PROJECT REPORT

Low-Cost Drinking Water Purification by Dual and Combined Treatment with Natural Coagulants and Solar Disinfection"

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Submitted By

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1.0 Introduction

General Assembly in synthesis report 2018 on water and sanitation declares access to clean water and sanitation is a human right–Safe and clean drinking water and sanitation is a human right essential to the full enjoyment of life and all other human rights, the General Assembly declared, voicing deep concern that almost 900 million people worldwide do not have access to clean water. The 192-member Assembly also called on United Nations Member States and international organizations to offer funding, technology and other resources to help poorer countries scale up their efforts to provide clean, accessible and affordable drinking water and sanitation for everyone.

Almost fifty per cent of the developing world's population –over 884 million people still uses unsafe drinking water sources. Inadequate access to safe water services, coupled with poor hygiene practices, kills and sickens thousands of children every day, and leads to impoverishment and diminished opportunities for thousands more. Unsafe- water has many other serious repercussions. Women are forced to spend large parts of their day fetching water. Poor farmers and wage earners are less productive due to illness, health systems are overwhelmed and national economies suffer. Without safe water sustainable development is impossible.

The Millennium Development Goal (MDG) aims at halving the portion of the population without sustainable access to safe drinking water by 2015. The indicator for the MDG is "use of an improved drinking water source" as defined by the World Health Organisation (WHO). Although 2 billion people have gained access to improved water sources between 1990 and 2010, more than 780 million people are still relying on unimproved sources such as surface water and unprotected wells for drinking water (WHO/UNICEF 2011). Access to fresh water is a human right, yet more than 780 million people, especially in rural areas, rely on unimproved sources and the need for finding ways of treating water is crucial. Although the use of natural coagulant protein in drinking water treatment has been discussed for a long time, the method is still not in practice, probably due to availability of material and limited knowledge.

There is also a great inequity between genders in the sustentation of water. In households without access to drinking water on the premises the responsibility for collecting water falls on women in 64% of the cases, the tribute of men, girls and boys are 24, 8 and 4% respectively. This is a significant burden and very time consuming, in some cases girls have to stay home from school to help their mothers in the household. Although a water source is considered as improved, this does not take into account if the water is of good quality. In Southern-Asia, the number of people that have access to water from boreholes has increased by 310 million over the last 20 years; nevertheless, the quality of this water is of concern and might contain microorganisms or other contaminants (WHO/UNICEF 2011).

For instance, in India, rapid population growth and other factors such as industrial discharge, agricultural run-off and poor sanitation practices put the long-term availability and quality of the potable water at stake. Water from boreholes is often too hard and although most people in the urban area have access to water treated by the municipality through tap or protected pumps; this water is rarely fit for drinking unless treated first. Microbial contamination through faecal contamination in water is the major reason for the poor water quality, transmitting a large number of diseases. The pathogens present in the drinking water include: *Shigella* species, *Salmonella* species, *Klebsiella* species, *Escherichia coli*, *Enterobacter* species, and parasites such as *Giardia lamblia* and *Entamaeba histolytica*. Drinking water treatment involves a number of combined processes based on the quality of the water source such as turbidity, amount of microbial load present in water and the others include cost and availability of chemicals in achieving desired level of treatment.

Generally drinking water treatment protocols consist of two major steps: coagulation/flocculation and disinfection. Commonly alum (aluminum sulfate) is used as a coagulation agent, as it is efficient and relatively cost-effective in developed countries; while, disinfection is achieved by the addition of chemical disinfectants like chlorine-based compounds. The chemicals most commonly used for disinfection of the water are chlorine, ozone, chlorine dioxide, and chloramines, and these chemical disinfectants are all removing microorganisms present in the water. However, they are powerful oxidants and will react

with natural organic matter and contaminants in the water, and form disinfection by-products (DBPs). These DBPs have been associated with increased risk for cancer and other health related issues (Morris et al., 1992; Cantor et al., 1998; Villanueva et al., 2006; Richardson et al., 2007). In addition to the health concerns, such complicated methods are difficult to adopt, especially in poor or developing countries, where cost-effective and simple drinking water treatment methods are needed. Therefore, usage of safe, traditional water treatment agents from natural sources becomes essential.

There are a few methods commonly advocated for the disinfection of drinking water at the household level. These include boiling of water for about 10 minutes, or the use of certain chlorine compounds available in the form of tablets (Halazone tablets, or calcium hypochlorite tablets) or solutions (sodium hypochlorite solutions). As each of these procedures has its own drawbacks, their application is extremely limited in the developing regions of the world where water-borne diseases are prevalent, and the safety of drinking water supplies cannot always be assured. Availability and costs are only part of the problem. In the case of boiling, for instance, the need for about one kilogramme of wood to boil on litre of water is totally unjustifiable in fuel-short regions already suffering from aridity and desertification. Besides, the disagreeable taste of boiled water often discourages consumers. The addition of 1 to 2 drops of 5% sodium hypochlorite solution per litre of water requires the use of a dropper and litre measure, both being uncommon devices in most homes. In view of these difficulties and constraints, it was deemed necessary to search for an alternative method for the disinfection of water on an individual basis using simple and inexpensive technology that would be more appropriate for application in the Third World. Unlike other kinds of energy, the utilization of solar energy would not lead to negative environmental impacts.

Although the technology and the efficiency of treating water are rapidly increasing it will take time before these techniques will be available for all. This is an urgent matter and it is very important to find alternative means of treating water in areas where the advanced treatment methods are not yet available. There is no universal solution for solving the problem with water supply in the world, every place and village is unique, and hence it is

desirable to find alternative methods for water treatment to access potable water. Moreover, due to the emerging threat of climate changes WHO is now recommending small-scale water treatment rather than relying on large-scale treatment plants that constitute a more fragile system.

Safe drinking water should generally be free from heavy metals, turbidity, organic compounds and pathogens. Turbidity may contain these compounds and also shield pathogens from chemical or thermal damage. It is also important to remove turbidity for the aesthetic values of the drinking water. Organic substances in water might originate from industrial and agricultural operations, which contribute with compounds such as chloroform, gasoline, pesticides and herbicides. Finally, protozoa, bacteria and viruses are all pathogens that can cause diseases. Water is undoubtedly the most vital element among the natural resources. In many developing countries, access to clean and safe water is a crucial issue. More than six million people die because of diarrhea which is caused by polluted water. Developing countries pay a high cost to import chemicals for water treatment

The water condition of the surface water has become highly polluted due to indiscriminate discharge of untreated waste from tannery, textile, and other industries, municipal waste into water bodies, poor drainage system, population increasing and urban encroachment.
Water from all sources must have some form of purification before consumption. Various methods are used to make water safe and attractive to the consumer. The method employed depends on the character of the raw water. One of the problems with treatment of surface water is the large seasonal variation in turbidity

For the treatment of surface water, some traditional chemicals are used during the treatment of surface water at its various steps. Commonly used chemicals for various treatment units are synthetic organic and inorganic substances. In most of the cases, these are expensive since they are required in higher dose and does not show cost effectiveness. Many of the chemicals are also associated with human health and environmental problems, Kaggwa . So,

there raised a voice to develop cost-effective, easier, and environmental friendly process of water clarification.

The history of the use of natural coagulants is long. Natural organic polymers have been used for more than 2000 years in India, Africa, and China as effective coagulants and coagulant aids at high water turbidities. They may be manufactured from plant seeds, leaves, and roots. These natural organic polymers are interesting because, comparative to the use of synthetic organic polymers containing acryl amide monomers, there is no human health danger and the cost of these natural coagulants would be less expensive than the conventional chemicals alike since it is locally available in most rural communities. We have developed an economically, feasible and environmentally sound combined turbid water treatment technology with natural coagulants and solar disinfection to provide potable water to the rural people.

2.0 - Objectives

- To develop an economically feasible and environmentally sound combined purification method with natural coagulants and solar disinfection for providing potable water to the villagers.
- To validate the effectiveness of the two methods (natural coagulants along with solar disinfection) when used sequentially.
- To identify new plant materials with coagulating properties, which should have competitive characteristics such as being cost effective, easily available and having an effect against microorganisms and as a potential substitute to chemicals for water purification
- To evaluate and compare the effectiveness of natural coagulants seeds with aluminium sulphate (Alum) chemical coagulant by treating low, medium and high turbid waters.
- Design a field unit for treating 100 liters of raw turbid water with a provision to scaling up later.
- To make the water treatment process easier and environmental friendly for household applications.

3.0 - Methodology

3.1- Natural coagulant preparation:

Seeds were collected from nearby market. Dissections of the seed pods were performed by hand: The seeds were removed from the pods and were dried in the hot sun. Fine powder was made by using mortar and pestle and was stored in air tighten packets for future use.

Figure 1:  Seeds and seed powder for various seeds

3.2- Coagulant solution preparation:

The pulverized seed material of about (optimum) was made into paste using little amount of water and mixed into 50 ml of clean water which was shaked for 1minute in order to activate the coagulant properties of the seed to form a solution . The solution was filtered through a muslin cloth into the 1000ml of turbid water to be treated. Figure 2: Synthetic turbid water with various turbidity

3.3 - Model turbid water:

A stock of synthetic turbid water samples was prepared by suspending 10g of Kaolin in 1L of tap water. The suspension was stirred for 30 minutes and left to stand for 24hrs to hydrate particles. The desire turbidity of 20 NTU (low), 40 NTU (medium) and 80 NTU (high) was prepared by mixing a fraction of decanted kaolin suspension with tap water. The pH of synthetic water samples was maintained constant at 7.0 using 0.1 M HCl. E.coli and Coliforms was mixed in stock turbid water from preserve lab culture samples.

3.4- Solar Exposure time

Poly Ethylene Terephtalate (PET) bottles made of transparent, clear plastic, cylinder shape with a surface area of 23 x 7.2 x 6.0 cm was used for experimental purpose as they are good transmitters of light in the UV and visible range of the solar spectrum. The total exposure time of experiments varied from 2 to 8 hours. Sunlight is strongest from 10 am to 2 pm so initial experiments were conducted to encompass this time bracket by up to 1.5 hours before and up to 3 hours after (from 8:30am to 4:30 pm). Figure 3: Solar disinfection

3.5 - Physico – chemical and microbial analysis

Samples were analyzed before and after treatment for its potability using APHA methods. The turbidity of water samples was measured using the turbidity meter (ELICO CL 52 D). pH was determined using a pH strip. The Escherichia coli and Coli forms bacteria counts were enumerated on Eosin Methylene Blue and Mac Conkey were performed hourly during the experimental period. The inverted Petri dishes were incubated for 24 hrs at 37 ^{0}C. Colonies with a gold metallic sheen on the EMB were considered to be positive for E.Coli growth and white colonies on Mac Conkey agar as positive for coliform growth. All results were reported as log CFU (Coliforms units)/100 ml). The colonies are enumerated by using digital colony meter and the log reduction is given by the following formula.

$$\text{Cfu/ml} = \frac{\text{No. Of colonies formed}}{\text{Sample plated}} \times \frac{1}{\text{Dilution factor}}$$

3.6 - Estimation of Protiens in Seeds by Lowry's Method

Principle: The principle behind the Lowry method of determining protein concentrations lies in the reactivity of peptide nitrogen with the copper [II] ions under alkaline conditions and the subsequent reduction of the folin-ciocalteay phosphomolybdic phosphotungstic acid to heteropolymolybdenum blue by the copper-catalyzed oxidation of aromatic acids [Dunn, 13]. The Lowry method is sensitive to pH changes and therefore the pH of assay solution should be maintained at 10 - 10.5.

The Lowry method is sensitive to low concentrations of protein. Dunn [1992] suggests concentrations ranging from 0.10 - 2 mg of protein per ml while Price [1996] suggests concentrations of 0.005 – 0.10 mg of protein per ml. The major disadvantage of the Lowry

method is the narrow pH range within which it is accurate. However, we will be using very small volumes of sample, which will have little or no effect on pH of the reaction mixture. A variety of compounds will interfere with the Lowry procedure. These include some amino acids derivatives, certain buffers, drugs, lipids, sugars, salts, nucleic acids and sulphydryl reagents [Dunn, 1992]. Price [1996] notes that ammonium ions, zwitter ionic buffers, non-ionic buffers and thiol compounds may also interfere with the Lowry reaction. These substances should be removed or diluted before running Lowry assays.

Reagents:

A. 2% sodium carbonate in 0.1N sodium hydroxide:
   - 100 ml of 2%Sodiumcarbonate- take 2 gm of sdium carbonate in a 100 ml standard flask and makeup to the mark using 0.1 N sodium hydroxide.
   - 100 ml of 0.1 N sodium hydroxide - take 400 mg of sodium hydroxide in 100 ml standard flask and makeup to the mark using distilled water.

B. 1% potassium sodium tartarate in water:
   - 100 ml of 1% potassium sodium tartarate- take 1 gm of potassium sodium tartarate in 100 ml of standard flask and makeup to the mark using distilled water.

C. 0.5% copper sulphate in water:
   - 100 ml of 0.5% copper sulphate- take 0.5 gm of copper sulphate in 100 ml standard flask and makeup to the mark using distilled water.

D. REAGENT I: 48 ml of A, 1 ml of B, 1 ml of C

E. 1 part folin-phenol (2 N) : 1 part water
   - 10 ml of 2 N folin-phenol- take 1.9 ml of folin-phenol and add 8.1 ml of distilled water.
   - To the above solution add 10 ml of distilled water.

F. BSA STANDARD: bovine serum albumin 1 mg/ml
   - Weigh accurately 50 mg of BSA and dissolve in distilled water and makeup to 50 ml in a standard flask.

Procedure:

- From the BSA standard 0.2 ml, 0.4 ml, 0.6 ml, 0.8 ml and 1.0 ml was taken five test tubes respectively and made up to 1.0 ml using distilled water.

- In another test tube 1.0 ml of distilled water was taken as a blank.
- Extraction of protien from sample- 500 mg of the sample was weighed and ground well in a motor and pestle by adding 5.0 ml of buffer. Then the sample was centrifuged for 10 minutes and the supernatant was used for protein estimation.
- The protein estimation in the samples was carried out in three different volumes that are 0.1 ml, 0.2 ml and 1.0 ml.
- The samples were taken in different test tubes.
- To the all the test tubes including blank 4.5 ml of reagent-I was added and incubated for 10 minutes.
- After incubation 0.5 ml of reagent-II was added and incubated for 30 minutes.
- The absorbance was measured at 660 nm in spectrophotometer.
- Standard graph was plotted with the BSA standard concentrations from which the amount of protein present was estimated.

3.7- Turbidity Procedure

Procedure

- Solution I- In a 100 ml standard flask 1 gm of hydrazine sulphate was taken and made up to the mark using distilled water.
- Solution II- In a 100 ml standard flask 10 gm of hexamine (hexamethylenetetramine) was taken and made up to the mark using distilled water.
- In another 1000 ml standard flask 50 ml of solution I and 50 ml of solution II was taken and mixed well and allowed it to stand for 24 hours for the development of turbidity.
- After 24 hours made up to the mark using distilled water, the solution developed was of 400 NTU.
- For treatment three different concentrations were prepared from 400 NTU standard by taking 50 ml, 100 ml and 150 ml in different 1000 ml standard

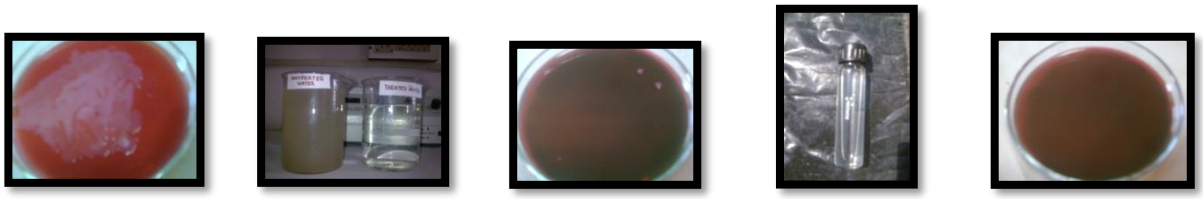
flasks and made up to the mark using distilled water which resulted in 20 NTU, 40 NTU and 60 NTU respectively.

- Each concentration three sets were prepared for obtaining optimum concentration of the seeds.
- Standard graph was plotted using different solutions of 20 NTU, 40 NTU, 60 NTU, 80 NTU and 100 NTU from 200 NTU.
- From 400 NTU 200 NTU was prepared by taking 50 ml of solution in a 100 ml standard flask and made up to the mark using distilled water.
- Standards were prepared from 200 NTU of 50 ml each by taking 5 ml, 10 ml, 15 ml, 20 ml and 25 ml in separate 50 ml standard flaks and made up to the mark using distilled water resulting in 20 NTU, 40 NTU. 60 NTU, 80 NTU and 100 NTU respectively.
- Treatment was carried out by adding 0.2 gm of seeds powder in all the first set three different concentrations turbidity (20,40,80 NTU) and flocculated for and then let it stand for settling for 30 minutes.
- The above procedure was repeated by using different concentrations of seeds powder that is 0.4 gm and 0.6 gm.
- The treatment procedure was done on soil sample with different concentrations of turbidity (20, 40, 60 NTU) using different concentrations of seeds powder (0.2, 0.4, 0.6 gm) similarly as the above synthetic sample.
- The parameters like pH, turbidity and total dissolved solids were recorded before treating the samples and after treating the samples.

3.8 - Combined turbid water treatment methodology

The dried seeds of natural coagulants were pulverized in to fine powder. Preliminary coagulation experiments were conducted at rapid and slow mixing speeds of 100 RPM and 40 RPM for duration of 1 min and 10 min respectively. Different coagulant dosages were added into beakers during rapid mixing. After various settling intervals samples were drawn at 5 cm from the surface and residual turbidity were measured using nephlometer for optimum dose and settling time. The clarified water with natural coagulant was then poured in to plastic

poly ethylene terephthalate (PET) bottles was placed on the black cloth lying down in a sunny place, in order to absorb more sunlight. Transparent bottles containing samples were placed indoors served as control. After various exposure hours of solar disinfection, bottles were placed in cool place. The water samples were analyzed for its potability before and after treatment with combined treatment (natural coagulant treatment followed by solar disinfection). All of the experiments were performed in duplicates and the average values were presented.

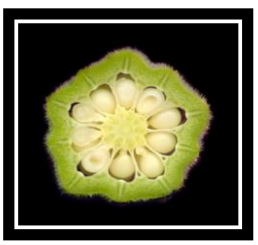


E.coli count in turbid water | Treatment with natural coagulant (NC) | E.coli count after NC treatment | Solar disinfection | E.coli count after solar disinfection

Figure 4: Process of combined turbid water treatment methodology with natural coagulants and solar disinfection

3.9- Description and Characterization of natural coagulants (seeds)

Table 1: Scientific names and active component in agro based seeds

S.No	Scientific Name and Common Name	Natural Coagulant Seeds	Active agent
1	Phaseolus vulgaris (Green bean)		Albumin proteins
2	Abelmoschus esculentus (Ladies Finger or Okra)		Cyclo propenoid fatty acid

3	Moringa oleifera (Drumstick)		Dimeric cationic proteins
4	Coccinia grandis (Dondakaya)		Oligomeric globulins
5	Zeemays (Corn)		Legumin like proteins
6	Carica Papaya (Papayee)		Cysteine protease
7	Strychnos potatorum (Nirmali)		Alkaloids & polysaccharides
8	Pysum sativum (Peas)		Albumin proteins

4.0. Moringa Oleifera (Drumstick)

"Drumstick tree" and variants thereof redirect here. This name is also used for Cassia fistulosa*, the golden rain tree. Moringa oleifera* is the most widely cultivated species in the genus *Moringa*, the only genus in the plant family Moringaceae. Common names include moringa, drumstick tree (from the long, slender, triangular seed-pods), horseradish tree (from the taste of the roots, which resembles horseradish), and ben oil tree or benzoil tree (from the oil which is derived from the seeds).*M. oleifera* is a fast-growing, drought-resistant tree, native to tropical and subtropical regions of South Asia. It is widely cultivated for its young seed pods and leaves used as vegetables and for traditional herbal medicine. It is also used for water purification. *M. oleifera* is considered to be an aggressive invasive species.

