KENYA STANDARD

KS2767-13:2022

ICS ##.###

1st Edition

Wastewater treatment plants —

Part 13: Chemical treatment —

Treatment of wastewater by precipitation/flocculation

TECHNICAL COMMITTEE REPRESENTATION

The following organizations were represented on the Technical Committee:

1. CSI International ltd
2. Dousglobal Management solutions
3. Ecosave Africa Ltd
4. Embu Water and Sanitation Company LTD
5. Environment Institute of Kenya
6. Green Kenya Investment Corporation
7. Jomo Kenyatta university of agriculture and technology
8. KenGen PLC
9. Kenya Chemical Society
10. Kenya water Institute
11. Kenyatta university
12. Nairobi City Water and Sewerage Company
13. National Environment Management Authority
14. National Public Health Laboratory
15. Ministry of Transport, Infrastructure, Housing, Urban Development and Public Works
16. Synergy Ltd
17. Taita Taveta University
18. TANATHI Water Works Development Agency
19. United States International University-Africa
20. Kenya Bureau of Standards — Secretariat

REVISION OF KENYA STANDARDS

In order to keep abreast of progress in industry, Kenya Standards shall be regularly reviewed. Suggestions for improvements to published standards, addressed to the Managing Director, Kenya Bureau of Standards, are welcome.

KS 2767-13:2022

Wastewater treatment plants —

Part 13: Chemical treatment —

Treatment of wastewater by precipitation/flocculation

Kenya Bureau of Standards, Popo Road, Off Mombasa Road,
P.O. Box 54974 - 00200, Nairobi, Kenya

+254 020 6948000, + 254 722202137, + 254 734600471

info@kebs.org

@KEBS_ke

kenya bureau of standards (kebs)

Foreword

This Kenya Standard was prepared by the Water and Sanitation Technical Committee under the guidance of the Standards Projects Committee, and it is in accordance with the procedures of the Kenya Bureau of Standards.

During the preparation of this standard, reference was made to the following document (s): EN 12255: Wastewater treatment plants — Part 13: Chemical treatment — Treatment of wastewater by precipitation/flocculation.

Acknowledgement is hereby made for the assistance derived from this (these) source (s)

The parts of these series are as follows:

– Part 1: General construction principles

– Part 3: Preliminary treatment

– Part 4: Primary settlement

– Part 5: Lagooning processes

– Part 6: Activated sludge processes

– Part 7: Biological fixed-film reactors

– Part 8: Sludge treatment and storage

– Part 9: Odour control and ventilation

– Part 10: Safety principles

– Part 11: General data required

– Part 12: Control and automatization

– Part 13: Chemical treatment

– Part 14: Disinfection

– Part 15: Measurement of the oxygen transfer in clean water in activated sludge aeration tanks

– Part 16: Physical (mechanical) filtration)

Wastewater treatment plants — Part 13: Chemical treatment — Treatment of wastewater by precipitation/flocculation

1 Scope

This Standard specifies the requirements for chemical treatment of wastewater by precipitation/flocculation for removal of phosphorus and suspended solids.

The application of polymers is not described in this Standard.

2 Normative references

This Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 752-6, Drain and sewer systems outside buildings — Part 6: Pumping installations.

KS 2766, Wastewater treatment — Vocabulary.

EN 10088-2, Stainless steels — Part 2: Technical delivery conditions for sheet/plate and strip for general purposes.

KS 2767-1, Wastewater treatment plants — Part 1: General construction principles.

KS 2767-6, Wastewater treatment plants — Part 6: Activated sludge process.

KS 2767-11, Wastewater treatment plants — Part 11: General data required.

EN 12518:2000, Chemicals used for treatment of water intended for human consumption — High-calcium lime.

3 Terms and definitions

For the purposes of this Standard, the terms and definitions given in KS 2766 and EN 12518:2000 and the following apply.

