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ETHEKWINI'S EFFORTS IN EFFECTIVE WATER CONSERVATION AT MUNICIPAL TREATMENT PLANTS:

A SIMPLE, SMALL-SCALE, METHOD TO DIRECT WATER-REUSE

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ABSTRACT

In the larger eThekwini Wastewater Treatment plants, final effluent undergoes tertiary treatment in order to create a non-potable water supply i.e. (a large-scale grey water system), which is used for onsite process demands (e.g. wash water, chemical make-up, etc.).

AECOM further optimised the design in order to suit installation for private industrial complex developments – with particular reference to those located in rural out-of-border African areas where services are lacking and in-house treatment facilities are required.

This article will identify possible non-potable water demands in both municipal and typical industrial plants, as well as examine the water quality specifications that will be required to be adhered to in order to service these demands. The tertiary treatment method used at the EWS's municipal treatment plants will be discussed practically in terms of ease of installation, operation and maintenance - using a schematic of the recommended installation. The automation controls required in order to protect users and maintain a sufficient non-potable supply will then be explained, concluding with brief list of common installation and operational problems, as well as the corresponding mitigation strategies.

INTRODUCTION

Water scarcity is a universal concern. And whilst the investigations into the most effective large-scale solutions oscillate between building new

FIGURE 1: **Bank of pressurised sand filters located at Kwa-Mashu WWTW, eThekwini Municipality**

dams, desalination plants or (the more controversial) water -re-use plants, the *eThekwini Water and Sanitation* (EWS) Design Branch has been applying the principles of direct water re-use in a simple, small scale, yet effective manner.

As far back as the late seventies, the *eThekwini Municipality* has installed tertiary treatment in its larger wastewater treatment plants in order to create a non-potable water supply – which is referred to as 2nd class water. Their first 2nd class water plant was installed in their then flagship plant, *Kwa-Mashu WWTW*. Since then, tertiary plants were constructed in five other plants. Great emphasis was placed on sustainable water re-use within the municipality; resulting in the 2nd class water plant located at the *Southern WWTW* being awarded to a concessionaire (Durban Water Recycling (Pty) Ltd) in 1999, to be constructed and operated for a period of 20 years in order to provide 2nd class water to not only the treatment plant itself, but also to the surrounding industries.

DEMAND FOR NON-POTABLE WATER

The *eThekwini Municipality* has recognised the significant demand for water on a wastewater treatment plant. This water demand is not necessarily required to be of a high potable water quality, but is essential in running certain equipment, keeping process areas clean (to reduce pathogens and their corresponding vectors) and for odour control. This 2nd class water is used for, but is not limited to:

- spray water for screens, dewatering screw presses and belt presses
- wash water used in screening washer-compactors, grit classifier-washers, etc.
- fluidising settled grit in chambers prior to airlifting operations in degritters
- inline dilution for chemical dosing – especially with polyelectrolyte and chlorine dosing
- flushing of chemical and sludge pipelines in between shifts in order to reduce blockages caused by hardening product
- top up of water seals across site, for example the water seal in biogas-holders
- site wash down to keep process areas clean: decreases pathogen load in pedestrian areas and reduces bad odours
- sprays for odour control and dampening
- quenching and scrubbing in fluidised bed reactors

This demand is substantial – for example, *Kwa Mashu WWTW* is a 65 Ml/d plant which is designed to use up to 2 200 m^3 of water a day for the requirements listed above. Depending on the cost rate of water applicable, this could produce savings (construction and pump operating costs unaccounted for) in excess of R1 600 000.00 /month including VAT.

The graph below indicates the distribution of how this 2nd class water demand is consumed onsite, on daily basis.

AECOM found that private industrial complex-developments – with particular reference to those, located in rural African areas where services are lacking and in-house wastewater treatment is required – also shared the same demand for a cheap, non-potable water supply. In addition to the onsite wastewater treatment facility requirements, this non-potable water supply could be extended to irrigation, truck and external facility washing, flushing of toilets, etc. Figure 3 below indicates an example of the 2nd class water demand distribution for such an industrial development – note that this is variable based on the type of industry.

When calculating the demand for 2nd class water, in order to determine the sizing of the storage infrastructure and feasibility, one would look at the average daily demand – however, it is important to also characterise the range of operation flows. The requirement for this shall be explored further below.

