Multi-Functional Powder for Advanced Water Treatment and Contaminant Removal

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***Abstract*—Access to safe drinking water remains a significant challenge in many rural and semi-rural communities in Ghana, where untreated sources, such as rivers and rainwater, are commonly used. This study presents the development of a low-cost, multi-parameter water treatment powder designed for household-level application. The formulation, consisting of calcium hypochlorite, aluminium sulfate, lime, and starch, integrates disinfection, coagulation, pH adjustment, and turbidity reduction in a single step. Laboratory trials demonstrated a reduction in turbidity from 9.9 to 4.98 NTU, adjustment of pH from 7.2 to 6.79, and complete elimination of both total and faecal coliforms. Additional improvements were observed in total dissolved solids and electrical conductivity. The economic assessment revealed a production cost of ₵22.48 per unit, with a marketable price of ₵25.00, making it affordable for low-income households. Compared to commercial alternatives such as Aquatabs, the powder achieved superior performance by addressing multiple water quality parameters simultaneously. This innovation demonstrates significant potential for decentralised water purification, particularly in resource-limited settings, and supports Sustainable Development Goal 6 by enhancing access to safe and affordable drinking water.**

***Keywords*— Household Water Treatment, Multi-Parameter Formulation, Safe Drinking Water, Rural Communities, Ghana.**

I. HIGHLIGHTS

- Developed a multi-parameter water treatment powder integrating coagulation, disinfection, pH adjustment, and turbidity reduction.
- Achieved complete removal of total and faecal coliforms and a significant reduction in turbidity (from 9.9 to 4.98 NTU).
- Improved water quality parameters, including pH stability, electrical conductivity, and total dissolved solids.
- Demonstrated cost-effectiveness, with production cost per unit at ₵22.48 and affordable retail price of ₵25.00.
- Outperformed commercial products (e.g., Aquatabs) by addressing multiple contaminants simultaneously.
- Provides a scalable, household-level solution supporting Sustainable Development Goal 6 for safe and affordable drinking water

I. INTRODUCTION

Safe drinking water is essential for public health and socio-economic development. In Ghana, particularly in rural and semi-rural communities, access to potable water remains limited due to inadequate pipe-borne supply and reliance on untreated sources such as rivers, rainwater, and shallow wells. These untreated sources are often contaminated by industrial effluents, agricultural runoff, and domestic waste, resulting in a high incidence of serious waterborne diseases, including cholera, typhoid, and diarrheal infections.

Household-level water treatment methods have been explored globally. Conventional approaches such as boiling, sand filtration, and chlorination are widely applied and effective for microbial control but often fail to address turbidity or stabilise pH [1], [2]. High-end technologies such as reverse osmosis and distillation, while effective, are expensive and impractical in resource-limited settings [3]. Commercial chlorine tablets such as Aquatabs are common in Ghana, yet they primarily provide disinfection without removing turbidity or adjusting pH [4]. Research by Hatta and Daud [5] further highlights this limitation, reporting minimal turbidity reduction despite effective microbial removal.

Thus, there is a clear need for a more holistic purification solution—defined here as a process addressing multiple water quality parameters simultaneously, including turbidity reduction, pH stabilisation, and microbial control. The present study introduces a multi-parameter purification powder formulated from aluminium sulfate ($Al_2(SO_4)_3$), calcium hypochlorite ($Ca(OCl)_2$), lime (CaO), and starch. This innovation integrates coagulation, disinfection, pH adjustment, and stabilisation in a single, low-cost product designed for household use. The study evaluates its performance against Aquatabs and benchmarks it against the WHO/Ghana standards.

II. MATERIALS AND METHODS

A. *Materials*

The formulation included Aluminium Sulphate ($Al_2(SO_4)_3$), Calcium Hypochlorite ($Ca(OCl)_2$), Lime (CaO), and starch. Their respective functions were coagulation, disinfection, pH adjustment, and stabilisation. All chemicals were of analytical grade and weighed using an analytical balance.

B. *Formulation and production*

Each 5 g sachet contained 3.50 g $Al_2(SO_4)_3$, 0.285 g $Ca(OCl)_2$, 0.35 g CaO, and 0.865 g starch. Ingredients were weighed precisely, ground into fine powder, and mixed thoroughly. Starch was added last to ensure consistency.

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The final blend was passed through a 40-mesh sieve for homogeneity before packaging in airtight sachets

C. Testing protocols

The powder was tested using river and rainwater samples. Parameters measured included turbidity, pH, residual chlorine, total dissolved solids (TDS), electrical conductivity, and microbial contamination (total and faecal coliforms). Tests followed the WHO and Ghana Standards Authority protocols. Aquatabs served as the benchmark. Figure 1 presents the sequence of unit operations for the powder preparation process.

