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APPROPRIATE RAW MATERIAL MIX FOR A LOW COST WATER FILTER CANDLE

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By

SHAHANA HUSSAIN
B.Sc.(H.Sc.)

THESIS SUBMITTED TO THE
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN HOME SCIENCE

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CERTIFICATE

This is to certify that the thesis entitled, **APPROPRIATE RAW MATERIAL MIX FOR A LOW COST WATER FILTER CANDLE** submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN HOME SCIENCE** of the Andhra Pradesh Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Ms.SHAHANA HUSSAIN** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of investigation have been duly acknowledged by the author of the thesis.

(Dr.(Mrs.) VIJAYA NAMBIAR)
Chairman of the Advisory Committee

Thesis approved by the Student's Advisory Committee:

Chairman:	(Dr.(Mrs.) VIJAYA NAMBIAR)	
Member:	(Mrs.D.MRIDULA REDDY)	
Member:	(Dr.R.M.C.V.PRASAD RAO)	
Member:	(Dr.CHOWDHARY)	
Member:	(Mr.M.JAYAWARDHAN)	

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N93 STIA

CERTIFICATE

Ms.SHAHANA HUSSAIN has satisfactorily prosecuted the course of research and that the thesis entitled, **APPROPRIATE RAW MATERIAL MIX FOR A LOW COST WATER FILTER CANDLE** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination.

I also certify that the thesis or part thereof has not been previously submitted by her for a degree of any University.

Date: 25th February '94

Vijaya Nambiar 25th Feb. '94

(Dr.(Mrs.) VIJAYA NAMBIAR)
Major Advisor

DECLARATION

I, **SHAHANA HUSSAIN** hereby declare that the thesis entitled, **APPROPRIATE RAW MATERIAL MIX FOR A LOW COST WATER FILTER CANDLE** submitted to Andhra Pradesh Agricultural University for the Degree of **MASTER OF SCIENCE IN HOME SCIENCE** is a result of original research work done by me. It is further declared that the thesis or any part thereof has not been published earlier in any manner.

Date: 25-2-94

Shahana Hussain
(SHAHANA HUSSAIN)

ACKNOWLEDGEMENTS

I wish to express my most sincere gratitude to my major advisor **Dr. Vijaya Nambiar**, Associate Professor, Department of Family Resource Management, College of Home Science, Andhra Pradesh Agricultural University, for her immense help, ever encouraging advise and valuable guidance rendered for the successful completion of this thesis.

I am highly indebted to **Mr.M.Jayawardhan**, Assistant Professor in Physics, College of Agriculture, Andhra Pradesh Agricultural University, Rajendranagar for his invaluable guidance, continuous encouragement and support throughout the research work.

My profound thanks to **Mr. Chelpath Rao**, Chief Water Analyst, Water Microbiology Section, **Mrs. Shyamala Reddy**, Senior Water Analyst, **Mrs.Padma Shree** and **Mr. Kareemullah**, Junior Water Analyst, Water Microbiology Section, Institute of Preventive Medicine, Narayanguda, Hyderabad, for extending their utmost cooperation and providing infrastructural facilities for carrying out all experiments concerned with my research work.

I also gratefully acknowledge **Mrs.D.Mridula Reddy**, Assistant Professor, Department of Family Resource Management, College of Home Science, Andhra Pradesh Agricultural University, for her useful suggestions during my research work.

My heartfelt thanks are due to **Dr.Mohan Kumar**, Associate Professor and Head, Regional Biogas Training and Development Centre, Andhra Pradesh Agricultural University, Rajendranagar, for his guidance and assistance in carrying out the study.

The encouragement given by Dr.S.Renuka, Associate Professor and Head, Department of Family Resource Management, College of Home Science, Andhra Pradesh Agricultural University, is duly acknowledged.

The assistance rendered by Dr.K.R.Chowdhary, ~~Associate~~ Professor, Dept. of Agricultural Economics, APAU, and Dr.R.M.C.V. Prasad Rao, Associate Professor and Statistician, Dept. of Family Resource Management, College of Home Science is highly appreciated.

I wish to express my deepest gratitude to my parents without whose unstinted backing and continued encouragement I would not have succeeded in achieving my goal.

Last but not the least, I would like to place on record the contributions by my friends and relatives who have done their bit in helping me tide over the various impediments that came my way during the course of the research work.

Shahana Hussain

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ABSTRACT

Water used for drinking has to be subjected to some kind of treatment before consumption due to the presence of many undesirable impurities. One of the useful conventional methods of domestic purification of water, is to clean it through the use of domestic water filter candles. Most of the commercially marketed filters are not within the economic reach of majority of the rural population. Hence the production of cheap water filter candles using low cost, indigenous raw materials for production of filters is a necessity.

This study was therefore taken up with the following objectives.

1. To identify raw materials to mix with clay in the preparation of a low cost water filter candle.

2. To examine the comparative efficiency of different water filter candles.

Filter candles were made with all possible combinations of coal and clay and rice bran and clay as these raw materials are inexpensive and easily available in rural areas.

All the candles were tested by subjecting the water filtering through them, to multitube dilution test. Five trials were conducted with each candle, using fresh water for each trial, to determine its efficiency. In order to compare the efficiency of newly developed candles with those already developed, a commercial water filter candle and a low cost clay-sand mix candle were selected.

The filteration rate and efficiency of candles in terms of microbial quality of filtered water were studied.

It was observed that the candle made with 80 per cent clay and 20 per cent coal worked out better than all the other proportions tested, as it was efficient in filtering out the bacteria that was introduced, but for a limited period only, after which the quality of the candle started deteriorating.

None of the candles made with rice bran and clay were found to be effective in filtering bacteria-free water. The candle made with 60 per cent sand and 40 per cent clay was also found to be defective with several drawbacks, as such unable to filter bacteria free water for even a single trial. This is contrary to an earlier study done by Rama (1986), in which it was found that clay sand mix candle was 100 per cent efficient in the removal of bacteria. This is apparently due to the absence of a mechanised procedure in preparing the clay-sand mix candle and no standardised procedure in mixing the raw materials which may give room for human error due to which the filter in question proved inefficient.

The commercial candle was found to be working efficiently filtering cent per cent bacteria free water. It was filtering water uniformally at a desirable rate, throughout the experiment. In case of both the candles C_7 and clay-sand mix candle, the rate of filteration was found to be gradually decreasing obviously due to the fact that the candle pores were getting clogged very easily.

The study revealed that the commercial water filter candle, filters water most optimally and candle C_7, although efficient in trapping bacteria for three trials had a life span which was limited, and therefore its use can be recommended only after further research has been done on this particular candle mix to improve its durability and efficiency.

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INTRODUCTION

CHAPTER I

INTRODUCTION

"Water is life and
clean water is healthy life"

Water is a basic human need for survival and health. The availability of clean and adequate drinking water through appropriate technologies has a direct bearing on the working conditions and health of people. Human existence is threatened if there is not enough fresh, clean water. Water contributes in a variety of ways to the enjoyment, safety and progress of human existence.

Water intended for human consumption should be safe and wholesome and should not harm the consumer even when ingested over long periods. Over one billion people in developing countries have no access to safe drinking water. Although water covers as much as 81 per cent of the earth's surface, most of it is salty and of no use to the people. Fresh water forms only 1.9 per cent of the earth in the form of rivers, lakes, ponds etc. Water from these sources is potentially dangerous, as a carrier of disease. In such cases instead of being health giving, the water brings on disease (Srinath, 1993).

Water may be classified as potable or clean, polluted and contaminated (Placida, 1990).

1. A potable or clean water is one that is free from injurious agents and is of pleasing taste, odour and appearance.

2. A polluted water is one which has suffered impairment of physical qualities through the addition of substances causing turbidity and changes in colour, odour and taste.

3. A contaminated water is one that contains injurious bacterial and chemical agents. It is one which has been rendered unwholesome by reason of pollution by human excreta or animal waste or by poisonous chemicals.

When one refers to water in relation to health, it does not relate to its indispensability to life but its harmful effects on health of people if impure. Consiousness of the importance of pure and safe drinking water for personal and environmental hygiene, that could reduce the spread of water borne diseases to a significant level, needs great emphasis (National Research Development Corporation, 1992).

Water, because of its very nature, can become a potential transporter of disease from one point to another. From polluted water a number of diseases may start and spread like typhoid, cholera, dysentry, and viral jaundice. Especially during the summer months, when rivers and streams are dry and water is scarce and stagnant, chances of pollution are more. Villagers depend entirely on these sources to meet their water needs. As these sources are common for varied needs of human and livestock, there is every chance of the water being contaminated. Moreover unhygienic personal habits and neglect of the environment also agravates the water problem.

In view of the many undesirable impurities in natural water, its pre-treatment has become a practical necessity in water supplying schemes. Money spent on safe water supply is a sound investment which pays huge dividends in the long run. In Uttar Pradesh after the inception of the water works and sanitation, the cholera death rate decreased by 74.1 per cent, typhoid death rate by 63.6 per cent, dysentry death rate by 23.1 per cent and the rate for diarrhoeal disease by 42.7 per cent (World Health Organisation, 1964).

The type and extent of water treatment varies from place to place, depending upon the condition of raw water. Treatment involves a three stage process of sedimentation, filteration and disinfection as displayed below (Prasad, 1993).

Stage I

Sedimentation

Sedimentation is done for removal of suspended and settlable solid particulate when 70% to 90% of impurities are removed

Stage II

Filteration

Here water is passed through sand media. When 99.9% of impurities including bacteria are removed

Stage III

Disinfection

Sterilization is done by chlorination to oxidise the organic matter present in filtered water

Inspite of all these treatments, water is not safe to drink. Sanitary surveys reveal that potable water is not always free from the deliterious effects of contamination. Due to poor maintenance of pipe lines, water oozing out of the leakages comes in contact with the polluted underground atmosphere. This contaminated water is carried through the pipe during non-supply hours by the back flow under negative pressure or vaccum. Thus the people at the consumers end get contaminated water even though the water is treated at the source (Central Glass and Ceramic Research Institute, 1984).

The water-borne epidemies at Aurangabad, Sangli and several other places reported by National Environmental Engineering Research Institute in 1976 are evidences of supplying polluted water to the consumers. It is also reported at Surat and Lucknow there was nearly 4 per cent loss of water due to leakages in pipe lines, which has enough potentiality to endanger public health through consumption of polluted water.

In rural and in certain parts of urban areas, open dug wells and lakes are the main sources of drinking water. Water sample experiments have shown that the bacterial quality of water from these sources on the whole, is seldom entirely satisfactory. These evidences suggest that in order to protect public health although water is treated at one end, it should be compulsorily treated at consumers end also. Chemical analysis can only provide information as to what extent the water is contaminated but does not provide any method of its purification (Central Glass and Ceramic Research Institute, 1984).

Contaminated water can be made safer to drink, if it is stored for at least 2 days. Within that time, many harmful organisms die and most of the dirt sinks to the bottom of the pot, but this does not kill the pathogens and is not effective for very dirty water. One of the useful conventional methods for purification of domestic water, is to filter it through beds of sand, gravel and charcoal consecutively, to remove suspended impurities, followed by boiling, to kill bacteria. This method although efficient, is cumbersum and demands recurring expenditure on fuel.

To combat this ordeal, many techniques are currently being employed to check and control water quality deterioration which include chlorination, ozonisation and ultra violet radiation. However these techniques have their own drawback and limitations and do not necessarily imply destruction of pathogenic organisms. In some cases, the running cost of the technology is too high to be easily afforded by the common Indian masses. Hence, in order to improve the quality of water to the drinking grade, several household filteration methods have come into existence. The main objective of developing such devies is the removal of suspended particles and bacteria in water (Industrial Toxicological Research Centre, 1990).

Filteration is achieved by passing water through pores, impregnated either in membrane filter or unglazed porcelain candles. Filters that are currently marketed fall into two categories (Vallunders and Sheath, 1984).

1) Filters that can remove particulate matter and

2) Filters that can remove particulate matter and microorganisms, known as sterasyl filters, which are basically of two types
   a) Candle filters
   b) Ultra violet water technology systems.

The present trend followed for filtering water at the household level, is through domestic water filter on account of its compactness, utility and efficiency. Since most of the commercially marketed water filters are not within the economic reach of the rural people and lower income groups, the evolvement of economical water filter candles using low cost indegenous raw materials for candle mixes, would go a long way to serve the rural households effectively. Keeping this in view, the investigator felt the need to develop and study the efficiency of low cost domestic water filter candles comprising specific raw materials, that can be easily prepared and used by the rural population and later serve as a potential medium for self-employment.

The objectives of the study are as follows:

1) To identify raw materials to mix with clay in the preparation of a low cost water filter candle
2) To examine the comparative efficiency of different water filter candles.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

A retrospective survey of literature is essential for any kind of research, as it calls for a clear perspective of the overall field. The relevant literature and researches are presented under the following heads.

2.1 Importance of water

2.2 Sources of water and its pollution

2.2.1 Causes of water pollution and contamination

2.3 Water borne diseases

2.4 Assessment of water quality

2.5 Methodologies for purification of water

2.6 Domestic water filters

2.6.1 Filteration of water by three pitcher system

2.6.2 Domestic candle water filter

2.6.3 Design for candle water filter

2.7 Research studies

2.1 IMPORTANCE OF WATER

Water is synonymous with life. A basic necessity, water is nature's most generous gift to man. It is required for many purposes. Park and Park (1977) stated the purposes broadly as follows;

Domestic purposes : On the domestic front, water is required for drinking, cooking, washing and bathing.

Public purpose : Water is required for public cleansing, fire fighting, maintenance of public gardens and swimming pools and numerous other civic purposes.

Industrial purposes : Without water there cannot be industrial development. Some industries like the iron and steel industry and paper industry need water in abundance.

