MINISTRY OF HEALTH

WHO COLLABORATING CENTRE FOR OCCUPATIONAL HEALTH

NATIONAL INSTITUTE OF OCCUPATIONAL AND ENVIRONMENTAL HEALTH

# DFC REPORT

## PILOTING CERAMIC FILTERS AS ONE HOUSEHOLD WATER TREATMENT AND SAFE STORAGE (HWTS) OPTION


By

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Hanoi, December 2011

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**Project number: WPVNM1002485**

**Activity number: Task 9.2**

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| | |
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| BHCF | Bo Huong ceramic filter |
| FC | Fecal coliform |
| HWTS | Household Water Treatment and Safe Storage |
| MOH | Ministry of Health |
| NIOEH | National Institute of Occupational and Environmental Health |
| PFP | Potters for Piece |
| SEM | Scanning electron microscope |
| TC | Total coliform |
| WHO | World Health Organization |

# 1 Background

## 1.1 Introduction

Kofi Annan, former United Nations Secretary-General stated that "Access to safe water is a fundamental human need and, therefore, a basic human right. Contaminated water jeopardizes both the physical and social health of all people. It is an affront to human dignity".

In fact, nowadays, more than 1.1 billion people have no access to an improved water supply and far more lack access to safe water, 1.2 billion people do not have access to safe drinking water throughout the world[1].

Point-of-use water treatment (household water treatment and safe storage, HWTS) has been advocated as a means to substantially decrease the global burden of diarrhea and to contribute to the Millennium Development Goals. UNICEF announced HWTS as one of the seven-points for the strategy for the treatment and prevention of diarrhea among children (UNICEF, 2009).

There are many methods for HWTS, and ceramic pot filters for household water filtration have undergone many studies worldwide in countries producing them such as America, France, India, Korea and China. Ceramic pots are usually made from local clay mixed with a combustible material which has been proven to be very effective for the removal of bacteria, protozoa, helminthes, turbidity, taste, odour, colour and they are most appropriate for water sources contaminated by microbiological contaminants, iron and turbidity like in Vietnam's Red Delta area and are also appropriate during the flood season. The ceramic pot typically hangs at the top of a larger plastic container (20-30 litres), which is fitted with a tap at the bottom. Then, the system both treats the water and provides safe storage for the household. In Vietnam, ceramic filters are being extensively used at the household level for drinking water because of their convenience and nice design (residents in Binh Nghia have said they look like a decorative object). These filters are present on the Vietnamese market but are imported by a number of companies, some examples including: Korea King, Royal King of Korea, Kangaroo of Australia, etc. The water quality after filtration by imported ceramic filters seems to be acceptable but the prices are high and filters are not readily available when they need replacement.

Clay is widely available in Vietnam and there is a traditional ceramic village named Bat Trang which is home to a number of skilled potters. In order to cut down costs and transportation time for filter replacement materials from abroad, some imported filter companies ordered Bat Trang residents to produce replacement materials for the ceramic filters. Therefore, Bat Trang producers end up not selling their products directly to Vietnamese consumers forcing them to buy locally-made products at a

[1] http://water.org/learn-about-the-water-crisis/facts/ Last access on 1st Dec, 2011

higher price. Additionally, Bat Trang potters don't know how to get their products certified to sell directly to the community.

We believe that villagers of Bat Trang could become producers for lower cost, locally-made ceramic filter pots for affordable household wastewater treatment and safe storage. Binh Nghia commune was one of WHO's field study locations in past projects and the Binh Nghia authorities were willing to cooperate and actively participate. Furthermore, Binh Nghia still uses sand filters as their primary filtration systems which were supplied by WHO. For the above reasons, we believe that conducting the pilot project of domestic ceramic filter pots for HWTS at Binh Nghia will be feasible and successful.

## 1.2 Objectives

To explore the possibility of developing Vietnamese ceramic filters as an affordable and safe HWTS option.