3.1
chemical treatment of wastewater
treatment of wastewater by chemical coagulation/precipitation with metal salts (including lime) or organic polymers in order to remove inorganic and organic phosphorus compounds and suspended solids and colloids

4 Requirements

4.1 General

Chemical treatment of wastewater can be divided into two processes: a reaction phase, that consists of precipitation of dissolved phosphates, destabilisation of colloids and the formation of flocs, and a separation phase, in which the flocs are separated from the water.

The reactors and floc separators (sedimentation tanks, flotation units etc.) for the chemical treatment can be integrated with the other parts of the wastewater treatment plant (pre-precipitation, simultaneous precipitation, see 4.2.2.2 and 4.2.2.3) or be a separate part of the treatment plant (post precipitation, direct precipitation).

The water level in the chemical reactors and tanks may be controlled by fixed or adjustable weirs. It is particularly important where there are multiple parallel reactors.

The design of the process shall take into account variations in flow and load as stipulated in KS 2767-1 and KS 2767-11.

4.2 Chemical background and process options

4.2.1 Chemical process

In order to obtain coagulation/precipitation a cationic chemical has to be added to the wastewater. Most commonly this is a salt of aluminium or iron, and cationic polymers. Lime may also be used. If only coagulation (removal of particles) is aimed at, a cationic polymer may be added alone or in addition to a metal salt.

Phosphorus can be present in the wastewater in the following forms:

a) organically bound phosphorus,

b) inorganic phosphorus,
   - polyphosphate,
   - orthophosphate.

Polyphosphates are eventually converted to orthophosphates and the organically bound phosphorus is converted to orthophosphate during biological treatment.

In primary treatment, phosphorus fixed to settleable particles is removed (5 % to 15 % of the total influent phosphorus depending on the character of the wastewater). In the biological treatment a certain amount of phosphorus is consumed at the microbial synthesis of new cellular material (10 % to 30 % of the influent phosphorus). By introducing an anaerobic stage where volatile fatty acids are produced and phosphates are released an increased biological removal of total phosphorus can be reached without addition of chemicals (60 % to 90 % of the influent concentration).

In the chemical precipitation, a precipitation agent (such as aluminium sulphate, ferrous sulphate, ferric chloride or calcium hydroxide) is added to the wastewater. The orthophosphate phosphorus is precipitated as metalorthophosphate. Al^{3+} and Fe^{3+} also form colloidal hydroxides. The solubility of the precipitates is pH-dependent.

Organic polyelectrolytes are used as flocculation agents for colloidal and suspended matter. Organic polymers may be used as primary coagulants as well as in the more traditional flocculation step of binding already formed small flocs into larger particles. The polymer acts as a destabilising agent via a charge neutralisation/precipitation mechanism, and is also an agent for floc growth.

Chemical coagulation/precipitation can be carried out in six different ways, namely
- direct precipitation,
- pre-precipitation,
- simultaneous precipitation,
- post-precipitation,
- multipoint precipitation,
- precipitation on filters.

4.2.2 Precipitation processes

4.2.2.1 Direct precipitation

Direct precipitation is used in wastewater treatment plants without a biological stage.

In a direct precipitation plant, the precipitation agent should be added after the preliminary stage (screen, grit chamber and possibly a primary settlement tank).

The precipitation agent should be added in a way that assures rapid and complete mixing of the chemical. After mixing flocculation takes place in a flocculation tank. The chemical flocs are then separated in a final sedimentation tank or another floc separation device.

4.2.2.2 Pre-precipitation

Pre-precipitation can be used in wastewater treatment plants having both mechanical and biological treatment.

With pre-precipitation, the addition of the precipitation agent is effected before the biological stage, often before the aerated grit chamber, pre-aeration tanks, or flocculation tanks. The chemical flocs are separated together with the primary sludge in the primary settlement tanks.

Chemical flocs which are not removed in the primary settlement tank are transported with the wastewater and separated in the secondary settlement tank together with the biological sludge.