Agricultural purposes : The food and raw materials needed by the world cannot be raised without water.

Marwah (1980) states that the amount of water required daily for domestic use varies greatly and depends mainly on the habits and standard of living of people and particular sanitary arrangement of place. From the sanitary stand point, one should encourage a free use of water and at the same time discourage unnecessary waste.

The quality of water required has been variously estimated by different observers. Table 1 gives the daily supply allowances for all purposes per head.

Table 1: Water requirements

S.No.	Purpose	Quantity in gallon/head/per day
1.	Drinking and cooking	1
2.	Washing clothes, utensils and house washing, ablution and bathing	11
3.	Water closets	5
4.	Trade and Industry	5
5.	Municipal purposes	5
6.	Animal drinking and maintenance of stables	3
		30 gallons

Therefore, a daily supply of 30-35 gallons per head is considered an adequate allowance. Water is not only indispensable for sociological activities but has a physiological role, related to various processes going on within the human body. The body needs adequate amounts of water for maintaining healthy blood, fighting against disease, and in performing vital body functions.

Water is therefore an essential factor in economic, social and cultural development of a community. It is not only a refreshing drink and an effective cleansing agent, but also a vital medicine that can eliminate different health problems, promote rural development and improve quality of life.

2.2 SOURCES OF WATER AND ITS POLLUTION

According to Bedi (1969) a consideration of all existing and possible sources of water is necessary before planning a scheme for ensuring safe water supply. There are three main sources of water.

1. Rain
2. Surface water
   a) Artificial lakes
   b) Rivers, streams
   c) Tanks, ponds and lakes
3. Ground water
   a) Shallow wells
   b) Deep wells
   c) Springs

1. Rain

Rain is the prime source of all water. It is the purest water in nature. Physically, it is clear, bright and sparkling. Chemically, it is a very soft water and contains only traces of dissolved solids. Bacteriologically, it is free from pathogenic bacteria. But, rain water becomes impure as it passes through the atmosphere and reaches the ground. It picks up impurities such as dust, soot, gases and even bacteria. To be used as drinking water, therefore, rain water needs to be carefully collected and stored.

2. Surface water

When rain water, reaches the surface it is called "surface water". Many Indian towns and cities depend upon surface water sources. These are artificial lakes rivers and tanks. The stored water in tanks encourage bad taste and odour and also growth of microscopic organisms that are hazardous to health.

a) **Artificial lakes :** These are lakes usually constructed in upland areas, for the storage of rain water. These are also called impounding reservoirs. The area drained into a reservoir is called "catchment area". The water in these lakes is usually of good quality, but nevertheless, it requires purification.

b) **Rivers :** Rivers are an important source of water supply. The chief drawback of river water is that it is always polluted and the water is never safe for drinking, unless it is purified. The sources of pollution of river water are many - surface washing, sewage, industrial and trade wastes and drainage from agricultural areas. Besides these, customs and habits of the people such as bathing, washing and defecation along river banks, add to the pollution of river water.

c) **Tanks :** Tanks are excavations in which surface water is stored. Tanks are a source of water supply in some Indian villages. Tank water like river water is never safe for drinking and domestic purposes. This is because, tanks in India are like cesspools, all the filth of the surrounding area is washed directly into them during the rainy season.

3. Ground water

When rain water sinks into the ground, it becomes ground water. The water gets purified by percolation. The advantages of ground water are :

1. It is superior to surface water because it is likely to be free from pathogenic organisms.

2. It usually requires no treatment.

3. The supply is likely to be constant, even during summer.

But, the disadvantages of ground water are :

1. The water is harder than surface water, sometimes very hard.

2. It requires pumping.

The usual ground water sources are wells and springs. Deep wells are usually free from contamination compared to shallow wells which are more exposed to surface filth.

2.2.1 Causes of water pollution and contamination

One of the problems of the modern day is pollution and contamination of water supplies by man himself. According to Park and Park (1990) the sources of pollution are:

(1) Sewage : This is a serious source of water pollution. Sevage contains decomposable organic matter and pathogenic agents. The Delhi epidemic of viral jaundice in 1955 is a clear illustration, over 40,000 cases of viral jaundice occured due to the pollution of the Jamuna water by sewage. The decomposable organic matter absorbs the oxygen in the water, kills fish and produces an offensive smell, thus exposing large communities to risk of water-borne diseases and epidemics.

(2) Industrial waste : Pollution by industrial wastes is a growing problem in many countries. Toxic agents from industries, if permitted to enter water supplies, kill not only fish, but also harm man. The toxic agents range from metal salts to complex synthetic organic chemicals.

(3) Agricultural pollutants : Drinking water sources may be polluted by fertilizers or pesticides, used in agricultural practices. These pesticides are eventually drained into water sources and cause serious water pollution. Irrigation can thus be a major cause of water pollution.

(4) Physical pollutants : Heat and radio activity are the most important physical pollutants. Heat contributes to deoxygenation of water with marked effect on the flora and fauna of the water. Radio active substances have far reaching carcinogenic, toxic and physiological effect on man.

2.3 WATER-BORNE DISEASES

The water upon which we live can also destroy us if it is not properly protected. It is a carrier for numerous kinds of disease-causing organisms. In developing countries, water-borne diseases like cholera, typhoid, diarrhoea and dysentry kill thousands every day. Children and infants are the most frequent victims.

An estimate made by the World Health Organization at end of 1985 indicated that 23 per cent of urban population and 64 per cent of rural population in developing countries other than China, lacked access to safe and adequate water supply. Drinking water is the primary medium for transmission of diseases notably typhoid, choleera, hepatitis and those caused by intestinal protozoa (Deepa, 1988).

The various water-borne diseases are enumerated in Table 2 and 3 (Srinath, 1993).

Table 2: Water-borne diseases due to the presence of infectious agents in drinking water

S.No.	Mode of contamination	Disease caused
1.	Viruses	Hepatitis, poliomyelitis, Rota viruses, diarrhoea in infants
2.	Bacterial	Cholera, typhoid and Para-typhoid, Bacillary dysentry
3.	Protozoal	Amoebiasis, Giardiasis
4.	Helminthic	Round worm, thread worm, whip worm, hydatid worm
5.	Leptospiral	Weil's disease

Toxicants are chemicals of organic and inorganic origin as well as disease causing micro-organisms, present in water which retard/stop the rate of biochemical reactions catalyzed by enzymes and in turn adversely affect a chain of inter-related reaction causing lethal effects of varying nature such as nausea, dysentry, fever, mutagenic, carinogenic, neoplastic teratogenic gerontogenic and fatel effects.

Table 3: Water-borne diseases due to the presence of aquatic host toxicants in drinking water

S.No.	Mode of contamination	Disease caused
1.	Cyclops	Guinea worm, fish tapeworm
2.	Snail	Schistosomiasis
3.	Agricultural (DDT) & Industrial wastes	Peripheral neuropathy, CNS toxicity, liver damage
4.	Metals like arsenic, cadmeum, cyanide, lead, mercury, etc.	Various types of ill-health as Itai-Itai, Ina-zmita, Skin cancer
5.	Inorganic nitrates and nitrites	Mathaemoglobinaemia in infants
6.	Organic chemicals like polyaromatic hydro-carbons, polychlori-nated compounds	Carcinogenic, mutagenic Teratogenic
7.	Due to presence of radio-active sub-stances	Teratogenic, mutagenic carcinogenic

The diseases spread by water are usually those whose causative organisms leave the body by way of alimentary tract, and water-borne infections are usually contacted by drinking contaminated water. Most important of the diseases that may be spread by water are typhoid, bacillary dysentery, amoebic dysentry and cholera. In rural areas, water available in ponds, wells, tube wells, rivers etc., is used for drinking purpose without any purification. In urban areas, water gets polluted through leakages in pipelines before it reaches the consumer.

Hence, in both cases, general public consume polluted water and get affected with permanent health problems (Maiti and Prasad, 1993).

2.4 ASSESSMENT OF WATER QUALITY

According to World Health Organization (1984), potable water should satisfy prescribed quality or standards. In assessing the quality of drinking water, the consumer relies completely upon his senses. Water constituents may effect the appearence, smell or the taste of the water and the consumer evaluates the quality and acceptability on these criteria. Water that is highly turbid, coloured or has an objectionable taste is regarded as dangerous. Presence of chemical substances in water such as fluoride, nitrate and metallic ions may be toxic or injurious to health. Hence such water will be rejected for drinking purpose.

However, one cannot rely entirely upon our senses in the matter of quality judgement. The absence of any adverse sensory effect does not guarentee the safety of water for drinking. The guidelines for drinking water quality has been set up by the World Health Organisation. The quality of water defined by guidelines for drinking water quality is such that it is suitable for human consumption and for all usual domestic purposes including personal hygiene.

For hygienic purposes the examination of water is generally done under the following heads (Park and Park, 1990).

a) Physical examination

b) Chemical examination

c) Bacteriological examination

a) Physical examination : The water is examined for colour, turbidity, smell and taste. Drinking water must be clear, sparkling, odourless and palatable. But physical examination alone is not sufficient to declare the safety of water. A chemical and bacteriological examination are also needed for complete assessment.

b) Chemical examination : Chemical examination is done to determine

i) The amount of inorganic salts which determine the hardness of water and type of hardness

ii) The nature and amount of organic pollution

iii) The percentage and amount of poisonous chemicals.

Water is tested for total solids chlorides, hardness, ammonia, nitrites, nitrates, oxygen content and the presence of certain toxic substances such as arsenic, mercury, lead etc. Certain important chemical standards for assessing water quality are presented in table 4.

Table 4: Chemical standards of water

Substance	Prescribed standard
Total solids	500 mg per litre
Chlorine	200 mg per litre
Free and saline ammonia	0.05 mg per litre
Nitrites	Nil
Nitrates	1.0 mg per litre
Total hardness	150-300 mg per litre

If the above standards are exceeded, the water is considered unfit for drinking.

c) Bacteriological examination

According to Rao (1990), in judging the quality of water, its bacterial quality is of crucial importance. This is reflected in the fact that there were several outbreaks of typhoid fever, when waters found chemically safe were consumed. The bacterial quality of drinking water therefore, is of greatest importance and must not be compromised for.

Bacteriology offers the most sensitive and delicate test for detecting the contamination of water. The organisms commonly used as indicators of foecal pollution are the coliform organisms.

There are several reasons why coliform organisms are identified as indicators of foecal pollution rather than water-borne pathogen directly. They are;

1. The coliform organisms occur in great abundance in the human intestine. These organisms are foreign to potable water and hence their presence in water is looked upon as evidence of foecal contamination.
2. They are easily detected by cultural methods whereas the methods for detecting the pathogenic organisms are complicated and time consuming.
3. They survive longer than pathogens which tend to die out more rapidly.

4. The coliform bacteria have greater resistance to the forces of natural purification than the water borne pathogens.

The coliform organisms are all aerobic and facultatine anaerobic gram negative, non-sporing, mobile or non mobile rods, capable of acid and gas production at $37_{o}C$ in less than 48 hours. Since the E. Coli is undoubtedly of foecal origin, its presence in water is considered a sure indicator of foecal pollution calling for immediate abstinance from consumption. Routine bacteriological examination of water for the presence of coliform bacteria, takes nearly 72-96 hours by the standard "Multi-Tube Dilution" test.

2.5 METHODOLOGIES FOR PURIFICATION OF WATER

According to **Swami Vivekananda**

"To cure is the voice of the past
To prevent is the divine whisper of today"

Aptly then, the purification of water is a necessary step before consumption. Purification involves disinfection of water that kills the pathogenic disease-carrying micro organisms. This process is required well before water is consumed (Rangwala, 1980).

Impure water may be purified by either of the following methods (Marwah, 1980).

A. Natural
- (a) Pounding or storage
- (b) Oxidation and settlement

B. Artificial
- I. Physical
  - a) Distillation
  - b) Boiling
- II. Chemical
  - a) Precipitation
  - b) Disinfection/sterilization
- III. Filteration
  - a) Slow sand filteration
  - b) Rapid sand filteration
  - c) Domestic filters

From the above, the methods employed for purification of water at the domestic level are

a) Boiling (b) Chemical methods (c) Filteration

(a) Boiling : Boiling is a satisfactory method of purifying water for household purposes. Boiling for 5-10 minutes kills bacteria, spores, cysts and ova of intestinal parasites. Boiling also removes temporary hardness by driving off carbondioxide and precipitating calcium carbonate. The water is rendered soft. While, boiling is an excellent method of purifying water it offers no "residual protection". For this purpose boiled water should be stored in a clean container, otherwise the water may get contaminated because of bad storage and defeat the very purpose of boiling. It is a good practice to boil water in the same container in which it is going to be stored.

(b) Chemical methods : The chemicals most commonly used for disinfecting water are (i) Bleaching powder (ii) Potassium permanganate (iii) Certain chlorine tablets.

(i) Bleaching powder : Bleaching powder or chlorinated lime is a white amorphous powder. When freshly made it contains about 33 per cent of "available chlorine". On exposure to air, light and moisture it rapidly looses the chlorine content.

In direct chlorination one ounce of good quality bleeching powder is employed to disinfect 1,000 gallons of water. This amount gives a concentration of about 1 mg. The principle in chlorination is to ensure a free residual chlorine of 0.2 mg/ml at the end of 30 minutes contact. Highly polluted and turbid waters are not suitable for direct chlorination.

(ii) Potassium permanganate : Although a powerful oxidizing agent, it is not a satisfactory agent for disinfecting water. It may kill cholera vibrios, but is of little use against other disease causing organisms. It has other drawbacks too, such as altering the colour and taste of water. People often refuse to drink permanganated water on account of these changes.