SPECIFICATIONS FOR WATER QUALITY

There is currently no South African specification that guides the effluent quality for a non-potable water system in general – however, this is understandable as the degree to which effluent needs to be treated before use, is dependent on the application. To begin with, the treated effluent entering the tertiary treatment facility (to create 2nd class water) needs to comply with the discharge water quality requirements, as stated by the relevant standards, which in South Africa would be those listed in the Revision to the General Authorisations in terms of Section 39 of the National Water Act, 1998 (Minister of Water and Environmental Affairs, South Africa, 2013)

Thereafter, one would need to examine the specific uses for 2nd class water identified onsite and consider the required water quality for each, in order to then formulate an effluent water quality by taking the most stringent requirement for each parameter. For example, if used as a replacement for grey water in order to flush toilets, one would have to request the minimum suspended solids concentration from the *flushmaster*-valves manufacturer. The British Standards Institution (2010) has published BS 8525 which deals with the use of grey water for similar domestic applications – the quality standards may be applied within reason.

A minimum suspended solids concentration for specialised treatment equipment using the non-potable water would also have to be investigated with the various suppliers, especially those with spray-bars which can easily get blocked. For equipment, the concentration of fats and oils may also be problematic if too high.

The water quality required for using treated effluent for irrigation purposes in South Africa is indicated in Revision to the General Authorisations, however, there are many studies being conducted in order to determine the acceptable ranges and limits for the various contaminants. The articles written by Engelbrecht & Murphy (n.d.) and Mzin & Winter (2015), listed in the references below are interesting reads. In these articles, the contaminants present in treated effluent which affect plant growth are

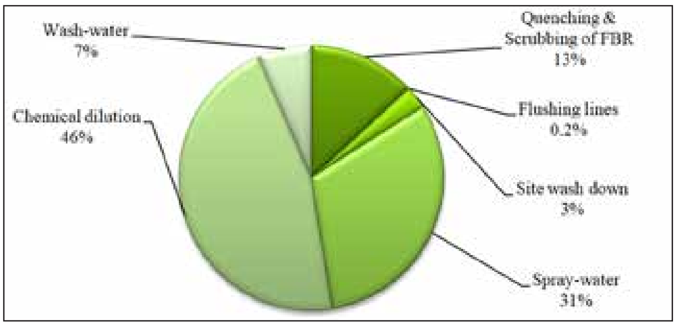

FIGURE 2: Distribution of the daily 2nd class water demand for the Kwa Mashu WWTW

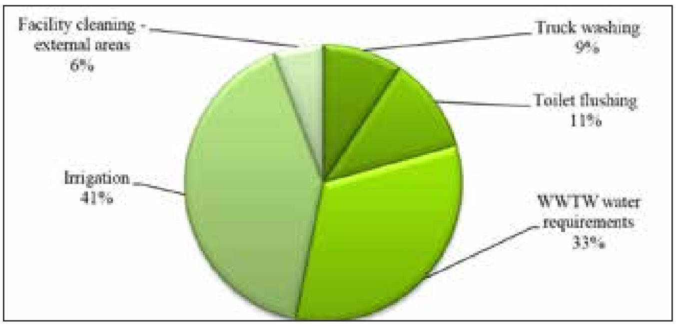

FIGURE 3: Distribution of the daily 2nd class water demand for an example of an industrial development with onsite WWTW

highlighted, the effects are discussed and allowable ranges for various plants are proposed.

An example of the 2nd class water quality specified for a certain industrial development application is indicated in the table below: the fourth column indicates the treated effluent achieved through conventional treatment through the wastewater plant, and the fifth column specifies the 2nd class water quality required post tertiary treatment.

TABLE 1: Example of 2nd class water quality requirements

Parameter	Unit	Qualifier	Treated Effluent Quality	2nd Class Water Quality
BOD5	mg/l	max.	50	50
pH		min.	6.5	6
		max.	8	9
Phosphorous - total	mg/l	max.	2	2
Nitrogen - total	mg/l	max.	5	5
Ammonia - total	mg/l	max.	2	2
Sulphate	mg/l	max.	250	250
Total dissolved solids	mg/l	max.	2 000	2 000
Turbidity	NTU	max.	No Value	5
Oil & Grease	mg/l	max.	10	2.5
Chlorine (residual / free)	mg/l	max.	0.1	0.2 - 2
Faecal Coliforms	MPN/100 ml	max.	0	0
Fluoride	mg/l	max.	No Value	3

It must be reiterated that the parameters and the corresponding treatment levels above were based on local and client specifications, as well as the requirements of the site-specific non-potable water demands that were being designed for.