4.2.2.3 Simultaneous precipitation

Simultaneous precipitation can be used in wastewater treatment plants with biological treatment depending on the activated sludge process used.

With simultaneous precipitation the addition of the precipitation agent is effected in the aeration tank, at the end of the aeration tank or together with the return sludge, where both a biological and a chemical process takes place.

The mixed biological and chemical sludge is separated in the secondary settlement tank or a flotation unit. The return sludge, the excess sludge and the mixed liquor suspended solids contain a larger part of inorganic material as compared to the sludges in a normal activated sludge plant.

4.2.2.4 Post-precipitation

Post-precipitation can be used in wastewater treatment plants with biological treatment (activated sludge, trickling filter etc.).

With post-precipitation the addition of the precipitation agent is done in a mixing tank after the secondary settlement. Floc formation takes place in a flocculation tank followed by a final clarification tank where the chemical sludge is separated. Alternatively, lamella sedimentation or flotation can be used for separation.

4.2.2.5 Multipoint precipitation

The efficiency of the precipitation may be increased by adding the chemicals at two or three different points, e. g. the grit chamber, the aeration tank, the final sand filter.

4.2.2.6 Precipitation on physical filters

Precipitation on filters is normally a complement to biological phosphorus removal or to a pre-precipitation or a simultaneous precipitation. The chemical is added in the channel or pipe leading to the filter. An effective mixing shall be arranged.

4.2.3 Selection of precipitation chemicals

Details of chemicals often used are given in annex A. Apart from that some waste products or by-products and products ready for use can be used as precipitation or flocculation chemicals.

Careful consideration of the heavy metal concentration and other pollutants shall be made.

NOTE Details about limits can be obtained from relevant national and legislation.

Table 1 — Normal use of chemicals

	Al-sulphate	Polyaluminium chloride	Ferrous sulphate	Ferric chloride	Lime	Cationic polymer
Direct precipitation	x	x	- x	x	x	x
Pre-precipitation	x	x	x	x	x	x
Simultaneous precipitation	x	x	x	x	-	x
Post-precipitation	x	x	-	x	x	x
Multipoint precipitation	x	x	(x)	x	x	x
Precipitation on filters	x	x	x	x	-	x

The different precipitation chemicals have different pH-optima (see annex A). The addition also influences the pH of the water.

Type and dose of the chemical is dependant on the type of wastewater and its content of bicarbonate. They should both be determined in a precipitation test.

On the specific wastewater, this test may be done in beakers equipped with stirrers with variable velocity or in pilot or full-scale trials.

4.3 Storage of chemicals

4.3.1 General

The manufacturers directions shall be observed.

The following issues shall be considered:

- safety precautions in handling chemicals (e. g. protective goggles, respiration masks etc.);
- maximum storage time of chemical;
- safety precautions to contain leakage of full tank volume;
- material data sheet
- housing
- climatic conditions.
- For safety precautions see also KS 2767-10.

4.3.2 Aluminum salts

4.3.2.1 Aluminium sulphate

Granulated aluminium sulphate in dry form is not corrosive and can be stored in contact with all types of construction materials. A silo for storage has to be completely tight to avoid humidity.

Solutions of aluminium sulphate are acidic and corrosive and the construction material should be appropriate plastic or stainless steel of suitable quality with minimum Molybdenum content of 2 % (e. g. 1.4571 (X6CrNiMoTi 17-12-2) in accordance with EN 10088-2).

4.3.2.2 Polyaluminium chloride

The solutions are acidic and corrosion proof material as appropriate should be used (plastic or rubber-covered steel).

4.3.3 Iron salts

4.3.3.1 General

Iron based precipitation chemicals can be produced of by-products.

4.3.3.2 Ferrous sulphate (monohydrate)

The dry granulate of ferrous sulphate is not corrosive. Silos for storage shall be completely tight to avoid humidity.

