Review Article

A Review on Water Pollution: Causes, Effects and Treatment methods

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ABSTRACT

Water is a natural resource which is considered as a superb solvent and a critical component that make the processes of life possible. It is used in many ways from drinking to industrial and agricultural purposes. This review focuses on the main source of water pollution, health effects of water pollution and methods used to treat polluted water. Suitability of water for various uses depends on biological and physico-chemical properties of water (pH, alkalinity, TDS, DO, BOD, salinity, turbidity, heavy metals, anion measurements etc.), which are used to quantify the quality of water. Water is said to be polluted when it contains micro-organisms of human or animal origin, poisonous chemical substances, industrial or domestic sewage, agricultural chemicals, organic and inorganic substances etc. The treatment of waste water is not only important for our own health but also to keep our environment clean and healthy. Inorganic salts and polymeric organic coagulants are used for primary coagulation, as coagulant. Use of natural coagulants instead of synthetic coagulants is more advantageous in most rural communities of the world. Natural coagulants are derived from seeds, leaves, bark, sap, jel, roots, and fruits of various plants such as *Moringa oleifera*.

Keywords: Alum, Coagulation, Natural coagulant, *Moringa oleifera*, Waste water.

INTRODUCTION

Life on earth was established and has been sustained due to one very essential resource, water. Water plays a considerable role in every aspect of our lives- from being the integral part of our bodies to having colossal importance in many operations [1]. Water is the most important natural and vital source for the survival of life on the earth [2]. Almost 71% of the earth's total surface is covered with water [3]. It is a well-known fact that fresh water is an important necessity for our health [4].

Fresh water is a resource that has many uses, including drinking, irrigation recreation, transportation, hydroelectric power and domestic, industrial, commercial uses, and habitat for economically important animals [5]. Water is said to be pure when it is colorless, free from turbidity and abnormal taste and smell. Water is said to be polluted when it contains micro-organisms of human or animal origin, poisonous chemical substances, industrial or domestic sewage, organic and inorganic substances. Water pollution is the contamination of natural water bodies (like lakes, rivers, oceans, and groundwater) by chemical, physical, radioactive or pathogenic microbial substances that change in the quality of water that has a harmful effect on any living thing that drinks or uses or lives (in) it[6].

The most common source of drinking water for the rural people is groundwater [7]. Groundwater gets polluted as a result of human activities including extensive use of pesticides, herbicides, fertilizers, leaking fuel, chemical tanks, industrial chemical spills, drainage of house hold chemicals and badly managed landfills etc [8]. About 1.2 billion people in the world do not have safe, potable and affordable water for their domestic use [9]. Diseases: cholera, diarrhea, dysentery, hepatitis A, etc. are directly linked to the unhygienic and contaminated potable water. It is estimated that each year more than 842,000 people die from diarrhea globally [10].

Due to industrialization and urbanization, it is becoming more polluted and risk of this polluted water consumption and its sanitation problem is increasing day to day in most of the developing countries [11]. This growing problem of water scarcity has significant negative influence on economic development, human livelihoods, and environmental quality throughout the world. Hence it has become an essential need for today's environment to protect water from getting polluted or to develop cost effective remedial method for its protection [12]. Contaminated water causes problems to health and leads to waterborne diseases.

High turbidity, which decreases the quality of drinking water, is one of the major problems of sources of drinking water in Africa [13]. Conventional methods used for water purification include coagulation, sedimentation, filtration, aeration and also disinfectant processes [14]. The various conventional methods for waste water treatment are present since ancient times but they are very costly and not economical. Common coagulants are aluminum sulphate, ferric chloride, polyaluminum chlorides and synthetic polymers [15]. Aluminium salts are most commonly used in water purification all over the world [16]. Due to the environmental concerns many authors put their doubt towards the application of aluminium salts. Serious draw backs linked to the use of aluminium salts such as Alzheimer's disease associated with high aluminum residuals in treated water, excessive sludge production during water treatment and considerable changes in water

chemistry due to reactions with OH and alkalinity of water[17]. In addition, the use of alum salts is inappropriate in developing countries because of the high costs of imported chemical coagulants [18].