Over the past two decades, many reports have appeared in mainstream scientific journals describing its nutritional and medicinal properties. Its utility as a non-food product has also been extensively described. Every part of Moringa tree is said to have beneficial properties that can serve humanity. People in societies around the world have made use of these properties.

Moringa oleifera	
Scientific classification	
Kingdom:	Plantae
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Rosids
Order:	Brassicales
Family:	Moringaceae
Genus:	*Moringa*
Species:	*M. oleifera*
Binomial name	
Moringa oleifera Lam.	

Figure 5- Moringa oleifera

4.1. *Strychnos potatorum (Nirmali)*

Strychnos potatorum also known as clearing-nut tree. It is a deciduous tree which has height up to 40 feet (12 meters). The seeds of the tree are commonly used in traditional medicine as well as for purifying water in India and Myanmar.[1]Traditional Medicinal Uses: According to Ayurveda, seeds are acrid, alexipharmic, lithotriptic and cure strangury, urinary discharges, head diseases etc. Roots cure Leucoderma whereas fruits are useful in eye diseases, thirst, poisoning and hallucinations. The fruits are emetic, diaphoretic alexiteric etc. According to Unani system of medicine, seeds are bitter, astringent to bowels, aphrodisiac, tonic, diuretic and good for liver, kidney complaints, gonorrhea, colic etc. Seeds are used to purify water. Seeds are rich source of polysaccharide gum suitable for use in paper and textile industries.

Scientific classification	
Kingdom:	Plantae
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Asterids
Order:	Gentianales
Family:	Loganiaceae
Genus:	*Strychnos*
Species:	*S. potatorum*
Binomial name	
Strychnos potatorum L.f.	

Figure 6: ***Strychnos potatorum***

4.2. Zea mays (Corn)

Maize (*Zea mays* L**)** is one of the most important cereals of the world and provides more human food than any other cereal. Maize is of American origin having been domesticated about 7000 years ago. Maize provides nutrients for humans and animals and serves as a basic raw material for the production of starch, oil and protein, alcoholic beverages, food sweeteners and, more recently, fuel. Maize is high yielding, easy to process, readily digested, and costs less than other cereals. It is also a versatile crop, allowing it to grow across a range of agroecological zones. Every part of the maize plant has economic value: the grain, leaves, stalk, tassel, and cob can all be used to produce a large variety of food and nonfood products.

Scientific classification	
Kingdom:	Plantae
Clade:	Angiosperms
Clade:	Monocots
Clade:	Commelinids
Order:	Poales
Family:	Poaceae
Genus:	*Zea*
Species:	*Z. mays*
Binomial name	
Zea mays L.	

Figure 7– Zea mays

4.3. Coccinia Grandis (Dondakaya)

Coccinia grandis, the ivy gourd, also known as scarlet gourd, tindora, and kowai fruit, is a tropical vine. It grows primarily in tropical climates and is commonly found in the southern Indian state of Kerala, where it forms a part of the local cuisine. Coccinia grandis is cooked as a vegetable. In Southeast Asia, it is grown for its edible young shoots and edible fruits. Occurs in agricultural areas, natural forests, and planted forests, rural/distributed. Native range: Africa and Asia; India, Philippines, China, Indonesia, Malaysia, Thailand, Vietnam, eastern Papua New Guinea, Northern Territories (Australia). Known introduced range: Commonwealth of the Northern Mariana Islands, Federated States of Micronesia, Fiji, Guam, Hawai'i, Marshall Islands, Samoa, Tonga, Vanuatu. **Medicinal uses:** Medicinal qualities as follows "The juice of the roots and leaves is used in the treatment of diabetes. The leaves are used as a poultice in treating skin eruptions. The plant is used as a laxative. It is used internally in the treatment of gonorrhea. Aqueous and ethanolic extracts of the plant have shown hypoglycaemic principles.

Scientific classification	
Kingdom:	Plantae
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Rosids
Order:	Cucurbitales
Family:	Cucurbitaceae
Genus:	*Coccinia*
Species:	*C. grandis*
Binomial name	
Coccinia grandis (L.) Voigt	

Figure 8 - Coccinia Grandis

4.4. Phaseolus vulgaris (Green beans)

The common bean, *Phaseolus vulgaris*, is an herbaceous annual plant domesticated independently in ancient Mesoamerica a nd the Andes, and now grown worldwide for its edible bean, popular both dry and as a green bean. The leaf is occasionally used as a leaf vegetable, and the straw is used for fodder. Botanically, the common bean is classified as a dicotyledon. Similar to other beans, the common bean is high in starch, protein and dietary fiber and is an excellent source of iron, potassium, selenium, molybdenum, thiamine, vitamin B6, and folic acid.

Scientific classification	
Kingdom:	Plantae
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Rosids
Order:	Fabales
Family:	Fabaceae
Genus:	*Phaseolus*
Species:	*P. vulgaris*
Binomial name	
Phaseolus vulgaris	

Figure 9 : Phaseolus vulgaris

4.5. *Abelmoschus esculentus* (Lady finger)

Okra (*Abelmoschus esculentus* Moench, pronounced, known in many English-speaking countries as lady's fingers or gumbo) is a flowering plant in the mallow family. It is valued for its edible green seed pods. Originating in Africa, the plant is cultivated in tropical, subtropical and warm temperate regions around the world.

Scientific classification	
Kingdom:	Plantae
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Rosids
Order:	Malvales
Family:	Malvaceae
Genus:	*Abelmoschus*
Species:	*A. esculentus*
Binomial name	
Abelmoschus esculentus(L.) Moench	

Figure 10- ***Abelmoschus esculentus***

4.6. Pisum sativum (Peas)

A pea is most commonly the small spherical seed or the seed-pod of the legume *Pisum sativum*. Each pod contains several peas. Peapods are botanically a fruit, since they contain seeds developed from the ovary of a (pea) flower. However, peas are considered to be a vegetable in cooking. *P. sativum* is an annual plant, with a life cycle of one year. It is a cool season crop grown in many parts of the world; planting can take place from winter through to early summer depending on location. The average pea weighs between 0.1 and 0.36 grams. The species is used as a vegetable, fresh, frozen or canned, and is also grown to produce dry peas like the split pea. These varieties are typically called field peas.

Figure 11 - Pisum sativum

Pea plant: *Pisum sativum*	
Scientific classification	
Kingdom:	Plantae
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Rosids
Order:	Fabales
Family:	Fabaceae
Genus:	*Pisum*
Species:	*P. sativum*
Binomial name	
Pisum sativum L.	

4.7. Carica papaya (Papayee)

The widely cultivated papaya (also called papaw or pawpaw), a tropical fruit plant. For the mountain papaya (Vasconcellea pubescens) of South America, see Mountain papaya. For the Eastern North American tree (and fruit) called "pawpaw", see Asimina triloba. For other uses, see Papaya (disambiguation). The papaya is a small, sparsely branched tree, usually with a single stem growing from 5 to 10 m (16 to 33 ft) tall, with spirally arranged leaves confined to the top of the trunk. The lower trunk is conspicuously scarred where leaves and fruit were borne. The leaves are large, 50–70 cm (20–28 in) in diameter, deeply palmately lobed, with seven lobes. All parts of the plant contain latex in articulated laticifers. Papayas are dioecious. The flowers are 5-parted and highly dimorphic, the male flowers with the stamens fused to the petals. The female flowers have a superior ovary and five contorted petals loosely connected at the base. Male and female flowers are borne in the leaf axils, the males in multiflowered dichasia, the female flowers is few-flowered dichasia. The flowers are sweet-scented, open at night and are moth-pollinated.[6] The fruit is a large berry about 15–45 cm (5.9–17.7 in) long and 10–30 cm (3.9–11.8 in) in diameter. It is ripe when it feels soft (as soft as a ripe avocado or a bit softer) and its skin has attained amber to orange hue.

Scientific classification	
Kingdom:	Plantae
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Rosids
Order:	Brassicales
Family:	Caricaceae
Genus:	*Carica*
Species:	*C. papaya*
Binomial name	
Carica papaya L.	

Figure 12 : Carica papaya

Table 2: Proforma –Dual Treatment Design for treating Turbid Water by Natural Coagulants and Solar Disinfection

	Step 1	Step 2	Step 3		Step 4	Step 5			Step 6			
S.No	Coagulant name	Dosage (gm/l)	Stirring speed		Settling Time (min)	Before Treatment			After Treatment with Natural Coagulant			
			Rapid	Slow		NTU	E.coli	Coliform	Control (NTU)	Sample (NTU)	E.coli (CFU/ml)	Coliform (CFU/ml)

Step 7				Step 8			
Treatment with Solar disinfection (Exposure time for E.coli Inactivation)				Treatment with Solar disinfection (Exposure time for Coliforms Inactivation)			
Control	1 hr	2hr	3hr	Control	1 hr	2hr	3hr

5.0 - Study Area

5.1. About Hyderabad

Hyderabad is the capital of the Indian state of Telangana . Occupying 650 square kilometres (250 sq mi) along the banks of the Musi River, it has a population of about 6.9 million and a metropolitan population of about 7.75 million, making it the fourth most populous city and sixth most populous urban agglomeration in India. At an average altitude of 542 metres (1,778 ft), much of Hyderabad is situated on hilly terrain around artificial lakes, including Hussain Sagar—predating the city's founding—north of the city centre.

Hyderabad is full of natural beauty. Lakes and ponds are just anywhere you can find. The outskirts of the city has preserved the lakes, giving them the regular cleaning, and making it the must visit tourist spot. The best part about them is that you could gather up your group, go on a leisure walk through its rough path that leads to the lake, where you can set up a nice picnic for a long day ahead. And if the weather is pleasant with a little rain here and then, then you could have the most wonderful time. Some of these lakes are man-made with the purpose of storing water for irrigational purposes. With time, the migratory birds come and nestle here making this their temporary home.

Figure 13: Location map of Hyderabad

5.2. Surface water sample collection locations in and around Hyderabad

Table 3: Sampling Locations

S.No	Sampling locations
1	Mir Alam Tank (S1)
2	Safilguda Lake (S2)
3	Saroornagar lake (S3)
4	Langarhouz Cheruvu (S4)
5	Ramakrishnapuram Lake (S5)
6	Kapra Lake (S6)
7	Durgam Cheruvu (S7)
8	Alwal Lake (S8)
9	Nacharam Cheruvu (S9)
10	Ramanthapur Cheruvu (S10)
11	Jeedimetla Cheruvu (S11)

5.3 Description of Lakes (Sampling locations)

1. Mir Alam Tank:

Mir Alam Tank is a reservoir in Hyderabad, Telangana, India. It is located to the south of Musi river. It was the primary source of drinking water to Hyderabad before Osman Sagar and Himayat Sagar were built. It is connected to National Highway7 near Palm Valley (Tadbun). Coordinates 17°21′N 78°26′E and Surface area600 acres (240 ha).

2. Safilguda Lake

Safilguda lake, also known as Nadimi Cheruvu and Mini Tank Bund, is a lake located in Old Neredmet, Secunderabad, Telangana, India. There is a park

adjacent to the lake called Safilguda Lake Park. The lake has a small island called Nadimi Bird Island. It is covered with thick trees, which attract a variety of wildlife, especially migratory birds. Katta Misamma Temple is located on the shoreline of the lake. The road around the lake is similar to the Necklace Road around the "tank bund" on the Hussain Sagar Lake and hence the lake is also called "Mini Tank Bund". The park is a popular attraction for jogging and evening walks. Coordinates17.46372°N 78.53626°E, Surface elevation, 1759 ft (536 m).

3. Saroornagar Lake

Saroornagar Lake is a lake in Hyderabad, India. From the year of its creation in 1626, the lake remained largely clean until 1956 when Hyderabad expanded. Spread over 99 acres (40 ha), the lake was restored by the Hyderabad Urban Development Authority in 2003–04 at a cost of ₹200 million (US$2.8 million). After the restoration of the lake, migratory birds returned to the lake in big numbers a few years later. Coordinates 17.35584°N 78.52714°E, Surface area99 acres (40 ha) and Max. depth 6.1 metres (20 ft).

4. Langarhouz Cheruvu

Langar Houz is a suburb of Hyderabad, located near Golconda. It is a part of the city. Langer houz is located on the bank of River Musi, and is home to the sangam of Musi and Esi rivers. River musi carries water from Osman Sagar lake and River esi carries the water from Himayat Sagar lake.Langar houz lake, that is getting polluted with huge amounts of sewage flowing into it directly, can be seen foaming and frothing on a daily basis even today. In 2005, the erstwhile Hyderabad Urban Development Authority (HUDA) had constructed a 1.2 Million Liters per Day (MLD) STP beside the lake to restore it so that sewage from

nearby areas can be channelised to the STP, treated and then released into the lake. A park was also constructed beside the lake as part of beautification.

5. Ramakrishnapuram Lake

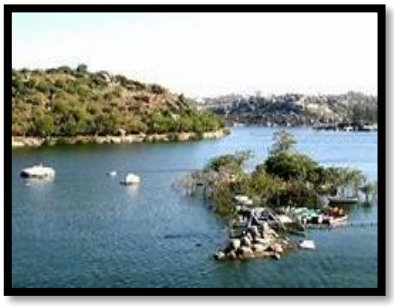
Ramakrishnapuram Lake, also known as Mukidi Cheruvu, is a lake located in Neredmet, Hyderabad near Ramakrishnapuram Railway Station. It is home to many migratory birds.[1] The lake is currently facing many problems, including water pollution. GHMC is trying to stop pollution but the efforts are not effective. Migratory birds and other animals are also affected by the pollution. Coordinates17.476°N 78.533°E Surface elevation 1,1759 ft (536 m).

6. Kapra Lake

Kapra lake or Oora Cheruvu is a lake located in the Kapra municipality near Sainikpuri in the north-east part of Greater Hyderabad.[1]Length of its bund is measured at 1254 Meters. Coordinates 17.49558°N 78.55278°E, Surface area 113 acres (46 ha), Average depth 547.873 m (1,797.48 ft), Max. depth 551.614 m (1,809.76 ft) Surface elevation1,759 ft (536 m).

7. Durgam Cheruvu

Durgam Cheruvu also known as Raidurgam Cheruvu is a freshwater lake located in Rangareddy district, Telangana, India. The lake, which is spread over 83 acres (34 ha), is located near the city of Hyderabad. The lake is also known as Secret Lake because it is



hidden between the localities of Jubilee Hills and Madhapur. Surface area 83 acres (34 ha) Max. depth 28 feet (8.5 m) Water volume 1,679,430 cubic metres (1,361.54 acre·ft)

8. Alwal Lake

Alwal Lake is an artificial lake near Hyderabad, India, about 8 kilometers north of Secunderabad. It is situated in Alwal. There were many issues associated with the lake, which made a highly tensed situation for the Alwal Municipality Officials. Coordinates17°30′28″N 78°30′41″E.

9. Nacharam Cheruvu

It is a manmade lake. Nacharam Cheruvu with HMDA lake id 3806This is a fresh water lake spread over, about 90 acres. Coordinates: 17°25'15"N 78°33'12"E

10. Ramanthapur Cheruvu

Ramanthapur Lake, also known as *Pedda Cheruvu*, is a lake located in Ramanthapur, Hyderabad. It is one of the largest lakes in Hyderabad. 'Pedda Cheruvu' means 'Large Lake' in Telugu language. Coordinates 17.42124°N 78.55403°E Surface area 9 acres (3.6 ha) Surface elevation1,759 ft (536 m).

11. Jeedimetla Cheruvu

Fox Sagar Lake, also Jeedimetla Cheruvu or Kolla Cheruvu, is the fifth largest lake, spread over 500 km², in Hyderabad, India. It is located in Jeedimetla near Kompally, Hyderabad. The lake is popular for fishing and a popular spot for picnics. Coordinates 17.524°N 78.470°E Surface area 500 km² (190 sq mi).

5.4 Surface water sampling method

Grab surface water samples in duplicate were collected from 3 areas of Hyderabad, A.P, India. Polypropylene bottles of one litre capacity were used for sampling. Sample was collected from 15 cm (6 in) from surface water. ID tag was attach immediately to bottles which contain the details of sampling time, location, quantity and date according to APHA (1982) methods.

Figure 14: Surface water samples

Table 4: Surface water sample physico-chemical, microbiological analysis before treatment

#	Parameters	Standards (As per IS: 10500)	Sampling Locations (Lakes)										
			S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**
1	Color (Hazen)	< 05	80.1	90.5	59.2	10.2	25.6	58	45	35.6	54	48	39
2	Odour	Un-Objectionable	Obj	Obj	Obj	Obj	Obj	Obj	Obj	Obj	Obj	Obj	Obj
3	pH	6.5 – 8.5	7.8	8.74	8.76	8.18	9.0	8.30	8.1	8.4	8.4	8.7	8.1
4	Turbidity (NTU)	< 05	56.3	85.6	65.8	90.5	150	78	250	52.3	200	121	156
5	Chlorides (mg/l)	<250	199	320.2	41.56	303	150	253	336	1082	407	537	458
6	TDS (mg/l)	<500	1589	3508.3	565.4	643.7	1059	1195	1000	1066	689	1569	598
7	Alkalinity (mg/l)	200	300	259.6	175.3	356	198	625	581	522	256	304	250
8	E.coli (cfu/ml)	0 – 10	TMC	TMC	TMC	TMC	TMC	TMC	TMC	TMC	TMC	TMC	TMC
9	Coliforms (cfu/ml)	0 – 10	TMC	TMC	TMC	TMC	TMC	TMC	TMC	TMC	TMC	TMC	TMC

Note: TMC – Too many to count

5.5 - Results and Discussions

Table 5: Standard graph readings for protein estimation

S.No	Vol. of BSA (ml)	Conc. of BSA (mg/ml)	Vol. of distilled water (ml)	Vol. of reagent-I (ml)	Incubated for 10 minutes	Vol. of reagent-II (ml)	Incubated for 30 minutes	Absorbance at 660 nm
1	Blank	-	1.0	4.5		0.5		0.000
2	0.2	0.2	0.8	4.5		0.5		0.281
3	0.4	0.4	0.6	4.5		0.5		0.404
4	0.6	0.6	0.4	4.5		0.5		0.521
5	0.8	0.8	0.2	4.5		0.5		0.672
6	1.0	1.0	-	4.5		0.5		0.845

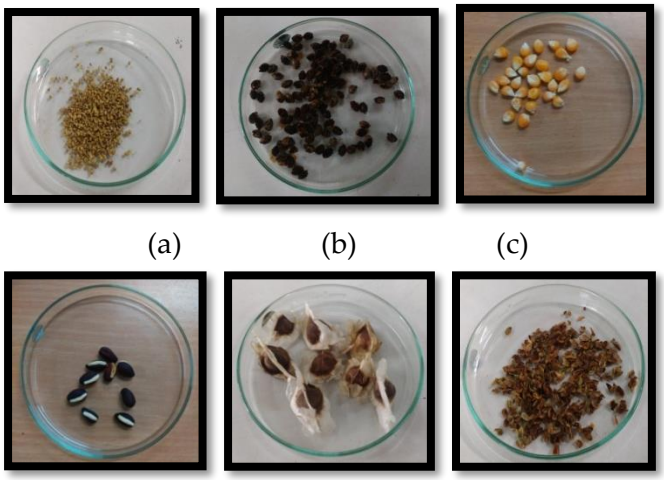
Table 6: Sample (seeds) readings for protein estimation

S. No	Sample name	Vol. of sample (ml)	Vol. of distilled water (ml)	Vol. of reagent -I (ml)	Incubated for 10 minutes	Vol. of reagent-II (ml)	Incubated for 30 minutes	Absorbance at 660 nm
1	Phaseolous vulgaris	0.1	0.9	4.5		0.5		0.406
		0.2	0.8	4.5		0.5		0.413
		1.0	-	4.5		0.5		1.037
2	Abelmoschus esculentus	0.1	0.9	4.5		0.5		0.759
		0.2	0.8	4.5		0.5		0.843
		1.0	-	4.5		0.5		1.342
3	Moringa oleifera	0.1	0.9	4.5		0.5		0.356
		0.2	0.8	4.5		0.5		0.878
		1.0	-	4.5		0.5		2.45
4	Coccinia grandis	0.1	0.9	4.5		0.5		0.479
		0.2	0.8	4.5		0.5		0.542
		1.0	-	4.5		0.5		0.894
5	Zea mays	0.1	0.9	4.5		0.5		0.369
		0.2	0.8	4.5		0.5		0.447
		1.0	-	4.5		0.5		2.084
6	Carica papaya	0.1	0.9	4.5		0.5		0.542
		0.2	0.8	4.5		0.5		0.942
		1.0	-	4.5		0.5		2.026
7	Strychnos potatorum	0.1	0.9	4.5		0.5		0.628
		0.2	0.8	4.5		0.5		0.732
		1.0	-	4.5		0.5		2.000
8	Pisum sativam	0.1	0.9	4.5		0.5		0.400
		0.2	0.8	4.5		0.5		0.512
		1.0	-	4.5		0.5		1.230

