Experimental Study On The Replacement Of Sand Filters By Granular Activated Carbon Filters At La Presa (Valencia) Water Works

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Abstract: In the following paper the results and conclusions of the direct sand filter replacement by granular activated carbon filters will be presented. This leads to a simple and fast solution to odour and taste removal, as well as dissolved organic matter, without investments in works at the water works.
Results lead to the conclusion that the direct sand filter replacement by granular activated carbon filters is suitable and works as a conventional sand filter.

Keywords: adsorption, agglomeration, granular activated carbon, potable water, sand, water works

INTRODUCTION

EMIVASA (Empresa Mixta Valenciana de Aguas) is in charge of the potable water works of El Realón (Picassent) and La Presa (Manises), which supply drinking water to the city of Valencia and surroundings. La Presa water works was selected as a model to run an industrial scale experiment to test the benefits of the use of granular activated carbon (GAC) for odour and taste removal, and dissolved organic matter in general, from the raw water provided by the Turia river.
The reason behind contemplating this improvement was the increasing demand to reduce taste and odours in the public water supply in order to improve final customer satisfaction. Thus changing the silica sand filters to GAC ones was found to be an immediate and feasible strategy to produce odourless, taste-free water. Nevertheless, almost no experience on the convenience of using GAC as first step filtration (replacing the sand filters) existed, so a filter was prepared to test not only adsorption but also the filtration efficiency of GAC.
Other alternative systems, like the dosage of powder activated carbon, were not considered as they turned out to be a more expensive investment, as no automatic dosing system was present in the water works.

EXPERIMENTAL

To be able to follow correctly the experimental results, the filter with GAC and the sand filters, objective of this study, were provided with sampling devices, so all filters could be compared immediately, as well as over a certain period of time. In order to check the filtration capacity of the GAC, pressure drop sensors were installed at different heights in the filters. These pressure drop sensors were adequately separated from the sand or GAC to avoid any interference in the results, as can be seen in the photograph below. Also flow measurement cells were installed in each filter.

Photography 1: Pressure drop measurement devices and protection

The parameters studied during the period in the treated water, after the filter exit, were aluminium, turbidity, pH, conductivity, trihalomethanes (THM), suspended particles as well as organoleptic and microbiological analysis.
At the same time, the necessary instrumental devices were installed in order to control the pressure and the flow of water and air during the backwash.
The analyses were performed on a daily basis except for the microbiological analysis of the treated water at the filter exit, which was carried out on a weekly basis over a 4-month period.

Actual filters

The filters under study are of the type Aquazur V of Degremont, and are placed at the so called Alta II line of La Presa water works.

The design data of the filters are as follows:
Type: Aquazur V of Degremont open filters with two semifilters
Semifilter surface: 4x12. 82 m
Total surface: 102. 56 m^2
Sand bed depth: 0. 8 m
Sand volume: 82.05 m^3
Opening size of the underdrain nozzles: 0. 2 mm
Unitary flow at design: 200 l/s
Unitary flow at work: 120 l/s
The original silica sand installed in the filters has the following granulometric characteristics:
Effective size of the sand: 1.2 mm
Uniformity coefficient: 1.58

The selected GAC is the Filtrasorb TL-820 of Chemviron Carbon produced by reagglomeration and suitable for the study purpose, having the following granulometric characteristics:
Effective size of the GAC: 1.0 mm
Uniformity coefficient: 1.4
Granulometry: US Mesh 10x20

Filter check and evaluation of the sand replacement by GAC
Regarding the raw water characteristics, as well as the treatment objective, Chemviron TL-820 activated carbon was selected because it is produced by reagglometation. This lends it a higher abrasion resistance against the continuous backwash that the GAC will be forced to undergo as it fulfils its function both as a filtration and adsorption media at the same time. Another basic feature is the low floating content of only 0.1 %, compared to 3-5% of activated carbons produced by direct activation, which allows the operational losses to be kept very low. Obviously the adsorption characteristics were also evaluated, giving the TL-820 an iodine index of 950 mg/g, a blue methylene index of 200 mg/g and 30 mg/g of atrazine loading at 1 µg/l as well as 15 mg/g of trichloroethylene loading at 50 µg/l, as model contaminants.