(iii) Chlorine tablets : Halazon chlor-dechlor and hydro-chlonazone tablets are sold in the market. They are satisfactory for disinfecting small quantities of water, but they are costly. The tablets are capable of disinfecting but not removing the turbidity. The Central Public Health Engineering Research Institute, Nagpur developed double action tablets capable of removing the suspended matter and disinfecting simultaneously. Each 1000 mg of tablet is sufficient to treat about 2 gallons of water containing upto 500 ppm turbidity. The treated water will contain about 2 mg/lt of residual chlorine.

C. Filteration : According to Rangwala (1980) filteration is the process whereby water is purified by passing it through porous medium.

During the process of filteration the following effects occur in water.

i) The suspended and colloidal impurities which are present in water in a finely divided state are removed to a great extent.

ii) Chemical characteristics of water are altered.

iii) The number of bacteria present in water is also considerably decreased.

Methods of filteration : Filteration is a method of removing bacteria, suspended solids from water, sewage or industrial particles or waste by the following three methods.

1. **Mechanical straining :** This is responsible for removing such articles of suspended matter that are too large to pass through the interstices between the sand grain.

2. **Sedimentation and absorbtion :** Sedimentation and absorbtion is for removal of colloide suspended and bacterial particles. The interstices between the sand grains act as minute sedimentation basins in which the suspended particles smaller than the voids in the filter

bed, settle upon the sides of sand grains. The particles adhere to the grains because of the physical attraction.

3. **Biological metabolism :** Biological metabolism is the growth and life process of living cell. The surface of filtering material, in the filter, gets coated with the skin or layer formed due to bacterial action of finely suspended matter and other organic matter, present in raw water with the algae, fungi, protozoa and yeast which filters the suspended particles.

Electrolytic changes : The action of filter is also explained by the ionic theory which states that when two substances with opposite electric charges are brought into contact with each other, the electric charges are neutralised and in doing so, new chemical substances are formed. It is observed that some of the sand grains of filters are charged with electricity of some polarity. Hence, when particles of suspended and dissolved matter containing electricity of opposite polarity come into contact with such sand grains, they neutralize each other and it ultimately results in the alteration of chemical characteristics of water.

2.6 DOMESTIC WATER FILTERS

A number of household filters are available in the market. Some of them are directly attachable to the tap, but some have separate body in which water can be stored as well as filtered.

According to Marwah (1980) the essential features of a good filter are :

a) It should be strong, compact, simple, all parts being easily accessible for cleaning.

b) It should be cheap and its purifying power fairly lasting.

c) It should be effecient to keep back all germs.

d) The filtering medium should not require frequent changing.

e) It should not impart anything injurious to water.

2.6.1 Filteration of water by three pitcher system

Three pitchers are placed one above the other on a wooden stand. The top pitcher containing sand is filled with water, which percolates through a hole made at its bottom, along with a piece of cloth or cotton plugged into the hole, into the second pitcher which contains a mixture of sand and vegetable charcoal water passes through a hole at its bottom into the third, viz., the lowest pitcher. This last pitcher contains the filtered water (Marwah, 1980).

Pot filter is however found to be unsatisfactory and unreliable due to which commercial filters combining the straining and disinfection action have been developed. These filters are good enough for household purposes (Ghosh, 1985).

2.6.2 Domestic candle water filters

The theory of candle water filter is based on mechanical straining and the filteration rate of bacteria depending on the pores of the candles. If the pores are small or tiny, then the rate of filteration of bacteria will be less and if the pores are big then the rate oif filteration will be more (Park and Park, 1977).

The filter candles are made of porcelain and clay and infusorious earth and moulded into bougies or candles (Marwah, 1980).

2.6.3 Design for candle water filter

The Rama brand of candle filters are available in polypropylene, stainless steel or an aluminium alloy sheet. The filter comprises two compartments (Fig. 1).

1. Upper chamber
2. Lower chamber

Upper chamber : The height of the upper chamber depends on the capacity of the water filter as it is available in different capacities eg. 11 lt., 5 lt. 18 lt. etc. Candle is always fixed within the upper chamber.

Filter candle : The candle is made from special earth ceramic (called kusulgurh) under high temperature and pressure condition, reducing its pore size to the smallest micron. These pores trap germs, dirt and other suspended impurities. The candle is fixed in the upper chamber with help of a thick rubber and metal washer. The candle has a nozzle with the help of which the purified water drips down.

Plastic plate : A plastic plate is present, the purpose of which is to separate the lower chamber from upper chamber.

Lower chamber : Lower chamber is made for collecting the pure water. The raw or polluted water is filled in the upper chamber which after filteration through the candle drips through the nozzle into the lower chamber. The lower chamber is provided with a tap with the help of which water can be taken out.

Working : Impure water or raw, polluted water is filled in the upper chamber which passes through the candle. As a result the impurities are seperated from the water. The water passes through nozzle into the lower chamber and this water is considered fit for consumption and is collected through the tap attached to the base of the lower chamber.

Maintenance : The effeciency of water filter depends mainly on the condition of its candle. It is very necessary to remove the candles atleast once a fortnight and place them under running tap water and then clean it with a brush provided with every water filter. This clean up the clogged pores. The container should be washed with a mild soap.

Sterilization : According to most of the manufactures the candle should be sterilized once in three months. It should be soaked in water for about 15-20 minutes and then put in boiling water for 15 minutes. The candle should remain in the water till it cools down. The precaution generally increases the life of the candle (Rama Water Filter Pamplet, 1986).

Rate of filteration : According to Padalla (1988), the rate of filteration depends largely on the water level in the upper container. As the water level changes, so does the pressure of water on the candle, thus effecting the amount of water being filtered in a specific time.

For example, if the candle mounting is vertical and if 'h' is the height of the initial water level in the upper chamber of the filter, then the pressure acting at the bottom of the tank on the candle is P x gh, where 'P' is the density of water and 'g' the acceleration due to gravity. This is the pressure which pushes the impure water to come out from the cavity 'C' through micro holes.

As the filteration starts, the height of the coloumn gradually decreases. When the water coloumn height becomes smaller than the candle height, only the lower portion of the candle (i.e. the submerged portion) remains effective, reducing its effeciency of discharging water through it to about 50 per cent. Moreover different parts of the candle are worked at different pressures, thus altering the rate of filteration of the filter. Therefore it is necessary to maintain the water level in the upper container for better efficiency of the filter.

2.7 RESEARCH STUDIES

A probe into the recent researches on water purification through the filteration method, exposed only a few research studies on this area, which are detailed below. However a few early research recordings are also being mentioned here.

According to Illywelyn Robert (1952) Berkefield, filters consist of a cylinder made up of infusorial earth better known as "kieselgurh". The cylinder of the candle wears thin by constant cleaning and gradually ceases to filter efficiently. It is rapid in action and does not require additional pressure. The candle should be sterilized by boiling every third day.

According to Research and Industry (1975) two types of water filter candles are available in the market.

One gives bacteria free (steroisyl type) and the other gives water, free from suspended impurities. Only such filter candles especially the steroisyle type candles are not manufactured in the country in quantities sufficient to meet the demand, a bulk of it has to be imported. The market price of such candles ranges from Rs.25 to Rs.90 per piece. The life of these candles is reported to be 2-3 years for filtering the average quality of water.

The Central Glass and Ceramic Research Institute (1975) has carried out investigations on the production of steroisyl type candles, using indigenously available, ceramic materials and has succeeded in developing a process for the manufacture of such candle, without the use of Kieselguhr, which is commonly used for the manufacture of the filter element but is not available in our country in commercial quantities.

The process consists of grinding non-plastic materials like quartz and feldspar to the required fineness and mixing it with china clay and other organic combustible materials. The casting slip is prepared by the addition of electrolytes. The candles are first moulded by casting, using plaster of paris and moulds of desired shape. These can also be made by extrusion through plugmills. These are then turned and finished to required dimensions and baked at suitable temperature in an electrical or oil fired kiln. Candles are then tested for flaws and then given a special chemical treatment followed by second baking to make them suitable for filtering bacteria-free water. These are then fitted with caps and checking for leakages through the caps. Chemically treated and cap assembled candles were tested by four pathological laboratories for bacteria filteration tests and have been found satisfactory.

A study was conducted by Kulkarni (1980) on "Domestic water filters" and their limitation. The purpose of the study was to test the effeciency of four selected filters, in which two filters A and B are meant for attaching to the tap and filters C and D are household filter candle types. The study showed that filters A and B did not produce bacteriologically safe drinking water from contaminated water and also the turbidity removal was not to the desirable extent, with these gadgets. Filters C and D were found satisfactory so far as turbidity removal is concerned. The bacteriological quality is however considerably unsatisfactory and filtered water is unfit for drinking purposes.

However, filters C and D can be safely used for domestic purposes, if the water in the candle chamber is prechlorinated with National Environmental Engineering Research Institute developed chlorine ampoutes or solution.

The Central Glass and Ceramic Research Institute, developed filter candles for domestic as well as community use and National Environmental Engineering Research Institute (1984) studied the efficiency and performance of these candles from the bacteriological point of view. The results showed that both domestic and community candles could remove 70 to 90 per cent of total bacterial count of raw water. It was observed that the rate of filteration was in the range of 515 ml to 1050 ml and 1200 ml to 1690 ml/hr for domestic and community candles respectively. The filterate of both the candles were always free from coliform organisms. Even when raw water had a turbidity figure of upto 10 NTU and 9200 coliform per 100 ml the filterate from both the candles was always free from coliform organisms. Performance of the candles was satisfactory even when coliform count was as high as 10 per 100 ml of raw water since the filterate was always negative for coliform organisms. The study further showed that even after filtering 540 lit of well water through each candle for nearly 71 days, the filterate was negative for coliform organisms.

Srinivasan (1986) had discovered a special treatment of clay which could be used to filter and purify water used for drinking. In the process developed by him, clay is treated with aluminium hydroxide, which is not a costly material along with other chemicals. The clay mass, as a result gets endowed with a labyrinth of tiny pores. While the size of these pores are large enough to let water moleculues to pass through them easily, they are small enough to trap harmful chemicals like dioxins and dibenzoflurons, which exist in impure water.

Padalla (1988) points out that the water filters available in the market have special type of filtering candles, mounted in the upper chamber of the filter. The candle is usually a porous clay tube with a thick wall having micro-holes, which arrest the dirt particles larger than the size of the hole. Clean water comes out through the tube and is collected in the lower tank.

To maintain full discharge effeciency of the water filter candles, even with low water coloumns in the tank, Padalla suggests a horizontal mounting of the candle. In the suggested mounting, the candle remains submerged almost till the water level reaches the bottom level. Unlike the vertical mounting, in this case the candle experiences almost the maximum bottom pressure through out its length as it is kept horizontal. For easy draining out through the cavity of the horizontal candle, the filter stand can be slightly tilted towards the water tap.

A team of scientists working in the Industrial Toxicology Research Centre (1990) conceived an idea of developing an electronic gadget for providing disinfected water at a very low cost, which can be easily afforded by a common person. The scientist's claim that the gadget named "Bact-O-Kill" kills 100 per cent of the bacteria in just 40-45 mts. of treatment of water. Further, water samples have been analysed for metallic ion contamination in the treated water and it has been found that contamination on account of presence of copper, zinc, lead and cadmium had in fact reduced after treatment.

According to Maiti and Prasad (1993) the Central Glass and ceramic Research Institute, Khurja developed a process for the manufacture of ceramic water filter candle using locally available raw materials in Jhansi and Uttar Pradesh. The quality of filter candle manufactured also conformed to the respective Indian Standard (IS: 7402-1986) specification with reference to rate of filteration of water only.

Two clay namely Black clay and Datia clay available near Jhansi were used. Charcoal and rice husk were the combustible materials selected for the development of pores in the candles. Fire clay grog was also added for the creation of pores as well as for development of strength in the candles. The pores formed in the candle were of inter granular type. Clay components were used to develop plasticity and dry strength in the body. The rate of filteration of the developed candle was found to be 1.6 to 2.65 lit/hr with an apparent porosity of 50-55 per cent. Sediment free water could be obtained using such type of filter candles and the process can be easily adopted in the rural sector as the process of manufacturing is simple and less capital intensive.

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MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The present study is an experimental research on the development of a low cost water filter candle. An experimental study has been selected, as it is scientific and gives precise and accurate results.

The experimental design along with accompanying details adopted for the investigation are discussed under the following heads.

3.1 Basis for selection of raw material for filter candle
3.2 Preparation of the filter candle and containers
3.3 Selection of equipment
3.3.1 Measuring devices
3.3.2 Glass ware
3.3.3 Stainless steel containers
3.3.4 Water filters
3.3.5 Equipment for bacteriological analysis
3.4 Experimental procedure
3.4.1 Sterilization of candles and containers
3.4.2 Preparation of escherichea coli cultures
3.4.3 Bacteriological analysis
3.4.4 Determination of rate of filteration
3.5 Experemental set up
3.5.1 Multi-tube dilution test
3.6 Reporting of results

3.1 BASIS FOR SELECTION OF RAW MATERIAL FOR FILTER CANDLES

According to the National Research Development Corporation, one of the basic principles underlying the manufacture of bacteria free water filters is "to create pores of suitable dimensions in any material so as to check the passage of both colloidal material and bacteria through it".

Hence the raw materials required for making water filter candles should be of two types, one should function like a binder and the other should induce porosity into it. Keeping these properties in mind, powdered clay was selected as the basic raw material, that acts as a binder and also contributes to the strength of the candle. For inducing porosity into clay, coal ground to a fine state was used. As coal burns out completely on heating, it leaves fine pores in its place when heated to high temperatures. The candle made thus would have both porosity and strength. Likewise other raw materials that burn out completely when heated can also be used in combination with clay, for instance rice bran.

For the study, clay was the common binding material used in combination with either coal or rice bran. Candles in a series of known proportions of coal ands clay were moulded. Similarly candles with rice bran and clay were also prepared.

