



Review Article

REVIVING ANCIENT WATER PURIFICATION TECHNIQUES: A SIDDHA PERSPECTIVE

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ABSTRACT

Water contamination due to heavy metals, fluoride, and microbial pathogens remains a major public health concern, particularly in resource-limited regions lacking access to advanced purification technologies. Conventional methods such as reverse osmosis and chemical disinfection are effective but often expensive and may remove essential minerals, affecting long-term health. This study evaluates traditional Siddha-based water purification techniques, focusing on their combined role in contaminant removal and mineral restoration. A narrative review was conducted using classical Siddha literature and contemporary scientific sources. Selected plant-based materials, including *Cuminum cyminum*, *Caesalpinia sappan*, *Diospyros ebenum*, and *Chrysopogon zizanioides*, were analyzed for remineralization potential, while natural coagulants such as *Moringa oleifera*, *Strychnos potatorum*, and *Phyllanthus emblica* were assessed for their effectiveness in reducing turbidity, heavy metals, and microbial contamination. The findings demonstrate that these methods significantly improve water quality by increasing essential minerals such as calcium and magnesium, reducing turbidity by up to 60–90%, and decreasing microbial load, with *Strychnos potatorum* showing up to 77% antibacterial activity. The purification process operates through multiple mechanisms, including coagulation, adsorption, chelation, ion exchange, filtration, and antimicrobial action. In conclusion, Siddha-based water purification techniques provide a cost-effective, sustainable, and holistic alternative to modern methods by integrating detoxification with remineralization. These approaches are particularly suitable for rural and low-resource settings and have strong potential for large-scale application following further experimental validation.

INTRODUCTION

The Siddha system of medicine, one of the oldest traditional medical systems of South India, emphasizes natural and sustainable approaches to health, including water purification techniques using plant materials and mineral-based filtration systems^[1]. These methods not only remove contaminants but also restore essential minerals, aligning with the holistic principle of maintaining equilibrium among *Vali*, *Azhal*, and *Iyyam*.

Safe drinking water is fundamental to human health; however, contamination from industrial

pollutants, heavy metals, and microbial pathogens continues to pose serious global health risks^[2,3].

Waterborne diseases and toxic exposures remain major contributors to morbidity, particularly in low-resource settings where access to advanced purification systems is limited^[4]. Conventional technologies such as reverse osmosis, distillation, and chemical disinfection, though effective, are often expensive and may remove essential minerals, affecting long-term health.

This study aims to analyze Siddha-based water purification techniques, highlighting their mechanisms, effectiveness, and potential integration into modern water management systems^[5].

MATERIALS AND METHODS

This study is a narrative review and conceptual analysis based on classical Siddha literature and contemporary scientific evidence^[1,2]. Data were collected from peer-reviewed journals, WHO reports,

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and ethno pharmacological studies focusing on plant-based purification methods. [2,10]

Selected materials include

- *Cuminum cyminum*
- *Moringa oleifera*
- *Strychnos potatorum*

- *Phyllanthus emblica*

- Natural filtration media (charcoal, clay, sand)

These were analyzed for mechanisms such as coagulation, adsorption, chelation, ion exchange, and antimicrobial activity [8-10].



Figure 1: Illustrates the multi-barrier Siddha purification mechanism, combining coagulation, filtration, adsorption, chelation, and remineralization for comprehensive water treatment

Freshwater Contamination Risks

Natural water sources contain impurities including microorganisms, heavy metals, and organic pollutants due to industrial discharge, agricultural runoff, and environmental degradation[2]. Consumption of untreated water leads to diseases such as diarrhoea, typhoid, and cholera, as well as chronic toxicity due to heavy metals [3].

Demineralization and Health Implications

Demineralization is a purification process that removes dissolved inorganic salts and essential minerals through techniques such as ion exchange, reverse osmosis, distillation, and membrane filtration[2]. While these methods effectively eliminate contaminants, they also strip water of physiologically important minerals such as calcium, magnesium, and trace elements that contribute to human health.

