UNIVERSITI PUTRA MALAYSIA

PILOT PLANT STUDIES USING MORINGA OLEIFERA (KACANG KELOR) SEEDS AS A PRIMARY COAGULANT IN SURFACE WATER TREATMENT

AHMED HUSSIEN BIRIMA MOHAMMED

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By

AHMED HUSSIEN BIRIMA MOHAMMED

Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Engineering Universiti Putra Malaysia

October 2001

Dedicated To
My parents, brothers, sisters and
My uncle Mohammed Birima

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman : Suleyman Aremu Muyibi, Ph.D.

Faculty : Engineering

Many researchers have used *Moringa oleifera* (Kacang Kelor) as a primary coagulant, for water treatment. It can also be used as coagulant aid, and floc toughners to either supplement or replace alum, ferric salts and synthetic polymers. The present study involves use of a pilot plant constructed by the author to evaluate the efficiency of *Moringa oleifera* seeds (25 % extracted seed oil) in treating turbidity of surface water collected from a stream located beside the hydraulic laboratory in the Department of Civil Engineering Universiti Putra Malaysia. Two stages were involved in the preparation of the seeds for the test. The seed wings and coat were first removed and ground to powder using a domestic blender. The second stage was the extraction of 25 % of the seed oil using the Soxhlet. Like the normal water treatment plant, the pilot plant was operated under four stages: coagulation, flocculation, sedimentation and filtration (rapid sand filter). Both conventional treatment (CT) and direct filtration (DF) methods were considered in running the pilot plant tests. Pilot plant tests were carried out three hours per run over whole period of three months. The turbidity, pH, alkalinity and zeta potential as well as the

filter head loss were monitored regularly (every 30 minutes) during the test run. Average percentage turbidity removal of 75.4, 88.0, and 96.9 % resulted by DF for the low, moderate and high initial turbidity respectively, whereas CT gave average turbidity removal of 43.9, 93.5, and 95.7 for the same initial turbidity. The optimum dosages 20 and 30 mg/l of *Moringa oleifera* was applied for low and moderate turbidity respectively whereas for the high turbidity the *Moringa oleifera* dosage was varied from 50 – 80 mg/l depending on the initial turbidity. One out of eleven trials for CT gave a residual turbidity after filtration lower than 5 NTU. This value agreed with Malaysian guideline of 5 NTU. Eight trials gave a residual turbidity ranged from 8 – 15 NTU, which falls within the WHO maximum level of 25 NTU. 3 trials out of 7 for DF gave a residual turbidity after filtration lower than 5 NTU whereas 4 trials gave a residual turbidity ranged from 6.6 – 11 NTU. Turbidity removal of DF was found to be better than that of CT. *Moringa* oleifera was found to have no significant effect on pH or alkalinity of the water. Zeta potential of the water was found to decrease after treatment. The maximum filter head loss at depth 40 cm was found to be 24 cm for CT. In the case of DF the maximum head loss at depth 40 cm was found to be 29.3 cm for an average turbidity of 230.4 NTU and 70.9 cm for an average turbidity of 88.7 NTU. Therefore, oil extracted *Moringa oleifera* seeds was found to posses a great potential for coagulation as a primary coagulant for treating surface water.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KAJIAN TERHADAP TUMBUHAN YANG MENGGUNAKAN BIJIAN KACANG KELOR YANG MENGHASILKAN PEMBEKUAAN UTAMA DI PERMUKAAN RAWATAN AIR