Table 7: Concentration of proteins in the seed samples

S.No	Name of the seed	Quantity of sample (mg)	Volume analysed (ml)	Concentration at 660 nm in spectrophotometer	
				mg/l	mg/g
1	Phaseolus vulgaris	500	0.1	4000	4.00
			0.2	2700	2.70
			1.0	1180	1.18
2	Abelmoschus esculentus	500	0.1	4400	4.40
			0.2	2600	2.60
			1.0	1580	1.58
3	Moringa oleifera	500	0.1	13400	13.40
			0.2	6900	6.90
			1.0	2800	2.80
4	Coccinia grandis	500	0.1	8600	8.60
			0.2	5000	5.00
			1.0	1600	1.60
5	Zea mays	500	0.1	4000	4.00
			0.2	2250	2.25
			1.0	2360	2.36
6	Carica papaya	500	0.1	10000	10.00
			0.2	9100	9.10
			1.0	2360	2.36
7	Strychnos potatorum	500	0.1	12500	12.50
			0.2	5800	5.80
			1.0	2700	2.70
8	Pisum sativam	500	0.1	4400	4.40
			0.2	2200	2.20
			1.0	1350	1.35

Figure 15: Protein estimation reagents



(a) (b) (c)

(d) (e) (f)

Figure 16: Seed Samples analysed for protein concentration

(a) Abelmoschus esculentus , (b) Carica papaya, (c)Zea mays, (d) Phaseolus vulgaris, (e) Moringa oleifera, (f) Coccinia grandis

Figure 17: Seed samples after centrifugation

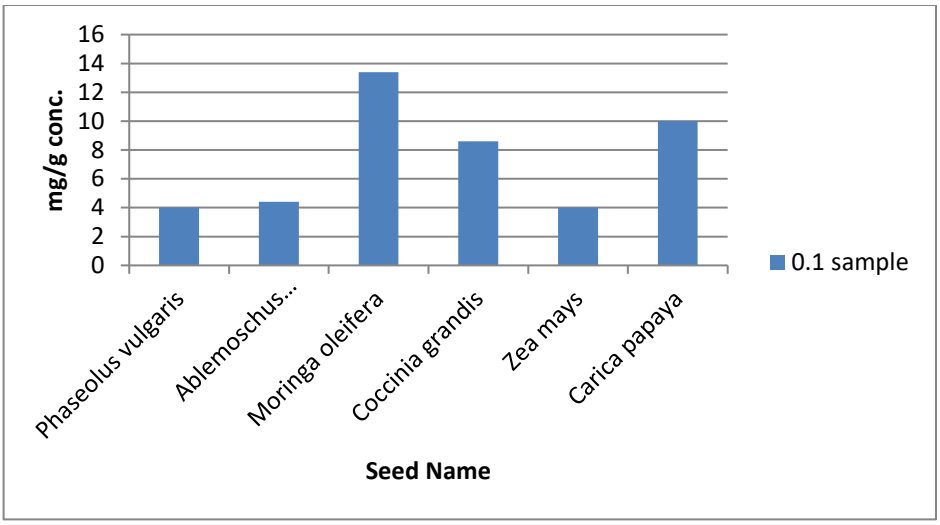


Figure 18: Concentration of protein in various natural coagulants

6.0- Turbid water treatment with aluminium sulphate (Alum)

Table 8: Optimization of aluminium sulphate dosages on different turbidity

Type of Turbidity (NTU)	Alum concentration (g/l)	Turbidity (NTU) Initial	Final	Settling Time (Minutes)	Turbidity Removal (%)	pH Initial	Final
Low (20 NTU)	0.7	20	000	30	100	7	7
Medium (40 NTU)	1.4	40	000	30	100	7	7
High (80 NTU)	1.6	80	000	30	100	7	7

Figure 19: Alum suspension

Coagulation & Flocculation

Treated turbid water

Figure 20: Synthetic samples (alum) with various turbidities

Figure 21: Seeds Powder

Figure 22: Soil sample

Figure 23: Flocculation-Coagulation with Seeds Powder and Filtration of the Sample

Table 9 : Standard graph readings for turbidity

S.No	Concentration (NTU)	Turbidity meter reading
1	20	61
2	40	133
3	60	200
4	80	285
5	100	372

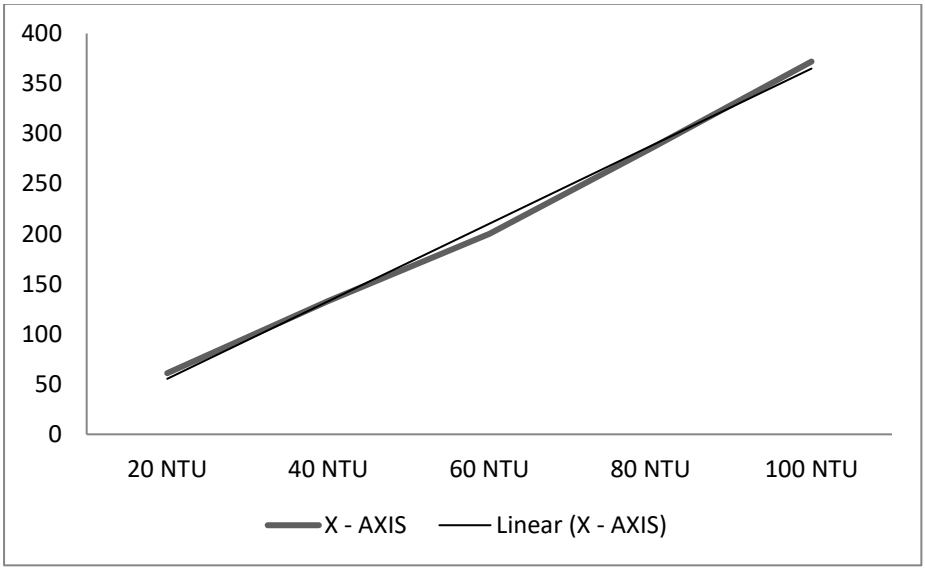


Figure 24 : Standard graph for turbidity

7.0 Dual turbid water treatment with natural coagulants and solar disinfection for various seasons (summer and rainy)

7.1- Abelmoschous esculentum

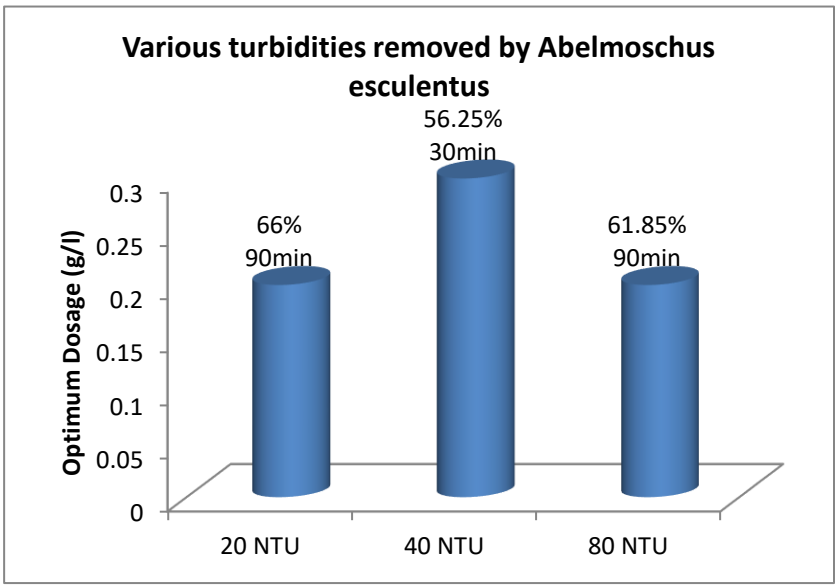


Figure 25 – Turbidity removed by Abelmoschous esculentum- Summer Season

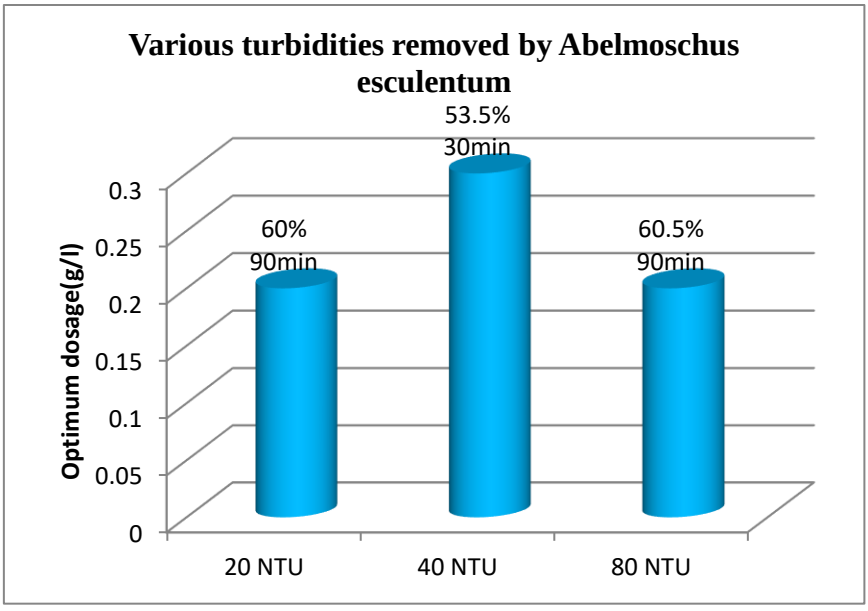
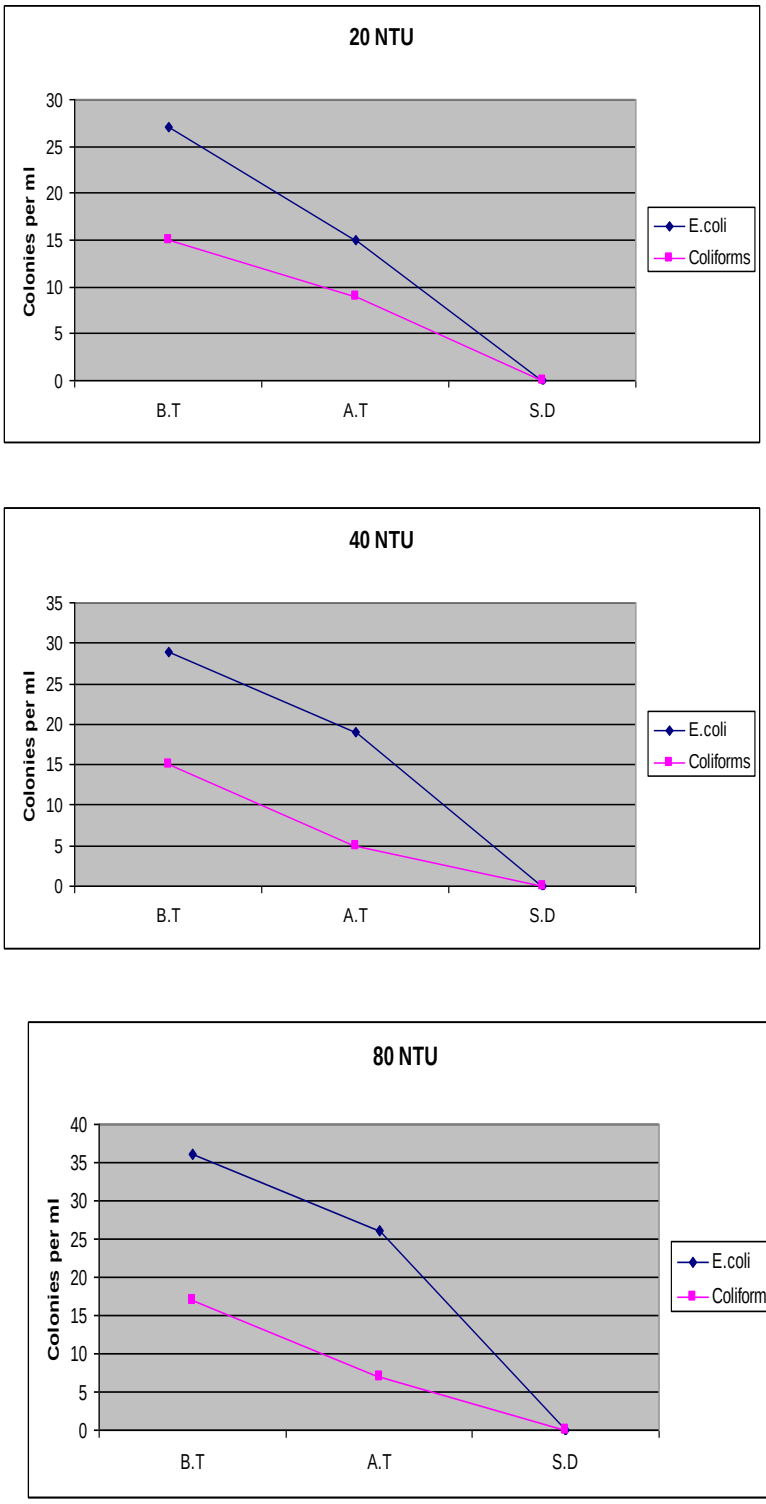


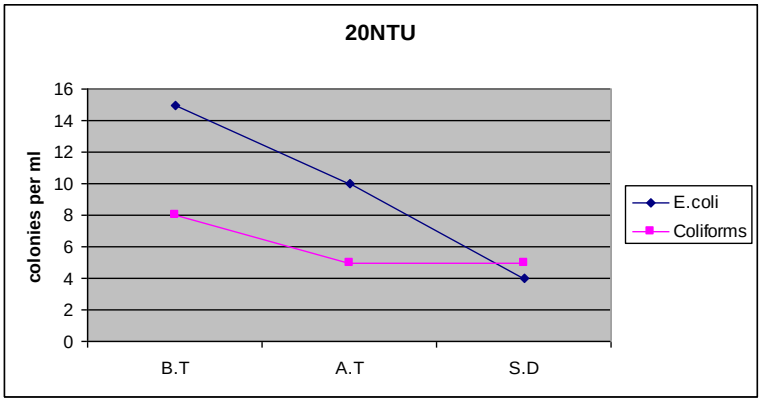
Figure 26 – Turbidity removed by Abelmoschous esculentum- Rainy Season

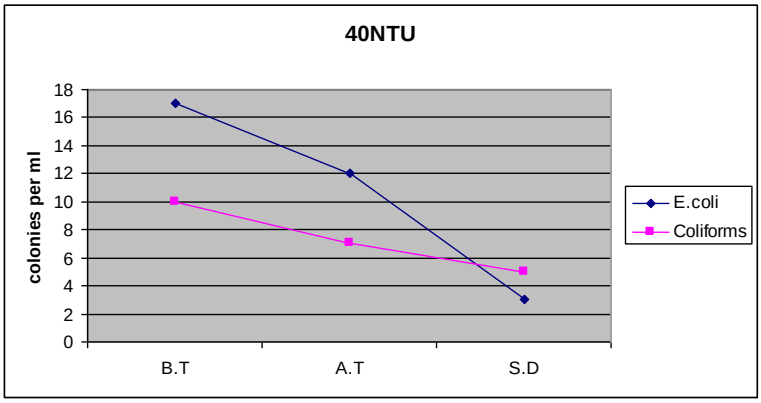
Figure 27- Bacterial inactivation by Abelmoschous esculentum at different turbidity levels - Summer Season

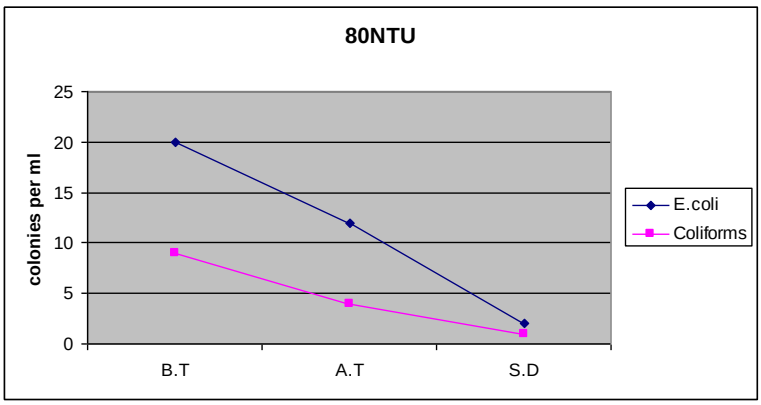


BT=before treatment, AT= after treatment with natural coagulants SD=solar disinfection

Figure 28- Bacterial inactivation by Abelmoschous esculentum at different turbidity levels - Rainy Season







7.2 Carica papaya

Table 10: Treatment with Carica papaya for synthetic sample

S.No	Treatment Time (minutes)	Papaya Seeds Quantity (gm)	NTU		TDS		pH	
			Before Treatment	After Treatment	Before Treatment	After Treatment	Before Treatment	After Treatment
1	30	0.2	20	0	45	74	5	6
2	30	0.2	40	0	83	103	6	6
3	30	0.2	60	0	139	164	6	6
4	30	0.4	20	0	45	70	5	7
5	30	0.4	40	0	83	107	6	7
6	30	0.4	60	0	139	185	6	7
7	30	0.6	20	0	45	100	5	6
8	30	0.6	40	0	83	152	6	6
9	30	0.6	60	0	139	185	6	6

Table 11: Treatment with Carica papaya for soil sample

S.No	Treatment Time (minutes)	Papaya Seeds Quantity (gm)	NTU		TDS		pH	
			Before Treatment	After Treatment	Before Treatment	After Treatment	Before Treatment	After Treatment
1	30	0.2	20	0	318	336	6	7
2	30	0.2	40	0	492	469	7	7
3	30	0.2	60	0	477	434	7	7
4	30	0.4	20	0	318	333	6	7
5	30	0.4	40	0	492	349	7	7
6	30	0.4	60	0	477	472	7	7
7	30	0.6	20	0	318	343	6	7
8	30	0.6	40	0	492	479	7	7
9	30	0.6	60	0	477	492	7	7

