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TECHNICAL OVERVIEW & METHOD STATEMENT: EMADO TRIALS STELLENBOSCH MUNICIPALITY

1. INTRODUCTION

Zinandi Engineering & Design Company (ZEDCo.) has been commissioned to set-up and oversee the Trial Tests of the EMAWS Water Treatment system on effluent drawn from the Stellenbosch Municipal Wastewater Treatment Works (WWTW).

The Trial Tests were concluded at Cape Town, South Africa on 9th March 2016.

The following document sets out to describe the plant equipment, the process, and the procedure by which the trial tests were concluded and evaluated.

2. TRIAL OBJECTIVES

The main application of the EMAWS Treatment system at the WWTW will be for Disinfection and Sanitization of the outgoing effluent.

The specific objectives for the Trial Tests are defined as follows:

- Reduce e-coli loading to a minimum of 10/100ml.
- Reduce Turbidity (improve water-clarity).

In order to fully qualify and quantify any additional effects/benefits of the treatment process, a comprehensive Water Quality Analysis of the treated water will be concluded by the Stellenbosch WWTW Laboratory.

3. PLANT EQUIPMENT AND CONFIGURATION

The EMAWS Water Treatment Process to be employed for the trials will now incorporate the following basic production steps:

- **Electro-Coagulation, followed by**
- **Electro-Flotation, followed by**
- **Electro-Oxidation (Disinfection/Sanitization), followed by**
- **Polishing Filter (50 micron)**

The EMAWS Pilot Plant Set-Up for the above steps is illustrated in the below Photographs 1-4, and consists of:

- One large reaction cell, deployed for the Electro-Coagulation step
- Two small reaction cells, connected in series and deployed for the Electro-Oxidation step
- Visual Sight-Glasses for monitoring the performance of each of the above steps

- Polishing Filter (50 micron) deployed to remove any residual suspended solids from the final treated water exiting the electro-oxidation step

The balance of the Pilot Plant set-up comprises:

- Raw Effluent Storage Tank and Infeed Pump
- Electro-Flotation Clarifying Tank (for flotation of electro-coagulated matter)
- Sludge Collection Tank
- Clarified Effluent Transfer Pump (submersed in Clarifying Tank with height-adjustment mechanism)
- Clarified Water Flow Meter
- Treated Water Collection Tank

4. PROCESS DESCRIPTION

For the purposes of practicality and security, the decision was taken to install the Pilot Plant in the factory and bring the effluent sample to the Pilot Plant (as opposed to installing the Pilot Plant on site, alongside the effluent stream).

The process employed for the Trials is illustrated in the attached Process Flow Diagram, which is included in Section 8, below.

The detailed process description is as follows:

a) Processing Philosophy

The trial-run will be on a "**batch-wise"** basis, whereby a fixed amount of Raw Effluent will be processed through the system.

Given that the removal of sludge from the Electro-Coagulation/Flotation process is via overflow from the Clarifying Tank, it is necessary to ensure that this vessel is operating at full-volume prior to commencement of the Electro-Oxidation step.

Whilst the Clarifying Tank is being filled, the Raw Material Infeed Rate is set to optimize the extent of electro-coagulation required against the level of electrical power being consumed. For the trial-runs, this was done by visual-inspection of the initial samples, and assessment of the corresponding degree and rate of clarification achieved. In full-scale plant, this would normally be via automatic turbidity monitoring and feedback control.

Once the Clarifying Tank is operating at full-volume, the rate of overflow will be the difference between the Raw Effluent Infeed rate, and the rate at which Clarified Effluent is drawn-off to the Electro-Oxidation Step.

Given that the Electro-Oxidation components of the Pilot Plant are designed for a fixed maximum throughput of Clarified Effluent of 150 liters per hour, the Raw Material Infeed rate is then adjusted accordingly, and so as to optimize the overflow rate and removal of algomated sludge from the Clarifying Tank into the Sludge Collection Tank.

The Clarifying Tank on the Pilot Plant is sized at 700 liters.

In order to accommodate this volume, and allow for at least a two-hour continuous run through the Electro-Oxidation cells, the batch size for the trials was fixed at 1m3 of Raw Effluent.

b) Electro-Coagulation

The initial part of the process involves the treatment and removal of front-end organic loading via electro-

coagulation and electro-flotation.

Raw Effluent Infeed is pumped from the Raw Effluent Storage Vessel via the Infeed Pump, directly through the Electro-Coagulation Cell, into the Clarifying Vessel.

Electro-Coagulation is achieved in the reaction cell, which is powered with an oscillating high-frequency electro-magnetic pulse.

Under these activated conditions, Aluminium Hydroxide ions are produced along with the release of Hydrogen Gas.

