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To Formulate and Evaluate Water Cleansing Powder by Flocculation

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ABSTRACT
Water pollution, especially in industrial and urban areas, poses a significant threat to human health and the environment. Conventional methods of water treatment often require high energy input or the use of chemical coagulants. This paper explores the development and application of a novel water cleansing powder utilizing flocculation as the primary mechanism for removing suspended particles and impurities. The water cleansing powder contains natural or synthetic flocculants that, when added to contaminated water, promote the aggregation of particulate matter into larger clusters or flocs. These flocs are then easily separated from the water through sedimentation or filtration. This study investigates the effectiveness, environmental impact, and cost-efficiency of the powder in comparison to traditional treatment methods. Results demonstrate that the water cleansing powder is capable of significantly reducing turbidity, heavy metals, and organic contaminants, offering an eco-friendly alternative for water purification. Additionally, the powder's ease of use, low cost, and sustainability make it a promising solution for small-scale water treatment applications, particularly in rural or resource-limited areas.

Keywords :- Water Treatment, Flocculation, Coagulation, Water Purification, Pollutant Removal, Flocculants, Sedimentation, Environmental Impact, Turbidity Reduction, Chemical Agents, Particle Aggregation, Water Quality, Natural Polymers, Sustainable Water Treatment, Efficiency, Powdered Flocculant, Rapid Settling, Heavy Metal Removal, Waterborne Contaminants, Ecological Safety

I. INTRODUCTION:

The need for drinking water of high quality is increasing, as the non-polluted water sources are continuously decreasing. Additionally, the discharge criteria of wastewaters are becoming stricter, according to the new legislation in force, in order to prevent environmental pollution and/or infection of drinking water sources. It is evident that more effective water and wastewater treatments are needed. A very important step in water and in wastewater treatment is the coagulation flocculation process, which is widely used, due to its simplicity and cost-effectiveness. Regardless of the nature of the treated sample (e.g. various types of water or wastewater) and the overall applied treatment scheme, coagulation-flocculation is usually included, either as pre-, or as post-treatment step. The efficiency of coagulation-flocculation strongly affects the overall treatment performance; hence, the increase of the efficiency of coagulation stage seems to be a key factor for the improvement of the overall treatment efficiency. The whole treatment process of coagulation – flocculation can be divided into two distinct procedures, which should be applied consecutively. The first one termed coagulation, is the process whereby destabilization of a given colloidal suspension or solution is taking place. The function of coagulation is to overcome the factors that promote the stability of a given system. It is achieved with the use of appropriate chemicals, usually aluminium or iron salts, the so-called coagulant agents. The second sub-process, termed flocculation, refers to the induction of destabilized particles in order to come together, to make contact and thereby, to form large agglomerates, which can be separated easier usually through gravity settling [1]. Coagulation usually completes in a very short period of time (e.g. about 10 s), whereas flocculation occurs usually over a period of 20 to 45 min. It is a common practice, especially in Greece, theenhancement of particles aggregation

1. Coagulation Process

- **Definition:**

Coagulation is the process of adding a chemical (coagulant) to water to neutralize the charge of suspended particles, allowing them to come together and form tiny clumps (micro flocs).

- How It Works:
- Water contains tiny suspended particles (clay, dirt, organic matter, bacteria) that have negative charges, which keep them repelled from each other.
- When a coagulant (like ferrous sulfate ($FeSO_4$) or aluminum sulfate ($Al_2(SO_4)_3$)) is added, it neutralizes these charges and allows the particles to stick together.
- These small clusters (microflocs) begin forming in the water.

2. Flocculation Process

- **Definition:**

Flocculation is the process of gently stirring the water after coagulation to help small clumps(microflocs) combine into larger, heavier particles (macro flocs) that can settle or be filtered out.

- **How It Works:**
- After coagulation, water is slowly mixedto allow the microflocs to grow into visible flocs**.**
- These larger flocs are easier to settle at the bottom or filter out.
- Sometimes, flocculants (polymers or natural starches) are added to enhance the floc formation process.