Once the GAC was chosen, the technical issues were evaluated in order to assure that the filter, after the installation of the GAC, would perform correctly. Therefore all the filter parameters were recalculated, leading to the conclusion that sand replacement is feasible and, what is more, the sand height can be lowered, giving the same treated water quality as regards suspended particles and turbidity. The main reason for the improved filtration is basically due to a smaller granulometry of the GAC compared to the original sand. Even though, theoretically, no media loss would occur during the backwash, the height of the overflow wall was increased to be on the safe side.

After all these considerations and improvements, 72 m^3 of GAC TL-820 with a bed height of about 0.70 m, equivalent to 120 l/s to an empty bed contact time of 10 minutes was installed.

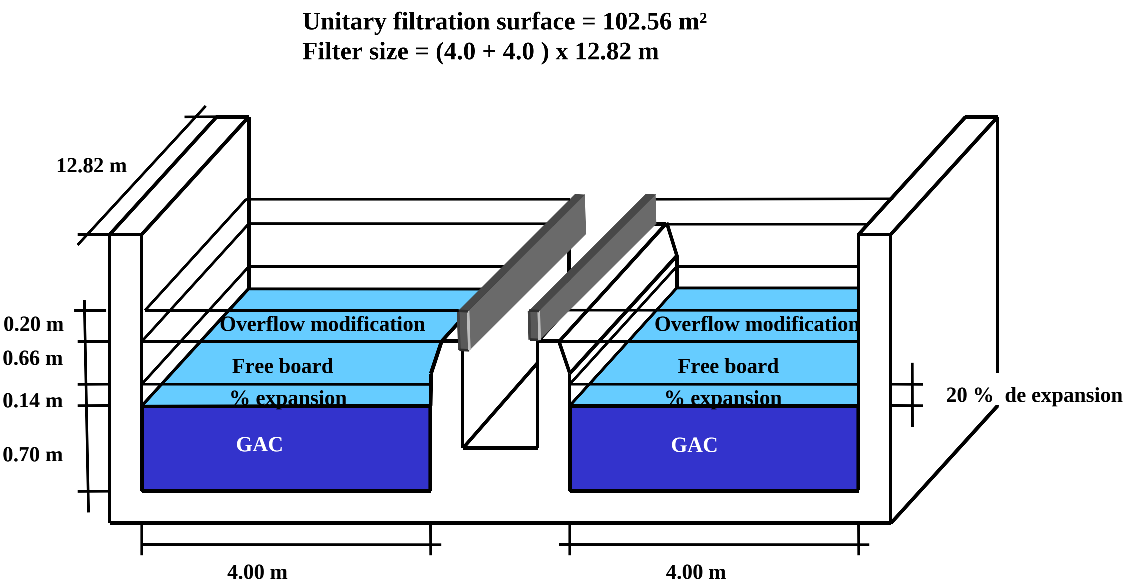

Figure 1: Schematic design modification of the GAC filter

Start up

After the filter has been under water for 48 hours, to eliminate the maximum air inside the GAC pores, the initial backwash has been started controlling at all times the backwash procedure, in order to eliminate fines and to be sure that the bed is fully segregated.

The start up of the filter has been carried out following the producers recommendations, reaching the same operational parameters as the sand filter. Beyond this study it could be verified that the GAC bed was even able to filter without problems at design flow of 200 l/s.

EXPERIMENTAL RESULTS

Pressure drop

The first test carried out was to check the pressure drop of the filter, as this parameter indicates the filter run previous to the operational backwash, and therefore the time left for potable water production. To compare the results the same test was carried out on the GAC and sand filter. The results can be seen in the following chart.