Calcium and magnesium are essential for cardiovascular stability, neuromuscular transmission, enzymatic reactions, and bone metabolism. Their absence in drinking water has been linked to increased cardiovascular morbidity, including hypertension and arrhythmias [2,3]. Furthermore, low-mineral water has been shown to increase diuresis, leading to electrolyte imbalance and reduced serum mineral levels.

Boiling, a commonly practiced household method, effectively eliminates pathogens but results in precipitation of calcium carbonate and magnesium

salts, thereby decreasing their bioavailability[2]. In addition, thermal treatment leads to loss of dissolved gases such as oxygen and carbon dioxide, altering pH balance and taste.

Importantly, demineralized water exhibits higher corrosivity, which can enhance leaching of toxic metals such as lead, cadmium, and copper from plumbing systems, increasing health risks [9,11]. Epidemiological studies have suggested that long-term consumption of mineral-deficient water may contribute to osteoporosis, impaired growth in children, and increased susceptibility to toxic metal absorption [2,3,11].

These findings emphasize that optimal water treatment should not only remove contaminants but also ensure adequate remineralisation to maintain physiological balance.

Natural Water Purification Techniques: Mechanisms and Applications

Siddha-based water purification systems employ a synergistic combination of physical, chemical, and biological processes. These include coagulation, adsorption, filtration, chelation, ion exchange, and antimicrobial activity, collectively forming a multi-barrier purification system [5,10,11].

Coagulation destabilizes colloidal particles, while adsorption removes dissolved contaminants through surface interactions. Chelation and ion

exchange reduce the bioavailability of toxic metals, and antimicrobial activity ensures microbiological safety. This integrated approach enhances both purification efficiency and water quality.



“Figure 2 illustrates the natural purification techniques”

Unlike conventional technologies such as reverse osmosis and chlorination, which primarily focus on contaminant removal, traditional Siddha methods aim to preserve the natural integrity of water. They maintain essential mineral composition, improve taste, and avoid the formation of harmful disinfection by-products such as trihalomethanes [9].

Additionally, these natural methods are sustainable, biodegradable, and cost-effective, making them highly suitable for rural and decentralized water treatment systems. Their low energy requirement and minimal infrastructure dependency further enhance their applicability in resource-limited settings [10].

Siddha-Based Remineralization of Water

Remineralisation is a crucial step in restoring the nutritional and physiological quality of purified water. Siddha medicine recommends herbal infusion techniques that enrich water with essential minerals and bioactive compounds [1].

- *Cuminum cyminum* (Jeera) is rich in calcium, magnesium, potassium, and iron, contributing to electrolyte balance and metabolic function. Its phytoconstituents also enhance digestion and bioavailability of nutrients.
- *Caesalpinia sappan* (Sappanwood) contains phenolic compounds and flavonoids that act as natural antioxidants and chelating agents, stabilizing mineral ions in water.
- *Diospyros ebenum* (Karungali) contributes trace minerals and exhibits mild antimicrobial properties, supporting water safety.
- *Chrysopogon zizanioides* (vetiver) roots possess high adsorption capacity and release trace elements

such as silica and calcium, improving both purification and remineralization [5].



Figure 3: Illustrates the herbal remineralization of water

In addition to mineral enrichment, these herbal infusions improve sensory characteristics such as taste and odor, thereby increasing acceptability and consumption. The presence of bioactive compounds may also confer additional health benefits, including antioxidant and antimicrobial effects.

Natural Methods for Heavy Metal Removal

Heavy metals such as lead, arsenic, cadmium, mercury, and chromium are persistent environmental pollutants with severe toxicological effects, including neurotoxicity, nephrotoxicity, and carcinogenicity [2,5,9]. Natural purification methods provide efficient and sustainable approaches for their removal.

• Plant-Based Coagulation and Flocculation

Natural coagulants such as *Moringa oleifera* contain cationic proteins that neutralize negatively charged particles, promoting aggregation and sedimentation. This process significantly reduces turbidity and removes heavy metals and microbial contaminants [5,10].