- **Advantages:**

1. **Effective Suspended Solids Removal** – Ferrous sulfate acts as a coagulant, helping to remove suspended particles by floc formation.
2. **Disinfection** – Calcium hypochlorite is a strong disinfectant that kills bacteria, viruses, and other pathogens.
3. **Iron Coagulation Efficiency** – Ferrous sulfate is effective in reducing turbidity and organic matter, making water clearer.
4. **Cost-Effective** – Both chemicals are relatively inexpensive and widely available.
5. **Simple Application** – The process does not require complex equipment, making it suitable for rural and emergency water treatment.
6. **Reduction of Heavy Metals** – Can help remove arsenic and other heavy metals by adsorption onto iron hydroxides.

- **Disadvantages:**

1. **Sludge Production** – Flocculation with ferrous sulfate generates a significant amount of sludge, requiring proper disposal.
2. **pH Sensitivity** – The process efficiency depends on pH levels, often requiring pH adjustment using additional chemicals like lime.
3. **Residual Chlorine Risks** – Excess calcium hypochlorite can leave harmful chlorine residues, which may cause taste issues and health concerns.
4. **Iron Residue Staining** – Ferrous sulfate can leave iron residues, leading to staining of surfaces and an unpleasant metallic taste in water.
5. **Storage & Handling Issues** – Calcium hypochlorite is a strong oxidizer and can be hazardous if not stored properly.
6. **Potential Formation of Harmful Byproducts** – Chlorination can lead to the formation of trihalomethanes (THMs) and other carcinogenic compounds when reacting with organic matter.

- **Applications**

1. Personal Drinking Water Purification-

- Ideal for hikers and trekkers to purify water from natural sources (rivers, lakes, and streams).
- Helps remove suspended particles, making water clearer, and disinfects it for safe drinking.

2. Emergency Water Treatment in Remote Areas-

- Useful in survival situations where clean water is unavailable.
- Can be used to purify water when traveling through unknown or contaminated regions.

3. Base Camp Water Supply-

- Helps in treating large volumes of water for groups camping at a fixed location.
- Ensures a continuous supply of clean drinking and cooking water.

4. Disaster Relief & First Aid Situations-

- Useful in case of injury or illness where clean water is needed for first aid.
- Prevents waterborne diseases in emergency scenarios.

5. River and Lake Exploration-

- Beneficial for kayakers, canoeists, and fishermen who need to purify water while on expeditions.
- Reduces the risk of ingesting harmful bacteria and parasites.

6. Travel to High-Altitude Regions-

- At high altitudes, boiling water takes longer due to lower temperatures.
- Using flocculation and disinfection powder can be a quick and energy-efficient alternative.

7. Eco-Friendly Camping Practices-

- Reduces the need to carry large amounts of bottled water, minimizing plastic waste.
- Allows hikers to responsibly use and purify natural water sources.

➢ **Other Applications:**

1. Drinking Water Treatment

- Used in municipal water treatment plants to clarify and disinfect water before distribution.
- Helps remove turbidity, organic matter, and pathogens, ensuring safe drinking water.

2. Wastewater Treatment

- Applied in industrial and municipal wastewater treatment to remove suspended solids, heavy metals, and organic pollutants.
- Reduces microbial contamination before releasing treated water into natural bodies.

3. Emergency and Disaster Relief Water Purification

- Used in portable water purification kits for emergency response in disaster-hit areas.
- Can be applied in military and field operations for quick water treatment.

4. Industrial Water Treatment

- Used in industries such as textiles, food processing, and pharmaceuticals for water purification.
- Helps remove harmful contaminants before industrial discharge or reuse.

5. Swimming Pool and Recreational Water Treatment

- Calcium hypochlorite acts as a disinfectant in swimming pools to maintain hygiene.
- Prevents algae growth and kills bacteria.

6. Agriculture and Irrigation Water Treatment

- Improves water quality for irrigation by reducing turbidity and microbial load.
- Prevents clogging in drip irrigation systems.