3.2 PREPARATION OF FILTER CANDLES AND CONTAINERS

Clay was softened by addition of water. Clay was then mixed and wedged properly to keep it ready for working. Coal that was used in candle preparation was obtained by burning wood. This coal was ground finely and sieved through a muslin cloth three times (Plate 1, 2). The fine coal was then mixed with clay in measured amounts using a standard measuring cup. Definite series of proportions of coal and clay were made. Experiments using the candle containing the highest proportion of coal that is 50 per cent of coal and 50 per cent of clay were designed first. The proportions of coal were changed in a descending order and the amount of clay used also varied automatically.

The table below illustrates the quantum distribution of coal and clay in each candle.

Table 5: Quantum Distribution of Coal and Clay in Different Candles

Candle	Proportion of Coal	Proportion of Clay
C_1	50	50
C_2	45	55
C_3	40	60
C_4	35	65
C_5	30	70
C_6	25	75
C_7	20	80
C_8	15	85
C_9	10	90

As can be diserned from the above ratios, as the coal proportion comes down, the clay proportion goes up.

A thorough mixture of coal and clay was prepared (Plate 4). This was then kept on the potters wheel and moulded to the shape of a filter candle (Plate 5, 6) (size and shape were according to BIS specification Appendix A). This candle was dried and baked in a furnance at a very high temperature (Plate 10). A similar procedure was followed for candles prepared with rice bran and clay. Candle C_7 comprising 20 per cent coal and 80 per cent clay was found to be working efficiently for the first three trials. Therefore only to find its rate of filteration, the candle was fixed to a filter container (Plate 7).

Plate 1: Grinding of coal

Plate 2: Sieving the coal through a muslin cloth

Plate 5: Potter setting the lump of coal and clay on the wheel

Plate 6: Potter seen moulding the lump to form a candle

Plate 3: Ratio of coal and clay taken in preparation of candle C_7

Plate 4: Mixing of coal and clay for moulding

Plate 7: Candle C_7 fixed to container

Plate 8: A mud water filter

Plate 9: A commercial water filter

Plate 10: The newly developed candles

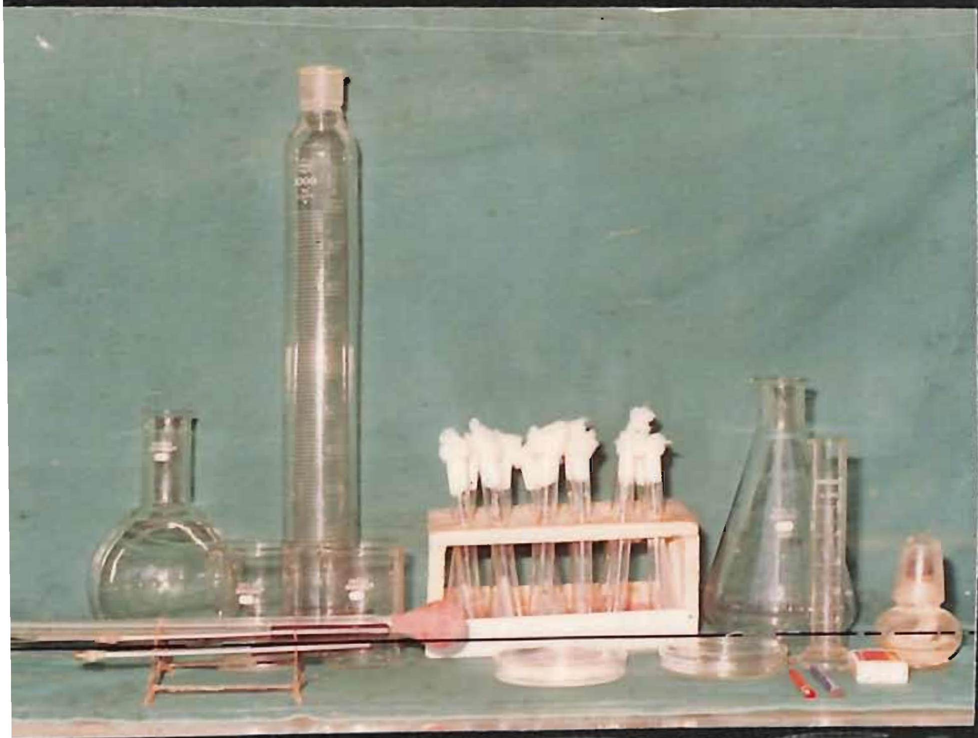

Plate 11: Glassware used during experiments

Plate 12: Incubator in use for incubating water samples

Plate 13: Streaking of endoagar plate being carried out by investigator

Filter containers were made with clay mixture commonly used for making mud pots. The design generally used for the commercial water filter was adopted. The capacity of the filter container was 6 lt. Freshly made candle C_7 was fixed to the upper container and the whole set was baked. After baking, a plastic tap was fixed to the lower fcontainer of the newly developed filter.

3.3 SELECTION OF EQUIPMENT

3.3.1 Measuring devices

Pipettes of sizes 1 ml, 5 ml, 10 ml with distinctly marked graduations were selected for innoculating the water samples. A graduated measuring jar was used to measure the volume of water. Standardised measuring cups were used to measure different proportions of coal and clay (Plate 11).

3.3.2 Glass ware

Glass ware, such as test tubes, petridishes were used for carrying out the experiments.

3.3.3 Stainless steel containers

Sterile stainless steel containers were used for keeping the filter candles immersed in test water. Stainless steel containers were selected as steel does not react with water even after long periods of time. No chemical reaction takes place between steel and water.

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3.3.4 Water filters

A stainless steel commercial water filter comprising of a top chamber with a candle and bottom receiver with a tap was selected (Rama Water Filter Plate 9). The capacity of the filter was 8 lt. A 5 lt capacity, mud water filter comprising an upper and lower container was also selected (Plate 8). The candle fixed in the upper container was made of 60 per cent of sand and 40 per cent of clay. The filtered water was collected through a tap fixed to the lower container of the filter. These water filters were used to compare their efficiency with the newly developed candles.

3.3.5 Equipment for bacteriological analysis

3.3.5.1 Hot air oven

An oven which gives uniform and adequate heat was used for drying the glassware. It contains a thermometer to read temperatures upto 250°C and posesses vents that are located appropriately.

3.3.5.2 Auto clave

An autoclave was used to sterilize the glassware before using the same in experiments. The autoclave was equipped with a pressure guage and safety valve. Sterilization was done in the autoclave using the moist heat method.

3.3.5.3 Electric incubator

This equipment was used to incubate the test tubes for necessary period as specified in the experimental procedure. The electric incubator, identified possessed a thermostat control, equipped with a thermometer and provided with shelves (Plate 12).

3.4 EXPERIMENTAL PROCEDURE

3.4.1 Sterilization of candles and containers

Glass ware such as test tubes, pipettes, petridishes, beakers, etc., required for bacteriological analysis were first washed with distilled water and then wrapped in brown paper and autoclaved at a pressure of 15 lb per square inch, for 30 minutes.

Before using the candles, they were subjected to the following procedures.

i) The candles were thoroughly cleaned with distilled water using a nylon brush.

ii) After rinsing, the candles, wrapped in butter paper were kept in stainless steel containers and autoclaved for 45 minutes under 15 lb pressure.

These procedures were followed to make newly developed candles and commercial filter candles sterile and prevent contamination of water samples via the candle itself. As the candle in the case of mud water filter was not detachable, the upper container of the filter containing candle was rinsed with distilled water and kept in hot air oven for 30 minutes.

3.4.2 Preparation of Escherichia Coli culture

Pure colonies of escherichia coli were allowed to grow on endoagar plate for a period of 24 hours. After 24 hours the green colonies of escherichia coli were transferred into a tube containing 5 ml of nutrient broth with help of a sterilized nichrome wire. The innoculated nutrient broth was kept in an incubator at $37^{o}C \pm 2^{o}C$ for 6-8 hours. This enabled the escherichia coli to multiply in large numbers. The culture thus prepared was used directly for contaminating the water. During the culture preparation, care was taken to avoid contamination with other bacteria as nutrient broth is a favourable medium for growth of several bacteria.

3.4.3 Bacteriological analysis

The raw and filtered water samples were tested for the presence of escherichia coli using Multi-tube Dilution test approved by the Indian Standards Institution 1986 (presently titled as Bureau of Indian Standards). Five trials were conducted on each candle to determine its efficiency in filtering of bacteria-free water.

The candle of the mud water filter, was made of 60 per cent sand and 40 per cent clay. To test its efficiency in filtering water, this candle was also subjected to the above mentioned procedures. The commercial water filter candle made of different percentages of china clay, quartz, silica etc. was also subjected to a similar procedure to test its efficiency in filtering the water.

3.4.4 Determination of rate of filteration

Rate of filteration was determined by measuring the amount of water filtered by the filter candle in a given period of time. For this tap water was poured in the upper chamber of the three filters i.e. the commercial water filter, the mud water filter and the newly developed filter.

As filteration starts, the level of water in the upper container was maintained so as to keep the whole candle immersed in water. This was done in order to ensure that the rate of filteration is maintained, as, decrease in the water level slows down the rate of filteration. The decrease in rate of filteration is due to reduced pressure of water over the candle, as the level falls down (Padalla, 1988).

Hence regular maintenance of water level is imperative to ensure authentic results. After every hour, the amount of water filtered in the lower container was collected and measured using a graduated measuring jar and this was done in five trials over a duration of 5 hours.

The mean value of all the five trials conducted, was taken as the rate of filteration of the candle.

3.5 EXPERIMENTAL SET UP

The sterilized commercial filter and newly developed candles were kept in an inverted position in stainless steel containers. Distilled water was then poured into the containers and was allowed to filter through the candle. The filtered water was tested for possible contamination. This procedure was followed for all the candles except the mud water filter to check contamination at the candle source itself. In case of mud water filter, as the candle was not detachable from the container, test water was poured into the upper container of the filter and the filtered water was collected through the tap fitted in the lower container of the filter.

Then 5 litres of tap water, artificially contaminated by innoculating it with 5 ml of the prepared escherichia coli culture was poured into the containers. Artificial contamination ensured the presence of the bacteria in the water which after filteration was tested for presence of the same to ascertain the efficiency of the candle.

The candles selected for the study viz., the commercial filter candles, the sand and clay candles (mud water filter) and the newly developed candles (coal and clay mix and rice bran and clay mix) were kept in test water till almost the candle brim. The test water was allowed to filter into the hollow of each candle and this was later subjected to sequential stages of bacteriological analysis.

3.5.1 Multi-tube dilution test

The multi-tube dilution test was conducted in three successive stages. This method, suggested by the "Bureau of Indian Standards" for testing the bacteriological quality of filtered water is simple and can be carried out in the laboratory. Hence this method was selected to test the quality of water filtered by the candles.

The three stages involved in this method are :

a) Presumptive test

b) Confirmed test

c) Completed test

a) Presumptive test : For this test, water was added in measured amounts to Mac Conkey broth using fermentation tubes, alone. Water was innoculated in three dilutions of 10 ml, 1 ml and 0.1 ml into test tubes containing Mac Conkey broth, using sterilized pipettes each time. For every trial three tubes of each dilution were employed in which 10 ml dilutions was innoculated into double strength medium (i.e. 10 ml of Mac Conkey broth) and 0.1 ml and 1 ml dilutions were innoculated into single strength medium (i.e. 5 ml of Mac Conkey broth). Then the test tubes were incubated at 37°C for 24 hours. After 24 hours the tubes were examined for change in colour and gas production and were reincubated for a further 24 hours. If there was no gas production the test tubes were again examined after 48 hours. Formation of gas in any amount in the durham tube and change in colour to pink or yellow was recorded as positive presumptive test. The absence of gas at the end of 48 hours, constitutes a negative presumptive test and no further tests need be performed. In the latter case the water may be considered satisfactory from a bacteriological stand point.

All tubes showing gas in any amount were subjected to the confirmed test.

False positive presumptive test and its elimination

A positive test does not mean necessarily that members of the coli form group are present. In most cases it is true, but in certain exceptions, false positive presumptive test may be construed by the presence of other organisms capable of fermenting lactose with formation of acid and gas. Also, positive presumptive tests are frequently caused by a type of association known as synergism. Synergism is frequently caused by a gram-positive and a gram negative organism, growing together.

A concentration of dye just sufficient to prevent the growth of gram positive organisms will have no effect on the gram negative bacteria. This will result in the elimination of a synergistic reaction. False presumptive test caused by the presence of gas forming gram positive anaerobes and aerobes will also be eliminated by this procedure (Clifton, 1958).

(b) Confirmed test : For this test endo-agar plates were first prepared and a small loopful of sample from each tube, displaying positive presumptive test was taken with help of a sterilized metal loop and this was streaked over the surface of an endoplate and then incubated in the inverted position at $35 \pm 2^{\circ}C$ for 24 hours (Plate 13). As a result, three types of colonies may develop on the medium with corresponding inferences.

i) If typical coliform colonies appear on the plate after 24 hours at $35^{\circ}C$, the confirmed test may be considered positive and the completed test becomes essential. The colonies are prominent by showing a green metallic sheen if contaminated with escherichia coli.

ii) If only 'A' typical colonies appear on the plate the confirmed test cannot be considered negative since some coliform organisms fail to produce typical colonies on this medium or the colonies develop slowly. Regardless of whether typical or a typical colonies appear, it is necessary to complete the test.

iii) If only negative colonies appear on the plate, the confirmed test may be considered negative and no further tests need be made.

(c) Completed Test : The completed test may be performed on the typical or 'A' typical colonies developing on endo agar plate. The purpose of the completed test is to determine whether the colonies developing on endo agar plates are again capable of fermenting lactose with production of acid and gas.