Strychnos potatorum seeds act similarly through adsorption and bridging mechanisms, enhancing floc formation.

• Adsorption Using Natural Biomaterials

Adsorption is widely recognized as an effective method for removing dissolved contaminants. Banana peel, rich in lignin and cellulose, contains functional groups capable of binding heavy metals through ion exchange and complexation. Activated charcoal provides a high surface area for adsorption of organic pollutants, pesticides, and chlorine [11].

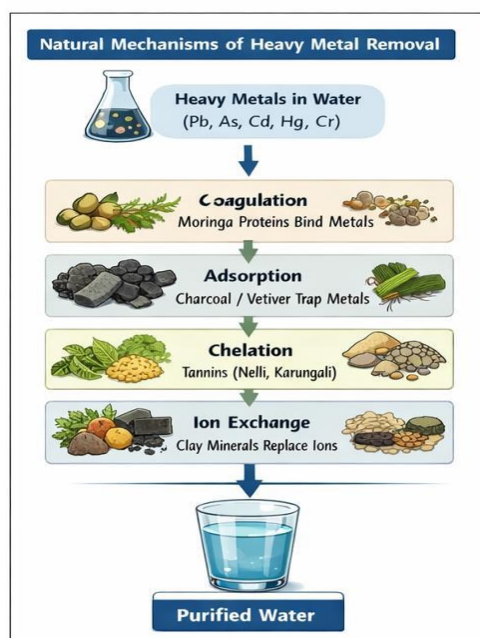


Figure 4: Illustrates the natural mechanism of heavy metal removal

• Filtration Techniques

Bio-sand filtration combines physical filtration with biological activity. The formation of a biofilm layer (schmutzdecke) enhances microbial degradation and pathogen removal. Clay filtration using bentonite and kaolin further contributes through adsorption and ion exchange.

• Chelation and Chemical Binding

Chelating agents derived from plants such as *Phyllanthus emblica* and *Acacia catechu* contain tannins and polyphenols that bind heavy metals into

stable complexes, reducing their bioavailability and toxicity.

• Ion Exchange Mechanisms

Natural minerals such as zeolites and clay exhibit ion exchange properties, replacing toxic metal ions with safer ions like calcium and sodium. This process is highly effective in reducing concentrations of lead and cadmium.

• Phytoremediation

Chrysopogon zizanioides (vetiver) is widely used in phytoremediation due to its extensive root system and high tolerance to toxic metals. It absorbs and accumulates heavy metals, thereby purifying water and improving its sensory quality [5].

• Integrated Multi-Barrier Approach

The integration of multiple purification mechanisms ensures comprehensive water treatment:

1. **Coagulation**– Removal of suspended particles and turbidity.
2. **Filtration**– Elimination of solids and microorganisms.
3. **Adsorption**– Removal of dissolved organic and inorganic contaminants.
4. **Chelation & Ion Exchange**– Detoxification of heavy metals.
5. **Remineralisation**– Restoration of essential minerals.

This multi-barrier approach significantly enhances purification efficiency, reduces health risks, and improves overall water quality [5,10,11].

Table 1: Illustrates the multiple purification mechanisms

Method	Material	Mechanism	Target contaminants
Coagulation	Moringa, Strychnos	Flocculation	Turbidity, heavy metals
Adsorption	Banana peel, charcoal	Surface binding	Heavy metals, organics
Filtration	Bio-sand, clay	Physical + biological	Microbes, particles
Chelation	Nelli, Acacia	Metal binding	Toxic metals
Ion exchange	Clay minerals	Ion replacement	Heavy metals
Remineralization	Herbal infusion	Mineral enrichment	Mineral deficiency

Reduction of Bacterial Contamination

Strychnos potatorum seeds exhibit strong antimicrobial activity due to the presence of natural polyelectrolytes that disrupt microbial cell membranes and promote aggregation [12-13]. Experimental studies have demonstrated up to 77% reduction in bacterial load, highlighting its effectiveness as a natural disinfectant [12].

