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Compiled by	**Authorized by**
Lebo M Pooe	Jenny A Reeves
[signature]	jreeves
Initials and Surname	**Initials and Surname**
Designation: Chemist	**Designation: AC&M Manager**
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Content

1. INTRODUCTION

Dissolved and suspended particles are present in natural waters (raw water). These suspended materials mostly arise from land erosion, the dissolution of minerals, the decay of vegetation and from several domestic and industrial waste discharges.

In Eskom's coal fired power stations, raw water from different sources is treated before being taken through the demineralisation or purification process. The pre-treatment process is one of the steps required to assist with the removal of dissolved and suspended particles which are present in most of natural waters.

Natural or raw water is treated to remove suspended materials, reduce the total organic carbon (TOC) and turbidity by flocculation and coagulation processes. Chemicals are mixed with raw water to promote the aggregation of the suspended solids into particles large enough to settle or be removed. Based on the organic removal study done previously by Eskom, pre-treatment chemicals can remove up to 68% of organics [Aspden JD, et al].

Flocculation process: Finer and suspended particles in natural water remain continuously in motion due to electrostatic charge (often referred to as negative – Zeta potential) which causes them to repel each other. Once their electrostatic charge is neutralized by the use of coagulant chemical, the finer particles start to collide and agglomerate (combine together) under the influence of Van der Waals's forces. These larger and heavier particles are called flocs. Metal salts (mainly aluminium salts) are used as coagulants and an organic polymer (normally referred to as polyelectrolyte) is used as a coagulant aid to give weight to the formed flocs for the flocs to settle (a low dose is usually used as these are usually organic substances and will increase the organic load if added in excess).

2. SUPPORTING CLAUSES

2.1 Scope

This document outlines a step by step process by which natural water can be treated in a laboratory scale to reduce turbidity and TOC as well as establish optimal pre-treatment chemical dosages for the water plant.

2.1.1 Purpose

The purpose of performing jar tests in Eskom's water plants (WTP) is to investigate the efficiency of different pre-treatment chemicals in removing or lowering the turbidity and total organic carbon (TOC) to the levels required by Eskom in the WTP pre-treatment guideline. Jar tests are also done to establish optimal pre-treatment dosages to optimize the WTP pre-treatment process. An optimally running plant will reduce the organic load on the anion resins hence reducing the frequency of brine washes which means effluent and water usage reduction and all this translates to cost reduction. Pre-treatment optimization improves the quality of our make-up water ensuring the purity of the steam/water cycle. Pre-treatment optimization also ensures that the potable water produced is low in organics reducing the risk of having high tri-halo methanes (THM) in water which are carcinogenic.

2.1.2 Applicability

This document is applicable to Eskom RT&D and all personnel working in Eskom's Generation water plants.

2.2 Normative/Informative References

2.2.1 Normative

[1] ASTM D 2035: Standard Practice for Coagulation-Flocculation Jar Test of Water.

[2] ISO 9001 Quality Management Systems.

[3] 240-53113712: Demineralised Water Production Using Ion Exchange Resins Chemistry Standard.

[4] 240-88257914: Chemistry Guideline for Demineralised Water Production Using Ion Exchange Resins

[5] 240-142682090: Chemical CoE Work Instruction for Chemical Storage, Handling and Dosing Systems Design

[6] 240-55864764: Chemistry Standard for Potable Water.

2.2.2 Informative

[1] ISBN 978-92-4-154995-0, Guidelines for drinking water quality, 2016, World Health Organisation Volume 4.

[2] ISBN 978-1-77005-862-0, A simple guide to the chemistry selection and use of chemicals for water and waste water treatment, 2009, Water Research Commission

2.3 Definitions

Definition	Description
Blends	In Eskom's water plant pre-treatment process a blend refers to a mixture of a coagulant and a flocculant chemicals in one product.
Coagulation	Coagulation is the neutralisation of electrostatic charge (zeta potential) by chemical coagulant addition where the resulting particles start to collide and combine together.
Enhanced coagulation	Dosing of an excess of water treatment coagulant chemical over and above that required solely for turbidity and TOC removal (this can range from 1.5 to 7 times excess of coagulant chemical addition).
Floc	A loosely clumped mass of fine particles
Flocculation	Flocculation is the agglomeration of destabilized particles into large particles, & can be enhanced by the addition of high-molecular-weight, water-soluble organic polymers.
NSF International	An accredited, independent third-party certification body that tests and certifies products to verify they meet the requirements of the public health and safety standards.
Monomer	A small-molecular-weight organic chemical that can be linked to itself or to another monomer to produce a high-molecular-weight polymer through one of many polymerization processes.