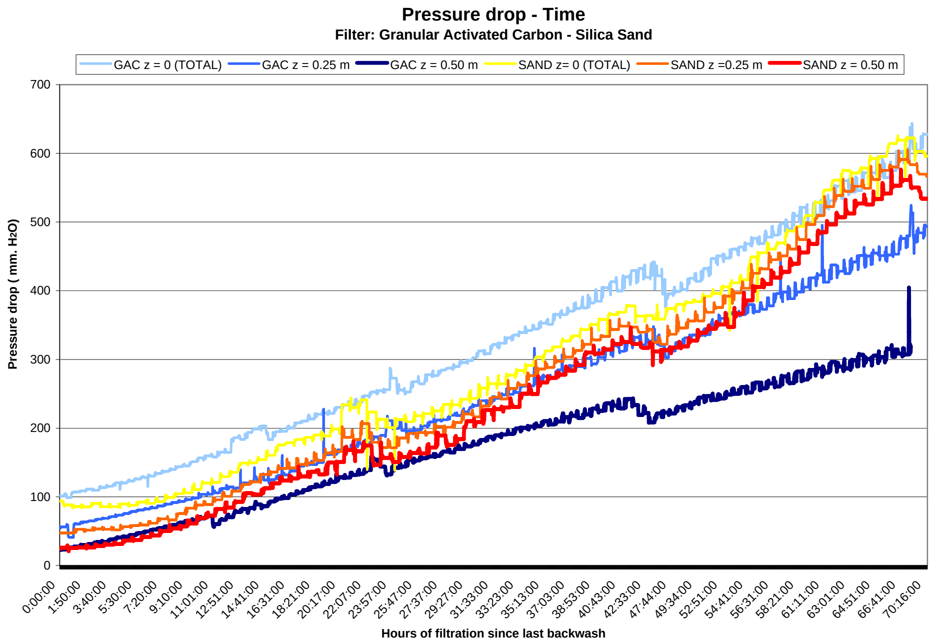

Chart 1: Pressure drop of the sand filter and GAC

The filter run has been controlled by routine, stopping the filters after about 70 working hours. The so called total value is the value corresponding to the measurement device placed at the filter bottom (z=0), that means under 0.80 m of sand and 0.70 of GAC. Therefore z=0.25 means a device at 0.25 m from the underdrain and with 0.55 m of sand and 0.45 m of GAC. The same has to be applied for the device at z= 0.5 m

As a first conclusion, we can say that the total pressure drop at the end of the filter run is practically the same for the sand bed than for the GAC bed, working both. at 120 l/s. On the other hand it can be seen that the different values at different heights for the GAC separate themselves from each other with time. This indicates that the filter is not only filtering at the surface, but also on the whole bed depth, that means it is increasing its filtration capacity. The sand filter has almost the same pressure drop at all heights, so it means that there is a surface filtration phenomenon. The main reason for this different behaviour is because the selected GAC has a smaller uniformity coefficient, which enables in depth filtration. This leads also to a better filtration, as can be seen from the particle counting results.

Aluminium retention

This parameter has been analysed in order to check the elimination rate of aluminium originated in the previous decantation, where aluminium polychlorur is being used. The idea was to find out if the GAC filter is as efficient as the sand filter in removing the aluminium. In this case we noticed that, apart from punctual deviations, surely due to fluctuations in coagulant at the influent, sand and GAC behave very similarly.