Additionally, bio-sand filtration enhances microbial removal through mechanical trapping, adsorption, and biological degradation within the biofilm layer. This combination of natural coagulants and biological filtration provides an efficient and sustainable method for improving microbiological water quality.

Health Benefits: Natural vs Modern Water Purification

Natural purification systems not only remove contaminants but also preserve essential minerals and avoid chemical by-products. In contrast, modern systems such as reverse osmosis and chlorination may lead to mineral depletion and formation of potentially harmful compounds [9,11].

Furthermore, natural methods support ecological sustainability by reducing chemical usage and energy consumption, while promoting long-term health benefits through maintenance of mineral balance and improved gut microbiota.

Table 2: Health benefits of Natural vs Modern water purification

Aspect	Natural purification techniques	Modern purification techniques
Mineral content	Retains essential minerals (Ca, Mg) beneficial for health.	Removes minerals (especially in RO), may cause deficiency on long-term use.
Antimicrobial Action	Natural antimicrobial effect (e.g., copper, herbs) without residues.	Effective but relies on chemicals (chlorine, ozone).
Chemical Safety	No harmful chemical by-products	Risk of by-products (e.g., trihalomethanes).
Gut Health	Supports gut microbiota; less irritation.	May alter gut flora due to chemical residues.
Taste & Palatability	Improves natural taste and odor	Sometimes flat or altered taste (demineralized water).
Holistic Effect	Maintains natural properties; aligns with traditional systems (Vali-Azhal-Iyyam).	Focus mainly on pathogen removal.
Toxic Exposure	No risk of synthetic contaminants or microplastics.	Possible exposure to filter residues, microplastics.
Long-term Health Impact	Safer and sustainable for prolonged use.	Long-term effects of chemical exposure remain a concern.

RESULTS

- Mineral content (Ca, Mg) increased significantly following herbal infusion ^[5]
- Turbidity reduced by 60–90% using natural coagulants
- Heavy metals such as lead and cadmium reduced effectively
- Microbial load decreased significantly, especially with *Strychnos potatorum* ^[12]
- Combined methods showed enhanced purification efficiency

Table 3: Effectiveness of Siddha-Based Water Purification Methods

Method	Material used	Mechanisms	Target contaminants	Observed effectiveness
Coagulation	<i>Moringa oleifera</i> , <i>Strychnos potatorum</i>	Charge neutralization & flocculation	Turbidity, suspended particles, heavy metals	60–90% turbidity reduction; significant metal removal
Adsorption	Banana peel, Activated charcoal	Surface binding, ion exchange	Heavy metals, organic pollutants	Table: Effectiveness of Siddha-Based Water Purification Methods
Filtration	Bio-sand, Clay filters	Physical + biological filtration	Microbes, suspended solids	Effective microbial reduction and clarity improvement
Chelation	<i>Phyllanthus emblica</i> , <i>Acacia catechu</i>	Metal binding via tannins	Toxic metals	Reduced bioavailability of heavy metals
Ion Exchange	Clay minerals	Ion replacement	Heavy metals (Pb, Cd)	Replacement with safer ions (Ca, Na)
Remineralization	<i>Cuminum cyminum</i> , Vetiver	Mineral enrichment	Mineral deficiency	Increased Ca, Mg levels
Antimicrobial	<i>Strychnos potatorum</i>	Cell disruption & aggregation	Bacteria, pathogens	Up to 77% bacterial reduction

DISCUSSION

The study demonstrates that Siddha-based purification methods provide dual benefits- detoxification and remineralization- unlike modern systems that focus only on contaminant removal [5]. These techniques are sustainable, low-cost, and suitable for rural populations.

Integration with modern systems can improve efficiency while maintaining ecological balance. However, standardization and experimental validation are necessary for large-scale adoption [2,5].

CONCLUSION

Siddha-based water purification techniques represent an effective, eco-friendly, and holistic approach to water treatment. Their ability to remove contaminants while restoring essential minerals makes them highly valuable in addressing global water challenges. These methods are particularly beneficial for rural and resource-limited settings and should be further explored for large-scale implementation [1,5].

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