These Hydroxide ions immediately attach to the dissolved organic matter (such as fats, oils, and grease) to form "algomated" particles, which are held in suspension.

c) Electro-Flotation

The Hydrogen gas is released in the form of tiny microscopic bubbles, which immediately seek to rise to the surface.

In so doing, they mechanically carry or "float" the algomated particles to the surface in a process known as Electro-Flotation.

In order to optimize this process, the Electro-Flotation is made to occur in the Electro-Flotation Clarifying Tank.

The geometry of the Clarifying Tank is such that the contact time between the rising bubbles and suspended particles is optimized, thereby causing effective flotation and separation of the sludge-layer from the clarified effluent.

Once the Clarifying Tank is full, the floated sludge is then allowed to overflow from the Clarifying Tank into the Sludge Collection Vessel.

The Clarified Effluent is then drawn from the middle-lower layers of the Electro-Flotation Tank and fed to the Electro-Oxidation cells.

5. TRIAL METHOD

a) Raw Effluent Storage and Infeed

The raw feed-stock was collected directly from the WWTW Effluent Channel into a 1m3 tank-tainer, which was transported and positioned alongside the Pilot Plant to act as the Raw Effluent Storage Tank.

A flexible suction-hose was then connected to the suction-port of the Infeed Pump, and positioned into the tank-tainer via the top inlet.

The plant set-up is demonstrated in the Photographs No. 1-4, below.

b) Electro-Coagulation & Electro-Flotation

Using the Infeed Pump, Raw Effluent was then pumped from the Storage Tank, through the Electro-Coagulation Cell, and into the Electro-Flotation Clarifying Tank.

The Raw Effluent Infeed flow rate was modulated/controlled by throttling the manual hand-valve on the pump discharge.

The flow-rate was initially set to 220 liters per hour (as first estimate for optimum feed-rate to be employed during simultaneous Electro-Coagulation and Electro-Oxidation).

A sample was then taken for visual assessment of the electro-coagulation performance.

The visual results of this initial run are presented in Photographs No. 5-7, below.

The photographs and video-footage clearly demonstrate the real-time effect of the electro-coagulation and flotation mechanism. Within 2-3 minutes of standing the sample to rest, the organic materials have been completely drawn out of solution and floated to the surface. The improvement in clarity in the layers below is clearly visible to the naked eye.

Photograph No. 9 below shows the results and the performance of electro-coagulation and flotation.

c) Electro-Oxidation

The Pilot-Plant was set at a Raw Effluent Infeed rate of 220 liters per hour. With 150 liters per hour being processed through Electro-Oxidation, the balance of 70 liters per hour represents the overflow of organic waste which is discharged into the Sludge Collection Vessel.

The plant was allowed to run in this fashion until the Raw Effluent feedstock had been exhausted.

The treated "electro-oxidized" water was collected in the Treated Water Collection Vessel for further sampling and analysis.

Samples of the treated water were taken both prior to and after the 50 micron Polishing Filter, in order to ascertain the effectiveness of the flotation/separation process.

6. QUALITY SAMPLING AND MEASUREMENT

Given that the trial was run on a batch-wise basis, it was only necessary to take sample from each of the following:

- Raw Effluent Feed
- Final Treated Water (Pre-Polishing Filter)
- Final Treated Water (Post-Polishing Filter)

Two samples of each stream were taken into 750ml sterilized glass bottles, and kept refrigerated over-night.

Pictures of the final samples can be seen in Photographs 10-12m.

The samples are to undergo a full Quality Analysis, as per the standard procedures and norms at Stellenbosch WWTW.

7. CONCLUSIONS

a) Electro-Coagulation and Flotation as a means of reducing Organic Load and improving Clarity

The effectiveness and performance of the electro-coagulation/flotation process is clearly demonstrated in the photographs and video footage of the samples under clarification stand-time.

Within 3 minutes of being placed to stand, the organic and particulate matter has been almost completely drawn out of solution, algomated, and floated to the surface.

A visual assessment of the improvement in turbidity between the Raw Effluent and the remaining water body of the Electro-Coagulated/Floated sample is in the region of 100%, and the final clarity can only be described as “excellent”. (Refer here to Photograph No. 8, below.)

The Certificate of Analysis for the water samples delivered to the Stellenbosch WWTW Laboratory is attached below in Section 10, and confirm the following results with regards to clarity/turbidity:

- Total Suspended Solids has been reduced from around 270 to 50 mg/l
- Turbidity has been reduced from “completely turbid” to around 4 NTU.

The Trial Tests also successfully demonstrated the flexibility of the plant, not only in physical set-up and processing options, but also with the ability to modulate and control the input parameters in order to optimize the output requirements.

As each specific application is inherently different, and given that the process variables/loadings within each application may vary from time to time, it is important that the overall treatment system is flexible in its set-up, and is capable of catering to these variations.

b) Electro-Oxidation as a means of Sanitization and Disinfection

The Certificate of Analysis for the water samples delivered to the Stellenbosch WWTW Laboratory is attached below in Section 10.