Solutions are corrosive and shall be stored in tanks of stainless steel (e. g. 1.4571 (X6CrNiMoTi 17-12-2) in accordance with EN 10088-2) or appropriate plastic.

4.3.3.3 Ferrous sulphate (heptahydrate)

The green crystaline heptahydrate is acidic and corrosive. Construction material shall be corrosion proof such as stainless steel (e. g. 1.4571 (X6CrNiMoTi 17-12-2) in accordance with EN 10088-2), appropriate plastic or plastic coated concrete.

Ferrous sulphate (heptahydrate) is not stored in a silo but is directly delivered to dissolving tanks in the wastewater treatment plant.

4.3.3.4 Ferric chloride and ferric chloride-sulphate

Ferric chloride is acidic and corrosive and shall be stored in corrosion proof tanks such as rubber-covered steel or plastic tanks.

The liquid should not be diluted or aerated.

4.3.4 Calcium salts

Calcium oxide (Quicklime) and calcium hydroxide shall be kept dry.

Calcium hydroxide can be stored in a silo and has good storage capability.

4.3.5 Polymers

The Shelf Life of the polymer coagulant depends on the physical types (ie Dry polymer , Emulsion polymer or Solution polymer). Dry polymer has a shelf life of up to 3 years, un-opened bag; Emulsion polymer has a shelf life of 6 months when stored in un-opened drum/tote, while Polymer solution shelf life depends of concentration and water quality. Polymer should be stored under Storage Temperature: 40 F - 90 F, and

Emulsion should not be allowed to freeze. Once frozen, thaw in heated area and mix well. During Handling of polymer, always wear latex gloves and eye protection, Minimize exposing to air, avoid dusting (dry polymer), Don't try to clean spilled polymer with water but Use absorbents (vermiculite, sawdust, paper towel, etc.)

4.4 Dosing equipment

4.4.1 General

Unless otherwise specified, the dosing system shall have some form of back-up, either built in or held in storage.

Where automatic controls are used, the system shall be designed to change into safe state (fail safe mode) in case of failure. In the majority of cases, the reaction between the chemicals and the wastewater is extremely rapid. It is therefore important that the precipitation agent is distributed uniformly throughout the entire waterbody. This can be done in many ways, e. g. with injection or mixing systems.

The design should include provisions for removal of scaling.

General requirements for dosing equipment that are not included in 4.4 may be specified in accordance with national standards.

4.4.2 Aluminium salts

4.4.2.1 Aluminium sulphate technical grade

This salt can be fed dry but is normally dissolved in water. A normal mass fraction is 10 % to 15 %. The concentration shall be higher than 5 % in order to avoid precipitation of metal hydroxide.

The velocity in pipes should not be lower than 0.5 m/s in order to avoid precipitation on the pipe surface.

4.4.2.2 Polyaluminium chloride

Technical polyaluminium chlorides are dosed directly from storage tanks. The solution is acid and corrosion proof pumps shall be used. Pipes and valves should be made of rubber-covered steel or appropriate plastic.

4.4.3 Iron salts

4.4.3.1 Ferrous sulphate (monohydrate)

The granules are normally dissolved in water. They are dosed with a screw to the dissolving tank. The dissolving equipment has to be designed to avoid clogging.

4.4.3.2 Ferrous sulphate (heptahydrate)

The bulk chemical ferrous sulphate (heptahydrate) is dissolved in a suitable tank e. g. of glass-fibre reinforced polyester. A precipitation can occur and the solution may need to be filtered before the dosing.

It is normally dosed as a saturated solution. Aerosols of ferrous sulphate solution attack tooth material and a safety mask should be used when mixing is achieved using aeration.

4.4.3.3 Ferric chloride

Ferric chloride solution is dosed directly (without dilution) from the storage tanks. The pumps shall be corrosion proof. Pipes and valves shall be corrosion proof and made of appropriate plastic or rubber-covered steel.