7.3 Coccinia grandis

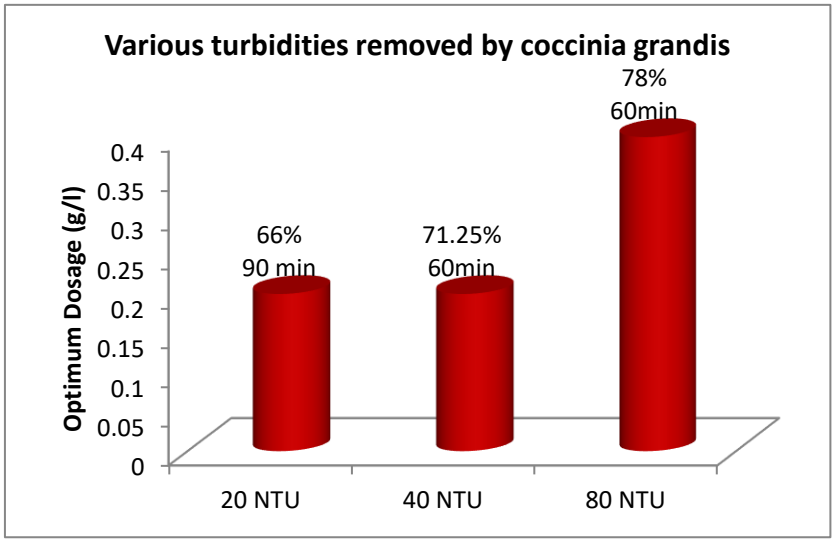


Figure 29 - Turbidity removal by Coccinia grandis - Summer Season

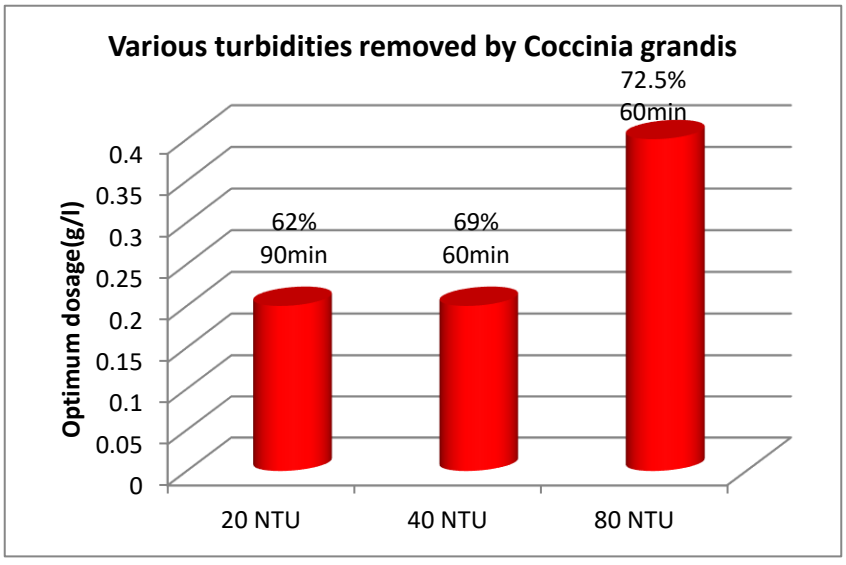
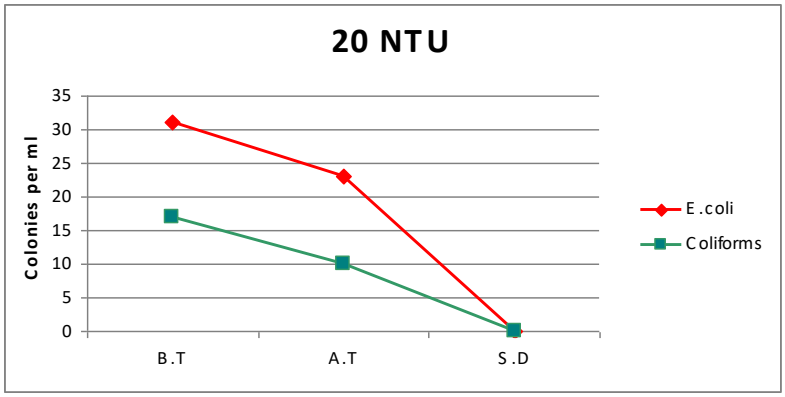
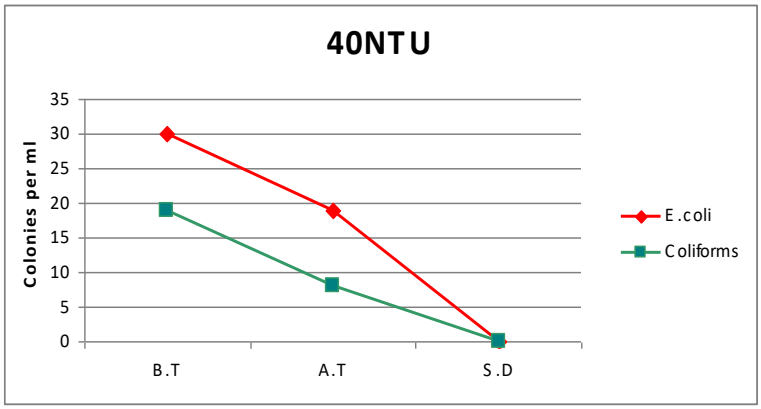
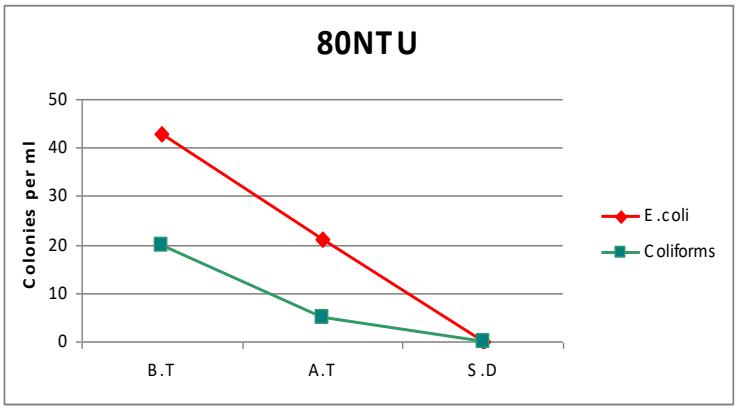


Figure 30 - Turbidity removal by Coccinia grandis - Rainy Season

Figure 31- Bacterial inactivation by Coccinia grandis at different turbidity levels - Summer Season

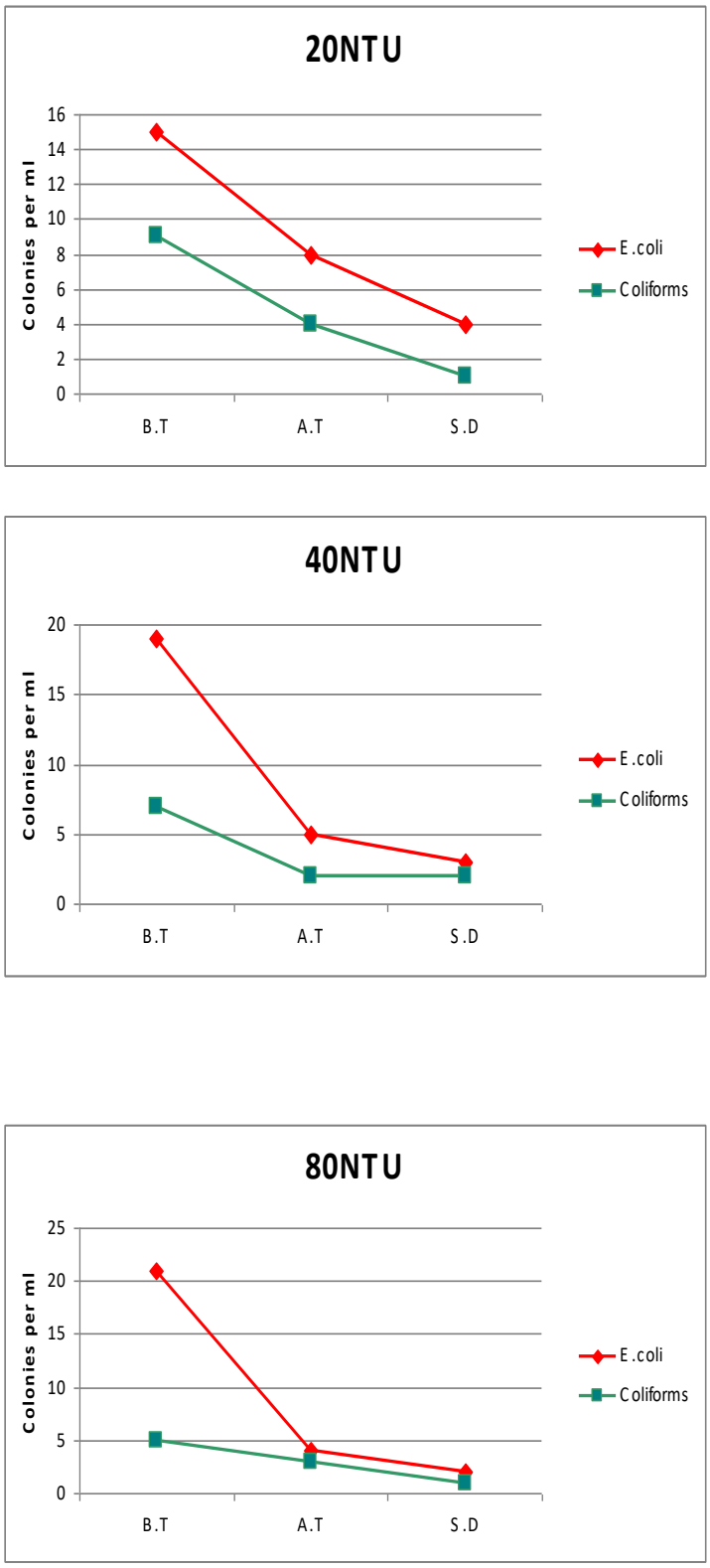






BT=before treatment, AT= after treatment with natural coagulants SD=solar disinfection

Figure 32 - Bacterial inactivation by Coccinia grandis at different turbidity levels - Rainy Season



7.4 - Moringa oleifera

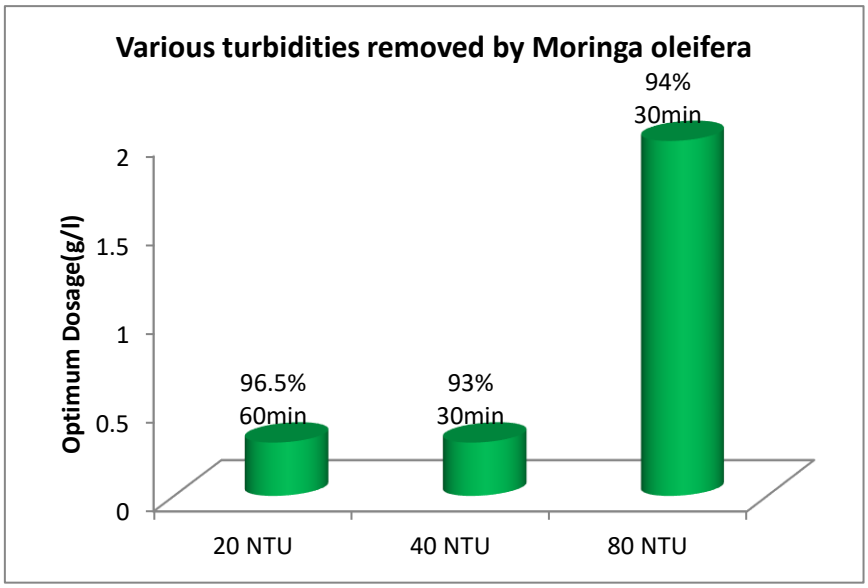


Figure 33- Turbidity removal by Moringa oleifera – Summer Season

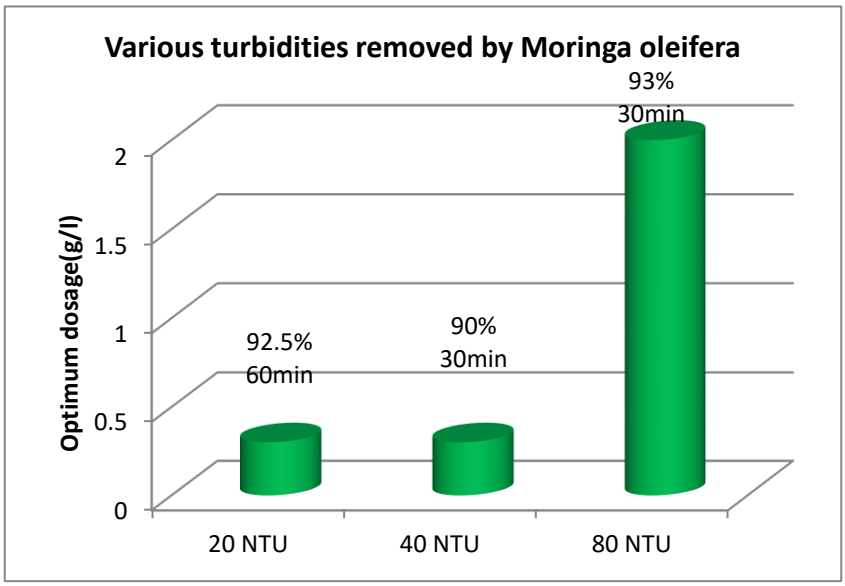
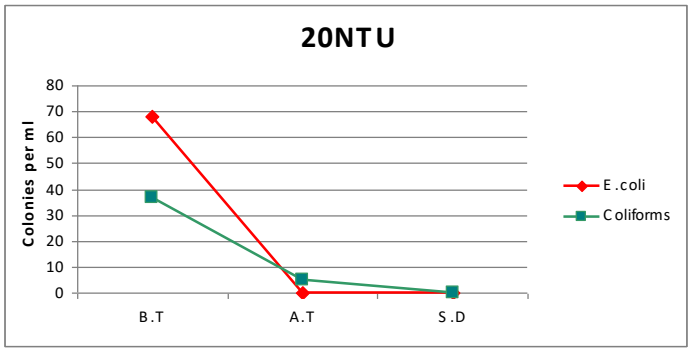
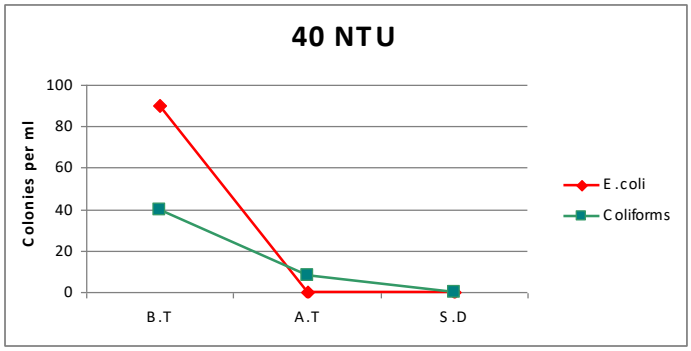
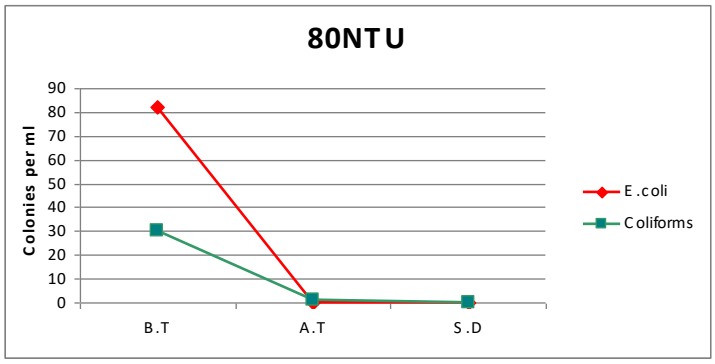


Figure 34: Turbidity removal by Moringa oleifera – Rainy Season

Figure 35 - Bacterial inactivation by Moringa oleifera at different turbidity levels - Summer Season

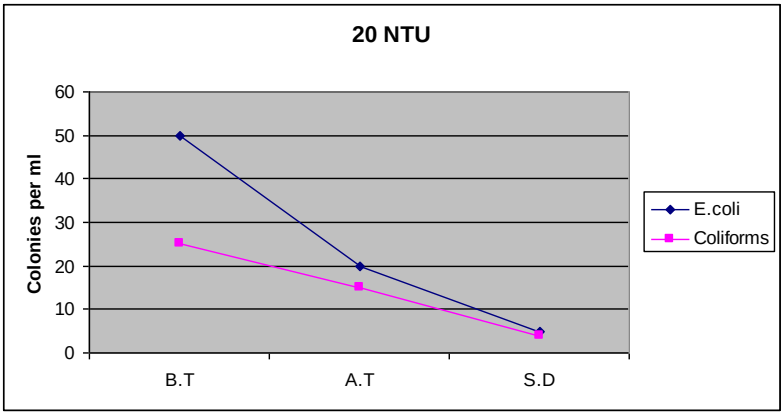


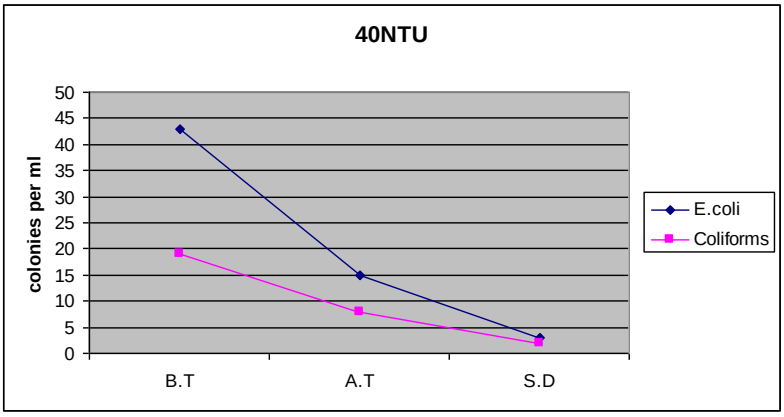


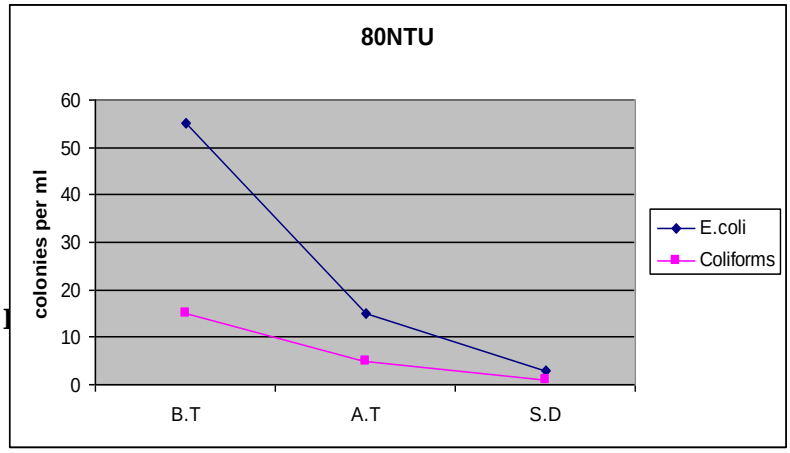


BT=before treatment, AT= after treatment with natural coagulants SD=solar disinfection

Figure 36 - Bacterial inactivation by Moringa oleifera at different turbidity levels - Rainy Season