Also to be noted is that suspended solids are no longer measured in the second class water quality, but that rather measure of turbidity is taken as it is easier to automatically measure using online instrumentation, therefore facilitating automation.

TERTIARY TREATMENT METHODOLOGY

From the table above, it is evident, that the treated effluent requires additional treatment, namely a further reduction of suspended solids and oils, as well as an increase in the chlorine residual. For the tertiary treatment of final effluent, EWS has primarily used a system of filtration i.e. a dual media, pressurised sand filter in order to reduce the suspended solids and oils load, followed by chlorine dosing. This simple yet effective technique was adopted and optimised by AECOM for use on commercial and industrial projects.

Figure 4 indicates an example of a cross section through a single pressurised filter, whilst Figure 5 below, indicates all the equipment and instrumentation required for tertiary treatment. Note that depending on the capacity required of a tertiary treatment system, a number of pressurised

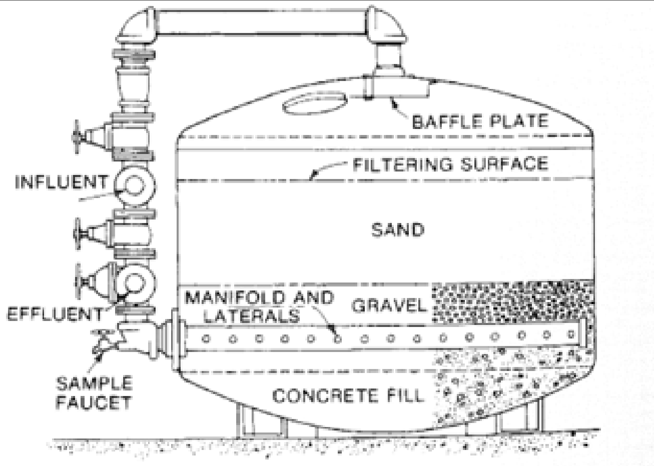

FIGURE 4: Cross section of an example of a pressurised filter used in tertiary treatment (American Waterworks Association, 2011)

filters maybe used simultaneously – as indicated in Figure 1 above. The required flow of treated effluent (after disinfection) is pumped, via immersible pumps located in the contact tanks of a treatment plant, through pressurised sand filters, into a Second Class Water Tank. A diluted chlorine solution is dosed directly into the tank in order to maintain chlorine residual levels as specified.

Various forms of disinfectants are available – to maintain a residual in the system, a form of chlorine is generally used. On larger eThekwini treatment plants, chlorine solution is made up from chlorine gas onsite. This is good for effective dosing and control, however, as it can be hazardous, skilled labour and constant monitoring is required. For the rural industrial development that AECOM used this application, a solution was made from solid calcium hypochlorite flakes. This does not allow for a consistent dosing concentration and does result in blockages of the dosing pipe, however, it is relatively safe, can be easily stored and made up. Another feasible option is the use of liquid sodium hypochlorite in order to make up a chlorine solution. It does allow for a consistent dosing concentration, however, due to its liquid nature, it is more difficult to transport and its shelf life is significantly lower than the other forms mentioned above. This is a good option to pursue if a chemical supplier is within a reasonable distance of the plant in question.

From the Second Class Water Tank, the non-potable water is supplied to its various required demand points through a dedicated second class water reticulation network, using an inline booster pump. In order to size this correctly, when one is calculating the average daily demand, one must also estimate an instantaneous peak flow rate. Equipment suppliers must also be consulted in order to determine the minimum pressure required in the reticulation network. For example, flush-master valves on toilets and urinals require 3-4 bar, and most wastewater treatment equipment require approximately 6 bar pressure. AECOM and EWS, in order to cater to this wide range of demands, specify an inline, vertical, multistage, centrifugal pump run using variable speed drives. This is used to maintain a system pressure of approximately 6 bar for a flow range of zero to the instantaneous peak estimate.

As with the nature of pressurised filters, as they are used, contaminants trapped within the media and its surface needs to be cleaned through backwashing. The backwash sequence can be initiated by various mechanisms that will be discussed further below.

