FLOCCULANTS: TYPES AND WHERE TO USE THEM

Literature Review

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OVERVIEW

- Literature exploring different types of flocculants is summarised in this document.
- Flocculants are used across many industries including the food industry, brewing industry and water treatment industry.
- Dissolved particles give water a "muddy" or "milky" appearance.
- Dissolved particles in water can b dangerous as they often contain toxic minerals or harbour harmful microorganisms.
- Flocculants are essential for proper water treatment as they removed dissolved particles in water.
- Flocculants cause dissolved particles in water to clump together and sink, thus clearing the water.
- This literature review also explores and compares the different types of flocculants, including their costs, after-effects and factors that affect their ability to remove dissolved particles from water.

INTRODUCTION

Particles finer than 0.1–100 µm in water remain in constant motion due to their electrostatic charge which causes them to repel each other. These particles are usually either clay, silt, tiny oil droplets, algae, decaying organic matter, or a combination of these [1], and are usually too small to be influenced by gravity. These particles enter water via surface run-off or rainfall. These particles raise the turbidity of water, the light-scattering property of water, and gives it a "muddy" or "milky" appearance clearly visible to the naked eye. In extreme cases, highly turbid water poses a significant health risk to anyone who uses the water for recreation or consumption. Water cannot naturally cleanse itself to produce safe water if turbidity is high and requires artificial treatment. Flocculation is a chemical and physical process in which microscopic particles that cause turbidity and colour clump together as giant particles, which are finally eliminated by sedimentation or skimming [2].

IMPACTS OF TURBID WATER

Health	• Suspended particles in water harbour pathogenic microorganism capable of causing serious disease in humans and livestock [3] • Turbid particles adsorb toxic compounds which also cause disease to humans and livestock when consumed [4] • Suspended particles are a source of nutrients that promote bacterial growth, and are responsible for many waterborne disease outbreaks [5] • Highly turbid water that appears red or black is an indicator of dissolved metal oxides in the water and causes disease in humans [6]
Economic	• A build-up of suspended particles can lead to clogged pumps, screens and emitters in agricultural irrigation systems [7] • High turbidity reduces the effectiveness of disinfectants as the particles shield and protect microbes in water [8] • Toxic contaminants in water limit the instances where the water can be utilised [6]
Social	• Suspended particles give water an unsightly muddy or milky appearance [3] • Water with slight discolouration is considered unsafe for consumption as consumers relate the appearance of water to its safety [3] • Unsafe water prevents recreational activities like fishing and swimming [5]

FLOCCULANTS

Flocculants are special additives that induce flocculation in turbid waters, the process by which dissolved particles agglomerate to form clumps, and are classified as either organic or inorganic depending on their active constituent [9]. Multiple flocculants are used in various industries, but only few of them work well under the conditions of dam water. Flocculation brings small particles together as small aggregates and allows them to sink under the influence of gravity or to float to the surface of the water, thus improving the overall quality of the water [10]. Flocculation is an efficient and cost-effective method for drinking water and wastewater treatment, and plays a major role in the fate of toxic contaminants in water; without sedimentation these dangerous particulates remain dissolved in the water [6].

HOW THEY WORK

By altering surface electrochemistry	• Flocculants bind to particles and create charge "islands", areas of negative or positive charge, and it is the attraction of these oppositely charged surfaces that causes particles to clump together [11]
By creating polymer bridges	• Flocculants bind to suspended particles and create complex networks of cross-linked polymeric bridges between particles that help to trap more particles and create large aggregates [12]

FACTORS THAT AFFECT PERFORMANCE OF FLOCCULANTS

pH	• The pH of raw water is one of the most important factors that affects efficiency of flocculants. Pollutants and dissolved particles in water affect the final pH levels of waterbodies [13] • Organic flocculants are only effective around neutral pHs, limiting the situations where they can be used. These include flocculants whose active constituents are cellulose/chitosan based [14] • Some inorganic flocculants like metal salts and polymers are affected by extreme pH levels. pH has no effect on Clear Dam (aluminium sulphate) flocculants [15] whereas flocculants whose active constituents are based on ferric chloride, ferric sulphate and hydrated lime are less effective at certain pH ranges [16,17]
Temperature	• Generally, temperature affects most chemical reactions; at lower temperatures reactions take longer due to less movement of reactants and low water viscosity [18]. At higher temperatures, particles move faster in water, thus increasing their chance of colliding with each other and creating clumps. • Certain flocculants are thermo-responsive and are effective only at optimal temperatures [19].
Other factors	• Waters that are highly turbid with suspended particles are ideal conditions for flocculants; more particles means that a higher probability of particle collisions take place that lead to more clumping. Conversely, less turbid waters are harder to flocculate as less particles means that fewer clumps are likely to form [20]. • Water stillness affects particle sedimentation as flocs can easily break into smaller parts when acted on by shear forces [21]. Therefore, the stability of flocs is dependent on the strength and number of inter-surface interactions between particles [22]. Effective flocculants are able to create three-dimensional networks between particles that are able to withstand large forces [23,24].

COMMON FLOCCULANTS AND THEIR PERFORMANCE

Table 1. Comparison of flocculant form, overall performance (coagulation pH range, performance, after-effects) and cost [13–17,23–35].

Flocculant	Form	Coagulation pH range	Performance	Overall Cost	After-effects
Aquatic Clear Drop	Solid (granules)	Optimum pH between 5.5–7.5	Very effective, and ideal for still/non-turbulent water	Low	Not ideal for potable water
Aquatic Clear Dam	Liquid	Optimum pH between 6.0–9.0	Very effective, and ideal for choppy/turbulent water	Medium	Ideal for potable water
Aquatic Clear Drop Flocculant Block	Solid (block)	Not affected by pH	Very effective, and ideal for choppy/turbulent water	Medium–High	Biodegradable; ideal for potable water
Chitosan	Solid (granules)	Optimum pH between 4.0–9.0	Very effective, and ideal for choppy/turbulent water, difficult to choose dosage	Medium	Biodegradable; ideal for potable water
Ferric Chloride	Liquid	Optimum pH between 4.0–9.0	Ineffective at high and low concentrations; difficult to choose dosage	Medium	Treated water may be corrosive for pump equipment
Ferric Sulphate	Liquid	Optimum pH 6.5–8.0	Ideal for choppy/turbulent water, requires large dosage	High	Treated water may be corrosive for pump equipment
Hydrated Lime	Solid (powder)	Not affected by pH	Difficult to choose dosage (may have opposite effect at high concentrations); ideally used as aid for other flocculants	Low	Treated water may be corrosive for pump equipment

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