7. Groundwater and Borewell Water Treatment

- Used to treat iron and microbial contamination in well water before domestic use.
- Prevents iron staining and improves water taste

II. MATERIAL AND METHOD:

2.1 MATERIAL-

2.1.1 Ferrous Sulfate ($FeSO_4$) –

Ferrous sulfate reacts with water to form iron hydroxide, which is a positively charged precipitate. This positively charged precipitate neutralizes the negative charges on the suspended particles, causing them to clump together (coagulate).

Ferrous Sulfate ($FeSO_4$)

❖ **Properties**:

- **Appearance:** Blue-green crystals or powder.
- **Density:** 2.84 g/cm³.
- **Molecular Weight/Molar Mass:** 151.908 g/mol.
- **Solubility:** Highly soluble in water.
- **Melting Point:** 56-64 °C.
- **Boiling Point:** >300 °C (decomposes).

2.1.2 Calcium Hypochlorite (Ca(OCl)2) –

While Calcium Hypochlorite is primarily used for disinfection and sterilization, it also aids in the flocculation process by oxidizing organic impurities, improving the formation of flocs. It assists in breaking down organic compounds and suspended solids during coagulation and flocculation**.**

Calcium Hypochlorite (Ca(OCl)2)

❖ **Properties**:

- A white solid with a strong chlorine smell
- Stable at room temperature, but decomposes slowly in moist environments
- Not very soluble in water
- Reacts with carbon dioxide to form calcium carbonate and chlorine
- Reacts with hydrochloric acid to form calcium chloride

2.1.3 pHAdjusters-

❖ **Materials**- (Sodium Carbonate)

pH adjusters are sometimes used to modify the pH of the water before or during the addition of coagulants. Ferrous Sulfate works best in slightly acidic conditions (pH between 5.5 and 7.0).

Maintaining the optimal pH for coagulation and flocculation is important for maximizing the effectiveness of Ferric Sulfate and Calcium Hypochlorite.

❖ **Properties:**

- **Chemical Formula:** Na_2CO_3
- **Appearance:** White, odorless powder
- **Solubility:** Water-soluble
- **Nature:** Strong base, forms alkaline solutions in water
- **Molar mass:** 105.99 g/mol
- **Density:** 2.54 g/cm³
- **Melting point:** 851 °C
- **Boiling point:** 1,600 °C

2.1.4Anti-Caking Agents -

❖ **Material**- (Silica)

Prevents powder from clumping together during storage.

❖ **Properties:**

- **Hardness:** Silica is relatively hard, scoring a 7 on the Mohs scale.
- **Color:** Pure silica is colorless, but impurities can cause variations in color, such as pink in rose quartz or white in milky quartz.
- **Melting and Boiling Points:** Silica has very high melting and boiling points: 3,110 °F (1713 °C) and 4,046 °F (2230 °C), respectively.
- **Density:** The density of silica is around 2.648 g/cm³.
- **Form:** Silica can exist in crystalline (like quartz) or amorphous forms.
- **Odor:** Silica is odorless.
- **Solubility:** Silica is insoluble in water and most acids, but soluble in hydrofluoric acid.

2.1.5 Clarifying Agents -

❖ **Material: (**Aluminum Sulfate)

Enhances the settling process, making the flocs denser for easy filtration.

❖ **Properties:**

- **Appearance:** White crystalline solid, hygroscopic (meaning it readily absorbs moisture from the air).
- **Density:** 2.672 g/cm³ (anhydrous form), 1.62 g/cm³ (octadecahydrate).
- **Melting Point:** 770 °C (decomposes, anhydrous), 86.5 °C (octadecahydrate).
- **Solubility:** Very soluble in water. Solubility increases with temperature.
- **Chemical Formula:** $Al_2(SO_4)_3$
- **Molar Mass:** 342.15 g/mol
- **Acidity:** Aluminium sulfate is acidic in nature.

➢ **Apparatus-**

- Sieves
- Measuring cylinder
- Beaker
- Tray dryer
- Weighing machine
- Test tube
- Stirrer
- Mortel pestle

2.2 METHODS:

Step 1: Weighing of Ingredients-

- Use a precision balance to measure each ingredient according to the formulation.
- Keep calcium hypochlorite separate initially to prevent unwanted reactions.