7.5 Phaseolus vulgaris

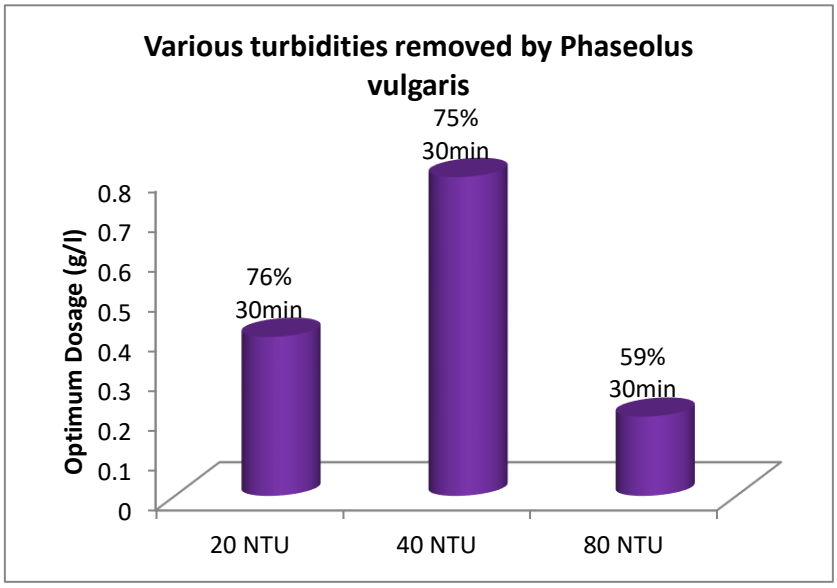


Figure 37– Turbidity removal by Phaseolus vulgaris - Summer Season

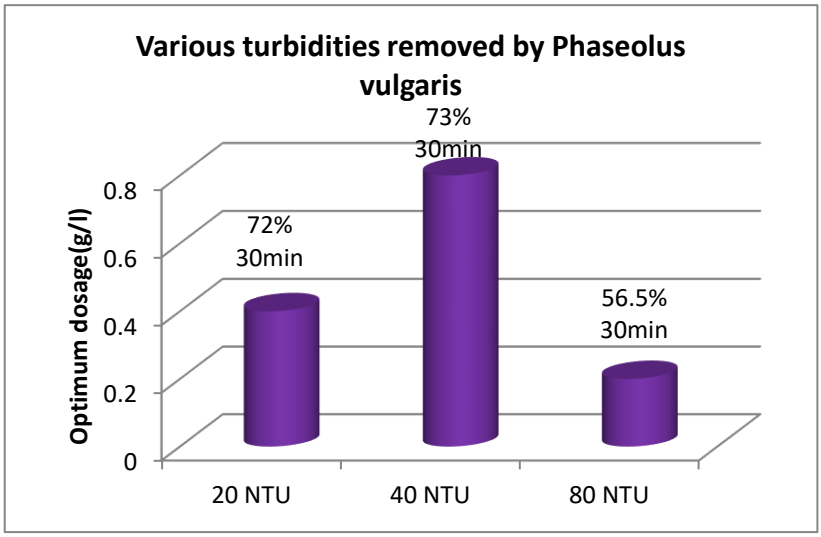
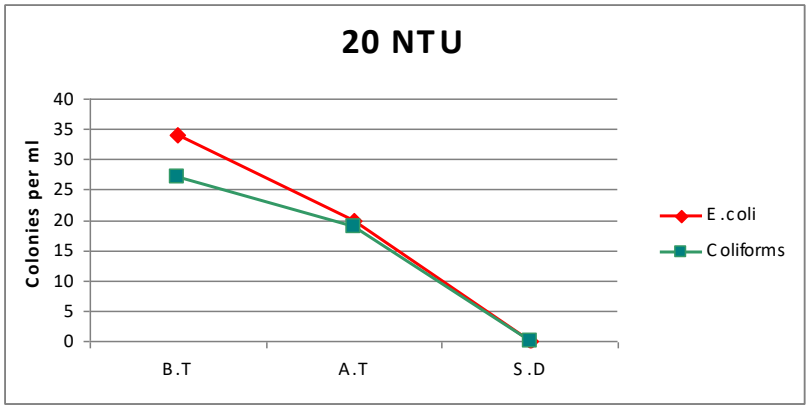
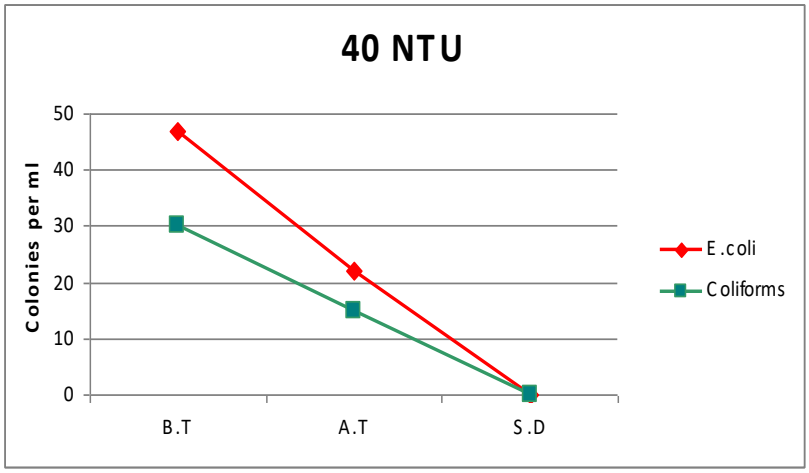
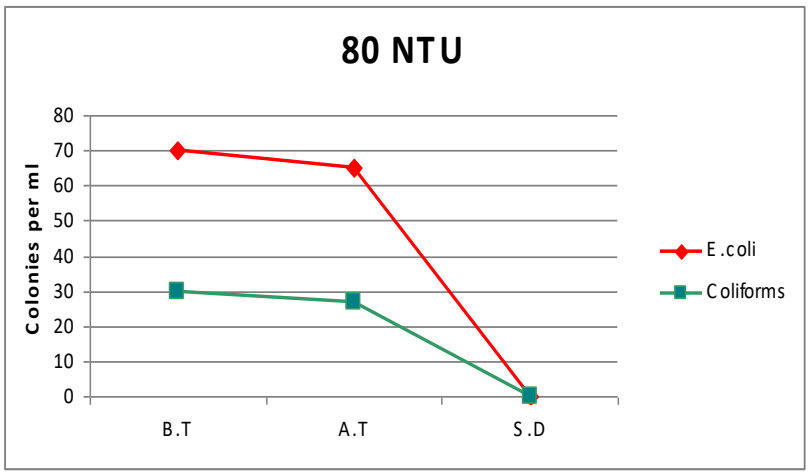


Figure 38 – Turbidity removal by Phaseolus vulgaris – Rainy Season

Figure 39 - Bacterial inactivation by Phaseolus vulgaris at different turbidity levels Summer Season

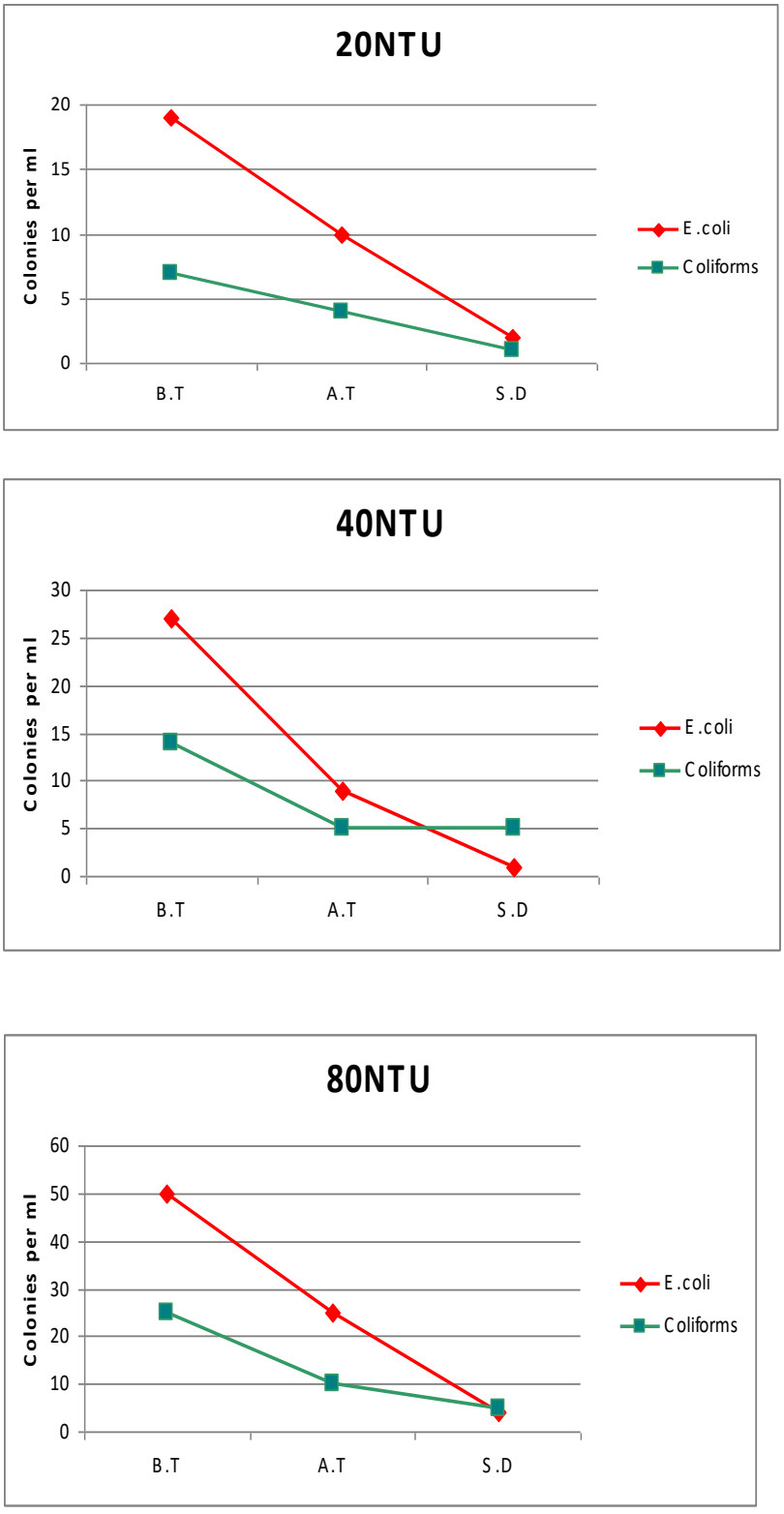






BT=before treatment, AT= after treatment with natural coagulants SD=solar disinfection

Figure 40- Bacterial inactivation by Phaseolus vulgaris at different turbidity levels - Rainy Season



7.6 Pysum sativum

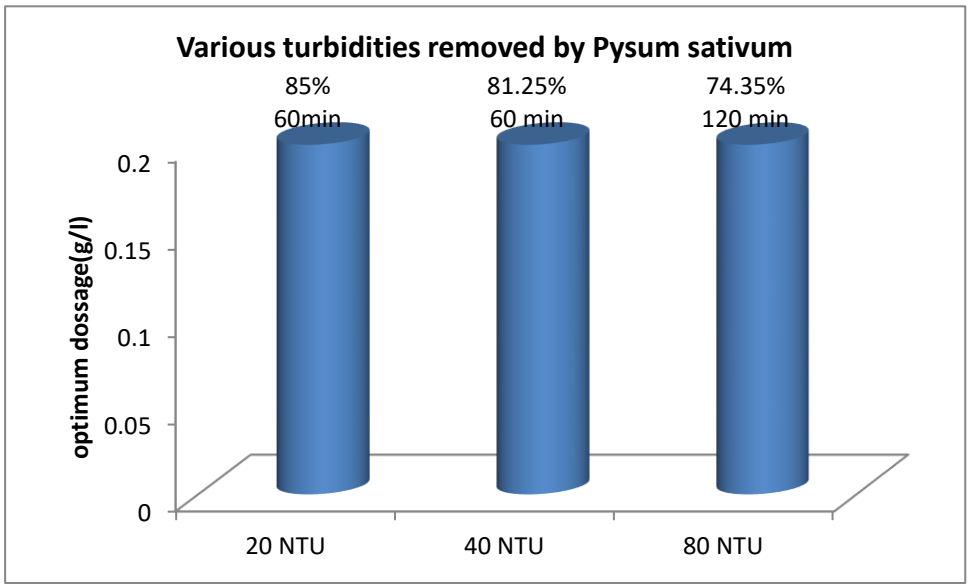


Figure 41– Turbidity removal by Pysum sativum - Summer Season

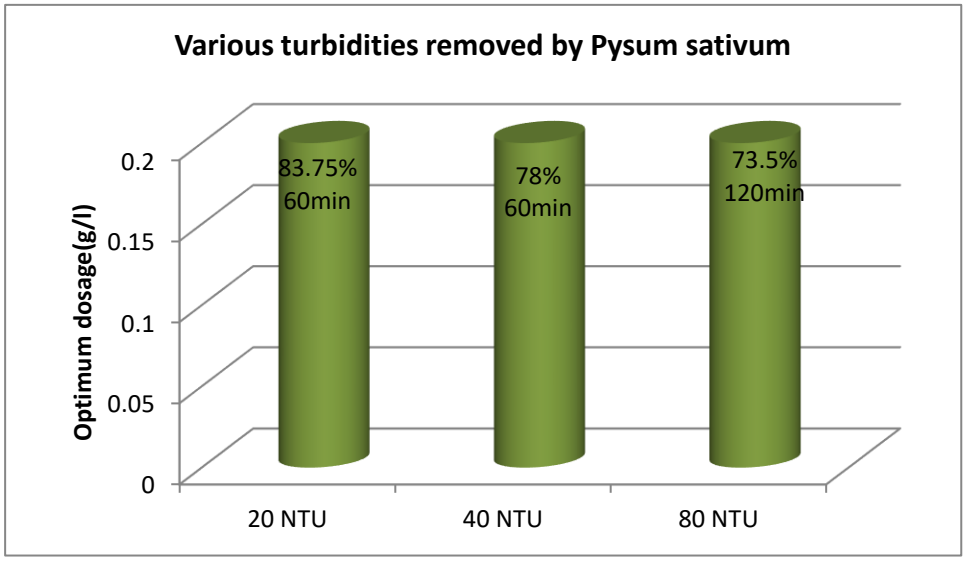
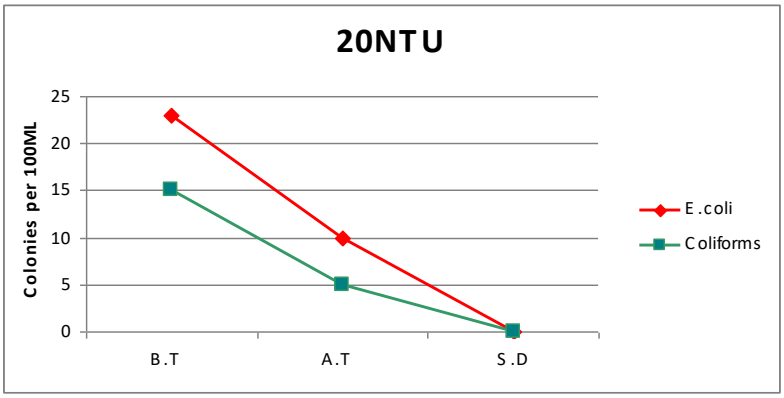
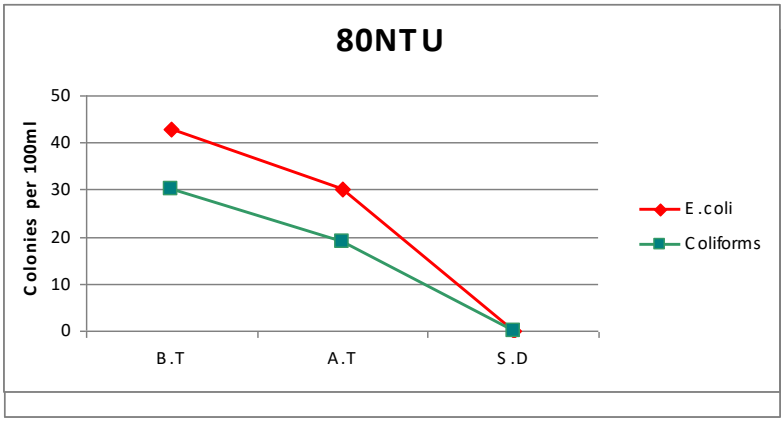


Figure 42 - Turbidity removal by Pysum sativum - Rainy Season

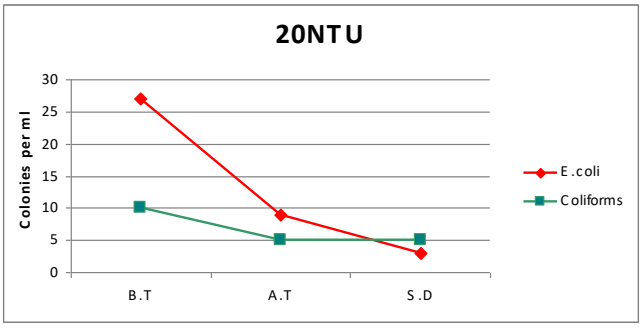
Figure 43- Bacterial inactivation by Pysum sativum at different turbidity levels - Summer Season

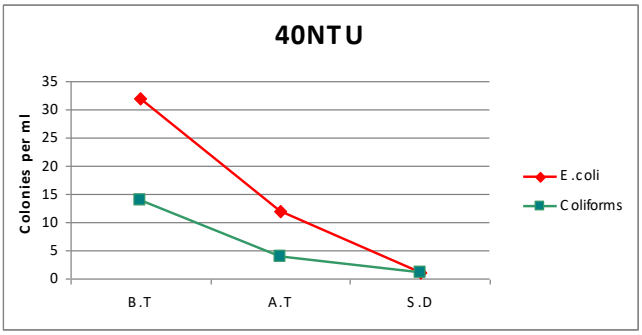


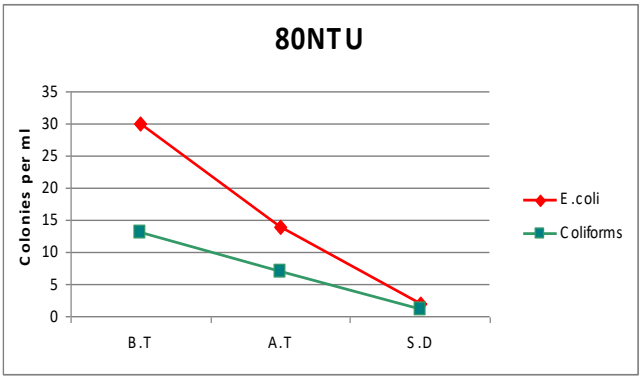


BT=before treatment, AT= after treatment with natural coagulants SD=solar disinfection

Figure 44- Bacterial inactivation by Pysum sativum at different turbidity levels Rainy Season