Advanced new green technical methods are being introduced to overcome the conventional methods of wastewater treatment. Natural coagulants have been attracting wide interest of researchers because they have the advantages of biodegradability, safe for human health, environmental friendly, generally toxic free and produce no secondary pollution [19]. Not only this, the sludge volume generated by the natural coagulants is smaller than chemical coagulants; it can further be treated biologically or can be disposed safely as soil conditioners because of their non-toxicity. These coagulants are extracted from natural and renewable sources, such as microorganisms, animals or plants [20]. The raw plant extracts are often available locally and hence, a low-cost alternative to chemical coagulants. In recent years, numerous studies on natural coagulants are growing and there is an urgent need to establish the use of natural low-cost coagulants for wastewater treatment.

The possibility of using plant-based coagulants in treating wastewater would prove useful for the country in terms of such environmental, health, and sustainable development objectives, as these coagulants are generally considered to be safe to human health, inexpensive, locally available, affordable, biodegradable and result in low level sludge production [21]. Therefore, it is necessary to search for other cost effective and more environmentally acceptable alternative coagulants from natural resources to present a viable alternative for water treatment processes.

Of the large number of plant materials that have been used over the years, the seeds from *Moringa oleifera* have been shown to be one of the most effective primary coagulants for water treatment, especially in rural communities [22].

This review paper discusses on physico-chemical parameters of water, causes of water pollution, effects of water pollution, and methods used to treat contaminated water.

Physico-Chemical Parameters of Water

People on globe are under tremendous threat due to undesired changes in the characteristics of water [23]. Humans need water in many daily activities like drinking, washing, bathing, cooking etc. The quality of water usually described according to its physical, chemical and biological characteristics [24]. It is necessary that the quality of drinking water should be checked at regular time interval before it is used for drinking, domestic, agricultural or industrial purpose, because due to use of contaminated drinking water, human population suffers from varied of water borne diseases [25]. The availability of good quality water is an indispensable feature for preventing diseases and improving quality of life.

The physico-chemical parameters used to quantify the quality of drinking water listed in Figure 1, which are used for testing of water quality.

The physicochemical properties help in the identification of sources of pollution, for conducting further investigation on the eco-biological impacts and also for initiating necessary steps for remedial actions in case of polluted water bodies [33]. Guidelines of different physic-chemical parameters also have been given for comparing the value of water sample [34].

Causes of Water Pollution

Water pollution is a major global problem which requires ongoing evaluation and revision of water resource policy at all levels (international down to individual) [35]. Wastewater may be defined as the outcoming used water flow from different resources like municipal, industrial plants and agriculture [36]. A body of water, such as a lake, stream, river, pond, ocean and even the water underground in the soil, can become polluted when it's contaminated by sewage leaks, agricultural runoff or chemical spills [37]. When water is polluted, it becomes unsafe for human consumption because the water contains dangerous or toxic substances and disease-causing bacteria and organisms [38]. Growing populations and expanding industries are pulling on water resources while adding nutrients and pollutants to water sources [39].

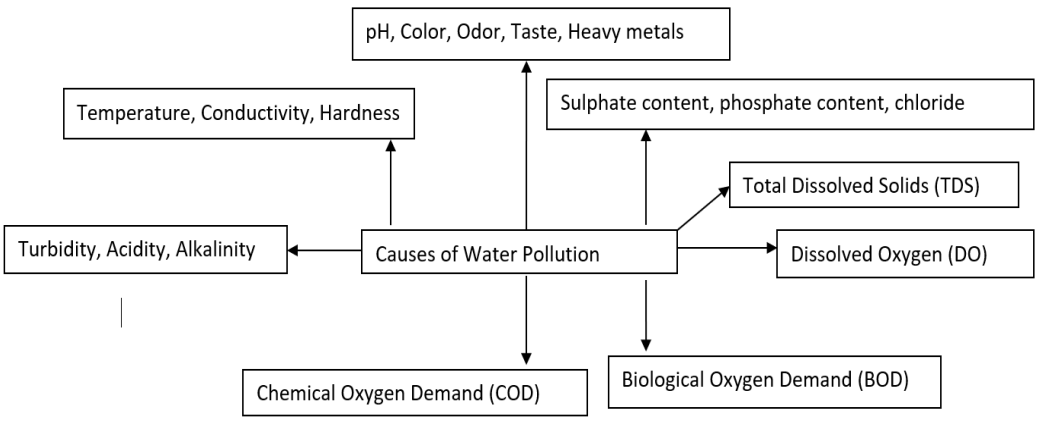

Figure 1: Physico-chemical parameters used for testing water quality [26-32].