2.4 Abbreviations

Abbreviation	Description
ACH	Aluminium Chlorohydrate
ANSI	American National Standards Institute
COA	Certificate of Analysis
MSDS	Material Safety Data Sheet
NOM	Natural Organic Matter
NSF	National Sanitation Foundation
NTU	Nephelometric Turbidity Unit
PACl	Polyaluminium Chloride
pH	The negative logarithm of the hydrogen ion concentration measured at a defined temperature, usually 25 °C
PPE	Personal Protective Equipment
RT&D	Research, Testing and Development
TOC	Total Organic Carbon
UV_{254}	A measurement of the amount of light absorbed by organic compounds, specifically aromatic, in a water sample at 254 nm wavelength.

2.5 Roles and Responsibilities

Eskom RT&D AC&M Manager

- Review the jar test procedure for corrections, addition or deletion of information as well as approve the procedure.

Eskom RT&D Chemist

- Testing pre-treatment chemicals from suppliers for efficiency in removing turbidity and TOC from raw water to levels required by Eskom as well as recommending suitable chemicals (including during the tender process).
- Perform jar tests to establish optimum chemical dosages for turbidity and TOC removal from raw water.
- Assist Eskom power stations by performing jar tests to optimise the station's pre-treatment process (including during the supplier plant trial runs).
- Assist Eskom power stations by providing the pre-treatment chemicals testing requirements for the tender process (can also be done during the supplier site meeting at the stations).
- Train the Eskom power stations WTP personnel on how to perform the jar tests.

Power stations WTP personnel

- Perform regular jar tests to establish optimum chemical dosages for turbidity and TOC removal from raw water.
- Performing jar tests to optimise the station's pre-treatment process.
- Perform jar tests whenever there are changes in the raw water quality or whenever there are suspicions of over/under dosing of pre-treatment chemicals.

2.6 Process for Monitoring

The performance of jar tests at Eskom power stations will be monitored during the WTP pre-treatment reviews/audits as well as the stations' peer reviews.

2.7 Related/Supporting Documents

None

3. SAFETY

- Always read the MSDS of each product and follow the recommended standard operating procedures
- PPE such as acid resistant laboratory coats, nitrile gloves, safety shoes and goggles must be worn
- When handling acids, bases and effluent water, care should be taken not to inhale the fumes. Technicians should wear breathing masks and surgical gloves to avoid samples coming into contact with their skin
- Work in the fume cupboards
- The toxicity or carcinogenicity of each reagent used in this method has not been precisely defined; however, each chemical compound needs to be treated as a potential health hazard. From this viewpoint, reduce exposure to these chemicals to the lowest possible level by whatever means available
- Personnel to adhere to good housekeeping and clean bench policy
- Safety in the laboratory is everyone's responsibility; hazards which were identified should be reported to the manager and the safety representative. Alert your colleagues of the potential danger
- Personnel should familiarise themselves with the laboratory safety shower and eye wash fountains
- Please pay attention to risk warnings and safety advice on the labels and reaction cells. The enclosed leaflets contain additional appropriate safety precautions

4. INTERFERENCES

- Temperature Change (during test): Thermal or convection currents may occur, interfering with the settling of coagulated particles. This can be prevented by temperature control.
- Gas Release (during test)-: Flotation of coagulated floc may occur due to gas bubble formation caused by mechanical agitator, temperature increase or chemical reaction.
- Testing Period: Biological activity or other factors may alter the coagulation characteristics of water upon prolonged standing. For this reason the period between sampling and testing should be kept to a minimum.

5. APPARATUS

1. Multiple Stirrer: A multi-position stirrer with continuous speed variation from about 20 to 200 rpm should be used. The stirring paddles should be of light gauge corrosion resistant material all of the same configuration and size.
2. 1000 or 1500 ml glass beakers (glass beakers used should all be of the same size and shape).
3. 5 or 10 ml syringes (for flocculant/poly-electrolyte dosing) and 20 or 50 ml syringes (for coagulant dosing).
4. 10 ml calibrated pipette and 100 ml pipette
5. 500 ml or 1000 ml measuring cylinder
6. 1000 ml volumetric flasks
7. 250 ml or 500 ml Scott amber bottles

6. REAGENTS

Reagent grade chemicals (chemicals of high purity) shall be used. Reagents should come with a COA and MSDS. The MSDS should outline the type of chemical as well as its active ingredient.