# 2 Methodology

## 2.1 Researching the application of ceramic filters in Vietnam

- Identification of ceramic filter structure and comparison between domestic and imported ceramic filters: Data on the structure of imported ceramic filters from Korea, England, China and others reviewed simultaneously with the domestic the domestic ceramic one (Bo Huong) by testing in the laboratory.
- Evaluation of ceramic filters effectiveness: water quality of existing ceramic filters was analyzed in the laboratory. All input water samples collected from the field (Binh Nghia commune) were mixed and used as the input for ceramic filters.
- Other aspects such as scope of production, price, marketing, methods of promotion, etc. of imported and domestic ceramic filters were studied.

## 2.2 Piloting domestic ceramic filter pots for HWTS in Binh Nghia, Ha Nam

- Assess the current situation of ceramic filter use in Binh Nghia
  - The interview and observation of households using ceramic filter pots were done during the trips of water sampling and monitoring.
- 40 households that met criteria listed below were selected to participate in the project
  - Households were provided sand filters by the NIOEH-WHO project in 2009 as well as households that built sand filters themselves for the removal of arsenic and iron.
  - Households which are identified as poor in the commune
  - Households willing to cooperate and actively participate in the project
  - Commitment from households for long-term usage of the filters by strictly following the guidelines for usage of the Vietnamese ceramic filters provided by the project.
- Provide Vietnamese ceramic filter pots free of charge to 40 households at Binh Nghia commune. Binh Nghia commune leaders signed an agreement letter committing themselves to actively participate in the project. The 40 households agreed also to be monitored and supervised to ensure that the filters were used properly and maintained regularly. If the filter was observed to not be in use after two follow-up visits and during monitoring trips of NIOEH staffs, the filter was to be taken away and the households and commune leaders would be requested to pay a fine.

- Water quality was monitored and evaluated after filtration by ceramic filter at each household every month to establish when a replacement candle needs to be installed. According to the common indicators of water quality of HWTS and therefore exposure/risk of a population to unsafe drinking water used by the WHO and UNICEF, microbiological and physio-chemical parameters were analyzed before and after implementation of HWTS (see table below). For details on the precise methods, reference should be made to Standard Methods[2].

| No | Parameters | Method for analysis | Reference |
|---|---|---|---|
| 1 | Total coliform | Membrane filter technique | Standard Methods for Examination of Water and Wastewater APHA 1998 |
| 2 | Thermo tolerant coliform | Membrane filter technique | Standard Methods for Examination of Water and Wastewater APHA 1998 |
| 3 | Total iron | Colorimetric method | Standard Methods for Examination of Water and Wastewater APHA 1998 |
| 4 | Turbidity | Nephelometric method | Standard Methods for Examination of Water and Wastewater APHA 1998 |

- Monitoring trips took place during the project period to ensure that all households followed the guidelines of ceramic filter usage as well as to allow timely replacement of the filters if any abnormalities were recorded. The project also ensured the opportunity to access replacement parts or an opportunity to buy a filter.
- Data collection and analysis.
- Develop ceramic water filter instructional brochure providing key requirements for using and maintaining the water filters safely for each household.
- Survey the acceptance of ceramic filter pots in the community: the activities were carried out after 3 months of implementing of the HWTS system. A questionnaire was designed and used to interview the 40 study households and non-study ones. The questionnaire includes questions regarding methods for household water treatment and safe storage, water usage practices and advantages of using Vietnamese ceramic filters compared with imported ones.

[2] Standard methods for the examination of water and wastewater, APHA-AWWA-WPCF, 1989

## 2.3 Organizing seminar

A seminar was organized for sharing lessons learnt and experience on the Piloting of domestic ceramic filter pots for HWTS in Binh Nghia, Ha Nam.

The participants included: representatives from Ha Nam province, Binh Luc suburban district and Binh Nghia commune, households that participated in the project, ceramic filter pot producers in Bat Trang, environmental experts from WHO, NIOEH and other partnerships. Key topics would be discussed in the seminar are:

- Advantages, obstacles and challenges
- Acceptance of ceramic filter pots in the community
- Heath aspect: microbiological safety
- Economic aspect: a manufacturing process that is inexpensive, using locally available and sustainable materials.
- What should be done to promote usage of the Vietnamese ceramic filters in the community as a means to supply safe and low-cost drinking water?
- Results of the pilot to share lessons learnt and experiences

# 3 Results

## 3.1 Research of the application of ceramic filters in Vietnam

### 3.1.1 Overview of ceramic water filter

There have been many studies and programmes on ceramic filters in regards to water filtration efficiency and applicability of these filters in communities. Results show that ceramic water filters are one suitable option for low-income households in developing countries for water treatment.