The analysis confirms the destruction of e-Coli and Coliforms, thereby demonstrating the suitability and efficacy of the EMAWS System in this application.

The disinfection capabilities of the system are further demonstrated via the reduction in Chemical Oxygen Demand ($COD_{unfiltered}$) from 835 to 224 mg/l.

c) EMAWS Water Treatment System

The trial results confirm that Electro-Coagulation and Flotation is certainly an effective means of:

- reducing organic loading
- removing suspended solids and particulate matter
- improving total water clarity.

The destruction of e-Coli and Coliforms, along with the marked reduction in Chemical Oxygen Demand ($COD_{unfiltered}$) confirms that the EMAWS System (Electro-Oxidation) is ideally suited for the sanitization and disinfection of the final Wastewater stream.

It should be noted that the above results were achieved with only Phase-One of the system.

Additional benefits and higher levels of performance (in terms of total treatment) can be achieved by adding Phase-Two and Phase-Three of the EMAWS system.

9. TRIAL PHOTOGRAPHS AND VIDEO FOOTAGE FILES



Photograph 1: Shows the EMAWS System with the Treated Electro-Oxidized Water Collection Tank in the foreground and the 0.75m3 Electro-Coagulation Clarifying Tank on the right. The Electro-Coagulated Sludge discharge line can also be seen discharging into the Sludge Collection vessel (partial view in right foreground).



Photograph 2: Shows the 1m3 Raw Effluent Feed Tank (right foreground), the 0.75m3 Clarifying Tank (left foreground), and Sludge Collection Vessel (at the back).



Photograph 3 & 4: Shows the EMAWS Water Treatment System with the larger Electro-Coagulation Reaction Cell on the right, and the two smaller Electro-Oxidation Cells on the left. In front of the Reactions Cells are the sight-glasses for each step, with the 50 Micron Polishing Filter installed between the two sight-glasses.



Photograph 5, 6 & 7: Shows the Electro-Coagulation Sample No.1 under Clarification Stand. The first picture was taken at 90 seconds from the time of placing the sample to stand, and the subsequent pictures at 30 second intervals thereafter/



Photograph 8: Shows the Electro-Coagulation Sample No. 1 after a clarification stand time of 5 minutes against sample of the Raw Effluent Feed-Stock. The reduction in turbidity and improvement in clarity can clearly be seen.



Photograph 9: Shows the results of the Electro-Coagulation/Flotation optimization.







Photograph 10, 11, & 12: Show the final samples sent for Water Quality Analysis at Stellenbosch WWTW.

Samples 1 & 2 are from the Raw Effluent Feed.

Samples 3 & 4 are Electro-Coagulated/Floated/Oxidized without polishing through the 50 micron filter.

Samples 5 & 6 are Electro-Coagulated/Floated/Oxidized with polishing through the 50 micron filter.

10. WATER SAMPLE CERTIFICATE OF ANALYSIS

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Certificate of Analysis (COA) For Scientific Services

Nature of the Sample/Descriptions		Sewage							
Analyst		Adeline Mogolegeng							
Contact Details									
Work Telephone		(021) 808 8259							
Email		adeline.mogolegeng@stellenbosch.gov.za							
Analysis Date		11.03.16							
Issue Date		15.03.16							
	ABR	METHODS	UNITS	Sample Nr1	Feed Sample Nr2	O2 Sample 3	Electro O2 Sample 4	O2 Sample 5	O2 Sample 6
pH @ 25°C	pH			7.47	7.40	7.71	7.53	7.25	7.29
Electrical Conductivity at 25 ° C	EC		mS/m	86.90	86.50	77.80	78.00	74.90	74.30
Total dissolved solids	TDS		mg/l	605.00	601.00	536.00	542.00	535.00	527.00
Suspended Solids	SS	2540 A, 2540 D, 25	mg/l	271	256	18	41	51	54
Turbidity	NTU		NTU				40.40	4.00	3.50
Free Chlorine	Cl_2							0.87	1.59
Escherichia coli	E. coli	9222 D.	cfu	5700.00	5500.00	0.00	0.00	0.00	0.00
Ammonia as N	NH_3-N	Salicylate	mg/l	49.60	44.40	47.50	43.60	40.10	60.00
Nitrate as N	NO_3-N	*Chromotropic Acid*	*mg/l*			0.75	0.74	0.67	0.55
Ortho-phosphate as PO4-P	O-PO^3-P	*Ascobic Acid*	*mg/l*	65.40	39.30	7.73	7.20	1.32	0.88
hemical Oxygen Demand (unfiltered) as C	$COD_{unfiltered}$	Reactor Digestion	mg/l	835.00	756.00	325.00	318.00	224.00	223.00

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