For this test, a few colonies from the endo agar plate are transferred to a tube of peptone water with the help of a sterilized nichrome wire. The innoculated tubes were incubated at 37^{o}C for 24 hours. After the incubation a few drops of Kovac's reagent were added to the test tube contents. The samples depicting a pink ring were recorded as showing a positive test, whereas, the samples displaying a yellow shade were regarded as being negative in conclusion. In this manner, the completed test delineated the trials showing specifically the presence or absence of escherichia coli in the samples.

3.6 REPORTING OF RESULTS

The number of positive findings of coliform group organisms, resulting from multiple portion decimal dilution planting was computed as combination of the positives and recorded in terms of the Most Probable Number (M.P.N.) for each sample of water, was computed based on the M.P.N. table (Appendix D).

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RESULTS

CHAPTER IV

RESULTS

This chapter gives a detailed appraisal of the various stages of experimental results as presented under the following heads.

4.1 Bacteriological analysis of water

4.1.1 Bacteriological analysis of water samples filtered through candles comprising coal and clay

4.1.2 Bacteriological analysis of water samples filtered through candles comprising rice bran and clay

4.1.3 Bacteriological analysis of water samples filtered through candles comprising sand and clay

4.1.4 Bacteriological analysis of water samples filtered through the commercial candle

4.2 Comparative filteration rate of mud water filter candle, commercial water filter candle and newly developed filter candle

4.1 BACTERIOLOGICAL ANALYSIS OF WATER

Municipal drinking water was used as raw water for testing the various water filter candles. The bacterial analysis of municipal drinking water revealed that it was safe to drink when subjected to standard microbial analysis method. Therefore it was artificially enriched with Escherichia Coli culture. Using the M.P.N.

method (Maximum probable number) the raw water i.e. the tested municipal drinking water was found to contain 2,400 cell of E. Coli per 100 ml of water.

The candles i.e. the newly developed candles and commercial filter candles were kept immersed in this test water upto their brim. The filtered water collected in the hollow of these candles was subjected to multitube dilution test. For the five trials conducted on all the candles the same magnitude of contamination was introduced. For each test the filterate was collected after a period of 24 hours.

4.1.1 Bacteriological analysis of water samples filtered through candles comprising coal and clay

The filterate of the candles made with different proportions of coal and clay mix was subjected to bacteriological analysis. The results for candles C_1, C_2, C_3, C_4, C_5, C_6, C_8 and C_9 were observed to be the same during all the five trials, conducted on each candle using fresh filterates each time.

When the filterate from each of the above mentioned candles was subjected to presumptive test, gas formation was observed in all the 8 set of tubes (each set comprising of 9 tubes) (Plate 14), after 24 hours of incubation period, indicating a positive test. As all the tubes showed gas production, the confirmed test was carried out i.e. the endoagar plate test.

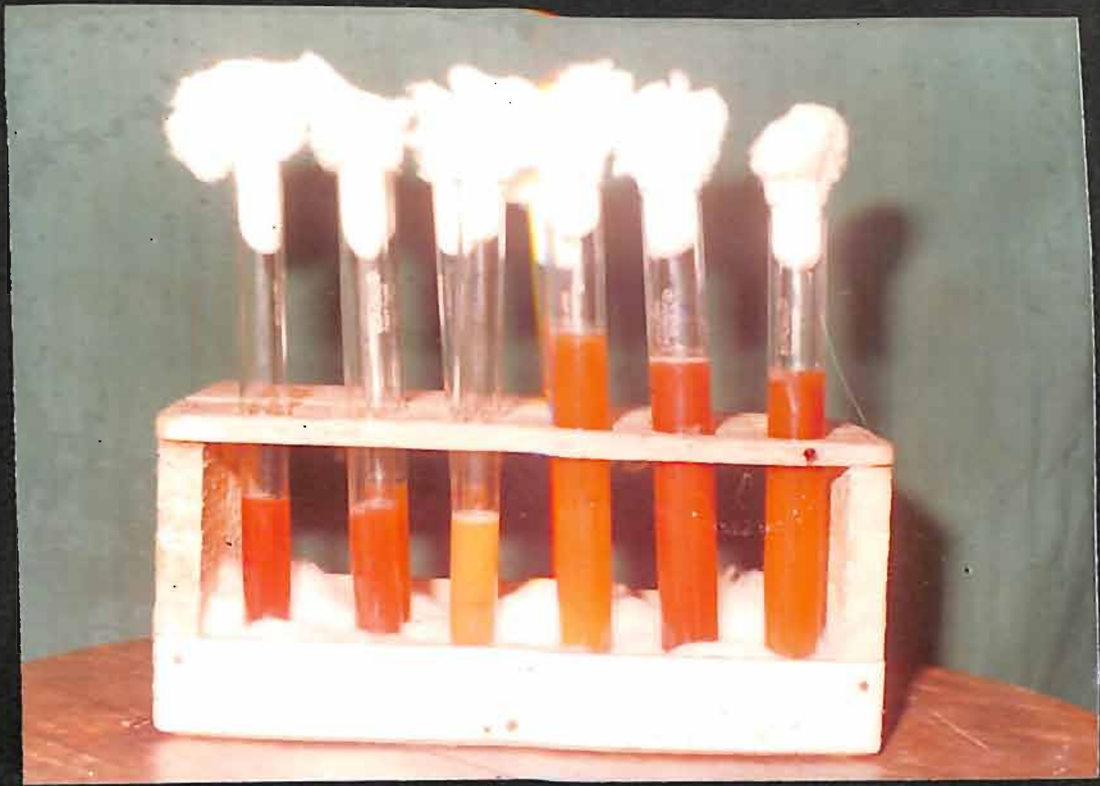


Plate 14: Positive presumptive test showing change in colour and gas formation

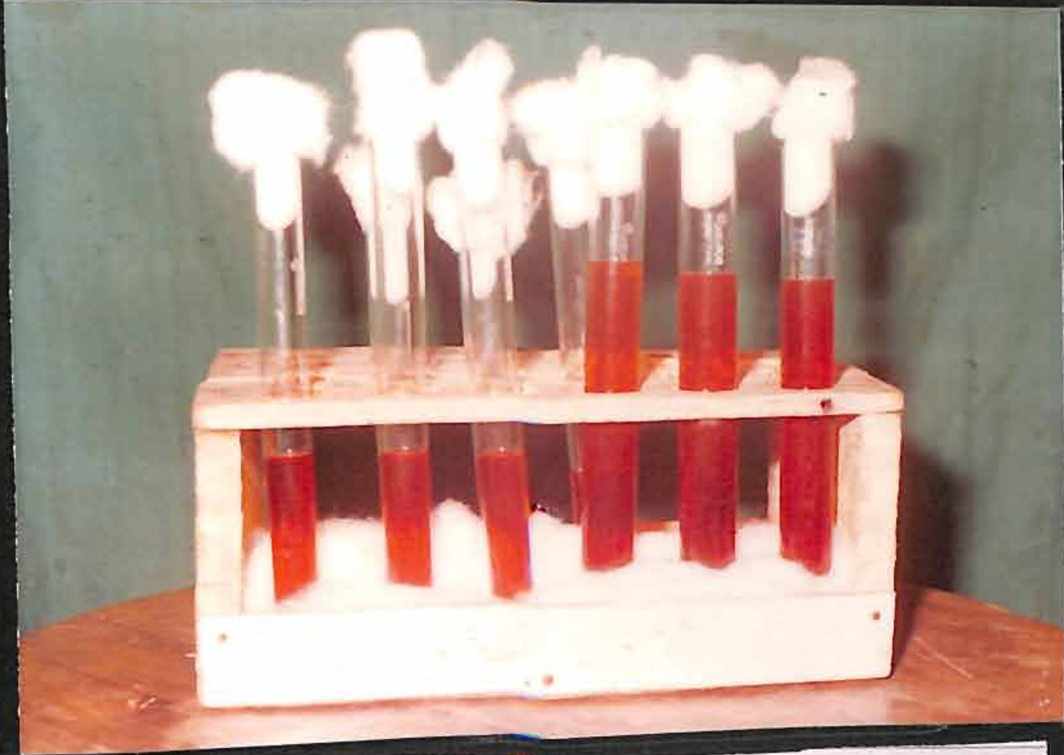


Plate 15: Negative presumptive test with no change in colour and gas formation

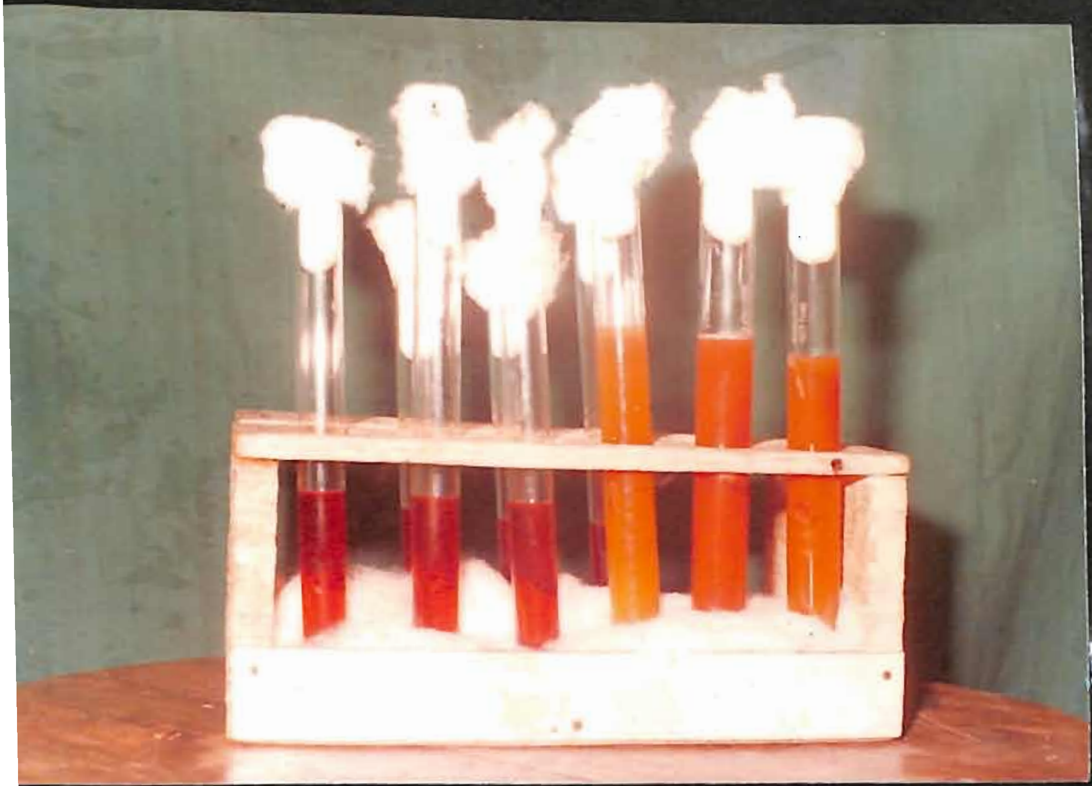


Plate 16: Positive presumptive test for only three tubes presumptive test negative for the other tubes

Plate 17: Positive completed test showing metallic green colonies of escherichia Coli

Plate 18: Negative completed test showing absence of any growth on streaked endoagar plate