**Figure 3-1. The Potters for Peace filter, locally produced in Nicaragua**

#### 3.1.1.1 Ceramic water filter

The main material used to make a ceramic filter is Diatomaceous Earth (in clay) and in order to have biological safety, the ceramic filter needs to be 0.01 – 1.0 micron with a very slow flow rate. Because of its reduced pore size, it is easy for it to get stuck but, on the positive side, it only requires simple and regular scrubbing to maintain it clean.

Ceramic filters were improved when adding a colloidal coat as a means to increase the bacteria removal efficiency. This new and improved model was produced as a flower-shaped pot which sits on a ceramic or a plastic tank. These improved filters are built with available local materials and have proven a high efficiency in removing bacteria. They are easy to use and have been produced and used in many countries, especially developing ones as a Household Water Treatment and Safe Storage (HWTS) option.

Bacterial reduction efficiency depends on the quality of the ceramic filter; however, a 60-70% reduction in diarrheal disease incidence has been documented in users of these filters. Studies have also shown significant bacterial contamination when poor-quality locally produced filters are used, or when the receptacle is contaminated at the household level. Because of the lack of residual protection, it is important that users be trained to properly care for and maintain the ceramic filter and receptacle.

**The benefits of ceramic filtration are:**

- Proven reduction of bacteria and protozoa in water;
- Acceptability to users because of the simplicity of use;
- Proven reduction of diarrheal disease incidence in users;
- Long life if the filter remains unbroken; and,
- A low one-time cost;

**The drawbacks of ceramic filtration are:**

- Lower effectiveness against viruses;
- Lack of residual protection can lead to recontamination if treated water is stored unsafely;
- Variability in quality control of locally produced filters;
- Filter breakage over time, and need for spare parts;
- Filters and receptacles need to be regularly cleaned, especially when using turbid source waters; and,
- A low flow rate of 1-3 liters per hour in non-turbid waters.

Ceramic filtration is most appropriate in areas where there is capacity for quality ceramic filter production, a distribution network for replacement of broken parts, and user training on how to correctly maintain and use the filter.

Ceramic water filters have been used in various places around the world as a means of treating drinking water at the household level. Some examples include the Potters for Peace Filtron (Nicaragua), the TERAFIL terracotta filter (India), and the candle filter (India, Nepal, Bangladesh, Brazil, etc).

#### 3.1.1.2 Types of ceramic water filters

**Disk filter**

Ceramic disk filter systems consist of an upper and lower container with a ceramic disk inserted between the two containers. Water is poured into the upper container and then allowed to filter through the disk into the lower collection vessel. A spigot is placed in the bottom container for dispensing the treated water. An example of a 100-year old ceramic disk filter from Spain is shown in Figure 3-2.

**Figure 3-2. 100-year-old Spanish ceramic disk filter**

A more recent example of a disk filter system from India, called the Indian TERAFIL filter, is shown in Figure 3-3. The TERAFIL consists of two metal or terracotta containers and a ceramic disk fitted into the bottom of the upper container. The disk retails for approximately 25 Indian Rupees (INR 25) (USD $0.49)a and a complete set consisting of a disk and two ceramic containers (not metal as in Figure 2.4) retails for approximately INR 180 (USD $3.51).[3]

**Figure 3-3. TERAFIL disk filter**

As reported, disk filter requires simple cleaning practices to maintain it and has a microbial removal rate of that fluctuates from 94 – 99.99%.