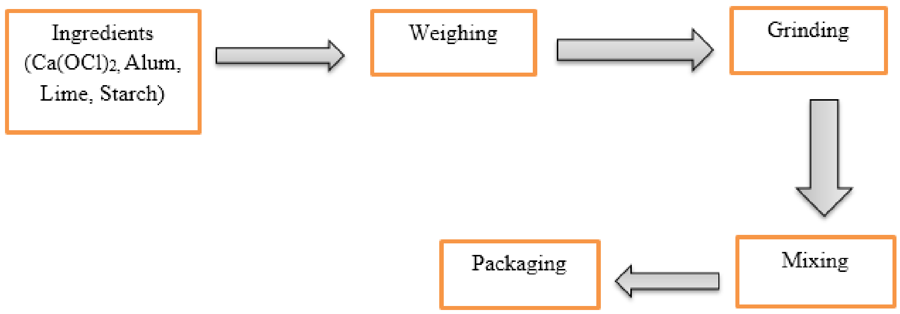

Fig. 1 Unit operations in the preparation process

III. RESULTS AND DISCUSSION

The results presented in Tables I clearly show that the developed water purification powder provides a more complete treatment compared to Aquatabs. For river water, turbidity was reduced from 9.9 NTU to 4.98 NTU, meeting the WHO guideline of less than 5 NTU, while Aquatabs only lowered it to 7.2 NTU. The powder also stabilised pH within the acceptable range (6.79), while maintaining safe residual chlorine levels (0.5 mg/L). Both treatments eliminated microbial contaminants, but the powder's ability to simultaneously reduce turbidity and adjust pH gave it a significant advantage as a holistic solution for household water treatment.

TABLE I. RIVER WATER PARAMETERS BEFORE AND AFTER TREATMENT

Parameter	Raw river water	After powder treatment	After aquatabs	WHO standard
Turbidity (NTU)	9.9	4.98	7.2	< 5
pH	7.2	6.79	7.1	6.5–8.5
Residual Chlorine (mg/L)	0	0.5	0.4	0.3–0.5
Total Coliforms (CFU/100 mL)	Present	Absent	Absent	Absent
Faecal Coliforms (CFU/100 mL)	Present	Absent	Absent	Absent

When applied to rainwater, the powder again proved more effective. The raw water's acidic pH of 5.5 was corrected to 6.54, bringing it within WHO standards, while Aquatabs only raised the pH slightly to 5.6, which remained outside the recommended range. In Table II, the rainwater parameters before and after treatment is presented

TABLE II. RAINWATER PARAMETERS BEFORE AND AFTER TREATMENT

Parameter	Raw Rainwater	After Powder Treatment	After Aquatabs	WHO Standard
Turbidity (NTU)	10.0	5.0	8.1	< 5
pH	5.5	6.54	5.6	6.5–8.5
Residual Chlorine (mg/L)	0	0.4	0.4	0.3–0.5
Total Coliforms (CFU/100 mL)	Present	Absent	Absent	Absent
Faecal Coliforms (CFU/100 mL)	Present	Absent	Absent	Absent

Turbidity was also reduced from 10.0 NTU to 5.0 NTU by the powder, meeting the guideline, whereas Aquatabs only lowered it to 8.1 NTU. In both cases, microbial safety was achieved, but the powder provided the additional benefit of improving clarity and taste while reducing the corrosive nature of stored rainwater. Table III further emphasises the practicality of the powder by showing its affordability.

TABLE III. ECONOMIC ANALYSIS OF POWDER PRODUCTION

Component	Cost (₵)	Percentage of Total
Aluminium Sulphate	10.50	46.7%
Calcium Hypochlorite	6.00	26.7%
Lime	3.50	15.6%
Starch	2.48	11.0%
Total Production Cost	22.48	100%
Selling Price	25.00	—

With aluminium sulfate as the largest cost component (46.7%), followed by calcium hypochlorite (26.7%), lime (15.6%), and starch (11.0%), the total production cost of ₵22.48 supports a retail price of ₵25.00. This makes the product accessible to low-income households without compromising quality. Unlike Aquatabs, which offer limited benefits at similar prices, the developed powder integrates coagulation, pH adjustment, and disinfection in one formulation. Altogether, the results confirm that the product is both technically reliable and economically sustainable, making it a strong candidate for safe drinking water provision in communities with limited resources.

IV. CONCLUSION

This study successfully developed a multi-parameter water purification powder capable of reducing turbidity, adjusting pH, and eliminating microbial contamination in a single step. Laboratory results demonstrated compliance with WHO standards and superior performance to Aquatabs. The product is cost-effective, easy to use, and scalable, offering a viable solution for rural and semi-rural communities. Future work should focus on field testing, user acceptance studies, and long-term storage stability assessments

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