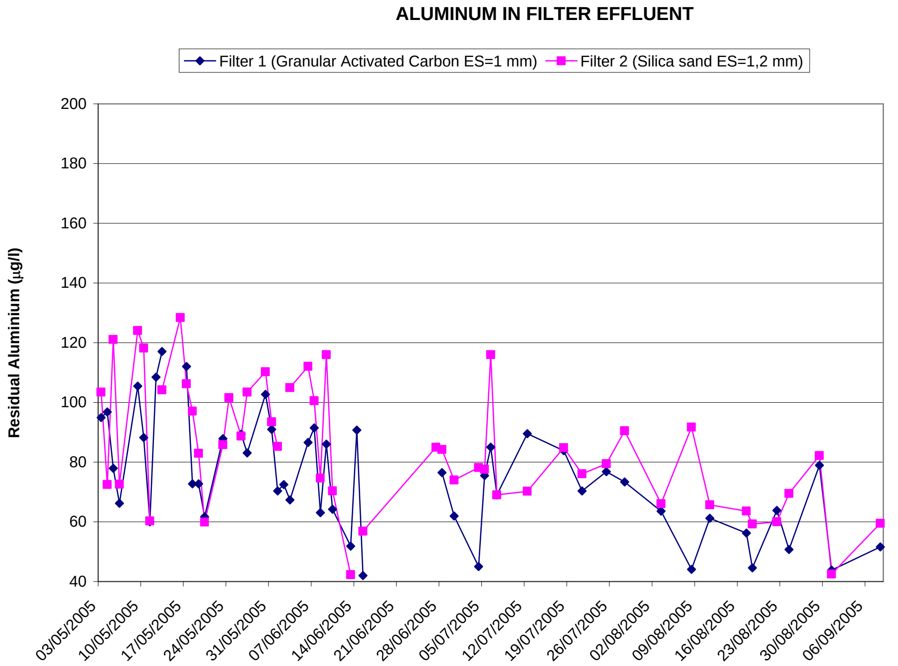

Chart 2: Analysis of aluminium at the filter effluent

Therefore, in practice it can be stated that the GAC as first step filtration has the same removal capacity of aluminium as conventional silica sand filters.

Turbidity

Under Spanish law (RD140/2003), values lower than 1 NTU have to be assured at the water works effluent, so it was important to check if the GAC was able to produce values under 1 NTU and to decrease turbidity just as well as the silica sand filters.
In the next chart the results for turbidity of filtered water during a filter run from the two types of media are plotted. It can be seen that practically during the whole period the GAC filters removed turbidity better than the ES = 1.2 mm silica sand, as expected, due to smaller granulometry, and lower uniformity coefficient of the sand, and always under 1 NTU, the average entrance value during the period of study being of 8.6 NTU.