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[3] Low, C.S.. (May 13, 2002) "Appropriate Microbial Indicator Tests for Drinking Water in Developing Countries and Assessment of Ceramic Water Filters". Master of Engineering thesis. Department of Civil and Environmental Engineering, Massachusetts Institute of Technology. Cambridge, MA

**Figure 3-4. Terracotta Ceramic Disk Filters**

## Pot filters

The Potters for Peacea (PFP) Filtron system is a silver-coated, flower-shaped pot of 17liters in capacity and the storage tank of 7.5 – 20 liters[4]. The PFP filter uses cement to attach the disk to container and then it can eliminate possible leakage along the interface between the disk and the container. PFP Filtron gives the flow rate at 1.0 – 1.75 L/hr.

After doing investigation on PFP Filtron in 2001, Consultant Daniele S. Lantagne concluded that (1) to remove E.coli physically, the PFP should have pore size of1.0 micron[5], (2) based on previous data, the PFP removed 98 – 100% bacteria in laboratory conditions but it was not really effective in households[6]

[4] Potters for Peace. Website: <http://www.potpaz.org> (Last accessed: May 8, 2003).

[5] Lantagne, Daniele S.. (December 2001) "Investigation of the Potters for Peace Colloidal Silver Impregnated Ceramic Filter – Report 1: Intrinsic Effectiveness". Alethia Environmental. Allston, MA

[6] . Lantagne, Daniele S.. (December 2001) "Investigation of the Potters for Peace Colloidal Silver Impregnated Ceramic Filter – Report 2: Field Investigations". Alethia Environmental. Allston, MA


**Figure 3-5. Potters for Peace Filtron**

*Picture source: Potters for Peace website*

### Candle filters

A candle filter consists of two containers, an upper one which contains one or more ceramic candles inside and the lower one to store filtered water (Figure 3-6). For candle filters have low flow rates (300 – 840 ml/hr/candle)[7], two or three candles are used to treat water. This system is commonly used in India and Nepal with the price of 8 – 21USD for filter produced in India and approximately 4USD for Nepalese filters[8].

**Figure 3-6. Indian ceramic filters**

[7], [7] Sagara, Junko. (2000). "Study of Filtration for Point-of-Use Drinking Water Treatment in Nepal". Master of Engineering thesis. Department of Civil and Environmental Engineering, Massachusetts Institute of Technology. Cambridge, MA

**Figure 3-7. Hari Govinda Prajapati ceramic candle filter**

*Picture source: Sagara. 200049*

After further research, the filter was improved both in the firing process and in the structure of the filtering core which finally attained a bacterial reduction efficiency of > 99% with raw inputs of 89 cfu/100 mL for total coliform (TC) and 56 cfu/100 mL for *E.coli.*

***Swiss Katadyn® Drip Filters***

Produced by Katadyn®, a Swiss company, Katadyn® Drip Filter has two versions, the Gravidyn and Ceradyn with retail price of US $160 and US $190[9], respectively. These filters are mainly used in cabins and base camp expeditions.

**Figure 3-8. Kadaryn ceramic filter**

*Picture source: Black Mountain Stores Website*

[9] Black Mountain Stores. Website: <http://www.katadyn.net/katadyn_drip.html> (Last accessed: May 1, 2003).

Both filters, coated with silver powder and with a the filtering rate of 1.3 l/hr/candle, are known as high efficiency in removing bacteria, protozoa and cysts. The filtration system (containers, lid and spigot) is made of a heavy translucent white plastic and the containers are shaped such that the upper container fits into the lower container for easy transport.

**Kisii Water Filter Bucket**

The Rural Water Development Programme (RWD), located in Western Kenya, has developed a filter system called the Kisii Water Filter Bucket. The Kisii filter system is composed of two translucent food-grade polyethylene containers and a tap in the bottom container (Figure 3-9). The containers are available in local markets and are manufactured by a company called Kentainers Ltd., based in Embakasi, Nairobi Kenya.

**Figure 3-9. Kisii candle filter**

*Picture Source: RWD Promotional Brochure*

RWD uses two types of candle filters: a "slow" speed ceramic candle filter from India ($1 USD) that filters approximately 3 liters of water per day and a "high" speed ceramic candle filter ($12 USD) from Brazil that filters 20 liters of water per day. The Brazilian candle filter uses silver and activated carbon[10].