Oleh

AHMED HUSSIEN BIRIMA MOHAMMED

Oktober 2001

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Fakulti : Kejuruteraan

Ramai penyelidik telah menggunakan kacang kelor sebagai pembeku utama bagi rawatan air. Ia juga boleh digunakan bagi pembekuaan bantuan dan penguat *floc* sebagai tambahan atau menggantikan alum, garam feric dan polmer sintetik. Kajian yang dijalankan ini menggunakan model skala perintis loji rawatan air untuk menentukan kecekapan bijian kacang kelor (25% minyak bijian diekstrak) ini dalam merawat kekeruhan air permukaan yang dikumpul dari parit bersebelahan makmal hidraul, Jabatan Kejuruteraan Awam, Universiti Putra Malaysia. Penyediaan bijian bagi kajian ini melibatkan dua proses. Bijian ini dibuang kulit terlebih dahulu sebelum ianya dikisar menjadi serbuk dengan menggunakan mesin pengisar. Peringkat kedua pula melibatkan pengekstrakan 25% minyak bijian dengan menggunakan Soxhelt. Sama seperti pusat rawatan air biasa, pusat perintis ini juga beroperasi dalam empat peringkat, iaitu pengentalan, *flocculation,* sedimentasi, dan penurasan (penapis pasir). Dua jenis rawatan konvensional (CT) dan penurasan langsung (DF). Ujian pusat perintis ini dijalankan selama tiga jam setiap hari bagi tempoh tiga bulan kajian tersebut. Sepanjang ujian dijalankan nilai parameter,

tempoh tiga bulan kajian tersebut. Sepanjang ujian dijalankan nilai parameter, kekeruhan, pH, kealkalian dan keupayaan zeta serta penyusutan kepala penapis diawasi setiap 30 minit. Purata penyingkiran peratusan kekeruhan yang dihasilkan melalui kaedah DF adalah 75.4, 88.0, 96.9% masing-masing bagi kekeruhan awal yang rendah, sederhana dan tinggi. Kaedah CT pula menghasilkan purata penyigkiran sebanyak 43.9, 93.5 dan 95.7 % bagi nilai kekeruhan awal yang sama. Sukatan optimum kacang kelor sebanyak 20 dan 30mg/l digunakan bagi kekeruhan rendah dan sederhana. Manakala bagi kekeruhan tinggi sukatan kacang kelor dipelbagaikan dari 50-80mg/l bergantung kepada nilai kekeruhan awal. Satu daripada sebelas percubaan bagi CT memberi baki kekeruhan selepas penapisan kurang daripada 5NTU. Nilai ini bertepatan dengan garis panduan Malaysia yang menetapkan 5NTU. Lapan percubaan memberikan baki kekerapan dari julat 8 ke 15 NTU; dimana kesemuanya masih berada dalam julat 25 ke 30NTU yang ditetapkan olh WHO. Kacang Kelor tidak mempengaruhi nilai pH atau kealkalian air. Keupayaan zeta air didapati berkurangan selepas rawatan. Penyusutan kepala penapis di kedalaman 40adalah 24cm bagi CT. Bagi DF penyusutan kepala penapis maksimum pada kedalaman 40 adalah 29.3cm bagi purata kekeruhan 230.4NTU dan 70.9cm bagi 88.7NTU. Minyak Kacang Kelor yang diekstrakan sebagai bahan pengental utama juga sesuai digunakan untuk merawat air memandangkan ia berkeupayaan bertindak sebagai pengental.

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I pry that Almighty God may bless all that have contributed in whatever way to the success of my study at Universiti Putra Malaysia but have not mentioned here.

I certify that an Examination Committee met on 15th October 2001 to conduct the final examination of Ahmed Hussien Birima Mohammed on his Master of Science thesis entitled "Pilot Plant Studies Using *Moringa Oleifera* (Kacaang Kelor) Seeds as Primary Coagulant in Surface Water Treatment" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follow:

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This thesis has been submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science.

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Date: 10 JAN 2002

DECLARATION

I hereby declare that the thesis is based on my original work except for quotation and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

(AHMED HUSSIEN BIRIMA MOHAMMED)

Date: 27/11/2001

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CHAPTER I

INTRODUCTION

The problem of securing and maintaining adequate and quality water supply has been preoccupying the development of human settlement. As population increases, more pressure are exerted on the limited high-quality surface water sources causing contamination of water sources with human wastes, which deteriorate water quality. Thus, sources of water quality could no longer be overlooked in water supply development.

Water treatment can be defined as the manipulation of water source to achieve a water quality that meets goals or standards set by the community through its regulatory agencies. An adequate supply of good quality and safe water is essential to the promotion of public health.