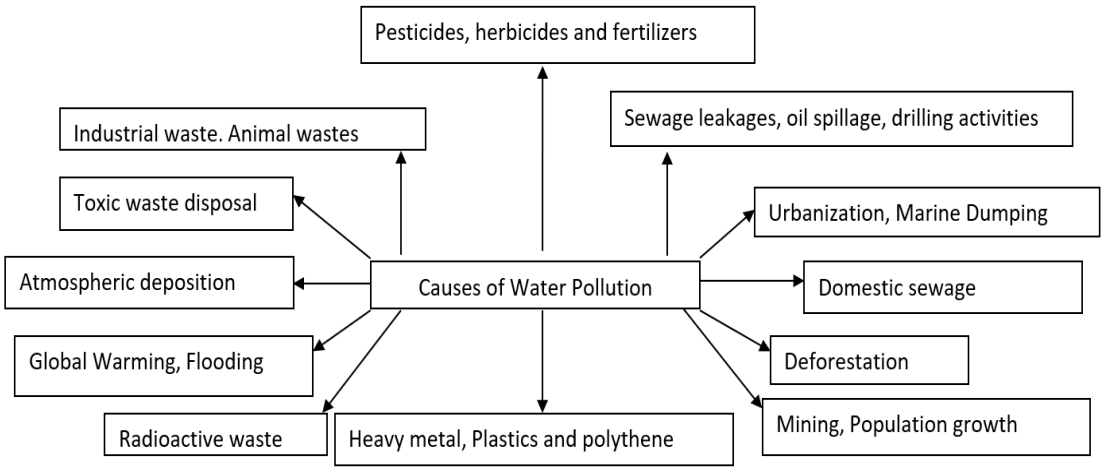

Figure 2: Causes of water pollution [40].

Water pollutants

Most pollutants result from non-point source pollution activities including runoff from agricultural lands, urban areas, construction and industrial sites, and failed septic tanks [41]. About 1500 substances have been listed as pollutants in freshwater ecosystems and a generalized list of pollutants includes acids and alkalis, anions (sulphide, sulphite, cyanide), detergents, domestic sewage and farm manure, food processing water, gases chlorine, ammonia), heat, metals (cadmium, zinc, lead), nutrients (phosphates, nitrates), oil and oil dispersants, organic toxic wastes (formaldehydes, phenols), pesticides, polychlorinated biphenyls and radionuclides, in addition to oxidizable materials, domestic sewage contains detergents, nutrients, pathogens and a variety of other compounds [42].

Other water pollutants are natural sources (weathering of soil and rock, erosion, forest fires and volcanic eruptions), domestic wastes (sewage and laundry wastes), agricultural chemicals and industrial wastes [43, 44, 45].

Industries are the major sources of pollutants in all environments and various levels of the pollutants are discharged into the environment either directly or indirectly [46]. Industrial activities, especially electroplating, mining metal, refining metal, smelting and chemical industries and manufacturing processes are sources of anthropogenic heavy metals in water [47]. Chemical industrial wastewaters usually contain organic and inorganic matter in varying concentrations [48]. Many materials in the chemical industry are toxic, mutagenic, carcinogenic or simply almost non-biodegradable.

In agriculture, while the application of organic manure and/or inorganic fertilizers boosts the production of crops, making food affordable to even the low socio-economic classes, nutrient application that exceeds plant needs is potential to pollute surface and groundwater [49]. The increased use of metal-based fertilizer in agricultural revolution could result in continued rise in concentration of metal pollutions in fresh water reservoir due to the water run-off [50]. Other sources of water pollution include water runoff from fields carrying agricultural chemicals such as herbicides (weed killers) and pesticides which exist as residues on and in the soil [51].

Effects of Water Pollution on Human Health

There is a greater association between water pollution and health problem. The availability of portable water is one of the major challenges facing developing and under developed countries of the world. Several chemical and microbiological contaminants can contaminate private water supplies. Nutrients (e.g. nitrates), pathogens, pharmaceuticals, hormones, heavy metals, nanomaterials and personal care products are some contaminants that have been identified in well water [52].