**Hong Phuc® Candle Filters**

The Hong Phuc® candle filter (Figure 3-10), which has been sold in 18 provinces in Vietnam[11], is made from diatomaceous earth and manufactured by Hong Phuc® Co.

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[10] Rural Water Development Programme. (December 2002) "The Kisii Water Filter Bucket. Proposal of the Rural Water Development, Western Kenya, for the 2003 Water Action Contest as part of the 3rd World Water Forum". Tokyo, Japan.

[11] Sobsey, M.D.. (July 2002) "Managing Water in the Home: Accelerated Health Gains from Improved Water Supply". World Health Organization. Geneva, Switzerland

Ltd. The Hong Phuc® filter of a 10 liter upper container with 3 candles and a 10 liter lower container is sold at the price of 7.5USD.

**Figure 3-10. Hong Phuc candle filter**

**Ceramic filters developed by Institute of New Technology**

The Institute of New Technology - Vietnam Economic Association has researched and produced successfully a water filter which is made of high quality, rich aluminosilicat ceramic. This ceramic is non-toxic, durable and 10 times cheaper than other imported ceramic filters.

Materials to manufacture ceramic filters are rich aluminosilicat clay (40%-60%). Aluminosilicat fired at high temperature can remove 100% of coliforms, 86%-95% of heavy metal ions like $Fe^{2+}$, $Fe^{3+}$, $Ca^{2+}$, $Mg^{2+}$, etc. The filter is suitable to treat groundwater. The filter has a life span of 20 - 24 months, equivalent to filtering 30.000l water. Treated water meets standards of MOH for drinking water.

Currently, there are three types of this filter, which are:

- Single filter panel with the size of 200 x 200 x 30 mm, the capacity of 10 - 12 l/hr. This filter is used to treat groundwater and sold at the price of 25.000 VND.
- The big single filter candle with the capacity of 6 – 8 l/hr. This filter is used to treat groundwater and it costs 35.000 VND.
- The small single filter candle is mainly used to filter surface water, groundwater and is 1.5 – 2.5 l/hr in capacity. The price of one candle is 40.000 VND.

**Korea ceramic water filters**

-


Korea Ceramics has been manufacturing and supplying high quality of ceramic water filters directly to approved distributors and through appointed representatives worldwide since 1985. Recent improvements in the product quality have been achieved with significant investment in modern manufacturing equipment. Korea Ceramics is distinguished in the ceramic filtration market.

Korea Ceramics manufactures various types of ceramic water filters such as the Dome type, the Dish type, the Pipe type, the Candle type and so on. Extrusion process is employed by Korea Ceramics to form the ceramic filter. This results in a filter with a consistent pore size ranging between 0.2micron and 0.8micron.

Ceramic water filters have very important advantages over fabric based filters. Fabric filters are made of materials which are elastic. This means that their pores may expand when the water pressure is too high while ceramic filters do not expand under pressure. Ceramic filter's pores always maintain their integrity so they are more effective. In addition, fabric filters quickly become useless and must be replaced when clogged with particles from the water while ceramic filters can be cleaned numerous times before replacement.

*Specification*
90mm x 100 Ø x 9t(mm)

*Flow Rate*

1Liter/hour in gravity water purifier.

*Service Life*
Average one year for a household of four but its service life depends on the water quality and on the quantity consumed.

*Special feature*
Korea ceramics water filters are burnt in the electric furnace while other imitations are burnt in oil furnace. In case the ceramic water filters are burnt by oil, they absorb all the harmful materials from the oil gas. But if they are burnt by electricity, just pure ceramic filters are made without adsorbing harmful materials. All the ceramic water filters have to be pure as they are used in water for human's health.