7.7 Strychnos potatorum

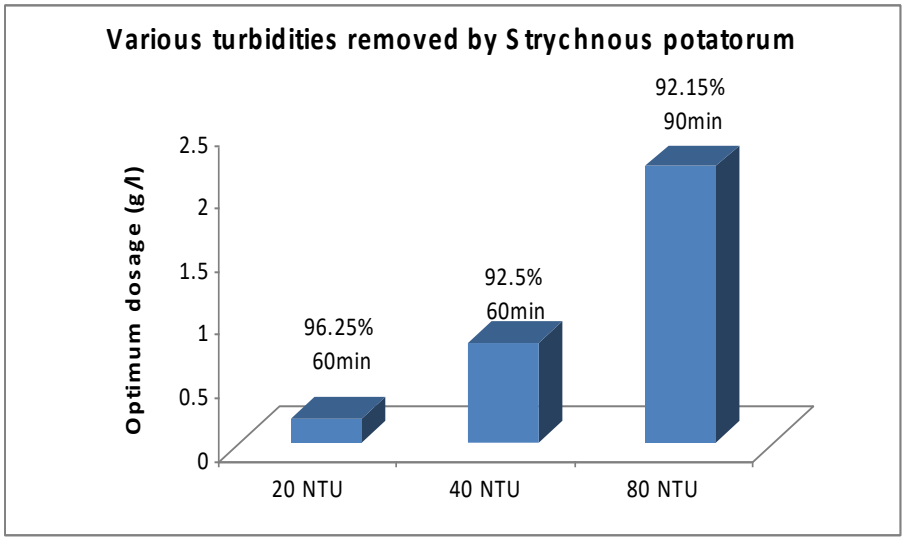


Figure 45 – Turbidity removal by Strychnos potatorum - Summer Season

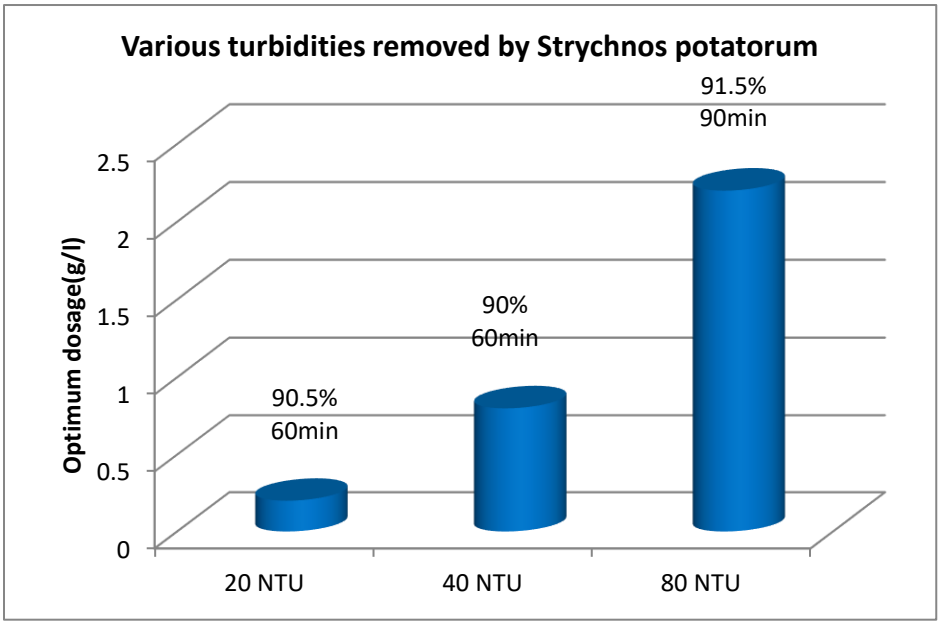
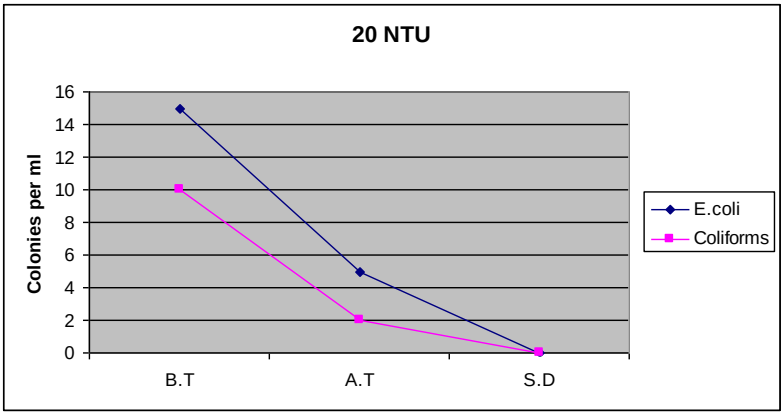
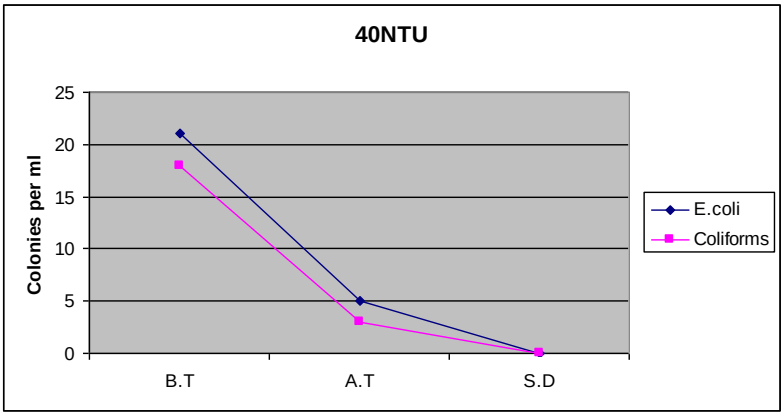
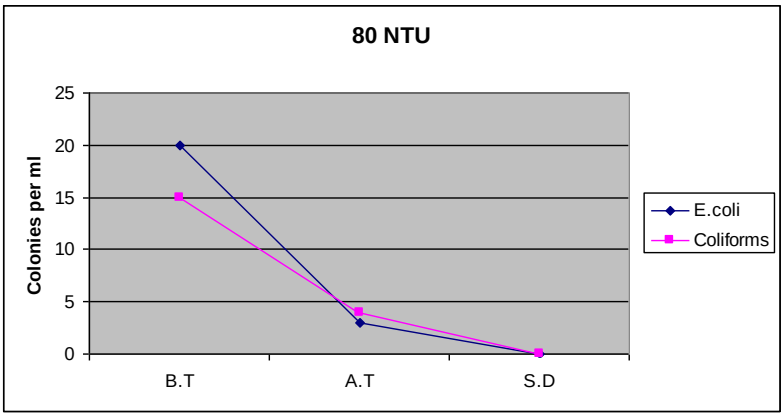


Figure 46 – Turbidity removal by Strychnos potatorum – Rainy Season

Figure 47- Bacterial inactivation by Strychnos potatorum at different turbidity levels – Summer Season

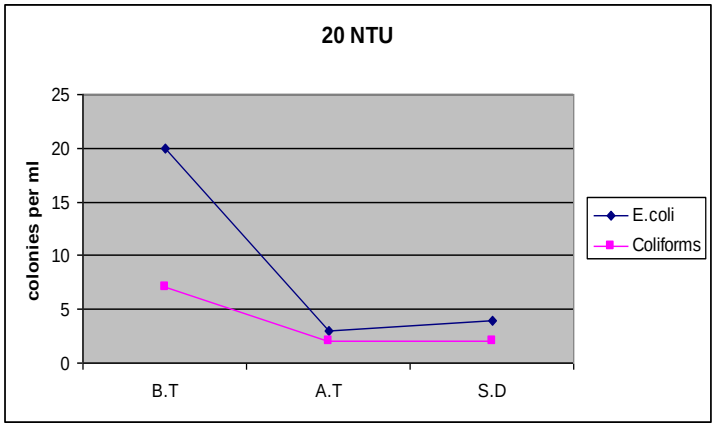


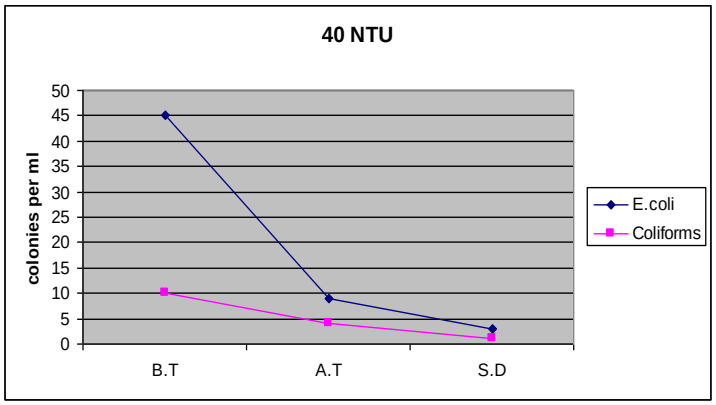


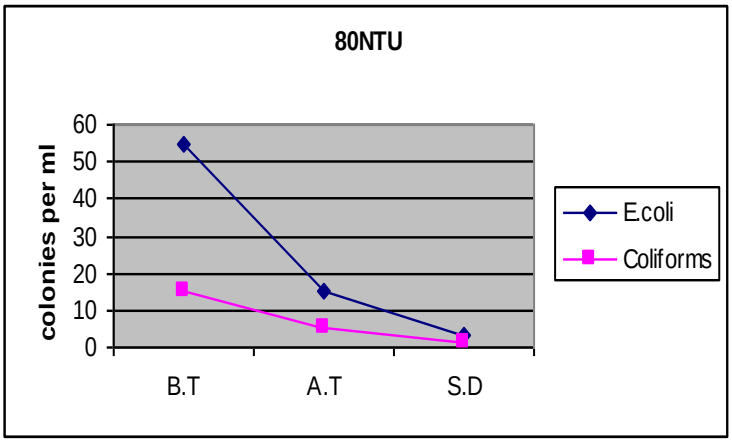


BT=before treatment, AT= after treatment with natural coagulants SD=solar disinfection

Figure 48- Bacterial inactivation by Strychnos potatorum at different turbidity levels – Rainy Season







7.8 Zee Mays

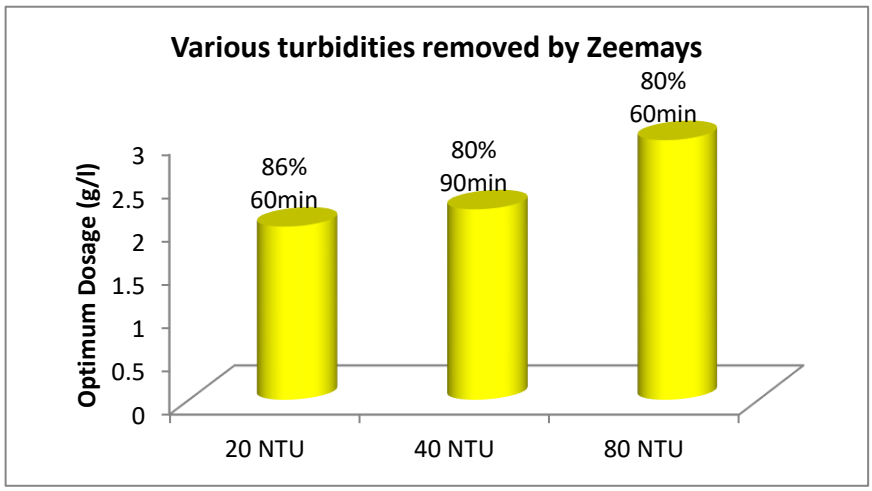


Figure 49- Turbidity removal by Zee Mays - Summer Season

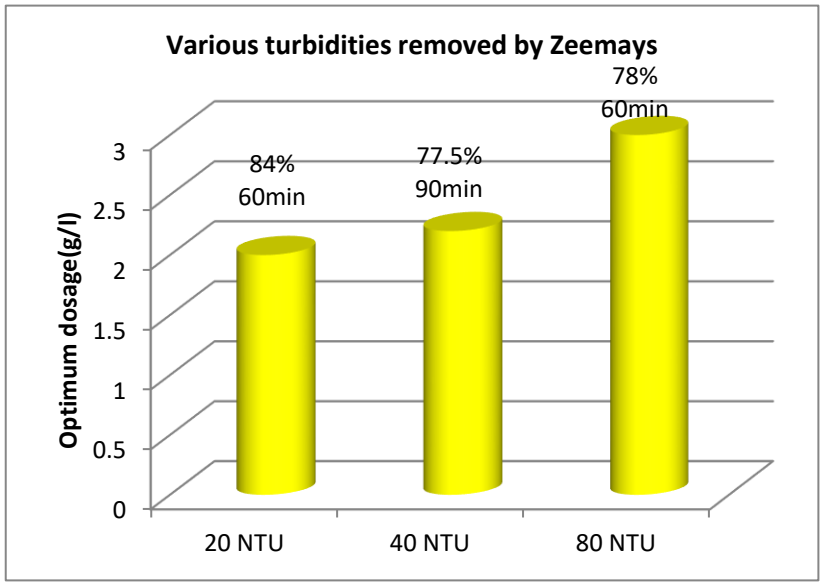
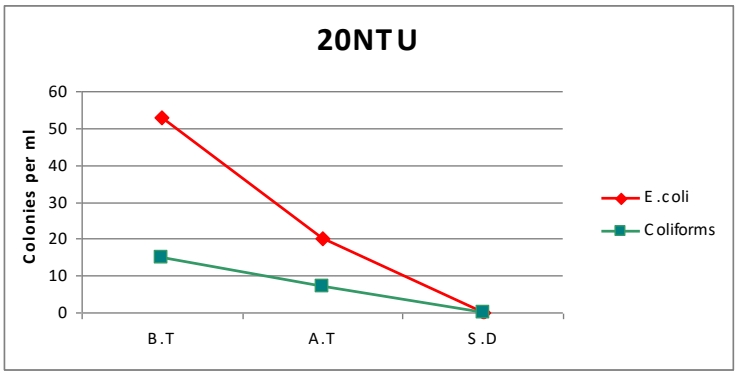
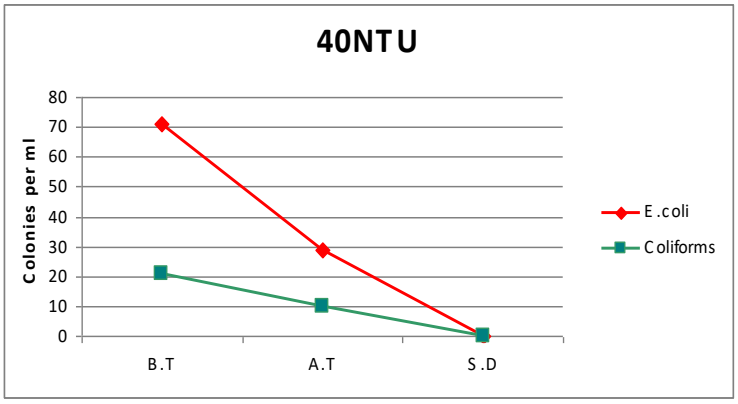


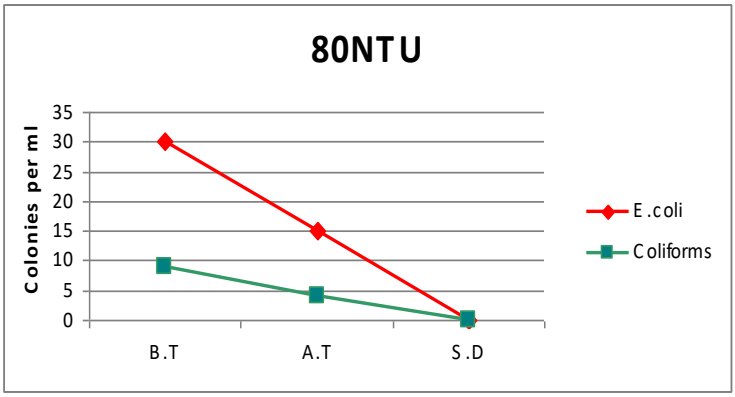
Figure 50- Turbidity removal by Zee Mays - Rainy Season

Figure 51- Bacterial inactivation by Zee mays at different turbidity levels

- Summer Season

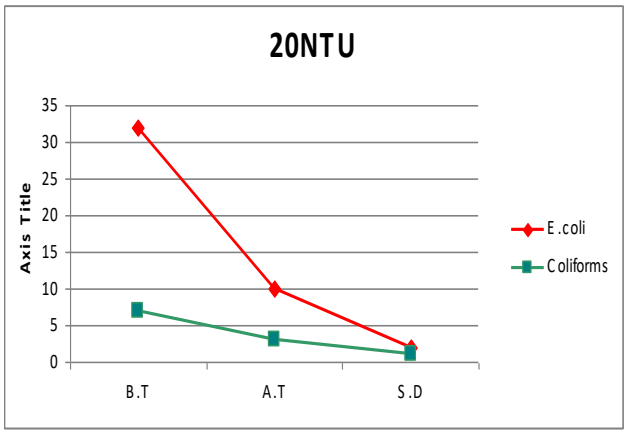


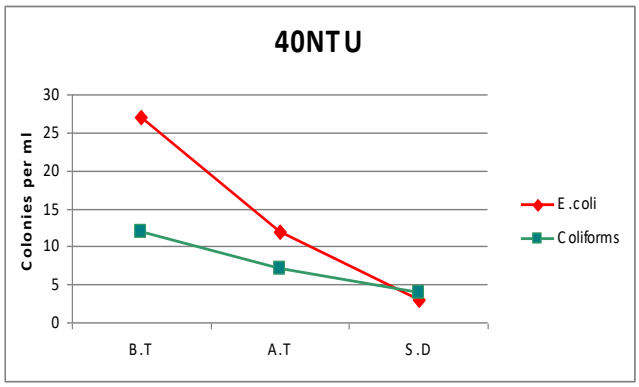


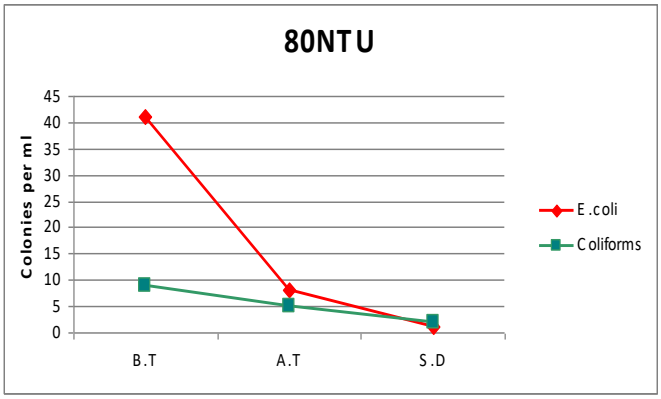


BT=before treatment, AT= after treatment with natural coagulants SD=solar disinfection

Figure 52 - Bacterial inactivation by Zee mays at different turbidity levels - Rainy Season



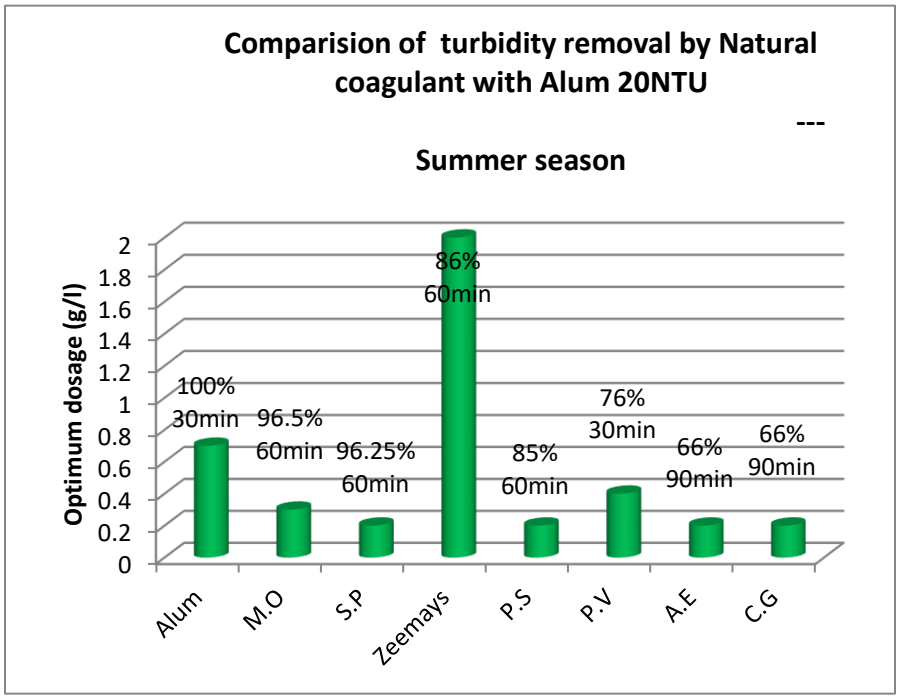


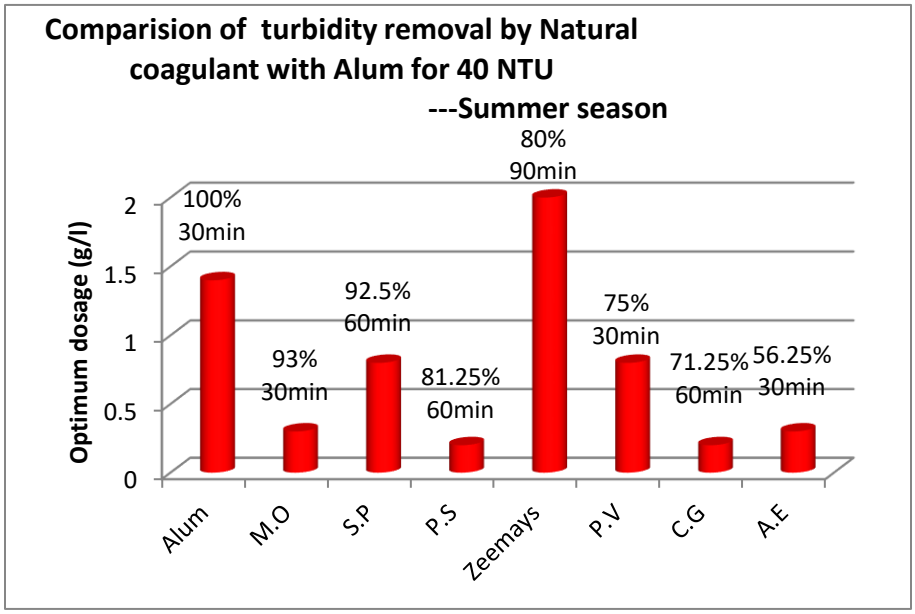


8.0 - Comparison of turbidity removal with alum and natural coagulants

Figure 53 - Comparison of turbidity removal for various NTU'S with Alum and Natural Coagulants for Summer Season

(Note: Carica papaya has shown "Zero" total removal of turbidity and total deactivation of coliforms when compared to other seven seeds mentioned in the graph)





