deposit removal during filter backwash”, Water SA, Vol 36 No 5 p. 633 (2006)
5. SJ van Staden, and J Haarhoff, “An Improved Filter Media Test for Troubleshooting and Rehabilitation of Problem Filters”, Water Quality and Technology Conference and Exposition, San Antonio, Texas, (2004)
6. J Haarhoff, Sand Filtration (Chapter B3) in “Handbook for the operation of water treatment works”, pub. Water Research Commission, South Africa (ed. F Schutte), TT 265/06, p. 115 (2006)