4.4.4 Calcium salts

Calcium oxide has to be slaked in a lime slaker and is then mixed with water to a lime slurry that is fed to the wastewater by a dosing pump.

Calcium hydroxide is typically dosed with a screw feeder at the bottom of the lime silo. The dry lime is mixed with water in a mixing tank and fed to the wastewater by a dosing pump. There is a risk of clogging of pipes.

Therefore the pipework shall be designed for easily cleaning and consideration should be given to

- constant circulation;
- a flushing system.

An alternative is to use rubber that are moved frequently to avoid clogging.

4.5 Silos and tanks

The silos or storage tanks should be placed near the dosing point of the chemicals. Pipe length should be as short as possible, and the pipework should be designed without any stagnation zones or sharp bends, especially when slurries (lime) or dissolved chemicals (e. g. aluminium sulphate) are used.

4.6 Mixing systems

The mixing system shall be capable of a rapid and uniform distribution of the chemical in the wastewater.
Provision should be made for easy removal of the mixing devices without emptying the tank. The choice of the device depends on the characteristics of the wastewater to be treated.

4.7 Flocculators

Where flocculators are needed, the hydraulic design shall minimise short circuiting. The distance between the flocculator and the separation unit (sedimentation tank, flotation) shall be short and the velocity of water flowing to the separator should be < 0.10 m/s.

It is important that the water leaving the flocculation process should not be subjected to greater shear forces than encountered in the flocculation process. Therefore, the flocculation unit should be situated directly adjacent to or in the sedimentation tank.

4.8 Sedimentation tanks

4.8.1 General

The sedimentation tanks shall adequately separate the chemical sludge solids from the effluent and provide a concentration zone for withdrawal of sludge. The efficiency of separation affects the quality of the final effluent.

Sedimentation tanks may be of upward flow type, horizontal flow type or a lamella separator.

4.8.2 Design considerations

Design requirements are found in KS 2767-1 and KS 2767-6.

4.8.3 Chemical sludge wasting

Sludge wasting involves removing the chemical sludge formed during the precipitation process.
The weight and volume of sludge to be wasted, depends primarily on the pollution load and the type of chemical used.

Sludge wasting shall be as regular as possible taking into consideration further sludge thickening and/or treatment.

Specifications in raw wastewater pumping installations according EN 752-6 and general construction principles according KS 2767-1 are applicable to the excess sludge wasting system.

4.9 Flotation

In flotation tanks air is used to float particles to the surface, where they can be separated as sludge. The flotation should be of dissolved-air flotation type. The surface sludge is collected by a surface scraper. In addition, there should be a collection system for the heavy sludge settled on the bottom of the tank.

Flotation is also described in KS 2767-8

.

4.10 Physical filtration

Filtering is normally used only as a complement to sedimentation and flotation in order to provide a better suspended solids removal. However, some types of filters are designed to be able to serve as the only separation stage necessary for chemical treatment of wastewater.

If sand filters are used as the only stage for separating chemical flocs from the wastewater, there shall be a primary settling step before the chemical treatment. Where lime is used as a precipitation agent, physical filtration is not appropriate.

Physical filtration is described in [3]

.

4.11 Sludge

4.11.1 Sludge production

In practical operation the sludge production can be different. It can be determined by precipitation tests.

The chemical precipitation with metal salts produces a mixed phosphate hydroxide sludge.
Typical relations are:

- 1 g Al produces 4 g suspended solids;
- 1 g Fe produces 2.8 g suspended solids;
- 1 g Ca produces 0.7 g suspended solids.

4.11.2 Sludge characteristics

The sludge flocs are fragile, especially the aluminium-hydroxide-phosphate flocs.

Iron-phosphate sludge has better settling and thickening characteristics than aluminium-phosphate sludge and forms a more compact sludge. Calcium-phosphate sludge settles rapidly and forms a compact sludge. In order to improve the sludge thickening and dewatering, polymers may need to be added.