Historical Background

The evolution of water treatment practices is a rich history of empirical development. The earliest water treatment techniques were primarily conducted in batch operation in households utilizing the water. From sixteen century on ward, the interest changed to the treatment of large quantities of water to maintain water supply in large human settlements. The challenge to water treatment professionals in the nineteenth century was the elimination of water borne diseases. During this period great successes in water treatment were achieved in developed countries as shown by elimination of the most deadly water borne diseases including typhoid, cholera, and amebiasis. Since

the early twentieth century, however, public health concerns have shifted from acute illness to the chronic health effects of trace quantities of organic, inorganic and microbiological contaminants (Montgomery, 1985).

Problem Statement

Aluminum salts are by far the most widely used coagulants in water and wastewater treatment. However, recent studies have pointed out several serious drawbacks of using alum salts (Ndabigengesere et al. 1995, Ndabigengesere and Narasiah, 1998, Muyibi, 1998). Alzheimer's disease and similar health related problems are associated with residual alum in treated waters, beside production of large sludge volumes. Also there is problem of reaction of alum with natural alkalinity present in water leading to reduction of pH and a low efficiency in coagulation of cold waters (Ndabigengesere and Narasiah, 1998). Current researches oriented towards producing more effective aluminum coagulants, such as polyaluminum chloride (PAC), have not corrected all the drawbacks mentioned (Ndabigengesere and Narasiah, 1998). Ferric salts and synthetic polymers have also been used as coagulants but with limited success because of the same disadvantages as in the case of alum salts. For example polyelectrolyte formulations contain contaminants from the manufacturing process such as residual monomers, other reactants, and reaction by products that could potentially affect human health (Letterman and Pero, 1990). In addition to these problems, chemicals used for water treatment in developing countries constitute a high percentage of annual running expenditure of water treatment companies and the cost has been increasing at an alarming rate. Local companies are not manufacturing alum in adequate quantities. Therefore, the short

fall has to be imported with scarce convertible foreign currency. These problems force many water treatment companies to resort in under-dosing of chemicals so as to meet the increasing water demand. The result is the supply of low quality water especially during the rainy season, when suspended solids and other polluted loads in surface water are very high (Muyibi, 1995, Muyibi, 1998).

Thus, it is desirable that other cost effective and more environmentally acceptable alternative coagulants be developed to supplement if not replace alum, ferric salts, and synthetic polymers. In this context, natural coagulants represent a viable alternative (Ndabigengesere and Narasiah, 1998, Muyibi, 1998). Natural plant materials, such as Strychnos Potatorum Linn, *Moringa oleifera*, *Moringa stenopetala* etc. have been used as primary coagulants, coagulant aids, floc toughners, etc. for the removal of suspended organic, and inorganic matter. The clarifying powers of natural plants are well known in many remote areas of developing countries and indeed their use has been traced back some 4000 years (Muyibi, 1995). *Moringa oleifera* is a native tree of the sub-Himalayan parts of northwest India, Pakistan and Afghanistan. It is now widely cultivated across Africa, south America most part of South-East Asia for example, Malaysia, Indonesia, Thailand.

Objectives of the Research

The main objectives of the research are

1. To design, construct and operate a model pilot water treatment plant using *Moringa oleifera* seed extract to treat surface water.
2. To evaluate the performance of the model pilot water treatment plant.

3. To explore the interactions between the turbidity, pH, alkalinity, and zeta potential before and after the treatment.
4. To monitor the filter head loss.

Benefits of the Study

The benefits, which may be gained from this study, are:

1. Contribution in the investigation of the potential of *Moringa oleifera* in water treatment with emphasis on coagulation.
2. Beside the benefit of using *Moringa oleifera* as a coagulant, oil can be extracted from it to be used for domestic and industrial purposes.

Scope of Research

The study involved use of *Moringa oleifera* seed oil extracted (25 %) as a primary coagulant for a model pilot water treatment plant. The four stages of water treatment were carried out with an initial turbidity ranged from 16.5 to 261 NTU and the results from the two treatment processes; conventional treatment (CT) and direct filtration (DF) were compared.