Step 2: Pre-Mixing of Dry Ingredients

- In a dry mixing container, combine:
  - **Ferrous sulfate** (flocculant)
  - **pH adjusters** (lime or sodium carbonate)
  - **Clarifying agent** (aluminum sulfate or polyacrylamide)
- Stir gently to create a uniform powder blend.

Step 3: Addition of Calcium Hypochlorite

- Slowly add the measured calcium hypochlorite to the dry mixture.
- Mix at low speed for 3-5 minutes to prevent heat buildup and degradation.

Step 4: Incorporation of Anti-Caking Agents

- Add silica (SiO_2) to prevent powder clumping.
- Sieve through a fine mesh (100-200 microns) to ensure consistency.

Step 5: Final Homogenization

- Blend all ingredients at medium speed for 10-15 minutes to achieve uniform distribution.
- Avoid excessive friction or moisture exposure.

Step 6: Packaging & Storage

- Weigh exact 10g portions and pack in airtight, moisture-resistant sachets.
- Vacuum-seal to prevent degradation of calcium hypochlorite due to moisture.
- Store in a cool, dry place away from sunlight.

III. PREFORMULATION STUDY :

- Bulk density
- Tapped density
- Porosity
- Carr's index
- Hausner's ratio
- Angle of repose
- % Ash Value
- Solubility

3.1 Bulk density

The bulk density of a powder is the ratio of the mass of an untapped powder sample and its volume including the contribution of the inter-particulate void volume.

$$\text{BULK DENSITY} = \frac{\text{MASS}}{\text{BULK VOLUME}}$$

3.2 Tapped density

The tapped density is an increased bulk density attained after mechanically tapping a container containing the powder sample.

$$\text{TAPPED DENSITY} = \frac{\text{MASS}}{\text{TAPPED VOLUME}}$$

3.3 Porosity

Porosity or void fraction is a measure of the void (i.e., "empty") spaces in a material, and is a fraction of the volume of voids over the total volume, between 0 and 1, or as a percentage between 0% and 100%.

$$\text{POROSITY} = \frac{\text{VOLUME OF VOIDS}}{\text{TOTAL VOLUME}} \times 100$$

3.4 Carr's index

Carr's Index of any solid is calculated for compressibility of a powder which is based on true density and bulk density.

$$\text{CARR}'\text{SINDEX} = \frac{\text{TAPPED DENSITY} - \text{BULK DENSITY}}{\text{TAPPED DENSITY}} \times 100$$

3.5 Hausner's ratio

Hausner ratio is defined as the ratio of a powder's tapped bulk density to its poured (loose) bulk density

$$\text{HAUSNER'S RATIO} = \frac{\text{Tapped density}}{\text{Bulk density}}$$

3.6 Angle of repose

Angle of repose powder poured from a vessel forms a cone-like pile. The angle of repose- the angle between the slope of the pile and the horizontal correlates with the strength of particle-particle interactions and, therefore, is measured to infer flow ability.

$$\emptyset = \tan^{-1}(h/r)$$

Where,

- h : the height in cm
- r : the radius in cm
- $\emptyset$: the angle of repose

3.7 % Ash value

The ash values usually represent the inorganic residues such as phosphates, carbonates and silicates present in herbal drugs

$$\%\ \text{ASH} = \frac{\text{W2} - \text{WO}}{\text{W1}} \times 100$$

- W2: weight of crucible + ash
- WO: weight of crucible
- W1: weight of sample

3.8 Solubility:-

Solubility is the ability of a solid, liquid, or gaseous chemical substance (referred to as the solute) to dissolve in solvent (usually a liquid) and form a solution. We are going to check solubility of our sample in water, acidic and alkaline solution.

IV. EVALUATION PARAMETERS:

4.1 Appearance
4.2 Color
4.3 Odour
4.4 pH test
4.5 Moisture content
4.6 Dissolution Test
4.7 Stability test
4.8 Turbidity Measurement

4.1 Appearance -

- Observe the physical form of the powder (e.g., fine powder, granules, crystalline).
- Check for uniformity, presence of lumps, or any foreign particles.