5. Disposal of final precipitate

The final precipitate shall be disposed in accordance to National Environmental Management Authority guidelines.

Annex A
(normative)
Precipitation chemicals

A.1 Aluminium salts

Aluminium salts suitable for chemical precipitation of phosphorus are
Aluminium sulphate $Al_2(SO_4)_3$ - 14 to 18 H_2O

The technical grade also contains iron as $Fe_2(SO_4)_3$ - $9H_2O$. The product is granulated. The pH-optimum is from 5.7 to 6.5.

— Polyaluminium chloride $Al_n(OH)_mCl_{3n-m}$

The technical grade also contains iron. The product is liquid. The density is 1.3 g/cm^3

The pH-optimum is from 5.7 to 8 (the interval is depended on basicity of the chemical and the hardness of water).

A.2 Iron salts

A.2.1 Ferrous salts

Ferrous sulphate, monohydrate $FeSO_4$ - H_2O
Ferrous sulphate, heptahydrate $FeSO_4$ - 7 H_2O

A.2.2 Ferrous sulphate, monohydrate

The technical grade is granulated (0.2 mm to 3 mm) and contains 87 % mass fraction to 88 % mass fraction $FeSO_4$. H_2O. The pH-optimum is > 6.5 (conversion to ferric ions and flocculation).

A.2.3 Ferrous sulphate, heptahydrate

The technical grade is light green with a structure like snow.

It contains about 90 % mass fraction $FeSO_4$ - 7 H_2O. The pH-optimum is > 6.5 (conversion to ferric ions and flocculation).

A.2.4 Ferric salts

Ferric chloride, solution of $FeCl_3$.

The pH-optimum is from 4.5 to 6.5 or > 8.5.

The widely used technical grade contains Ferric chloride-sulphate with a Fe3+ concentration of 11.6 % mass fraction. It has successively been replaced by a product with lower content of heavy metals and a Fe3+ concentration of 13.7 % mass fraction. This product should be used if possible.

A.3 Calcium salts

A.3.1 General

Direct precipitation or post-precipitation can be made with calcium hydroxide $Ca(OH)_2$ or calcium oxide (normally granulated) CaO.

The pH-optimum is from 9.3 to 11.2 (according to the effluent concentration required).

A.3.2 Calcium oxide

The fractions are: < 0.2 mm, < 2 mm, 2 mm to 12 mm and 12 mm to 25 mm.

The finest fractions (< 0.2 mm, < 2 mm) are creating dust and are delivered in tank cars or tank railroad cars.

Calcium oxide is very aggressive. Mixing with water creates alkaline calcium hydroxide and heat.

A.3.3 Calcium hydroxide

Calcium hydroxide is manufactured from calcium oxide by adding the stoichiometric amount of water. The calcium hydroxide is a fine powder (99.5 % finer than 0.2 mm and 97.5 % finer than 0.09 mm).

Calcium hydroxide is aggressive and personal protection equipment (protection goggles, respiration mask, gloves etc.) shall be used.

A.4 Polymers

A.4.1 General

A.4.2 Dry Polymer

This is either Cationic, anionic, or non-ionic. The Molecular weight: up to 10 M (cationic), up to 20 M (anionic, non-ionic). Dry polymer is up to 90% active with Polymer particle size: 0.1 - 2 mm. The cost for dry polymer is high

A.4.3 Emulsion Polymer

This is either Cationic, anionic, non-ionic with Molecular weight: up to 10 M (cationic), up to 20 M (anionic, non-ionic). It is 30 - 60% active, and Polymer gel size: 0.1 - 2 μm. the cost for dry polymer is high

A.4.4 Solution Polymer (Mannich)

This is Cationic only with molecular weight up to 10 M. Solution polymer is 4 - 6% active, is low in cost and has Limited usage

.