Health risk associated with polluted water includes different diseases such as respiratory disease, cancer, diarrheal disease, neurological disorder and cardiovascular disease. Nitrogenous chemicals are responsible for cancer and blue baby syndrome Bacterial, viral and parasitic diseases are spreading through polluted water and affecting human health. Disease causing microorganisms are known as pathogens and these pathogens are spreading disease directly among humans [53]. Many water borne diseases are spreading man to man. The release of untreated sewage to natural water systems can spread water-borne diseases such as cholera, typhoid, hepatitis, and polio. Poor sanitation and unsafe water cause 88% of the 4 billion annual cases of diarrhea, resulting in the death of about 1.8 million people per annum, mostly of children under five [54]. The world health organization has estimated that up to 80% of all diseases and sickness in the world is caused by inadequate sanitation, polluted water or unavailability of water [55].

Industries disposing wastewater into the surface water bodies without proper treatment, leads to several health disorders such as Cadmium (Cd) causes Kidney damage, renal disorder, human carcinogen, Copper (Cu) causes Liver damage, Wilson disease, insomnia, Nickel (Ni) causes Dermatitis, nausea, chronic asthma, coughing [56].

Therefore, the removal of contaminants of concern is now as ever imported in the production of safe drinking water

and the environmentally responsible release of great water problems.

Water Treatment Methods

The rapid pace of agricultural development, industrialization and urbanization has resulted in the over exploitation and contamination of water resources, resulting in various adverse environmental impacts, breakdown of the ecosystem, creating potential health risks and threatening its long-term sustainability [57, 58]. Water purification is the removal of contaminants from untreated water to produce water that is pure enough for an intended use.

The fundamental reason for the treatment of wastewater is to circumvent the effect of pollution of water sources and protect public health through safeguarding of water sources against the spread of diseases. The treatments used in water purification are physical treatment, chemical treatment and biological treatment [59]. The selection of a particular treatment technique primarily depends on a variety of factors, like waste type and concentration, treatment objectives, effluent heterogeneity, required level of cleanup, as well as economic factors.

Table 1: Methods of water treatment [60, 61, 62].

Physical treatment	Screening, Sedimentation, Filtration, Flotation, Membrane separation, Granular-medium, Comminution, Flow equalization
Chemical treatment	Coagulation, Chemical precipitation, Ion exchange, Adsorption, Neutralization, Solvent extraction, Disinfection, Chlorination, Other chemical applications
Biological treatment	Aerobic digestion, Anaerobic digestion, Activated sludge process, Aerated lagoon, Trickling filters, Rotating biological contactors, Pond stabilization, Biological nutrient removal

Wastewater treatment levels

Wastewater Treatment levels are: Preliminary, Primary, Secondary, and Tertiary/advanced.

Table 2: Wastewater treatment levels [63, 64].

Treatment levels	Process description
Preliminary Treatment	Physical separation of big sized impurities like cloth, plastics, wood logs, paper, rags, sticks, debris etc
Primary Treatment	Removal of floating and settleable materials such as suspended solids and organic/inorganic particles
Secondary Treatment	To remove, or reduce the concentration of organic and inorganic compounds
Tertiary (Advanced) Treatment	Removes remaining inorganic compounds, and substances, such as the nitrogen and phosphorus. Bacteria, viruses and parasites, are also removed at this stage

pH Control

The pH of the wastewaters can vary significantly depends on the cleaning strategy employed. The pH of wastewater also needs to be altered first because of the efficient coagulation exclusively work only in certain pH and conditions [65]. For acidic wastes (low pH): NaOH, Na_2CO_3, $CaCO_3$ or $Ca(OH)_2$ are used. For alkali wastes (high pH): H_2SO_4, HCl are used.

Coagulation

Coagulation refers to the way/ collecting small particles dispersed in a liquid form into bigger aggregates or become flocs by adding chemical or natural coagulant [66]. These particulates (flocs) will adsorb dissolved organic matter. An important design and control parameter during coagulation-flocculation is the size distribution of floc aggregates. Aggregation size distribution as well as aggregate structure and density are of great importance in solid-liquid separation processes such as sedimentation [67]. This whole process reduces turbidity and dissolved chemical species in liquids.

Coagulation is one of the most widely used physicochemical operations used in water, and wastewater treatment, as it is efficient and simple to operate and can be achieved by chemical and electrical means [68]. Coagulation reduce the suspended/ dissolved (especially non-settleable solids and colour), organic matter and colloidal materials responsible for turbidity of the wastewater for removal from the water being treated [69, 70, 71].