4.2 Color -

- Assess the color of the powder visually.
- Compare against a standard reference sample (if applicable).

4.3 Odour -

- Conduct a sensory evaluation to detect any unpleasant or characteristic odour.
- Ensure it does not have a strong or harmful smell that could indicate contamination.

4.4 pH Test -

- Prepare a solution of the powder in distilled water at a standard concentration.
- Measure pH using a calibrated pH meter or pH strips.
- Ensure the pH remains within the safe range for water treatment (typically 6.5–8.5).

4.5 Moisture Content -

- Determine moisture percentage using a moisture analyzer or oven drying method.
- Excessive moisture can affect stability and shelf life.

4.6 Dissolution Test -

- Assess the solubility or dispersion rate of the powder in water.
- Stir the powder in water and observe time taken for complete dissolution or dispersion.
- Check for undissolved residues.

4.7 Stability Test -

- Store the powder under different environmental conditions (temperature, humidity).
- Evaluate changes in appearance, moisture content, and effectiveness over time.
- Perform periodic pH and performance tests to ensure consistency.

4.8 Turbidity Measurement -

- Treat a sample of turbid water with the flocculant powder.
- Measure turbidity before and after treatment using a turbidity meter (NTU scale).
- Ensure significant reduction in turbidity, ideally below WHO drinking water standards (<5 NTU)

V. RESULT AND DISCUSSION:

5.1 Pre formulation tables-

A) Ferrous sulphate -

TESTS		Batch - 1	Batch - 2	**Batch -3**	Batch - 4	Batch - 5
1.	Bulk Density	0.65g/ml	0.64g/ml	**0.63g/ml**	0.65g/ml	0.64g/ml
2.	Tapped density	0.80g/ml	0.78g/ml	**0.79g/ml**	0.81g/ml	0.79g/ml
3.	Porosity (%)	18.75 **%**	18.72 **%**	**20.25 %**	19.75 **%**	18.99 **%**
4.	Carr'sindex (%)	18.75 **%**	18.72 **%**	**20.25 %**	19.75 **%**	18.99 **%**

5. Hausner's ratio	1.23	1.22	**1.25**	1.25	1.23
6. Angle of Repose (°)	32°	31°	**33°**	34°	32°
7. % ash value	2.5%	2.3%	**2.4%**	2.6%	2.5%
8. Solubility (g/100mL)	36	37	**35**	36	37

Table No. 1 - Pre formulation table of ferrous sulphate

B) Calcium hypochlorite

TESTS	Batch - 1	Batch - 2	Batch -3	Batch - 4	**Batch - 5**
1. Bulk Density	0.80g/ml	0.78g/ml	0.79g/ml	0.81g/ml	**0.80g/ml**
2. Tapped density	0.90g/ml	0.92g/ml	0.94g/ml	0.96g/ml	**0.93g/ml**
3. Porosity (%)	15.79%	15.22%	16.02%	15.62%	**14.52%**
4. Carr'sindex (%)	15.79%	15.22%	16.02%	15.62%	**14.52%**
5. Hausner's ratio	1.19	1.18	1.19	1.18	**1.17**
6. Angle of Repose (°)	34°	35°	33°	32°	**34°**
7. % ash value	3.5%	3.7%	3.6%	3.8%	**3.6%**
8. Solubility (g/100mL)	40	42	41	39	**40**

Table No. 2 - Pre formulation table of calcium hypochlorite

In this pre-formulation study of sample we observed that, the **Batch 3** of ferrous sulphate and **Batch 5** of calcium hypochlorite has good flow property and other parameters then can be utilized have final preparation of water cleansing powder

5.2 Formulation table:

Ingredients	**Batch 1**	Batch 2	Batch 3	Batch 4	Batch 5
Ferrous Sulfate ($FeSO_4$)	**2.5gm**	2.0gm	1.8gm	2.2gm	2.0gm
Calcium Hypochlorite (Ca(OCl)2)	**1.0gm**	1.2gm	1.0gm	0.8gm	1.2gm
Aluminum sulfate	**2.0gm**	1.5gm	2.2gm	1.8gm	2.5gm
Sodium carbonates	**1.5gm**	2.0gm	1.8gm	2.5gm	1.8gm
Silica	**3.0gm**	3.5gm	3.0gm	2.7gm	2.5gm