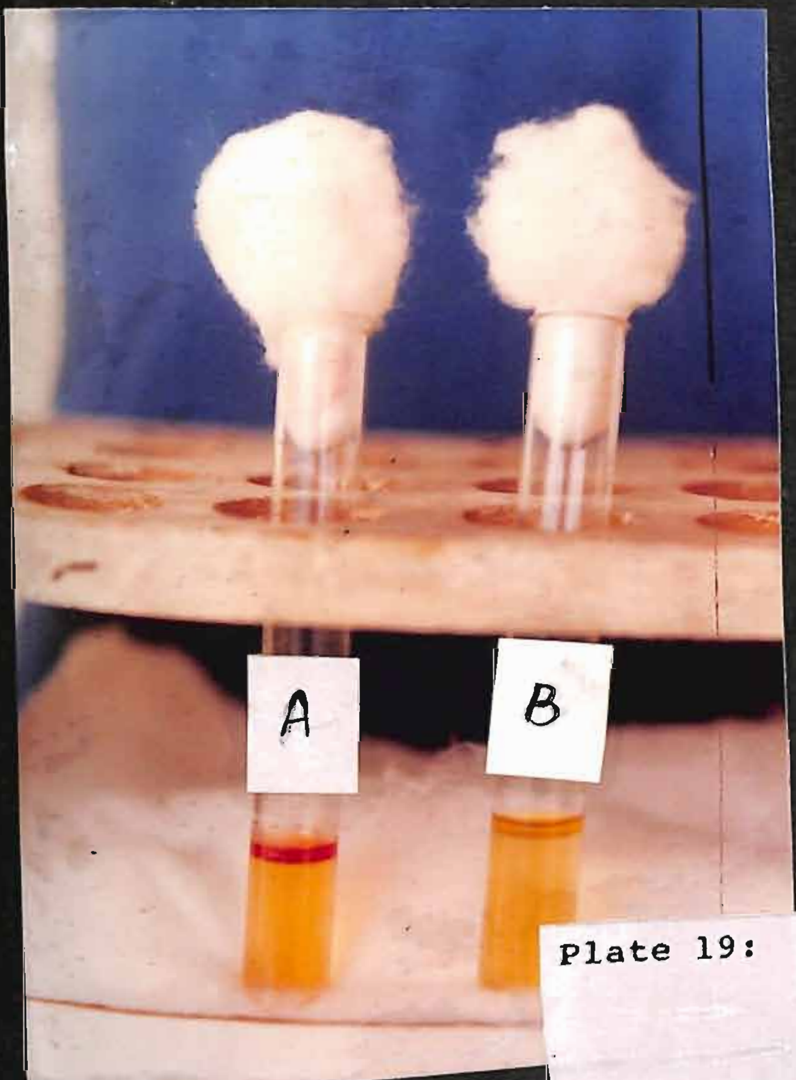


Plate 19: A Positive Indol test indicated by presence of pink ring

B Negative Indol test indicated by presence of yellow ring

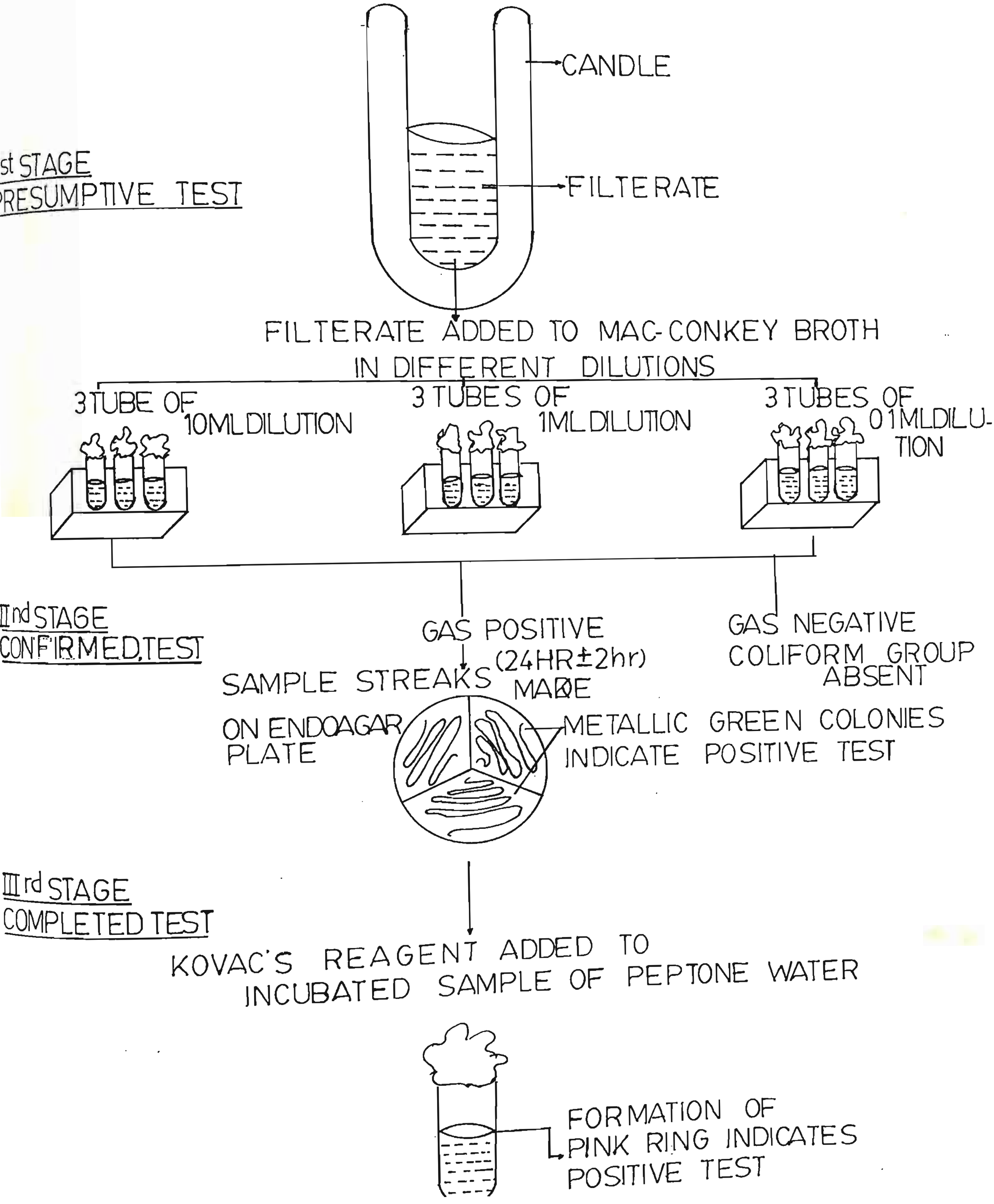
The confirmed test showed formation of metallic green colonies within 24 hours of incubation, indicating the presence of Escherichia Coli in water (Plate 17). A sample of metallic green colonies was taken to perform the last stage of the test i.e. the "Completed test", when a pink ring was observed on addition of Kovac's Reagent in the tube of peptone water that was incubated for 24 hours confirming the presence of Escherichia Coli (Plate 19).

All the subsequent four tests for each candle showed gas production and colour change in all the tubes during the presumptive test. The confirmed and completed test carried out also showed positive readings for the remaining trials for each candle as was observed during the first trial. These consequtive tests were sequentially repeated for five samples of filterate evolved from fresh test water each time. Therefore each of the respective candles i.e. C_1 to C_9 were subjected to the stages shown in figure 2 during each trial.

Thus after testing it was found that the candles C_1, C_2, C_3, C_4, C_5, C_6, C_8 and C_9 were not filtering the water to the desired quality. The bacterial count did not reduce to any degree after filteration of water through these candles, suggesting that these candles cannot be recommended for use in a water filter.

Candle C_7 however projected a slightly varied result. This candle made with 20 per cent of coal and 80

IGURE. 2 SCHEMATIC REPRESENTATION OF SEQU-
NTIAL STAGES IN MULTI-TUBE DILUTION TEST.



per cent of clay was found to be better in filtering the water. When the filterate of candle C_7 was subjected to presumptive test, no gas formation was observed in any of the tubes during the first three trials even after 48 hours of incubation (Plate 15).

The results of the bacteriological analysis of the water samples filtered through the candle C_7 were tabulated and are presented in table 6.

Table 6: Bacteriological analysis of water samples filtered by candle C_7

Test No.	MPN of E.Coli concentration in raw water	No. of positive tubes per filtered water levels(one) 10	1.0	0.1	M.P.N. of bacteria in filtered water
1	2,400	0	0	0	0
2	2,400	0	0	0	0
3	2,400	0	0	0	0
4	2,400	3	0	0	23
5	2,400	3	3	3	2,400

It is evident from the above table that candle C_7 is able to filter 100 per cent bacteria free water upto a certain period only. After the first three trials the presumptive test for the fourth trial showed gas formation in all the three tubes of double strength media, but the single strength dilution tubes did not show any gas formation (Plate 16). This shows that the number of organisms were reduced to a great extent during this trial, though the water was not 100 per cent free of bacteria. During the fifth trial, however, quality of filtered water further deteriorated as all the tubes of presumptive test showed gas formation and change in colour showing that more number of bacteria were able to pass through pores of the candle.

The samples from the positive tubes of presumptive test were then subjected to confirmed test i.e. the endoagar plate test. After 24 hours of incubation, metallic green colonies appeared on the streaked surface of endoagar plate, indicating the presence of escherichia Coli organisms. In order to confirm the presence of these organisms, the completed test i.e. the indol test was carried out. The addition of Kovac's reagent to incubated sample of peptone water produced a pink ring, thus confirming the presence of Escherichia Coli in water.

4.1.2 Bacteriological analysis of water samples filtered through candles comprising rice bran and clay

Water samples filtered through rice bran and clay mix candles were also subjected to multi-tube dilution test. As it was seen in the case of coal and clay mix candles, the higher proportion of coal had given a greater degree of porosity, which could be discerned by the higher level of water collected within the hollow of the candle and also by the bacterial quality of water. Hence in the case of rice bran and clay mix candles, the rawmaterial proportions selected for testing water filtering quality were only few starting with lower proportions of rice bran and higher that of clay.

Three candles were made with rice bran and clay mix, with proportions of rice bran varying from 10 per cent, 15 per cent and 20 per cent in each candle corresponding to the balance percentage being that of clay in the case of the three respective candles. The filterate of these three candles i.e. R_1, R_2 and R_3 when subjected to presumptive test showed gas formation in all the three sets of tubes (each set comprising of 9 tubes with different dilutions of media and filterate). Then the samples from positive presumptive test tubes were subjected to confirmed test i.e. the endoagar plate test, which showed a positive result with metallic green colonies appearing on the streaked surface. Thereafter the completed test was carried out, which confirmed the presence of escherichia Coli, with the formation of a vivid pink ring in the tube of peptone water.

Likewise for the second, third, fourth and fifth trials, fresh filterated was collected from each of the candles R_1, R_2, R_3 and subjected to various stages of multitube dilution test.

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The results of the bacteriological analysis of the water samples filtered through the candle 'R_1' were tabulated and are presented in table 7.

Table 7: Bacteriological analysis of water samples filtered through Candle R_1

Test No.	MPN of E.Coli concentration in raw water	No. of positive tubes per filtered water levels(ml)			M.P.N. of bacteria in filtered water
		10	1.0	0.1	
1	2,400	3	3	3	2,400
2	2,400	3	3	3	2,400
3	2,400	3	3	3	2,400
4	2,400	3	3	3	2,400
5	2,400	3	3	3	2,400

Apparently from the above table it can be seen that candle R_1 comprising 10 per cent of rice bran and 90 per cent of clay mix was not effective in reducing bacterial count of filtered water. All the five trials on fresh filtered water showed no improvement in the quality of water.

Candle R_2 comprising 15 per cent of rice bran and 85 per cent of clay also showed similar results for all the five trials. The bacterial quality of water did not show any improvement during all the five trials, conducted on the filterate of this candle.

The filterate of the third candle made with 20 per cent rice bran and 80 per cent clay i.e. candle R_3 was also found to be equally ineffecient. All the five trials conducted on different filterates of candle R_3 showed no change in the bacterial quality of water.

Therefore it can be inferred that none of the candles made with varying proportions of rice bran and clay mix proved effective in holding up E. Coli from the filtered water. Hence it is concluded that rice bran is not a suitable material for developing a filter candle.

4.1.3 Bacteriological analysis of water samples filtered through the clay and sand mix candle used in mud water filter

The test water containing E. Coli was allowed to filter through the clay-sand mix candle of the mud water filter. The filterate was subjected to presumptive test, where gas formation was observed in all the tubes, within twenty four hours of incubation, thereby indicating a positive presumptive test. The samples from the positive tubes of presumptive test were then subjected to confirmed and completed tests. The results for both these tests were positive, indicating the apparent presence of coliform bacteria in the filtered water.

Likewise the second, third, fourth and the fifth trials were performed using fresh test water each time.

The filterates collected during each trial were subjected to the various stages of multi-tube dilution test.

The results of the bacteriological analysis of the water samples filtered through the clay-sand mix candle were tabulated and are presented in table 8.

Table 8: Bacteriological analysis of water samples filtered by clay-sand mix candle of mud water filter

Test No.	MPN of E.Coli concentration in raw water	No. of positive tubes per filtered water levels(ml)			M.P.N. of bacteria in filtered water
		10	1.0	0.1	
1	2,400	3	3	3	2,400
2	2,400	3	3	3	2,400
3	2,400	3	3	3	2,400
4	2,400	3	3	3	2,400
5	2,400	3	3	3	2,400

It is evident from the above table that the clay-sand mix candle used for the test was not efficient in trapping bacteria. The quality of the filtered water is no better than the quality of raw water used. All the five trials using fresh filterates showed no improvement in the quality of filtered water.

4.1.4 Bacteriological analysis of water samples filtered through candles of the commercial water filter

Water samples filtered through candles of the commercial water filter were subjected to bacterial analysis. No gas formation or change in colour was observed in any of the tubes during the presumptive test, even after 48 hours of incubation, indicating a negative test. This proved the absence of any bacteria in the filtered water. Hence, the confirmed test and completed test were not carried out.

During the second, third, fourth and fifth trial also the presumptive test showed no gas formation or change in colour in any of the tubes. The results of all the five trials are presented in table 9.

Table 9: Bacteriological analysis of water samples filtered through candles of commercial water filter

Test No.	MPN of E.Coli concentration in raw water	No. of positive tubes per filtered water levels(ml)			M.P.N. of bacteria in filtered water
		10	1.0	0.1	
1	2,400	0	0	0	0
2	2,400	0	0	0	0
3	2,400	0	0	0	0
4	2,400	0	0	0	0
5	2,400	0	0	0	0

From the above table it is evident that the candle of the commercial water filter is efficient in restricting 100 per cent bacteria that was introduced. For all the five trials the results indicated the total absence of coliform organisms in the filtered water. Hence, the candle can be safely used to obtain bacteria free water. The candle is also comparatively better than the newly developed candles and clay-sand mix candle both in terms of longevity and bacterial quality of water.

4.2 COMPARATIVE FILTERATION RATE OF MUD WATER FILTER CANDLE, COMMERCIAL WATER FILTER CANDLE AND NEWLY DEVELOPED FILTER CANDLE

The rate of filteration of clay-sand mix candle of the mud water filter, candle of commercial water filter and newly developed candle C_7 was determined and the data was tabulated as shown in table 10.

Table 10: Rate of filteration of mud water filter candle, commercial water filter candle and newly developed filter candle

Trial No.	Mud water filter (ml/hr)	Commercial water filter (ml/hr)	Newly developed candle (ml/hr)
1	8,000	1050	1000
2	7,660	1000	500
3	6,000	1000	350
4	3,200	1000	200
5	1,000	1000	100
Average	5,172 ml	1010 ml	430 ml

The above table reveals that average rate of filteration of mud water filter is 5,172 ml/hr whereas the average rate of filteration of the commercial water filter is 1010 ml/hr and that of newly developed candle C_7 is only 430 ml/hr. The table further shows that the rate of filteration of clay-sand mix candle and newly developed candle C_7 is not uniform. In case of mud water filter the rate of filteration gradually decreases from an initial of 8 lt./hr to a final of 1 lt/hr only. This gradual decrease in the rate of filteration of mud water filter is further emphasised in table No.11, which shows a case experiment of within an hour variations in the rate of filteration of clay-sand mix candle, at regular intervals of 5 minutes.