A jar test was carried out to determine the optimum dosage of *Moringa oleifera* and the pilot trials were carried out for three hours per run to simulate the water treatment plant that can be operated for an intermittent supply.

CHAPTER II

LITERATURE REVIEW

Precipitation, Coagulation, Flocculation

Coagulation and flocculation are the pretreatment methods for the removal of finely divided particulate matter which, due to its small size (usually less than 10 μ m), will not settle out of suspension by gravity in an economical time frame. Aggregation of fine particulate mater to larger particulates by the use of coagulation and flocculation facilities permits cost-effective removal in subsequent solid separation processes for the removal of particulate contaminants. It may also assist in the removal of toxic contaminants, such as heavy metals, pesticides, and viruses, known to be associated with inorganic and organic particulate matter in water. Fine particulate material is removed from water by addition of organic or inorganic chemicals that accelerate the aggregation of the particulates into larger aggregates. The chemicals used in this process include metal ions such as aluminum or iron, which hydrolyze rapidly to form insoluble precipitates, and natural or synthetic organic polyelectrolytes, which rapidly adsorb on surface of the particulates, there by accelerating the rate of aggregation. The aggregates then removed from the water by physical means such as gravity sedimentation, flotation, or filtration through granular media (Montgomery, 1985).

Process Overview

Conceptually the aggregation of particulate material is a two sequential process. In the intial step, the interparticulate forces responsible for the stability of the particulates are reduce or eliminated by addition of suitable chemicals. Subsequently, aggregation occurs due to transport by molecular motion or mechanical mixing. If these collisions are successful, aggregation occurs. The chemicals used to destabilize particulates are known as coagulants. The coagulant is then injected in to the process stream through a mixing device that should provide rapid and through dispersion of the coagulant in the water. This rapid, flash, or initial mixing, which occurs over a short time frame (usually less than 1 min), serves to optimize the effectiveness of the coagulant for particulate destabilization. This phenomenon is called coagulation. Following destabilization, less intense mixing of particulate is provided to increase the rate of particulate collisions without breaking up or disrupting the aggregates being formed. This phenomenon is called flocculation (Montgomery, 1985). The term coagulation also is applied to the overall process of particle aggregation, including both particle destabilization and particle transport. While the term flocculation is used to describe only the transport step (Weber, 1972). For colloidal particles (less than 1 μm) Brownian motion provides some degree of particulate transport. This is known as perikinetic flocculation. For larger particulates Brownian motion is very slow, and transport requires mixing by mechanical means. Mechanical mixing device such as paddles or mechanical turbine mixers are used for this purpose. This sub process is termed orthokinetic flocculation.

Stability of Particulate

The principal characteristic of fine particulate matter suspended in water is its relative stability, which causes it to remain in suspension for long periods of time (Montgomery, 1985). Each colloid particle carries a like charge; which in nature is usually negative. The sign and magnitude of the primary charge are frequently affected by the pH and ionic content of the aqueous phase. Like charge causes adjacent particle to repel each other and prevent agglomeration and flocculation. As a result, charged colloids tend to remain discrete, dispersed, and in suspension (Weber, 1972 and Zeta-Meter, 1993). The particulate suspensions are thermodynamically unstable, and given sufficient time colloids and fine particles will settle. However, this process is not economically feasible (Montgomery, 1985). On the other hand, the reduction or elimination of the charge make the colloids gather together. They form firstly small groups, then larger aggregates and finally in to visible floc particles which settle rapidly and filter easily (Zeta, 1993). Coagulation-flocculation facilities must eliminate particulate stability and there by increase the rate of particulate removale.

Particulate Characteristics

The particulate in the water are categorized in to two major size groups: colloidal material, with an upper limit of approximately 1 μm and lower limit of approximately 5 nm, and suspended solids consisting of particulate larger than approximately 0.5 μm. Particulate smaller than 5 nm are considered to be in true solution. Colloids and coarse particulate suspension are also characterized according