Table No. 3- Formulation Table

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Fig No. 3- Batches of powder

TESTS	B1	B2	B3	B4	B5
Appearance/ texture	**Fine**	Fine	Fine	Fine	Fine
Colour	**White**	Yellowish white	White	light brown	Light yellow
Odour	**Mild**	Mild	Slight chlorine	Mild	Slight chlorine
Ph	**7.2**	7.0	6.8	7.5	7.1
Moisture content	**5.2**	5.0	4.8	5.5	5.1
Dissolution Test	**Complete**	Partial	Complete	Partial	Complete
Stability Test	**Stable**	Stable	Stable	Unstable	Stable
Turbidity Measurement	**1.5**	2.2	1.8	3.0	1.7

Table No. 4 – Evaluation table

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5.3 **Evaluation table:-**

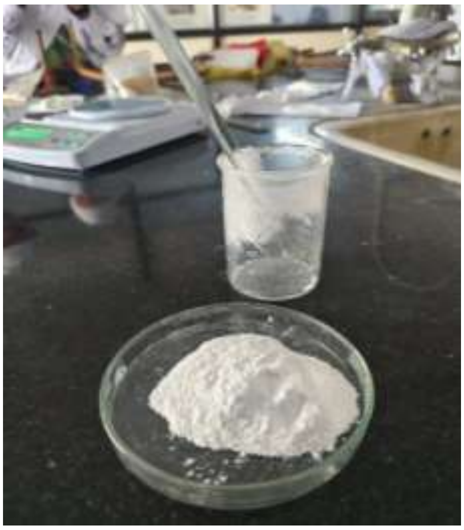
+ 

Fig No. 4 - Water cleansing powder

Fig No. 5 – pH Meter

Fig No. 6 – Before

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Fig No. 7 – After

VI. SUMMARY :

Water cleansing powder by flocculation is a widely used method for purifying water, particularly in municipal water treatment and industrial wastewater management. The process involves adding a flocculant powder, which is typically a chemical agent, to contaminated water. The flocculant helps to aggregate fine particles, such as suspended solids, organic matter, and microorganisms, by neutralizing their charges. This aggregation leads to the formation of larger clumps known as "flocs." These flocs become heavy and settle at the bottom of the water, making it easier to separate them from the clean water.The flocculation process is often preceded by coagulation, where a coagulant is added to destabilize the particles, allowing them to stick together more easily. After floc formation, the water is left to undergo sedimentation, where the flocs are allowed to settle, or the water is passed through filters to remove the solid particles.

VII. CONCLUSION:

The conclusion drawn from using water cleansing powder by the flocculation method highlights the effectiveness of this technique in improving water quality. Flocculation is a process where flocculants are added to water to promote the aggregation of suspended particles into larger clumps (or flocs), which can then be easily removed. The water cleansing powder, when mixed with contaminated water, encourages the formation of these flocs, thereby reducing turbidity, and removing various pollutants such as sediments, bacteria, and organic matter. This method significantly enhances the clarity and purity of the water.Flocculation is particularly useful for treating water with high levels of suspended solids and can be a cost-effective solution in areas with limited access to sophisticated water treatment technologies. The process not only helps in improving water aesthetics but also in ensuring its safety for consumption by reducing harmful microorganisms. The efficiency of the flocculation method depends on factors such as the type of flocculant used, water temperature, pH levels, and the concentration of contaminants.

In conclusion, the water cleansing powder via the flocculation method is a practical and efficient technique for purifying water, offering both environmental and health benefits. However, optimization of the process is necessary to ensure maximum effectiveness, and further studies can refine the use of these powders for different water qualities.

FUTURE PROSPECTIVES:

Water cleansing powder using flocculation has strong future prospects due to its cost-effectiveness and eco-friendliness. It offers an efficient, scalable solution for purifying water in both urban and rural areas, particularly in regions with limited access to advanced treatment facilities. This technology can revolutionize global water purification efforts.

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