Table 11: Variations in rate of filteration of clay-sand mix candle at an interval of every 5 mts

Date of experiment : 21-6-93

Time	Volume of water filtered (ml)
12.00 pm	900
12.05 pm	870
12.10 pm	820
12.15 pm	750
12.20 pm	710
12.25 pm	610
12.30 pm	570
12.35 pm	550
12.40 pm	520
12.45 pm	510
12.50 pm	420
12.55 pm	400
1.00 pm	370
Total	8,000 ml/hr

The above table shows how the rate of filteration, within an hour, gradually decreased from 900 ml/5 mt to only 370 ml/5 mt. The candle was then washed and rinsed as it was clagged, before it was reused for the next trial. During all the five trials the level of water in the upper containers of the filters was maintained constant.

The rate of filteration in case of candle C_7 was also found to be gradually decreasing (Table 10) with an initial rate of filteration of 1000 ml/hr to a final rate of filteration of 100 ml/hr only. This shows that the rate of filteration of candle C_7 is also not uniform and the candle pores were getting clagged easily.

In the case of the commercial water filter the readings were uniform and no clogging of the candle was observed. Apparently, thus it was not necessary to record within an hour variations in its rate of filteration.

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DISCUSSION

CHAPTER V

DISCUSSION

This chapter presents a concise interpretation of results under the following heads.

5.1 BACTERIOLOGICAL ANALYSIS OF WATER

The source of raw water used for testing the efficiency of all filter candles was municipal drinking water. The bacterial analysis of Municipal drinking water was found to be safe to drink by standard microbial analysis method. This may be due to the fact that the water supplied by the municipality is chlorinated to kill existing bacteria in the water. The effect of chlorine remains in water for some period, during which it effectively kills bacteria arising from any further contamination of water. Therefore this water was artificially enriched with escherichia coli for test purposes. The contaminated water was found to contain 2,400 cells of escherichia coli per 100 ml.

5.1.1 Bacteriological analysis of water samples filtered through candles comprising coal and clay

The filterate of the candles made with different proportions of coal and clay was subjected to bacterial analysis. It was found that candles C_1, C_2, C_3, C_4, C_5, C_6, C_8 and C_9 were not filtering water upto the desired quality. The results for all the above mentioned candles showed the presence of bacteria in the filtered water. The filtered water was subjected to presumptive test, confirmed test and completed test. All these three stages of the multitube dilution test indicated the presence of coliforms. Thus after testing it was found that candles C_1, C_2, C_3, C_4, C_5, C_6, C_8 and C_9 were not filtering the water to the desired quality. The water was passing through the pores of the candle without any change in the bacterial quality. This may be due to the pores in the candle. The pores may either be too large or too many in number, due to which the candle is ineffective in trapping the bacteria effectively.

The pore size depends on two factors, the first one being the particle size of the raw material and the other being the distribution of coal particles uniformly in the clay without formation of lumps during mixing of the raw materials as, the coal particles tend to stick together when lumps are formed and on burning, in the place of coal particles a large pore will be present, thereby increasing the pore size. The first factor was taken care of by sieving the powdered coal through a muslin cloth three times. The second factor was controlled by thorough mixing of coal and clay with addition of small amounts of water to help moisten the clay and for uniform distribution of coal particles.

Inspite of taking these precautionary steps the bacteria were still passing through the filter barrier. As the proportion of coal decreases the porosity decreases due to the fact that the number of coal particles that burn out or leave pores are reduced with lower percentages of coal in the candle. But in case of candles C_8 and C_9, even with reduced amount of coal, the bacteria could not be kept under check. This may be due to some physical deformities appearing in the candle like hair line cracks, holes, etc. that are not visible to human eye examination, leading to failure of the candle.

The formation of such physical deformities in the candle can be attributed to a peculiar quality of clay i.e. shrinkage, which is in proportion to the presence or absence of other ingredients like sand and coal particles, as observed in this case. Shrinkage occurs at the drying stage of the candle, due to the evaporation of water and in place of water, cracks appear in clay. These cracks are large or fine depending on the percentage of other ingredients that neutralize the shrinkage effect at a particular percentage. When the prepared clay mix is such that the shrinkage effect is neutralized, then it is called an optimum mix and a candle prepared from this mix will give best results as there will be no physical defects in the candle.

Candle C_7 made with 20 per cent of coal and 80 per cent of clay was found to be working efficiently for some time, being able to stop 100 per cent of the bacteria from entering the filtered water. This shows that the candle mix with 20 per cent coal and 80 per cent clay is the optimum mix for candle preparation. The absence of physical deformities in the candle can only be contributed to the optimum mix and the reduced number of pores formed in the candle on baking as the coal particles were limited to only 20 per cent. Candle C_7 was further able to withstand high temperatures of the autoclave without undergoing any change in its pore structure upto a short period.

However after the third trial the quality of candle C_7 started deteriorating, indicating a limited life span of the candle. During the fourth trial a few bacteria were able to pass through the filter barrier and during the fifth trial, the quality further deteriorated showing that the filter barrier was slowly getting degenerated.

This may have resulted due to repeated autoclaving of the candle for every trial. During the first three trials the candle could withstand autoclaving, after which perhaps it slowly weakened. As the candle was made with ordinary clay the strength of clay particles may have reduced after sometime, resulting in breaking up of two or more pores to form a larger pore.

Therefore to increase the durability of the candle C_7 some other appropriate raw material may have to be added which will increase its efficiency and make it more durable. Besides this the type of anneeling process followed in the manufacture of the candle also has an effect on the durability of the candle. As the candle was done under the guidence of an experienced potter and without the use of sophisticated technology as in the case of commercial water filters, certain technical defects are bound to arise, that may have also contributed to the failure of the candle.

Hence it can be inferred from the results that candle C_7 worked efficiently for the first three trials only, after which the quality of the filtered water started deteriorating. This leads to the inference that candle C_7 can be used for filtering water for a limited period only, but this particular proportion of the raw material mix does have ample scope for emerging as an efficient candle, provided further appropriate materials are added to further increase longivity of the candle.

Thus it can be said that out of all the candles prepared with coal and clay mix, candle C_7 with 20 per cent coal and 80 per cent clay mix was found to be the best but, because of its limited life span, it is not economically practicable and cannot be recommended to be used in water filters at the village level, without further probe on the scope of this raw material mix for filter candle.

5.1.2 Bacteriological analysis of water samples filtered through candles comprising rice bran and clay

Water samples filtered through rice bran and clay mix candles were also subjected to multitube dilution test. The proportions of rice bran were restricted to lower amounts as higher proportions of rice bran would give a higher degree of porosity to the candle.

Rice bran was ground to a fine powder and sieved through a muslin cloth three times before mixing with clay to prepare the candles. The results of the bacterial analysis of the water samples filtered through candle R_1, R_2 and R_3 were similar as all these three candles were not preventing the bacteria from passing into the filtered water. All the five trials conducted on each candle showed presence of coliform bacteria in the filtered water.

The percentages of rice bran in the three candles were kept low i.e., 10 per cent, 15 per cent and 20 per cent in candles R_1, R_2 and R_3 respectively to keep a check on the number of pores in the candle that effect the efficiency of the candle. As only the above three proportions of candle mixes were tested with rice bran the optimum mix using this raw material could not be found resulting in the failure of the candle.

The other factor that affects the working of the candle is the particle size of rice bran which is an important indicator of the pore size of the candle. This was controlled by sieving the rice bran through a muslin cloth, three times after being powdered, to check the size of the rice bran particles.

As the results with such low proportions of rice bran as 10 per cent, 15 per cent and 20 per cent showed that the water filtering capacity of the candles was poor, higher proportions of rice bran and clay mix were not prepared or experimented with.

Thus it can be said that none of the candles made with varying proportions of rice bran and clay mix proved effective in holding up E. Coli from the filtered water. Hence it is concluded that rice bran is not a suitable material for developing a filter candle.

5.1.3 Bacteriological analysis of water samples filtered through clay and sand mix candle used in mud water filter

The clay-sand mix candle is not detachable from the filter body, therefore it was used along with the filter, unlike the other candles where they were kept in separate containers and in inverted positions. The test water containing E. Coli was allowed to filter through the clay-sand mix candle of the mud water filter. The filterate was subjected to various stages of multitube dilution test. The results showed that the bacteria were freely flowing through the clay-sand mix candle of the mud water filter.

Five trials, carried out on fresh filterate each time showed the same results. The filtered water was containing E. Coli each time without any reduction even by a small fraction. These results are in contradiction to an earlier study carried out by Rama (1986), in which it was found that a candle made with 60 per cent sand and 40 per cent of clay was 100 per cent efficient in the removal of bacteria and collection of safe drinking water in the lower chamber of the water filter.

The present study however shows that bacteria are not being trapped by the clay-sand mix candle. The reason for this may be due to several technical features beyond the control of the potter as there is no standardised and mechanised procedure in preparation of the filter candle.

The grain size of sand used in preparation of the candle may perhaps be slightly larger, which could be one of the reasons for the inefficiency of the filter candle. To work effectively as proved in the earlier study (Rama, 1986) it is very important for the sand to be sieved through an appropriate size mesh before mixing the sand with clay. The size of the sand particles determine the degree of porosity the candle gets. Further the larger sand particles, result in an unstable structure which leads to reduced life span of candle and also makes the candle coarse and weak besides the appearance of surface cracks on the candle.

In the present study, the clay-sand mix candle was found to have a number of surface cracks that could have led to failure of the candle. The candle was also found to be very weak and got easily detached from the filter body on pouring water into the filter container. This can be due to inadequate baking of the candles. If the candles are fired at the required temperature and for a particular period this defect can be avoided.

Further in some candles made with clay-sand mix, holes were observed. This may be due to the quantity of sand used in the candle and also the size of sand grains used as, both these factors play an important role in imparting structural stability to the candle.

Since there is no standardised and mechanical procedure for preparation of the clay-sand mix candles, even a trained potter is liable to labour fruitlessly at evolving an effective candle, unless guided closely under specified instructions. As the candles have not been prepared carefully and appear ineffective in terms of shape and method of fixing to the filter, water filtering through these candles is not free of bacteria.

Therefore the present sand-clay mix candles, are not safe to be used, unless fresh candles be made keeping in view all the factors discussed above before fixing them in freshly prepared mud water filters.

When the existing clay-sand mix candle was compared to newly developed candle C_7, it was found that candle C_7 was working better, in terms of bacterial quality of water as candle C_7 worked effectively for the first three trials but clay-sand mix candle was incapable of doing so, during all the five trials.

5.1.4 Bacteriological analysis of water samples filtered through candles of the commercial water filter

Water samples filtered through candles of the commercial water filter were subjected to bacterial analysis. The results showed the absence of bacteria in the filtered water. All the five trials on fresh filterates showed that the candle was working efficiently and no E. Coli was passing through the filter barrier.

The commercial candle was effective in trapping all the bacteria as it is made of china clay, a very durable material. The smaller particle size of china clay makes it possible to have more strength. Binding resins are also used in the commercial candle mix that further add strength to the candle.

In the commercial candle, in addition to the porosity effect that helps in filtering of bacteria free water, chemical disinfection is also carried out due to the presence of silver ions deposited on the pores of candle. The bacteria that pass through the pores are killed due to the bactericidal effect of the silver ions. The phenomenon of disinfection of water by silver ions is known as oligodynamics (Central Glass and Ceramic Research Institute, 1984).

The candles are manufactured under controlled conditions in the laboratory controlled heating is followed by slow anneling process, followed by cooling and soaking the candles all of which determine the efficiency of the candle. The physical deformities of the candle are reduced or totally absent due to these processes. Further the candles are tested for any visible cracks before being marketed. Candles are also fitted with a metal cap which also prevents the bacteria from passing out.

Such a foolproof manufacturing technique, being absent so far in the newly developed candle and clay-sand mix candle may perhaps be the main cause for inefficiency of the latter.

Hence the commercial candles can be safely used to obtain bacteria free water. These candles are also found to be comparatively better than the newly developed candle C_7 and the clay-sand mix candle, both in terms of longivity and bacterial quality of water. The commercial candle could withstand usage and repeated autoclaving without undergoing any changes, showing the durability of the candle, unlike the coal-clay candle C_7 which showed major changes after the first three trials, ultimately giving contaminated water during the fourth and fifth trials. Therefore the commercial candle was found to be the best and can be recommended for use.

5.2 COMPARATIVE FILTERATION RATE OF MUD WATER FILTER CANDLE COMMERCIAL WATER FILTER CANDLE AND NEWLY DEVELOPED FILTER CANDLE

The rate of filteration of clay-sand mix candle of the mud water filter and candle of the commercial water filter was determined and it was observed from table 6 that rate of filteration of the commercial water filter was uniform and was found to be 1000 ml/hr. In case of mud water filter the rate of filteration was initially very high i.e. about 8,000 ml/hr. It started gradually reducing and after 5 hour the rate of filteration was found to be only 1000 ml/hr. This gradual decrease in the rate of filteration of clay-sand mix candle is further emphasised in table No.11 on Page No. which shows a case experiment of within an hour variations in the rate of filteration of sand-clay mix candle, at regular 5 mt intervals. This shows that as water is being passed through the clay-sand mix candle the pores of the candle are being clogged very frequently due to which the rate of filteration was reducing with every hour. In case of newly developed candle C_7 the initial rate of filteration was only 1000 ml/hr after which it started decreasing, finally at the end of the 5th hour it was found to be only 100 ml/hour. This decrease in rate of filteration may perhaps be due to the candle getting clogged very easily. Hence rate of filteration in case of candle C_7 was also not uniform.