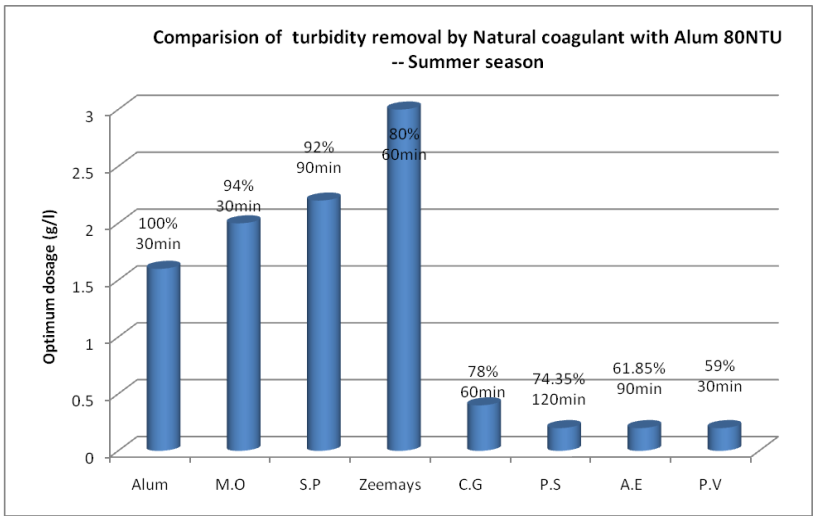
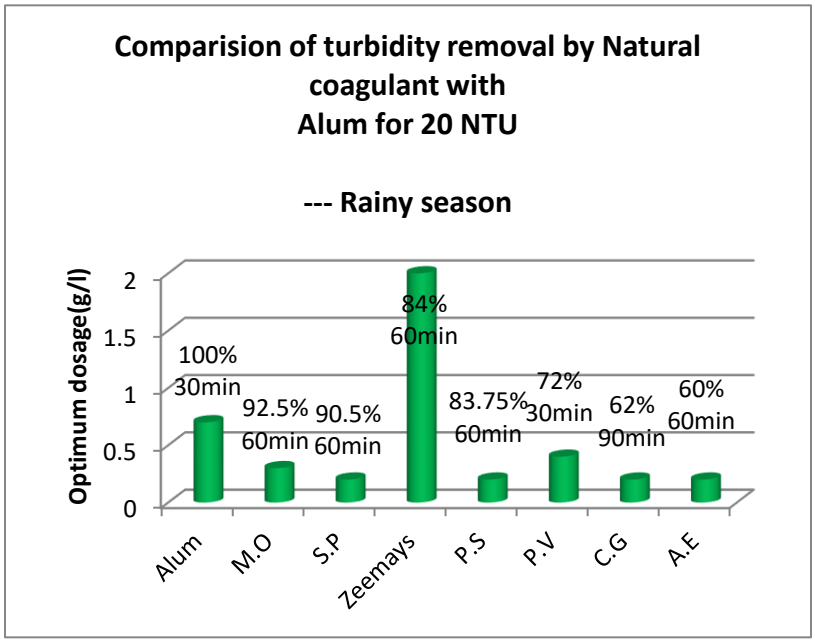
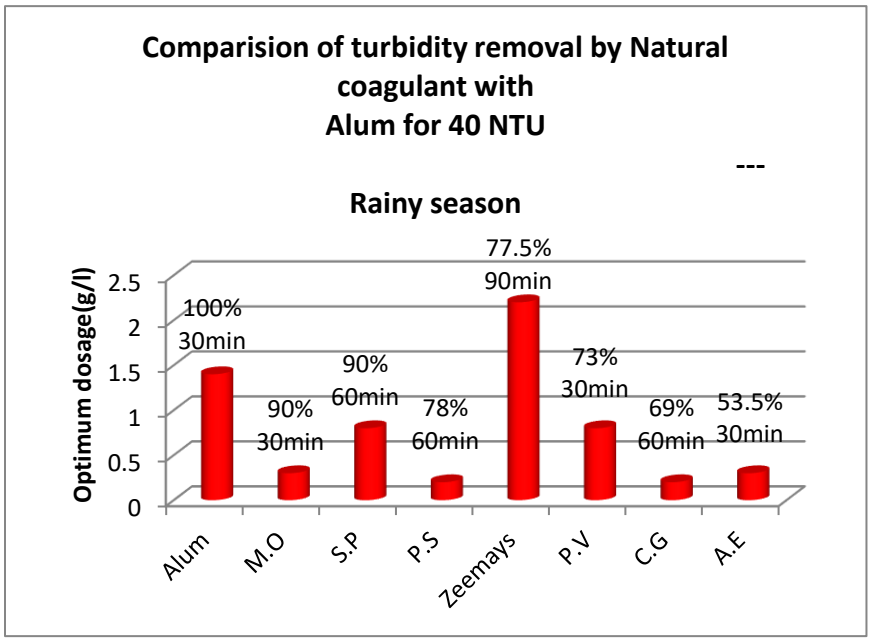
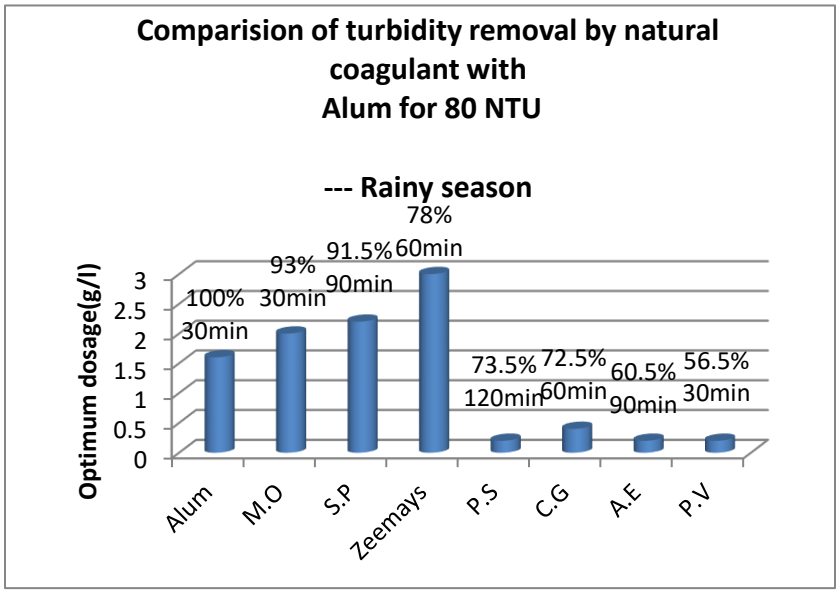


Figure 54- Comparison of turbidity removal for various NTU'S with Alum and Natural Coagulants For Rainy Season



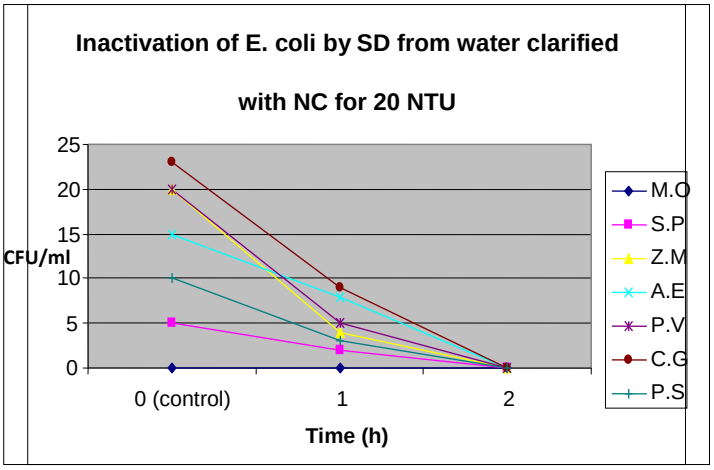

Comparision of turbidity removal by Natural coagulant with Alum for 40 NTU

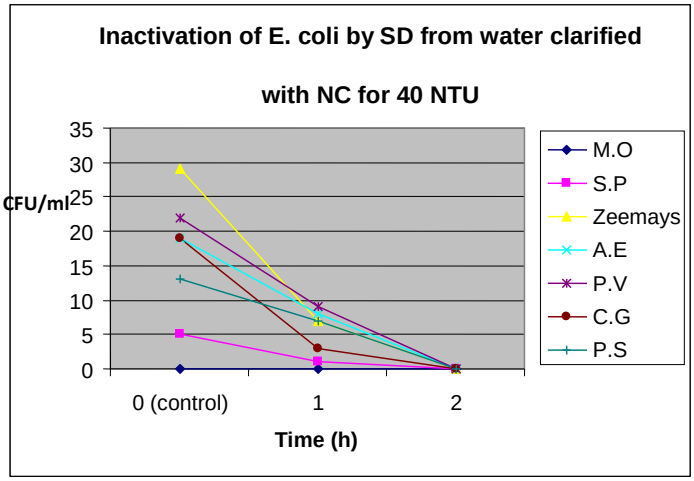
Rainy season
Optimum dosage(g/l)
2.5
2
1.5
1
0.5
0
100% 30min
90% 30min
90% 60min
78% 60min
77.5% 90min
73% 30min
69% 60min
53.5% 30min
Alum
M.O
S.P
P.S
Zeemays
P.V
C.G
A.E


Comparision of turbidity removal by natural coagulant with Alum for 80 NTU
--- Rainy season
Optimum dosage(g/l)
3
2.5
2
1.5
1
0.5
0
100% 30min
93% 30min
91.5% 90min
78% 60min
73.5% 120min
72.5% 60min
60.5% 90min
56.5% 30min
Alum
M.O
S.P
Zeemays
P.S
C.G
A.E
P.V

8.1 -Comparison of deactivation of E-coli and Coliforms with combined treatment with natural coagulants and solar disinfection

Figure 55- Comparison of Deactivation of E.coli with Combined treatment with Natural coagulants and Solar Disinfection for various NTU'S for Summer Season





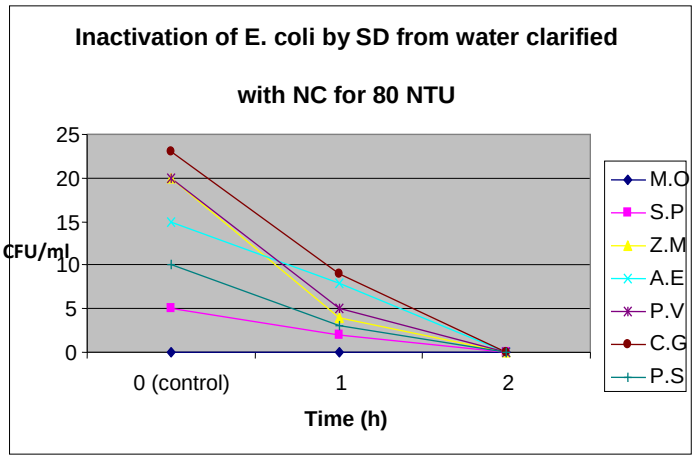
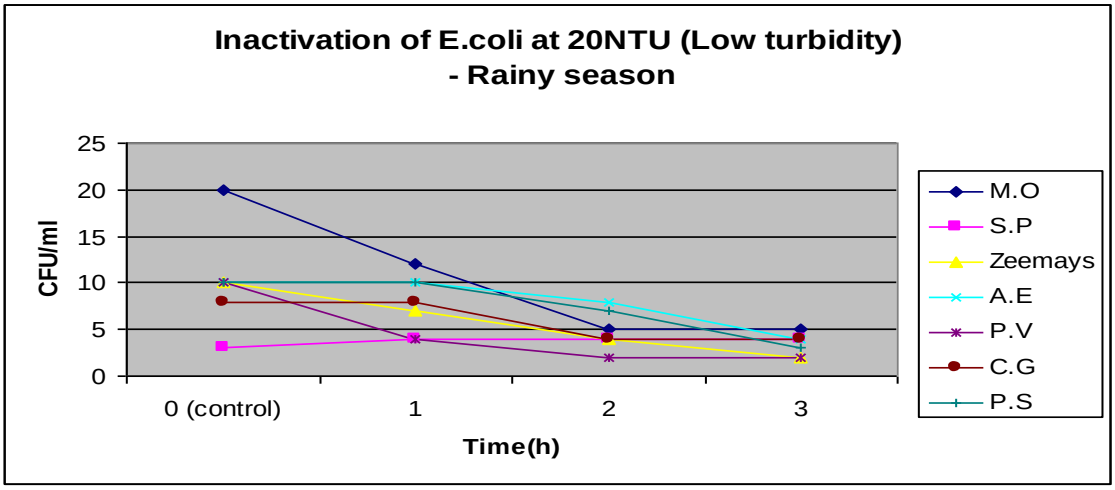
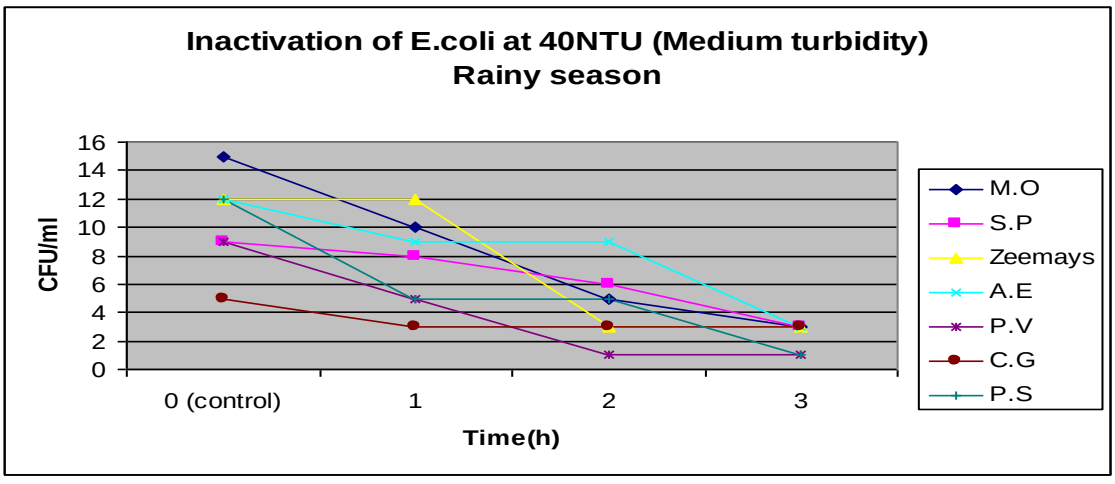


Figure 56- Comparison of Deactivation of E.coli with Combined treatment with Natural coagulants and Solar Disinfection for various NTU'S for Rainy Season





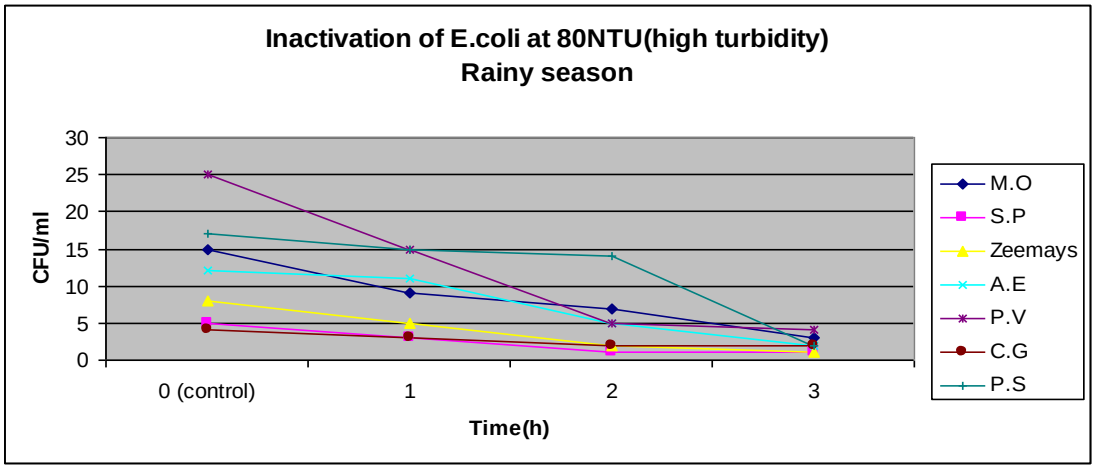
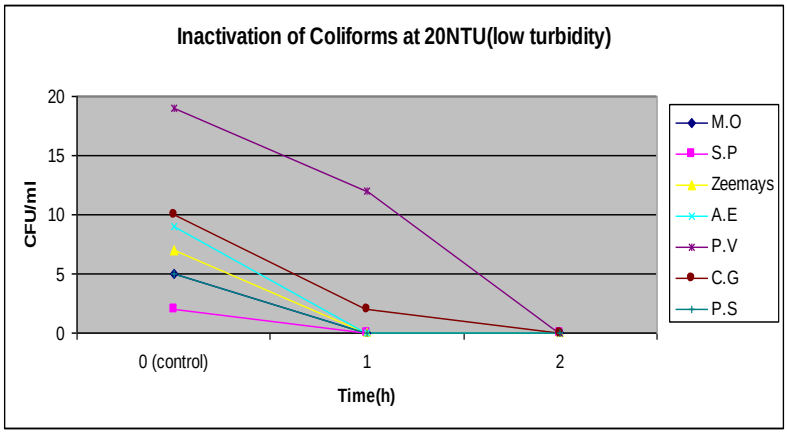
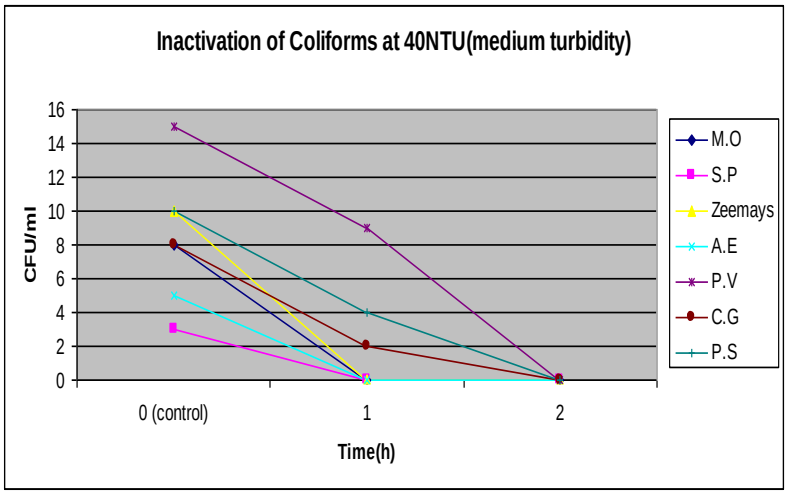


Figure 57-Comparison of Deactivation of Coliforms with Combined treatment with Natural coagulants and Solar Disinfection for various NTU'S for summer season