Steps of Coagulation

The steps involved in coagulation are: (i) formation of coagulant; (ii) destabilization of colloid/particle; and (iii) aggregation of particle [72]. Therefore, coagulation is the process of destabilizing the colloids, suspended substances and other organic matter by adding coagulants to the liquids and allowing them to be converted into a bigger form that is easier to remove later. Different mechanisms, such as neutralization of charge, adsorption, and sweep flocculation can be responsible for the removal of organics particles and compounds depending on the concentration of coagulant and properties of water [73].

Coagulants

A coagulant is a substance which in solution, furnishes ionic charges opposite to those of the colloidal turbid particles present in water [74]. Coagulants are added to the water to withdraw the forces that stabilizes the colloidal particles and causing the particles to suspend in the water[75]. Coagulation takes place when coagulants contain significant quantities of water-soluble proteins which carry an overall positive charge when in solution. The proteins bind to the predominantly negatively charged colloidal particles. Coagulation happens when the positively and negatively charged particles are chemically attracted together [76]. They can then accumulate to form larger and heavier particles that settle easily, reducing turbidity level of the given water sample. In the treatment of

contaminated water, removal of turbidity is of paramount importance because suspended particles represent transport vehicles for undesirable organic and inorganic contaminants, taste, odor and colour–causing compounds as well as pathogenic organisms, in search of lowest cost deployment, operation, maintenance, and reduced environmental impacts to the contiguous [77]. Once the coagulant is introduced in the water, the individual colloids aggregate and grows bigger so that the impurities can be settled down and separated from the water suspension [78]. Various types of coagulants show potential application in treating wastewater.

Types of Coagulants

There are plenty of coagulant materials available in the market. They can be classified into two types (Inorganic and Organic) or (Synthetic and Natural) [79].

Synthetic Coagulants

Inorganic coagulants are commonly divided into hydrolyzing metallic salts (like Alum, Ferric chloride and Ferric sulphate), pre-hydrolyzing metallic salts (like Polyaluminium chloride, polyaluminum sulphate and Polyferric chloride) and synthetic cationic polymers (like epichlorohydrindimethylamine, aminomethyl polyacrylamide, polyalkylene polyamine, polyethylenimine)[80].

Among all the available coagulants, including other inorganic and organic chemicals, Aluminium salts are the most widely used worldwide due to its proven performance, cost effectiveness, relative easy handling and storage and availability [81]. Aluminium sulphate (Alum, $Al_2(SO_4)_3.18H_2O$) is easy to handle and apply; most commonly used; most effective between pH 6.5 and 7.5)[82, 83]. This coagulant, under optimal conditions, can achieve between 90 % and 99 % efficiency.

High concentration of Alum causes several problems like neurotoxin and Alzheimer's disease, aluminium accumulation in the environment and can enters the food chain, causing potential health impacts [84, 85, 86]. Another drawback of alum coagulant is the production of huge amount of sludge which is non-biodegradable and causes disposal problems leading to increase in cost of treatment and requires treatment of the sludge [87].

In view of the need to overcome the drawbacks of inorganic coagulants and synthetic polymers associated with growing environmental concerns worldwide, there is a need to consider other potential alternatives for water treatment in order to minimize environmental damage and improve the wellbeing of human populations [88].

Natural Coagulants

The use of natural coagulants for the clarification of water and wastewater has been recorded throughout human history since ancient times and it is still current today. Natural organic polymers have been used for more than 2000 years in India, Africa, and China as effective coagulants[89].

Natural coagulants are divided into three categories; plant, microorganism or animal-based [90]. However, available sources of plant-based coagulants are much more widespread than animal-based coagulants, thus plant-based coagulants could be potential alternatives to chemical coagulants and have gradually gained in importance over the years. The use of plant-based materials as water treatment agents has long history, particularly the wood charcoal as an excellent adsorbent[91].

There has been considerable interest in the development and usage of plant (leaves, bark, sap, roots, and fruit) based natural coagulants as shown in Table 3.

Table 3: Plant-Based Coagulants [92, 93].