### 3.1.2 General information of ceramic filters in Vietnam

In the past decades, the Vietnamese economy has been developing at a fast rate in both agricultural and industrial sectors thanks to the application of new technologies. This has led to, on the one hand, the improvement of the quality life of Vietnamese people and an increase in the standards of living. Simultaneously, the awareness of Vietnamese residents in regards to the environment in general and the need for safe living conditions are increasing. On the other hand, pollution is a result of this fast economic development which has consequently increased the amount of disease, especially water borne disease of which many of them are related to unsafe drinking water such as digestive diseases including diarrhea, dysentery, typhoid and even cancers by using and drinking heavy metal (arsenic) contaminated water. These diseases, in combination with the subjectivity of patients and their families, can cause deaths. Thus, people are increasingly seeking equipment that helps them access safer drinking water is increasing.

Nowadays, there is a large number of water filters on the Vietnamese market offering a wide range of technologies. These filters have, more or less, gained the confidence of the population. Vietnamese consumer choices are based on the price, the brand, technology, quality of filtered water, promotions, etc.

Below is information about imported and domestic water filters in Vietnam which was collected, observed and reviewed by interviewing customers, sellers and by collecting information from the internet.

**Filters brands in Vietnam**

As mentioned above, there is a large number of water filters on the Vietnamese market, however, they are mainly imported filters with advanced technologies. Imported filters have different brands from China, United States, Korea, Japan, Australia or Taiwan. For instance, WATTS, Aquasana or Everpure are from USA; Kangaroo from Australia; Daiwa, Makxim, Aquasyn or Komasu from Taiwan; Korea King or Crown from Korea; Toray or Myota from Japan; Caribbean from China and many more.

Water filters are mainly imported; some are produced in Vietnam with imported materials and technologies thus the price of these products in the Vietnamese market is quite high. However, the price also varies with technologies applied, actual needs, the scope and aesthetic designs of these filters.

The scope of products can range from small ceramic filter pots with the capacity range from 10 to 19 liters for a price range of 350,000 – 1,000,000VND/product. There are also bigger filters, in other words, water purifiers. Producers apply higher filtration technologies like Reverse Osmosis (RO) or nanotechnology or they combine filtration technologies to produce multi filtration layer purifiers. The price of these purifiers is high and in a very wide range depends on the technology applied; the number of filtration layers, however, the average price ranges between 2,000,000 – 5,000,000VND/product (information retrieved from the internet and websites of water filter companies).

Based on the information given by these water filter companies and sellers, their products are suitable for household's removal of contaminants such as heavy metals (WATTS – USA, Kangaroo – Australia, Aquasyn – Taiwan, Korea King – Korea, etc.), chloramines, microorganisms, color, taste and smell and other substances harmful to human health.

In general, water filters on the Vietnamese market, more or less, meet the needs of Vietnamese people in urban areas for water filters to have a safe drinking water source. However, these products are still too high for people in rural areas.

**Technologies applied to water filters**

There are filtration methods which are used to purify water for domestic proposes, especially for drinking.

Microporous filtration method using ceramic as material is the common technology around the world (ceramic filters). This method is applied for household-scale filters which can remove pollutants and microorganisms. On the market, there are various ceramic filters, for instance, Kangaroo, Crown, Daiwa, Korea King, Carribean, etc.

Reverse Osmosis technology is the method applied to almost all products in Vietnam. In fact, it is the combination of several methods such as adsorption, microporous filtration, RO, etc., with the core of RO method. Water purifiers applying this method usually are larger – scale filters which contain 3 filtration levels (pots) and above. In addition to effects like ceramic filters, these purifiers can remove heavy metals and dissolved inorganic matters. Companies or brans supplying these filters are, for example, Kangaroo, Korea King, Watts, Toray, Aquasyn, etc.

Another technology is applied to water filters in Vietnam is nanotechnology. Geyser, Watts, Hanico, Gaizinc, etc. are some of the companies that supply filters used nanotechnology.

**Advertisement methods**

Producers and suppliers have applied various ways to advertise their products.

The most commonly used tool is the internet. This is an easy way for water filter producers and suppliers to advertise their products by providing information and images of their products or designing their own websites with comprehensive information about their products. Companies and producers built their own websites to advertise not only their water filters but their other products include Kangaroo, Aquasyn, Sunhouse, Watts, etc.