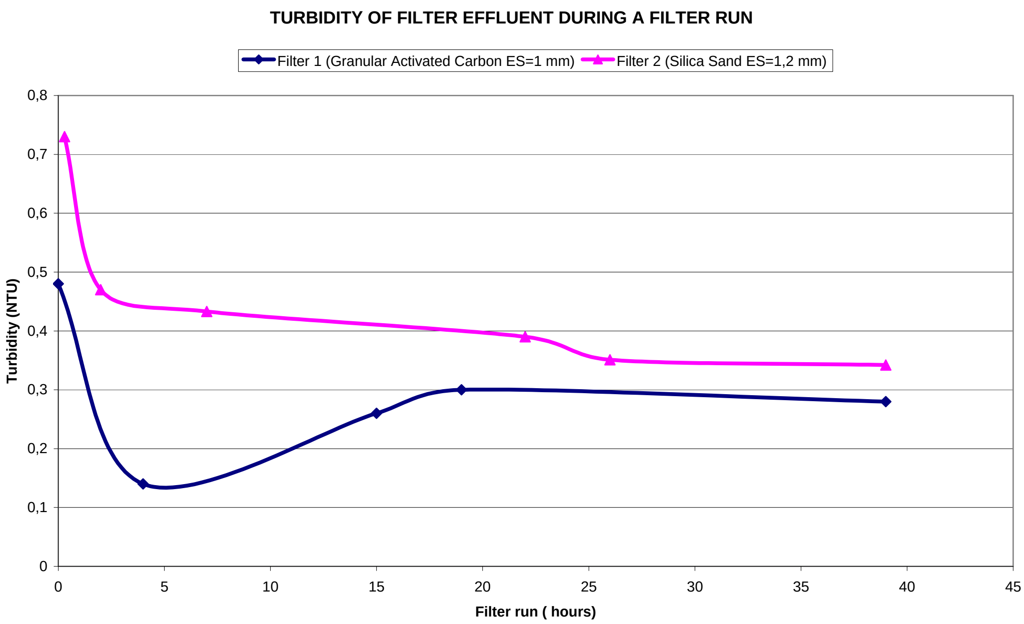

Chart 3: Turbidity at the filter effluent

Particle counts

An important parameter to check in the filtration capacity is the particle count at the filter exit, not only the total number but also classified by size. The sampling was carried out randomly and independently of the point the filter run was at that moment, in order to have a global overview of the filtration process. The results are presented as a mean of the single results.

	Particle Counts/ml						
	Particle size						
	< 2µ	*2-3µ*	*3-5µ*	*5-10µ*	*10-15µ*	*15-20µ*	*TOTAL*
Filter 1 Effluent (GAC ES=1)	318	250	106	16	6	3	721
Filter 2 Effluent (Silica Sand ES=1.2)	490	388	167	22	7	3	1.076
Influent (Water after decantation)	7.996	6.906	3.604	455	115	40	19.117

Table 1: Particle count analysis at filter effluent and influent.

It can be seen from the table that the GAC, as expected, had an improved capacity to retain particles of any size analysed, showing that the GAC, as first step filtration works correctly. It has to be mentioned, there was a special improvement for small particles, where the GAC filter decreased the value in about 35% at the filter exit. This improvement is due to the use of a smaller grain size and lower uniformity coefficient.

pH and Conductivity

For safety reasons the pH and conductivity was controlled to verify that the GAC is not changing the output value. The values as expected demonstrate that there is no influence on the pH or on the conductivity of the treated water, as the deviations are considered normal for the water works.

Trihalomethanes (THM)

For the THM the values of trichloromethane, dichlorobromomethane, dibromochloromethane and tribromomethane were analysed.

As expected, the THM concentration in the treated water with GAC was reduced dramatically at the start of the test, but increased with time.