Plant coagulant	Plant Part Used	Plant coagulant	Plant Part Used
Moringa oleifera	Seeds	*Habiscus sabdariffa*	Calyx
Vigna anguiculata	Seeds	*Corchorus tridens*	Leaf
Parkinsonia aculeate	Seeds	*Ocimum sanctum*	Leaf
Opuntia spp	Pods	*Vetiveria zizanioides*	Root
Jatropha curcas	Seeds	*Triticum aestivum*	Root
Cicer arietinum	Seeds	*Strychnos potatorum*	Seed
Prosopis laevigata	Seed gum	*Phyllanthus emblica*	Fruit
Opuntia Ficus indica	Mucilage (ficus)	*Azadirachta indica*	Leaf
Cassia alata	Leaves	*Maerua subcordata*	Tuber
Arachis hypogea (peanut seeds)	Seeds	*Moringa stenopetala*	Seed
Water melon	Seeds	*Plantago ovata*	Seed
Coccinia indica	Mucilage	*Cassia obtusifolia*	Seed
Mustard and Moringa	Seeds	Surjana	Seed
Strychnos potatorum	Seeds	Maize	Seed
Opuntia dillenii	Mucilage	*Tamarindus indica*	Seed
Trigonella foenumgraecum	Seeds	*Jatropha curcas*	Seed
Nelumbo nucifera	Flower	*Strychnos potatorum*	Nut
Magnolia champaca	Flower	*Aloe vera*	Gel
Stereospermum suaveolens	Flower	*Solanum inacunum*	Leaves
Mesua ferrea	Flower	*Arachis hypogaea (peanut)*	Seeds

Moringa oleifera

Moringa Oleifera is a tropical plant from the family of Moringaceae, a single family of shrubs with 14 known species. *Moringa oleifera* is native from India but is now found throughout the world. *Moringa Oleifera* is non-toxic natural organic polymer, a medicinal plant. It is drought tolerant and has nutritional and medicinal value [94].

Many plants have been used to clarify water. These include *Moringa oleifera*, *Moringa stenopetala*, and *Vicia faba* [95]. Among the most studied natural coagulants *Moringa oleifera* is one of them. *Moringa oleifera* seeds are also used as a primary coagulant in wastewater treatment due to the presence of a water-soluble cationic coagulant protein able to reduce the turbidity, COD, and TDS of the wastewater treated [96]. *Moringa oleifera* seeds, stand out due to high efficiency in turbidity removal in river waters and for not producing significant changes in pH and alkalinity of the treated water [97]. *Moringa oleifera* is used as a primary coagulant and does not carry any impact on human health, and has a high efficiency up to 99% in the removal of turbidity from surface water and up to 98% in the removal of heavy metals from surface water [98].

Moringa oleifera seeds possess antimicrobial, buffering capacity and also contains natural antioxidant compounds which are biodegradable, environmentally safe to humans and essential to the human's system [99].

In comparison with conventional inorganic coagulants, *Moringa oleifera* have several advantages, such as inexpensive, non-corrosive, non-toxic, a high level of biodegradability, lower cost, water treated without extreme pH, has good color and turbidity removal and also promotes removal of bacteria [100].

Advantages of natural coagulants

Natural coagulant gains the advantage over chemical coagulant due to various reasons. Table 4 summarizes the benefits of using natural coagulants as an alternative over chemical coagulants.

Table 4: Advantages of natural coagulants over chemical coagulants [101-104].

Criteria	Explanation
Nature of coagulant	Non-corrosive, Non-toxic, Highly biodegradable, Safe
Sustainability	Natural, abundant and renewable source (available in large quantities), More eco-friendly, Reduce chemicals dependency
Cost	Lower sludge handling and treatment costs, Local materials and local labor (available locally), No/less pH and alkalinity adjustments, Low procurement costs and generally abundant in source, Lower coagulant doses requirements, Low cost
Sludge	Reduced sludge volume, Biodegradable, Higher nutritional sludge value, Disposing no treatment

CONCLUSION

Water is a key substance in all natural and human activities. Current misuse of water coupled with growing population size, industrialization, change in climate, and urbanization has increased the shrink in cleaning the water reserve. An access of getting pure water remains a problem especially for people who live in developing countries. The physicochemical characteristics of water bodies should be studied and documented time to time. Major sources of water pollution are discharge of domestic wastes, agriculture wastes, industrial wastes, excessive use of pesticides and fertilizers and urbanization. Bacterial, viral and parasitic diseases are spreading through polluted water and affecting human health. Thus, water from all sources should have some form of purification before consumption. Plant-based natural coagulants have garnered growing interests from researchers over the years due to their biodegradability and environmental friendly nature. Moreover, the use of natural coagulants can substantially save money on the cost of chemical materials and reduce to a minimum the sludge produced and, hence, require fewer disposals. Some natural compounds have coagulant properties, and learning about these properties and understanding their exact mechanisms of action can lead to their correct application.

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