Actuated valves are used to shut of feed to the filters and the Second Class Water Tank. A combination of air (from blowers) and water (from

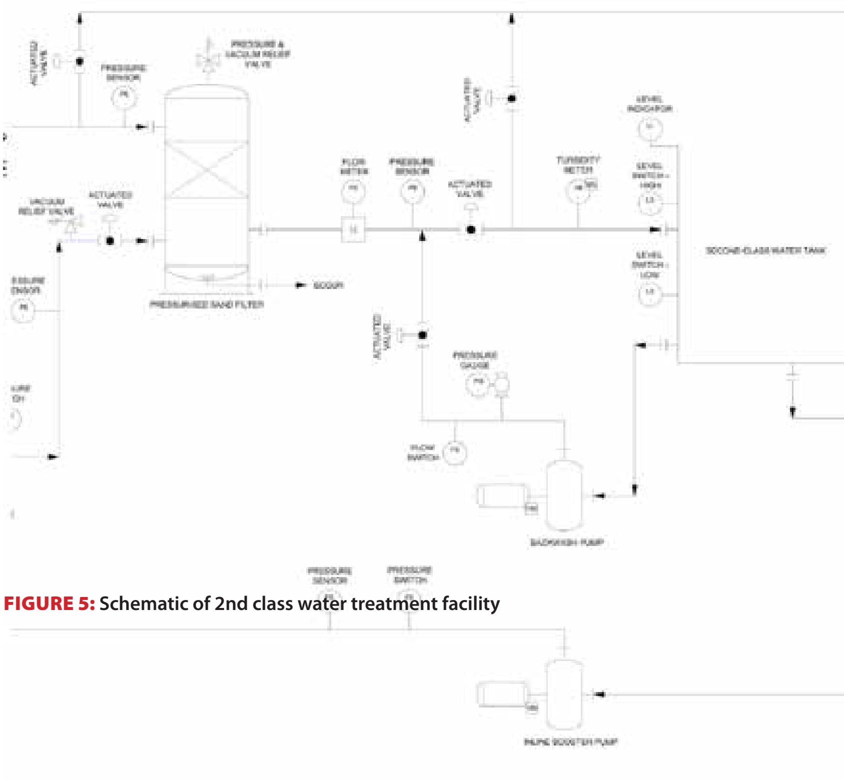

FIGURE 5: Schematic of 2nd class water treatment facility

Second Class Water Tank) is first used to agitate media and dislodge contaminants, after which water is then used to flush the media, removing collected contaminants. This backwash water, along with any water scoured/drained from both the filter and Second Class Water tank, is returned to the Head of Works of the treatment plant.

AUTOMATION & CONTROL

When it comes to running a second class water facility such as this, automation is critical. It would take an inordinate amount of operational effort to physically monitor and initiate the filtering and backwashing process. Fortunately, with instrumentation and actuated valves, this process is simplified and can operate seamlessly untouched by physical operators. As indicated above, Figure 5 above indicates the primary instrumentation (besides those essential for equipment protection) required for the control of treatment process above. Please note that for simplicity, only actuated and safety valves have been indicated, and no control loops are displayed.

a. Initiation of Treatment

An ultrasonic sensor located in the Second Class Water Tank is used for initiating tertiary treatment. When the water level is low, the feed pump in the contact tank is switched on and filtering commences – likewise, when the water level in the tank approaches the overflow height, the feed pump is switched off.

b. Top-up Water

If there is a problem and the second class water facility is unable to produce water, to avoid the reticulation system from running dry and not being able to use the equipment dependant on it (such as spray bars, chemical dilution, toilet flushing, etc.), a potable water top up feed into the tank is provided with an air gap. This prevents any backwater contamination. When the water level in the Second Class Water tank drops below the low-level where the filter feed pumps would normally switch on and supply filtered water to the tank, an actuated valve is opened to allow potable water to feed the tank.

c. Initiation of Backwash Sequence

The backwash sequence can be initiated by one or all of the following three mechanisms:

- when the pressure differential between the inlet and outlet of the pressurised filter vessel is high which would indicate a certain level of blinding
- when the turbidity reading on the Second Class Water Feed tank begins to exceed the quality requirement indicating a certain level of break through
- when a designated set period of time has passed, depending on situation, this can range from a day to a week.