Coagulant: This, depending on a power station, could either be ACH or PACl (the majority of Eskom's coal fired power stations use the ACH type of coagulant)

Flocculant: In most Eskom's coal fired power stations polyelectrolytes, often referred to as polymers, (these are high molecular weight synthetic organic polymers) are mostly used as flocculants.

Type IV reagent water (demineralised water) shall be used to prepare reagents.

<u>Type IV water specifications</u>:

Maximum Electrical conductivity at 25°C 5.0 µS/cm;

pH at 25°C 5.0 to 8.0;

Maximum sodium 50 µg/L;

Maximum chloride 50 µg/L.

6.1 Reagent Preparation

1. Pipette 1ml of coagulant (eg Bulab 5170/Rheofloc 5023/Zetafloc 2300L /Sudfloc 3365) into 1000ml volumetric flask. Make up to the mark with demineralised water. This is equivalent to 1000 mg/L.

2. Pipette 1ml of flocculant/coagulant aid (Poly-electrolyte, eg Bulab 5031/Rheofloc 5414/Zetafloc A50/Sudfloc 475) into 1000ml volumetric flask. Make up to the mark with demineralised water. This is equivalent to 1000 mg/L.

   2.1 From the 1000 mg/L stock solution of the flocculant, pipette 100 ml and dilute into 1000 ml volumetric flask. Make up to the mark with demineralised water.This will be equivalent to 100 mg/L flocculant. **NB: The flocculant dose should be kept below 1 mg/L.**

3. Powdered aids: Weigh 1g and dissolve in 1000 ml volumetric flask. Make up to the mark with demineralised water. This is equivalent to 1000 mg/L.

7. Jar Test Method

1. Record the raw water turbidity and take a raw water sample for Total Organic Carbon (TOC) analysis.

2. Measure equal volumes (6 x 500/1000 ml or as many samples as there are positions on the multiple stirrer/flocculator) of the raw water sample using a measuring cylinder. Locate the beakers so that the paddles are off-center but clear the beaker wall slightly.

3. Select the flocculant/coagulant concentration ranges to dose to the different raw water samples and withdraw the reagents (from the 100 mg/L prepared flocculant and the 1000 mg/L coagulant stock) using the syringes.

   NB: It is recommended that one reagent concentration (flocculant/coagulant) be kept constant in all beakers whilst the other reagent concentration (flocculant/coagulant) is varied throughout the beakers.

4. Start the multiple stirrers operating at the "flash mix" speed of approximately 200 rpm. Add the coagulant at predetermined dosage levels and 3 minutes after adding the coagulant add the flocculant. Flash mix for approximately 2 minutes after the addition of the flocculant (total flash mix time is 5 minutes).

5. Reduce the speed to approximately 80 rpm to keep the floc particles uniformly suspended throughout the slow mix. Slow mix for approximately 10 minutes. **NB: Excessive stirring tends to break up early floc formation and may redisperse reagents.**

6. After the slow mix period, withdraw the paddles to allow floc settlement. After 30 to 45 minutes of settling by means of a pipette or syringe withdraw an adequate sample volume of supernatant liquor from the jar/beaker at a point one half of the depth of the sample into the amber Scott bottles to conduct the Turbidity (in NTU), TOC (in mg/L), pH and other required analyses.

8. CALCULATIONS

Equation 1

$C_1V_1 = C_2V_2$

Where C is the concentration in mg/L, and V is the volume in ml.

Equation 2

%TOC removed = [(TOC of original untreated sample - TOC of treated sample) ÷ TOC of original untreated sample] × 100.

9. DEVELOPMENT TEAM

Lebo M Pooe

Jenny A Reeves

10. ACKNOWLEDGEMENTS

Kobe Mphela

Cody Makhuba

Annual Book of ASTM Standards; Section 11; Water and Environmental Technology; Volume 11.02 Water (II); 1992; Philadelphia USA