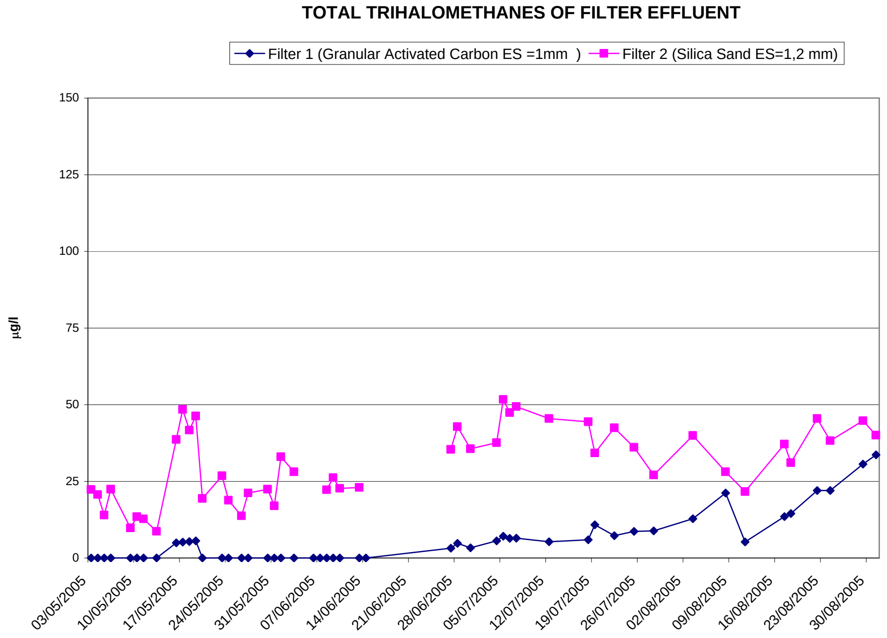

Chart 4: THM analysis at the filter effluent

This important reduction of THM at the beginning is because GAC adsorbs the THM that has been formed during the prechlorination. This THM has been adsorbed physically by the GAC, and therefore they maintain an adsorption equilibrium. As time passes the GAC filter adsorbs other less volatile compounds, like taste and odour, and so the adsorption equilibrium of the THM is broken and they desorb in favour of other contaminants. This effect is the reason why the THM concentration increases in the treated water after several months of operation. Anyway, it has to be remarked that the total THM content is under the actual legislation limit, as well as under the new legislation limit which will be applied in Spain in the coming year.

Even though it could be considered that the GAC bed has a very short life for THM reduction, this is only true for the THM formed in the water works, due to preoxidation. Nevertheless, GAC is a good instrument for controlling THM in the distribution network. The way GAC works is not by eliminating THM but their precursors, which means, reducing dissolved organic matter. As under Spanish law postchlorination is a must, the chlorine may react with the dissolved organic matter leading to the formation of THM in the distribution network.

As the study was carried out in only one filter, it did not make sense to check the decrease of formation potential for the THM as the treated water from the GAC filter was blended with the rest of the sand filters, so the dilution factor was too high to look for any conclusions.

Organoleptic analysis

Apart from the physicochemical properties, an analysis of taste was carried out in order to look far beyond the physicochemical analysis and to check the sensorial perception of the treated water by the population. Therefore samples were taken, renamed with codes,

in order not to give a hint of the water source. Also the people in the test were placed in a quiet, separate room in order to avoid any external interference. Between water samples the samplers were asked to drink mineral water in order to wash out any taste of the previous sample. Bottled mineral water with the same mineralization as the water of the water works was used as a reference.
The origin of the samples was the deposit exit just before entering the potable water distribution network, after the GAC filter, after each line of sand filters (shown in one single result in the table) and bottled mineral water.
The results were taken during the months of May, June, July and August, the results showing a mean for the whole period.

Recent Organoleptic results		TO DISTRIBUTION SYSTEM				REFERENCE MINERAL WATER			
		Not detected	Detected intensity			Not detected	Detected intensity		
			Low	Medium	High		Low	Medium	High
ODOR	CHLORINE	10%	80%	10%	0%	100%	0%	0%	0%
	EARTHY	100%	0%	0%	0%	100%	0%	0%	0%
	NOT DETERMINATED	90%	0%	10%	0%	100%	0%	0%	0%
TASTE	CHLORINE	10%	10%	80%	0%	100%	0%	0%	0%
	EARTHY	100%	0%	0%	0%	100%	0%	0%	0%
	PIPE	60%	0%	40%	0%	100%	0%	0%	0%
	NOT DETERMINATED	100%	0%	0%	0%	100%	0%	0%	0%
Recent Organoleptic results		**GRANULAR ACTIVATED CARBON FILTER**				**SILICA SAND FILTER**			
		Not detected	Detected intensity			Not detected	Detected intensity		
			Low	Medium	High		Low	Medium	High
ODOR	CHLORINE	100%	0%	0%	0%	20%	80%	0%	0%
	EARTHY	100%	0%	0%	0%	0%	0%	0%	0%
	NOT DETERMINATED	100%	0%	0%	0%	50%	37%	13%	0%
TASTE	CHLORINE	100%	0%	0%	0%	12%	63%	25%	0%
	EARTHY	100%	0%	0%	0%	100%	0%	0%	0%
	PIPE	100%	0%	0%	0%	88%	0%	12%	0%
	NOT DETERMINATED	100%	0%	0%	0%	100%	0%	0%	0%

Table 2: Organoleptic analysis

From the results above there is no doubt that the GAC filter has eliminated at once all the taste and odour problems referred to as chlorine, earthy, some kind of pipe-taste referred by the samplers, and other tastes which were not clearly defined by the samplers. Looking at the results, it is considered that the GAC is a very good taste and odour removal procedure.