AECOM designers have a preference to use all three automation mechanisms – with the third option (usage of a timer) used in case no backwash was triggered during a set period of time by the first two mechanisms.

d. Flow Measurement

As with a potable water system, it is important to measure the second class water used in your system for various administration (e.g. keep track of water usage, to achieve environmental KPIs in industrial scenarios) and operational issues (e.g. to troubleshoot leakages in network, keep track of average usage, balance against chemicals used). The simplest way to measure this flow is with the installation of a bi-directional magnetic flow meter on the common part of the pipe where filtered water exits the filter to feed the tank, and the backwash water is fed into the filter to clean it (refer to Schematic in Figure 5). This allows one to know the amount of water being filtered, the amount that is wasted due to backwash, and the resulted amount of 2nd class water used in the reticulation system.

It is also prudent to place a flow meter on the potable water top line, so that it gives an alarm when in use, as well as the quantity of potable water being used (and being paid for).

e. Mechanism for actuated valves

The decision of whether to use pneumatic or electrical actuators is important, especially in terms of costs and maintenance. The actual pneumatic actuators are much more cost effective than electrical ones, but require auxiliary equipment – namely compressors (standby and duty) and compressed air reticulation. Therefore this decision between use of the two mechanisms is dependent on the size of your 2nd class water treatment facility For example, the eThekwini plants utilise a number of filters, and therefore a significant amount of actuator valves are required. This makes it more cost-effective to use pneumatic actuators in the form of solenoid valves. The facility installed for the private industrial development completed by AECOM was a much smaller one, and required only seven small actuators – which made it prudent to utilise electrical actuators.

f. Determination of chlorine dose required

In order to maintain the correct chlorine residual in the Second Class Water Tank, there is online monitoring instrumentation, however this is very costly and is not as robust as the other instruments. In this regard, this is much easier to take manual samples and test frequently. Using these results, the chlorine dosage rates can then be adjusted to suit.

FIGURE 6: Labelling of pipework at Kwa-Mashu WWTW

LESSONS LEARNT FROM PAST EXPERIENCE

From the combined experiences of EWS and AECOM, the following mistakes were had and improved on in the next installations – it is our intention that others can learn from the notes below so as to not have the same unfortunate experiences:

- The instrumentation used to monitor turbidity can move out of calibration more easily than the other non-analytical instrumentation. It is therefore prudent to program your backwash sequence to be initiated first by a pressure differential, and if that does not work, then high turbidity can trigger a backwash. We found that if we had it the other way around, the turbidity meter was very sensitive and triggered multiple backwashes in short spaces of time.
- Carry over of non-settled activated sludge from secondary sedimentation tanks entering the contact tank can be drawn in by the filter feed pumps, thereby almost instantaneously blinding the filters. A way to prevent this is by having a turbidity meter either in the tank or inline of the feed pipe. If a high turbidity measurement is taken, the programming will not allow the feed pump to draw water to the filters.
- Manual over-riding of the system must be limited.
- Insufficient sizing of floor drains for the backwash water. The backwash water flow rate is generally underestimated, and as a result, the floor drains are not designed to cater for it sufficiently leaving floors wet, unsightly and hazardous. Either floor drains/manholes must be designed large enough, or a dedicated pipe from the backwash can be routed into an external point of discharge.
- Sufficient floor to ceiling clearance. Often the clearance required to install the filters is underestimated. Once must consider not just the filer height, but also height of the pipework required above and below the filters.
- Sufficient access for installation must be allowed for as the equipment required is sizeable.
- Bubble tests to ensure even air distribution across the filter during backwashed must be done and inspected prior to filter media being added.
- In order to ensure no damage is made to the filters protective coatings, if a multi-layer coating system is used, specify that each layer is to be a different colour. This will make it easier during inspection.
- The pipework in these filter systems are very complicated and can be confusing. Pipes and valves must all be labelled well in order to mitigate this. Refer to Figure 6 below. It is also important to follow a colour coding convention for pipework to differentiate from potable water, second class water, chemical lines, air, etc. It is also critical to label non-potable water onsite tap-stands (meant to be used for washing down or irrigation) very clearly to avoid people ingesting it.

CONCLUSIONS & RECOMMENDATIONS

Sustainable engineering and the conservation of water and energy must be promoted in both macro and micro-cosmic levels. The system explained and detailed in this presentation has been tried and tested by EWS and AECOM, and can be easily implemented in both municipal and industrial treatment facilities. This effective, small-scale solution is a tangible step towards combatting water scarcity. Widespread implementation thereof has the potential to result in substantial financial, social and environmental benefit.

It is hoped that the combined experiences of EWS and AECOM – and in particular, the insights related to lessons learnt to date - can facilitate the successful implementation of the proposed solution in a range of other applications.

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