As the rate of filteration of the mud water filter candle is abnormally high due to various reasons discussed under 5.1.3, and that of newly developed candle is very low, it can be concluded, that the commercial water filter candle, filters best and can be used for domestic purification of water as it filters water at a desirable rate and is 100 per cent effective in trapping the bacteria.

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SUMMARY

CHAPTER

SUMMARY AND CONCLUSIONS

Water is one of the prime necessities of life and has been considered next to air - the most important life sustaining element. Water is needed for many purposes such as drinking, cooking, personal hygiene, etc. The water used should be safe, both quality and quantity being important. Unfortunately the available water is often contaminated and not fit for drinking. There are different kinds of pollution by microbes and chemicals which pose health hazards.

In the case of wells and lakes used for drinking water, often there is no proper drainage of surface water. The result is gastroenteritis and other water related diseases. About 1200 million people in the developing countries do not have access to safe drinking water. The problem is acute in many parts of India. Instead of being health giving, the water brings on disease. So, the water has to be subjected to some kind of treatment before consumption.

At the domestic level, candle water filters are very popular for the filteration of drinking water. Since most of the filters are not within the economic reach of majority of the rural population and lower income groups, the investigator felt the need to develop and study the efficiency of low cost water filter candles using raw materials that are within easy economic reach of the rural people. Hence this study was undertaken with the following objectives.

1. To identify raw materials to mix with clay in the preparation of a low cost water filter candle.

2. To examine the comparative efficiency of different water filter candles.

Filter candles were made with all possible combinations of coal and clay. Candles were also made with rice bran and clay, as these raw materials are easily available in the rural areas and within easy economic reach of rural households. It was observed that candle made with 20 parts of coal and 80 parts of clay worked out better than all the other proportions.

All the candles were tested by subjecting the water filtered through them, to multi-tube dilution test. Five trials were conducted with each candle, using fresh water for each trial, to determine its efficiency. In order to compare the efficiency of newly developed candles with those already developed, a commercial water filter candle and a low cost, clay-sand mix candle were selected. The filteration rate and efficiency of the candles in terms of microbial quality of filtered water was studied.

The important findings of the study are as follows :

1. Candles were made with different proportions of coal and clay, on the potter's wheel with the help of an experienced and trained potter. Water filtering through these candles was subjected to bacterial analysis. Five trials were conducted on each candle, using fresh water for each trial. All the five trials conducted on candles C_1 to C_6 and C_8 to C_9 showed presence of bacteria in filtered water by "Standard Microbial Analysis" method. Hence it was concluded that these candles were not effective in trapping the bacteria.

2. Candle C_7 comprising 20 per cent coal and 80 per cent clay was however found to be working efficiently for the first three trials, being able to trap 100 per cent of the bacteria from entering the filtered water. The efficiency of this candle can be contributed to the right percentage of coal added to clay resulting in formation of an "optimum mix" due to which any physical deformities like hair-line cracks, holes, etc. in the candle do not arise. However after the third trial, the quality of filtered water started deteriorating, indicating a short life span of the candle.

3. Candle C_7 was found to be efficient in filtering bacteria free water for a short period. Therefore to increase the durability of this candle some other appropriate raw material may have to be added, which will increase its life span. Hence, this particular proportion of the raw material mix does have ample scope for emerging as an efficient candle, provided appropriate materials are added to further increase the longevity of the candle.

4. Candles were made with rice bran and clay and were tested for their efficiency in filtering bacteria-free water. Bacterial analysis of the water samples filtered through these candles showed that the candles could not retain the bacteria which was introduced into the raw water during all the five trials. Hence it can be said that none of candles made with varying proportions of rice bran and clay proved effective in holding up E. Coli, as such rice bran is not a suitable material for developing a filter candle.

5. In order to compare the efficiency of the newly developed candle C_7 with that of an already developed low-cost candle, the clay-sand mix candle was tested. Bacterial analysis of the

water samples filtered through this candle showed that the candle was ineffective in trapping the bacteria. The candle was further found to have physical deformities like hair-line cracks, holes, etc. that may have led to the failure of the candle. It was further observed that the candles were weak and got easily detached from the filter container on pouring water into the filter. This is mainly due to absence of a mechanised procedure in preparing the clay-sand *mix candle and* no standardised procedure in mixing the raw material which may give room for human error, due to which the candles in question proved inefficient.

6. Candle of the commercial water filter was also selected for comparing the efficiency of the newly developed filter candle. Bacterial analysis of water samples filtered through this candle showed that the candle was cent per cent efficient in holding up the E. Coli from the filtered water. The candle was found to be durable enough to withstand autoclaving without undergoing any change. The life span of the candle was also good when compared to the newly developed candle C_7, as it gave bacteria free water for all the five trials.

7. The rate of filteration of the newly developed candle was found to be 1000 ml/hr during the first hour after which it started gradually reducing and finally it was found to be only 100 ml/hr at the end of the 5th hour, showing that the pores of the candle were being easily clogged. In the case of clay-sand mix candle the initial rate of filteration was very high i.e. 8 lt/hr indicating the very high porosity of the candle. The rate of filteration started decreasing gradually and was finally found to be 100 ml/hr at the end of 5th hour, apparently due to the candle pores getting clogged. However in the case of the commercial water filter, it was observed that the rate of filteration was uniform through out the experiment i.e. 1000 ml/hr. The candle was able to filter water without getting easily clogged. The comme rcial candle was found to be conforming to the standards set up by the ISI (1986) for ceramic water filter candles both in terms of microbial quality and rate of filteration.

Therefore it can be concluded from the study that the commercial water filter candle, though costly was found to be the best due to highly mechanised and standardised procedures involved in its preparation and can be used for purification of water and domestic level.

The newly developed candles made with coal and clay and rice bran and clay were in no way comparable with the commercial filter candle, except for Candle C_7, made with 80 per cent clay and 20 per cent coal which was found to be filtering good quality water, though for a limited period only.

Candles comprising 60 per cent sand and 40 per cent clay can be made to work more effectively when they are prepared according to specific standards, taking into consideration all the finer details that improve the working of a filter candle. The candle made with 80 per cent clay and 20 per cent coal was better than clay-sand mix candle in terms of durability and efficiency in filtering of bacteria-free water. Therefore this candle can be recommended for use only after further work is done on this candle to make it more durable and improve its life span, thereby making it a low-cost useful technology at the village level.

Suggestions for future research

1. Further research must be done on the 80 per cent clay and 20 per cent coal candle in order to improve its life-span, thus making it of use of a rural family, since its capability to hold up bacteria for a certain working span has been identified through this research work.

2. Further research can be done on other low cost raw materials other than coal and rice bran in manufacture of filter candles.

3. The feasibility and acceptability of the newly developed candle C_7 in rural areas can be studied once its longevity is ascertained through further research.

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APPENDICES

APPENDIX - A

Indian Standard

SPECIFICATION FOR
FILTERS FOR DRINKING WATER PURPOSES
(First Revision)

1. SCOPE

1.1 This standard prescribes the requirements and methods of sampling and test for filter candles as well as filter containers for drinking water purposes.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definition given in IS : 2781-1964, and the following shall apply.

2.2 **Capacity** - It shall be indicated by lower container holding filtered water.

3. FILTER CANDLES

3.1 **Material** - Filter candles shall be fired, unglazed porous ceremicware and subsequently suitably treated chemically so that fine silver is embedded in the body of the filter candle.

3.1.1 **Workmanship and Finish** - Filter candle shall be regular in shape, symmetrical about their axis and properly fired so as not to shed particles under conditions of normal use. It shall also be free from large discrete cavities, warpage, uneven firing, protrusion and inadequate sealing. It shall have no visible cracks when seen from a distance of around 30 cm. It shall also pass the test for detection of cracks and inadequate sealing when tested by the method prescribed in Appendix A.

3.2 Requirements

3.2.1 Dimension - Filter candles shall be of shape and size as agreed to between the purchaser and the supplier. However a conventional pattern and dimensions for filter candle are given in Fig.1 for guidance.

3.2.1.1 Tolerance on all dimensions shall be ± 2 mm on the declared values.

3.2.2 Rate of Filtrations - When tested by the method prescribed in Appendix B, it shall be atleast 1.5 litres per hour per candle.

3.2.3 Freedom from Bacteria - Filter candles shall pass the test for freedom from bacteria when tested by the procedure given below.

3.2.3.1 Prepare a suspension of **Esherichia coli** (10^5 organisms per ml) and fill into a sterilized filter container fitted with the filter candle under test and collect the filtrate in a sterilized vessel. Test the filtrate for the presence of E. coli as prescribed in 4, 5 and 6 of IS : 5887.

3.2.4 Presence of Silver - When tested by the method prescribed in Appendix C, the test shall indicate the presence of silver.

3.2.5 **Freedom from Suspended Particles** - The filter candle shall pass the test for freedom from suspended particles when the filtered water taken in a clear 250 ml beaker made of colourless glass, shall not show any suspended particles when examined visually from a distance of 30-35 cm.

3.2.6 **Filter Cap** - The material used in the manufacture of filter cap shall be stainless steel, polypropylene or brass coated with nickel. It shall be jointed to the filter candle by portland or any hydraulic cement or any other suitable binding material.

4. CONTAINERS

4.1 The material of construction for the containers shall be such proven material known to be safe for storage of drinking water.

4.2 **Capacity** - The capacity of the lower container shall be minimum 8 litres. The capacity of the upper container shall not be less than the lower container and shall not exceed one and quarter times more than the capacity of the lower container.

4.3 **Workmanship and Finish** - The containers shall be regular in shape smoothly finished and free from cracks and imperfections. They shall be symmetrical (except for projections on the upper container for lifting) about the axis which shall be perpendicular to the base. The upper container shall be provided with hole(s) in the base for fixing the candle(s). The lower container shall be provided with hole of suitable size near the base for fixing a tap for draining water. The base of the lower container shall enable the container to stand vertically without rocking or spinning on a plain horizontal surface.

4.3.1 The upper container, the lower container and the lid of the upper container shall fit in such a manner that there would be no contamination of dust in the respective containers.

4.4 Leakage - The entire assembly shall be leakproof. Filter candles may be fitted with washers so as to ensure that no unfiltered water trickles in the lower container.

5. OTHER ACCESSORIES

5.1 **Brush** - The manufacturer shall provide a suitable non-metallic brush for cleaning the filter candle and the containers.

6. PACKING AND MARKING

6.1 **Packing** - The filter candles and filters shall be packed as agreed to between the purchaser and the supplier.

6.2 **Marking** - The filter candles and filters shall be marked with the following information:

a) Manufacturer's name and his recognized trade-mark, if any;

b) Rate of filtration;

c) Capacity of lower container in litres; and

d) Lot number or batch number to enable the batch to be traced from records

6.2.1 In addition, the manufacturer shall provide an information leaflet covering the volume of filtered water after which brushing is necessary and prescribing the time limit after which the filter candle be changed.

6.2.2 The filter candles and filters may also be marked with the ISI Certification Mark.

APPENDIX - B

MacConkey broth

Composition and method of preparation - Recommended by Indian Standards Institution (1986).

FORMULA

Peptone	:	20 g
Lactose	:	10 g
Sodium Chloride	:	5 g
Bile Salt/Sodium tauro-cholate	:	5 g
Distilled water	:	1000 ml

DIRECTIONS : Dissolve all the ingredient and adjust the pH to 7.4. After adjusting the PH, add 1 ml of 1 per cent alcoholic solution of bromocresol purple. This will be the single strength medium. Distribute 10 ml. of the medium into 150 x 15 mm test tubes and add a durham's tube in an inverted position. Plug the tubes with non-absorbent cotton and sterilize it at 115°C for 10 minutes in the auto clave. This medium is used for 1 ml. and the decimal dilutions of the water samples. For 10 ml. and larger aliquots a double strength medium is used. For double strength medium add the above ingredients in double the quantities in 1000 ml. of distilled water. This medium is dispended into 10 ml. quantities in 150 x 18 mm. test tubes added with durhams tubes and sterilized.

APPENDIX - C

PEPTONE WATER

Composition and method of preparation

Recommended by Indian Standard Institution (1981b)

FORMULA

Peptone	:	10 g
Sodium chloride	:	5 g
Distilled water	:	1000 ml

DIRECTIONS

Dissolve all the ingredients. Adjust the PH to 7.4. Dispense 4 ml. medium into test tubes and plug with non-absorbent cotton. Sterilize in the auto clave at 1.02 $\pm$ 0.03 kg/cm^2 guage pressure for 15 minutes.

APPENDICE - D

In order to arrange correctly a number of analytical results the laws of probabilities are applied and from the available statistics of test data, the most probable number or M.P.N. is determined. The following table is the standard table (American Public Health Association, 1971).

NUMBER OF TUBES GIVING POSITIVE REACTION OUT OF :

3 of 10 ml each	3 of 1 ml each	3 of 0.1 ml each	M.P.N. of Caliform Bacteria
0	0	1	3
0	1	0	3
1	0	0	4
1	0	1	7
1	1	0	7
1	1	1	11
1	2	0	11
2	0	0	9
2	0	1	14
2	1	0	15
2	1	1	20
2	2	0	20
2	2	0	21
2	2	1	28
3	0	0	23
3	0	1	39

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Contd..

3 of 10 ml each	3 of 1 ml each	3 of 0.1 ml each	M.P.N. of Caliform Bacteria
3	0	2	69
3	1	0	45
3	1	1	75
3	1	2	120
3	2	0	93
3	2	1	150
3	2	2	210
3	3	0	240
3	3	1	560
3	3	2	1,100
3	3	3	2,400

26.2.94

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