Microbiological analysis

Every week the presence of total Coli., E.Coli and aerobic Col. at 22ºC in the water after the GAC filters was checked. Any positive results were reported, so the conclusion is that the water was microbiologically correct.

Results after 2 years of operation

It has been found interesting to verify the results of turbidity, particle counting and organoleptic analysis to see if the GAC still performs correctly after these years.

The filtered water turbidity and particle count after the GAC filter, are as good as those obtained at the silica sand effluent, or even better. That means that the filtration efficiency of the GAC was maintained during the years the filter was working. The results of particle counting can be seen on table 3 as a yearly mean.

	GAC FILTER							SILICA SAND FILTER						
	Particle Counts/ml							*Particle Counts/ml*						
	Particle size							*Particle size*						
Year	*> 2µ*	*> 3µ*	*> 5µ*	*> 10µ*	*> 15µ*	*> 20µ*	*TOTAL*	*> 2µ*	*> 3µ*	*> 5µ*	*> 10µ*	*> 15µ*	*> 20µ*	*TOTAL*
2007	284	187	90	32	21	17	632	324	212	106	43	29	23	737
2006	149	87	43	16	12	10	316	203	125	61	24	18	15	446

Table 3: Particle counting analysis results during the year 2006 and 2007.

The organoleptic analyses were carried out 2 years later than the first analysis, and show that some taste and odour is found in GAC filtered water. Even so, the results are still much better than the ones for the silica sand filtered water or the distribution system water.

Recent Organoleptic results		TO DISTRIBUTION SYSTEM				REFERENCE MINERAL WATER			
		Not detected	Detected intensity			Not detected	Detected intensity		
			Low	Medium	High		Low	Medium	High
ODOR	CHLORINE	0%	0%	67%	33%	0%	0%	0%	0%
	EARTHY	100%	0%	0%	0%	100%	0%	0%	0%
	NOT DETERMINATED	100%	0%	0%	0%	100%	0%	0%	0%
TASTE	CHLORINE	0%	0%	67%	33%	0%	0%	0%	0%
	EARTHY	100%	0%	0%	0%	100%	0%	0%	0%
	PIPE	100%	0%	0%	0%	100%	0%	0%	0%
	NOT DETERMINATED	100%	0%	0%	0%	100%	0%	0%	0%

Recent Organoleptic results		GRANULAR ACTIVATED CARBON FILTER				SILICA SAND FILTER EFFLUENT			
		Not detected	Detected intensity			Not detected	Detected intensity		
			Low	Medium	High		Low	Medium	High
ODOR	CHLORINE	100%	0%	0%	0%	33%	33%	0%	33%
	EARTHY	67%	33%	0%	0%	100%	0%	0%	0%
	NOT DETERMINATED	67%	33%	0%	0%	100%	0%	0%	0%
TASTE	CHLORINE	100%	0%	0%	0%	67%	0%	0%	33%
	EARTHY	100%	0%	0%	0%	33%	0%	0%	67%
	PIPE	100%	0%	0%	0%	88%	0%	12%	0%
	NOT DETERMINATED	17%	83%	0%	0%	100%	0%	0%	0%

Table 4: Recent organoleptic results.

CONCLUSIONS

The study researched basically two objectives a) check the suitability of using GAC for taste and odour removal, as well as dissolved organic matter in general, and b) verify that it is possible to eliminate the sand of the filters by replacing it directly by specific first step filtration GAC.

For both objectives the results give no doubt that a high process satisfaction was reached and the suitability of the selected GAC for the treatment objectives of the water works.