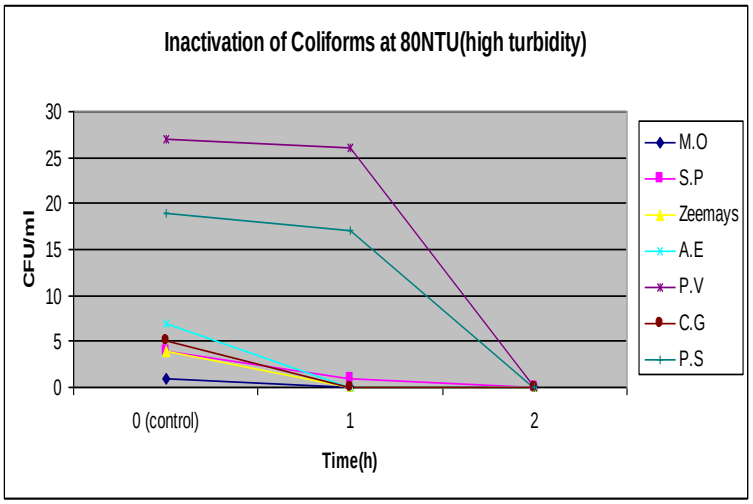
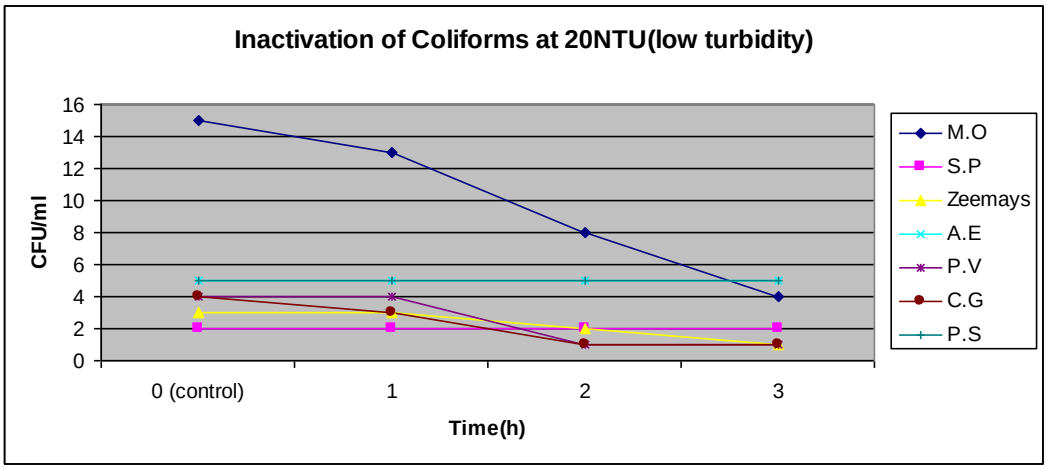
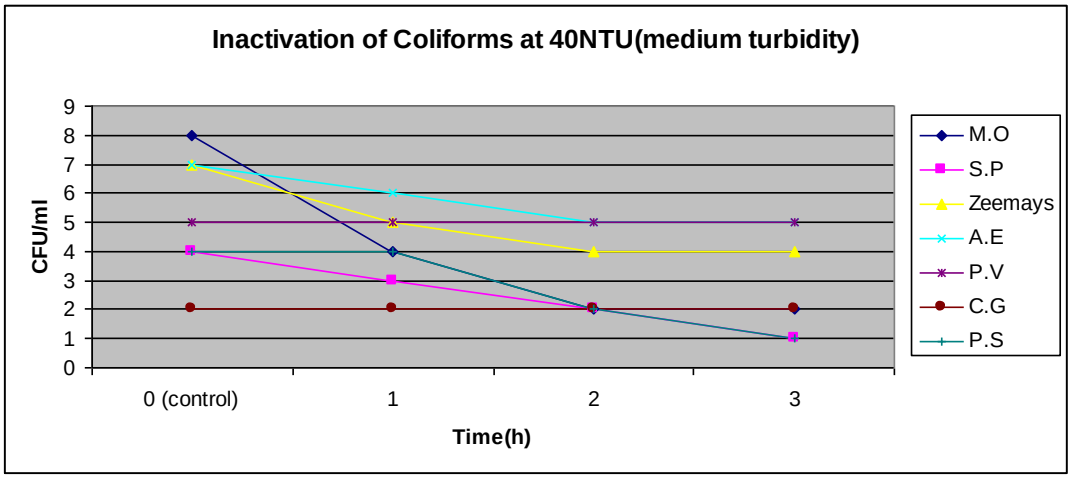
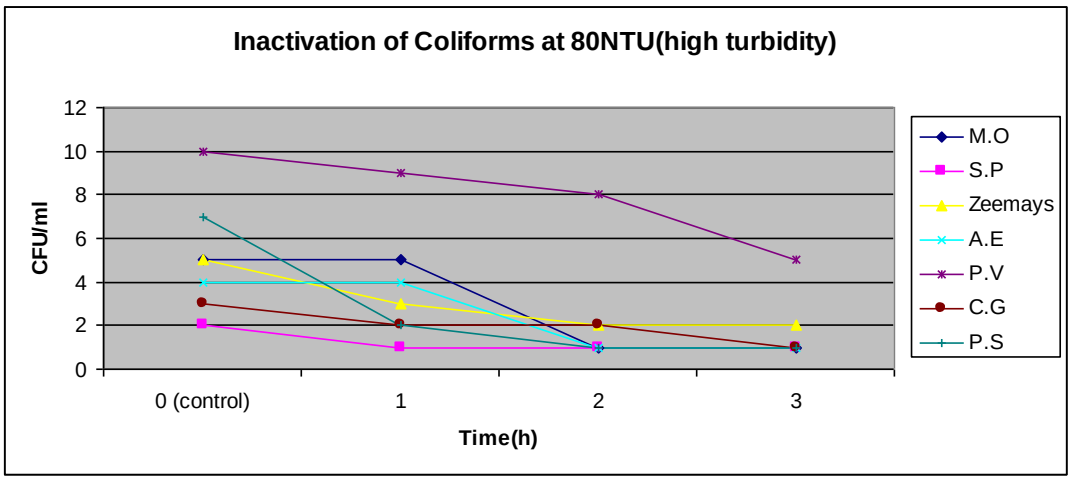


Figure 58 -Comparison of Deactivation of Coliforms with Combined treatment with Natural coagulants and Solar Disinfection for various NTU'S for Rainy season


Inactivation of Coliforms at 20NTU(low turbidity)
CFU/ml
16
14
12
10
8
6
4
2
0
0 (control)
1
2
3
Time(h)
M.O
S.P
Zeemays
A.E
P.V
C.G
P.S


Inactivation of Coliforms at 40NTU(medium turbidity)
CFU/ml
9
8
7
6
5
4
3
2
1
0
0 (control)
1
2
3
Time(h)
M.O
S.P
Zeemays
A.E
P.V
C.G
P.S


Inactivation of Coliforms at 80NTU(high turbidity)
CFU/ml
12
10
8
6
4
2
0
0 (control)
1
2
3
Time(h)
M.O
S.P
Zeemays
A.E
P.V
C.G
P.S

9.0 -Scientific Description of the Product/Process, give Specifications/Standards for the same - (Annexure -2)

Table 12 : Design of 100 litre treatment unit for treating turbid surface water

S.No	Coagulant name	Dosage (gms)	Settling time (mins)	Initial NTU	Final NTU	Turbidity removal	Cost (Rs/Ps)
1	Carica Papaya	1.0	60	80	0	100%	0.30
2	Moringa oleifera	1.0	60	80	8	90%	3.50
3	Zee mays	1.0	60	80	4	95%	0.50
4	Phaseolus Vulgaris	1.0	60	80	9	89%	0.25
5	Pysum sativum	1.0	60	80	9	89%	0.01
6	Abelmoschous Esculentum	1.0	60	80	9	89%	0.25
7	Coccinia grandis	1.0	60	80	5	94%	0.008
8	Strychnos potatorum	1.0	60	80	0	100%	0.50

Note : According to WHO standard the turbidity of water should be 5.0 NTU

10.0- Solar disinfection treatment for 100 L unit

Solar disinfection for treated alum water

After treating the water sample with the Alum, the treated water was kept for solar disinfection for 3 hrs along with control. The microbial tests were done before and after the treatment. The results of the microbial analysis are: before treatment the microbial colonies in the water sample were too many to count and after treatment with alum there are two coli form colonies and it was observed that there were no colonies present after 1hr of solar disinfection when compared to control.

- Clarified turbid water with natural coagulants can be exposed to solar disinfection for 3 hrs in between 42 to 48 ^{0}C in summer season for treatment of 100 L turbid surface water.
- Clarified turbid water with natural coagulants can be exposed to solar disinfection for 5 - 8 hrs for 2 days in rainy season for treating of 100 L turbid surface water.

11.0 Discussion

Using natural materials to clarify water is a technique that has been practiced for centuries and the seed materials used have been found to be effective. From the present research we have design 100 litre turbid water treatment unit for surface water having various turbidity shown in Table 4. Solutions of all the eight agro based seeds – Carica papaya, Moringa oleifera, Zee mays, Beans, Peas, Lady's finger, Coccinia grandis, Nirmali seeds for water treatment may be prepared from seeds. Solutions for treating water should be prepared fresh each time. All the eight agro based seeds are non-toxic and effective coagulant aids useful for removing turbidity and bacteria from water. The cost of solar disinfection is negligible as it is a natural source. The cost of seed treatment is very low, in some cases negligible. The seed treatment and solar disinfection does not remove 100% of water pathogens. It is acceptable for drinking only where people are currently drinking untreated and contaminated water.

The results of this study have shown that the seeds of eight natural plant species are powerful polyelectrolyte coagulant whether it is used as a primary or as a coagulant aid in

relation to alum. For raw water sample with turbidity of 20NTU, the analysis of the results show the **efficiencies** of the natural coagulants are in the order of:

20 NTU: CP>MO>SP>ZM>PS>PV>AE>CG;
40 NTU: CP>MO>SP>PS>ZM>PV>CG>AE;
80NTU: CP>MO>SP>ZM>CG>PV>PS>AE.
The **optimum dosage** of natural coagulant that was used in this phase is in the order of,
20 NTU: CP>ZM>PV>MO>CG>PS>AE>SP;
40NTU: CP>ZM>PV>ST>AE>MO>CG>PS;
80 NTU: CP>ZM>MO>ST>CG>PV>PS>AE

It is worth to say that the turbidity efficiency removal for these synthetic samples at 20 NTU, 40NTU and 80NTU were about 96.5 – 66%, 93- 56.25% and 94- 59% respectively. Carica papaya , Moringa oleifera and S.potatorum seeds resulted in producing treated water with turbidity less than 5 and remaining none of the seeds resulted in producing treated water with turbidity less than 5 NTU as per WHO guidelines. Therefore either they can be used as primary coagulant (or) coagulant aid in relation to alum. pH was retained at 7.0 before and after treatment with natural coagulant and alum. Initial alkalinity was found to be 100-250 mg/l. These coagulants are from agro based seeds if when mixed with the water does not release any constituents that are harmful to health and no objectionable taste and odour nor increase in the concentration of TDS was observed.

Water clarified with natural coagulant were immediately exposed to solar disinfection for 5 hours (11 am to 4 pm), the microbial load was reduced drastically which shows no colonies in the plates where the UV rays had inactivated the E.coli. For the present experiments the normal plastic bottles with 0.1 percent UV transmittance (at the wavelength of 254 nm) had been used. The average temperature was 28^0C at the beginning of the experiments, and also the average water temperature was obtained to be 39, 40 and 41 and 55 ^{0}C after 1-5 hour's radiation time, respectively. Solar disinfection efficiency of E.coli reduction was determined to be 100 percent for all types of turbidity at 2 hour radiation time, respectively. The present study shows that turbidity removed by natural coagulant at first stage of purification has increased the solar disinfection efficiency, and, in fact, it reduces the microbial inactivation compared to individual treatment.

The treatment of water with the common inorganic coagulants have a number of disadvantages such as cost of chemicals (especially for developing nations), concern for human health, sludge management among others. However there are constraints encountered in the use of chemical coagulants, such as scarcity of foreign currency for importation and inadequate supply of chemicals (WHO 2005). Although aluminium is the most commonly used coagulant in the developing countries, studies have linked it to the development of neurological diseases (e.g. pre-senile dementia or Alzheimer's disease) due to the presence of aluminium ions in the drinking water. More so, large non- biodegradable sludge volumes are produced containing residual aluminium sulphate needing treatment facilities to prevent further contamination into the environment (Lye 2002).

Moreover, researchers observed that the coagulation protein inhibits the growth of enteric and non- enteric bacterial strains. Such dual role of purified proteins in clarification and antimicrobial potential renders this simplified method of extraction and purification of coagulating proteins proper for poor countries where they cannot afford the costly conventional methods for protein purification (Sobsey 2006). Investigated the potential of plant seeds and roots on removal of turbidity and compared it with alum. The researcher used clean water to extract the coagulating agent from seed powder and roots analogous to what is done traditionally by women. It was observed that in terms of turbidity removal, the crude seed suspension compared well with that affected by alum with alum performing only 1% percent better than the natural coagulants. Moreover, they observed that the removal of turbidity was accompanied by bacterial reduction (50-60%) although upon storing the treated water for 24 hours secondary bacterial growth was noted.

Mc Connachie (1999) observed that the active agent is a water-soluble cationic protein that harbours very good coagulation properties which is used in extremely low dosages than that used for crude seed extract. Also, water treated by pure proteins is not prone to bacterial re-growth. The researchers thus affirmed that, the isolation and purification of active agents from the seed is relatively easy compared to laborious manipulation of other proteins and thus recommended it for use in water treatment processes. Studies have shown that

synergies from the combined application of radiation and thermal treatment have a significant effect on the die-off rate of micro organisms.

Most of the published investigation to date has been made using Escherichia coli as model microorganism, because it is a very well- known bacteria from all points of view (DNA, metabolism, structure and composition, morphology, behaviour under different nutrient media, pathogencity, types, strains, etc.).The results of the present study, namely the complete elimination of indicator bacteria within a few hours, showed that sunlight, given an appropriate intensity and good water transparency, was the most important factor in the reduction of hygienically relevant micro organisms in surface waters.

Turbidity is a significant factor in the disinfection process. The effectiveness of solar disinfection has been tested on samples with turbidity ranging from less than 10 NTU to approximately 300 NTU. Researchers have found that higher turbidity samples exposed to sunlight attained consistently higher water temperatures, which was attributed to absorption of radiation by the particulate matter (Barer 2004). More turbid samples, at 300 NTU, also had less inactivation of E.coli compared to samples with little or no turbidity.
This may be in part due shielding of organisms by particles (Mani 2006). Meera and Ahammed (2006) reported that less than 1 % of the total incident UV light is able to penetrate beyond a water depth of 2cm from the surface in samples with turbidities greater than 200 NTU. Therefore, it may be necessary to filter turbid waters before sun exposure. For over 4000 years sunlight has been used as an effective disinfectant (Kehoe 2001). When organisms are exposed to sunlight, photo sensitizers absorb photons of light in the UV – A and early visible wavelength regions of 320 to 450 nm. The photo sensitizers react with oxygen molecules to produce highly reactive oxygen species. In turn, these species react with DNA; this leads to strand breakage, which is fatal, and base changes, which result in mutagenic effects such as blocks to replication. The biocide effect of sunlight is due to optical and thermal processes and a strong synergistic effect occurs for water temperatures exceeding 45^0C (Martin 2005).

It has reported that the reduction of indicator bacteria in surface waters depended on physical parameters (e.g. temperature, pH, oxygen saturation, and sunlight), chemical parameters (inorganic and organic substances) as well as the activities of macro and micro-organisms (Rob Reed 2005).The viability of the bacteria Escherichia coli depends to a great extent on its temperature of incubation (Rose 2006). In general, the chemical composition of water as well as its content in suspended solid particles, their turbidity, etc. affect in a very important way the disinfection processes (Berney 2006; Fujioka et al 2002 and Masschelein 2002).

Compared the germicidal effects of different wavelengths of light by measuring the average number of E.coli inactivated upon exposure to the varying wavelengths. They found that the most significant decrease in viable bacterial organisms occurred when they were exposed to wavelengths between 260 to 350 nm (compared to inactivation at wavelengths between 550 to 850 nm) because wavelengths below 290nm do not reach the earth. Reed et al (2000) concluded that the most bactericidal wavelengths were between 315 to 400 nm, which corresponds to the wavelengths of the near- ultraviolet region that are not visible to the eye. The findings of (Mofidi 2001) are further supported by the research of others. Amir Hossein Mahvi (2007) attributed half of the toxic effects of sunlight to wavelengths lower than 370nm. Tandon et al (2005) concurred, stating that wavelengths between 300 and 370 nm have significant effects on inactivating bacteria and viruses.

Advantages of using natural coagulant

- Cheap and easy method for developing countries (especially at household level).
- The efficiency is independent of raw water pH.
- The processing doesn´t modify the pH of the water.
- It doesn´t alter the water taste (unless a very high doses is added).
- The low volume of sludge precipitated is biodegradable and hence an environmentally sound technology.

12.0 - Conclusions

Finally we would like to conclude that, the use of locally available natural coagulants in poor countries has a great potential of improving the economy and health of the people. Extensive studies have been done to know the efficiency of natural coagulant and solar disinfection when used sequentially. It is now up to the governments in poor countries to first recognize and duly support the initiatives of the poor and yet disadvantaged population segments. This will need communities of countries to strengthen the natural water coagulation and solar disinfection as point-of-use (POU) technology in a holistic approach and to support these initiatives including empowering and enabling local scientist and technologists to build up the POU technology that will suit the local requirements and situation based on scientific knowledge available.

13.0 - References

1. Amir Hossein, M. 2007 Feasibility of Solar Energy in Disinfection of Drinking Water in Iran. *Journal of American- Eurasian Agric. and Environ. Sci*. **2**(4), 410.

2. Barer, M. R. 2004 Batch process solar disinfection is an efficient means of disinfecting drinking water contaminated with Shigella dysenteriae type 1. *Journal of Applied Microbiology.* **38,** 414.

3. Berney, M. 2006 Efficacy of solar disinfection of Escherichia coli Shigella flexneri, Salmonella typhimuriam and Vibrio cholerae. *Journal of Applied Microbiology.* **101**, 836.

4. Cheesbrough, M. 1984 *Medical laboratory manual for Tropical Health Technology*.

5. Fujioka, R. S. & Yoneyama, B.S. 2002 Sunlight inactivation of human enteric viruses and fecal bacteria. *Journal of Water Science Technology.* **46**, 291- 295.

6. Kehoe, S.C. 2001 Effect of agitation, turbidity, aluminum foil reflectors and container volume on the inactivation efficiency of batch process solar disinfection. *Journal of Water Research*. **35**(4), 1065.

7. Lye, D.J. 2002 Health risks associated with consumption of untreated water from household roof catchments systems. *Journal of AWR.* **38**(5), 1306.

8. McConnachie, H. L. 1999 Field trial of appropriate flocculation processes. *Journal of Water Research.* **33**(6), 1434.

9. Mintz, E., Bartram, J. & Lochery, P. 2001 Not just a drop in the bucket: expanding access to point-of- use water treatment systems, *Am. J. Public Health*. **31,** 1565–1570.

10. Mofidi, A. A. 2001 Disinfection of Cryptosporidium parvum with polychromatic UV light. *Journal of American Water Works Assocciation.* **93**, 109.

11. Masschelein, W. J. 2002 *UV light in water and waste water sanitation.* Boca Raton, CRC Press.

12. Mara, D. D. 2003 Water, sanitation and hygiene for the health of developing nations, *Public Health*. **117**, 452–456.

13. Martin- Dominguez, A. 2005 Efficiency in the disinfection of water for human consumption in rural Communities using solar radiation. *Journal of Solar Energy*. **78**, 40.

14. Mani, S. K. 2006 Comparative effectiveness of solar disinfection using small scale batch reactors with reflective, absorptive and tranmissive rear surfaces. *Journal of Water Research.* **40**, 727.

15. Meera, V & Ahammed, M. M. 2006 Water quality of rooftop harvesting systems: a review. *Journal of Water Supply Research Technology- Aqua.* **55**(4), 268.

16. Reed, R. H., Mani, S. K. & V. Meyer, V. 2000 Solar photo oxidative disinfection of drinking water: preliminary field observations. *Journal of Applied Microbiology.* **30**, 436.

17. Rob Reed. 2005 Making the most of a scarce resource: Solar disinfection of drinking water in the arid zone of western Rajasthan. ALN.

18. Rose, A. 2006 Solar disinfection of water for diarrhoeal prevention in India. *Journal of Arch. Dis.Child.* **10**, 141.

19. *Standard Methods for the Examination of Water and Wastewater* 1998 18th edition. American Public Health Association / American Water Works Association / Water WE Environment Federation, Washington DC.

20. Sobsey, M. D. 2006 Drinking water and health research: a look to the future in the United States and globally. *Journal of Water Health.* **4**(1), 21.

21. Tandon, P., Chhibber. S & Reed, R. H. 2005 Inactivation of Escherichia coli and coliform bacteria in traditional brass and earthenware water storage vessels. *Journal of Water Research.* **88**,48.

22. United Nations (UN) Water for people, water for live: The United Nations World Water Development Report 1, United Nations Educational Scientific Cultural Organization Publishing/Berghah Books, 2003, available at: www.unesco.org/water/wwap/wwdr/index_es.shtml (accessed December 2007).

23. United Nations International Children's Emergency Fund, The state of the world's children 2005, available at:http://www.unicef.org/spanish/publications/index_24432.html (accessed July 2006).

24. United Nations, Millenium Development Goals, 2005, available at: http://www.un.org/millenniumgoals/ (accessed September 2007).

25. United Nations Development Programme, Beyond Scarcity: Power, Poverty and the Global Water Crisis, 2006, available at: http://hdr.undp.org/hdr2006/pdfs/report/HDR06-complete.pdf (accessed November 2007).

26. WHO 2004 Guidelines for drinking quality, 3rd edition, vol.1, Recommendations, Geneva, World Health Organization, available at: http://www.who.int/water-sanitation -health/dwq/gdwq3/en/index.html.