Another common means of advertisement is the television. It has proven to be a good method to gain the attention of potential customers. Mainly, these companies choose the “golden time” of media: from 7pm to 10pm when most of Vietnamese families gather and watch television shows. They choose the time to show their advertisements in between entertainment programmes, for example during a movie or a football match. Ortherwise, they can promote their products on an advertisement channels like Shopping TV. Kangaroo is known as one of the most famous water filters and is the brand that most frequently appears on the television.

In order to increase the effectiveness of the two methods mentioned above, they also focus on aesthetic designs and impressive slogans. Slogans, such as “the top-ranking water filter in Vietnam” (Kangaroo, Hanico) or “the top-ranking water filter supplier in Vietnam are used”.

**Promotion strategy**

Together with methods to popularize their water filters, managers provide promotional programs to customers. These programs are special offers for special anniversaries of companies, special occasions like Independencs Day, New Year’s Eve, etc. In addition, some companies can provide customers with a goods and services warranty.

**Community choice**

Among available water filters with good promotional programs, customers have a wide range of alternatives. However, their choices mostly depend on the economic status of their families. Thus, the price of a product is one of the most determining criteria for communities and households. The quality and brand name are second in line to customers. Famous names with good quality products quality and attractive advertisements will gain the attention of customers. These criteria create various options for customers and thus their choices vary and do not necessarily make them focus on a specific brand name.

In general, imported filters are accepted and used broadly in Vietnam.

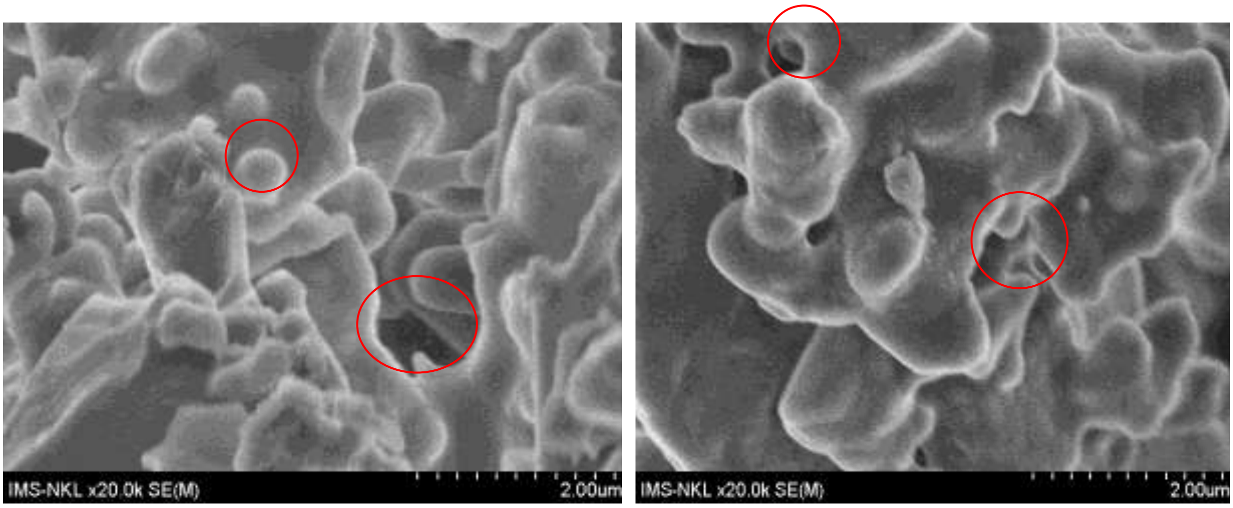
In order to have a closer look at ceramic filters, structures and water filtering efficiencies of these imported ceramic pots and BHCF pots were analyzed. Furthermore, these data were compared to each other to evaluate whether there were differences between imported and Bo Huong filters. The results were shown in following chapters.

### 3.1.3 The structures of ceramic filters in Vietnam

As mentioned above, the X-ray diffraction, energy dispersive X-ray analysis and scanning electron microscope (SEM) method were done to evaluate elements, concentrations of these elements and measure surface structure of candles. Below are results of the BHCF and noticeable imported ceramic candles.

#### 3.1.3.1 Surface morphology

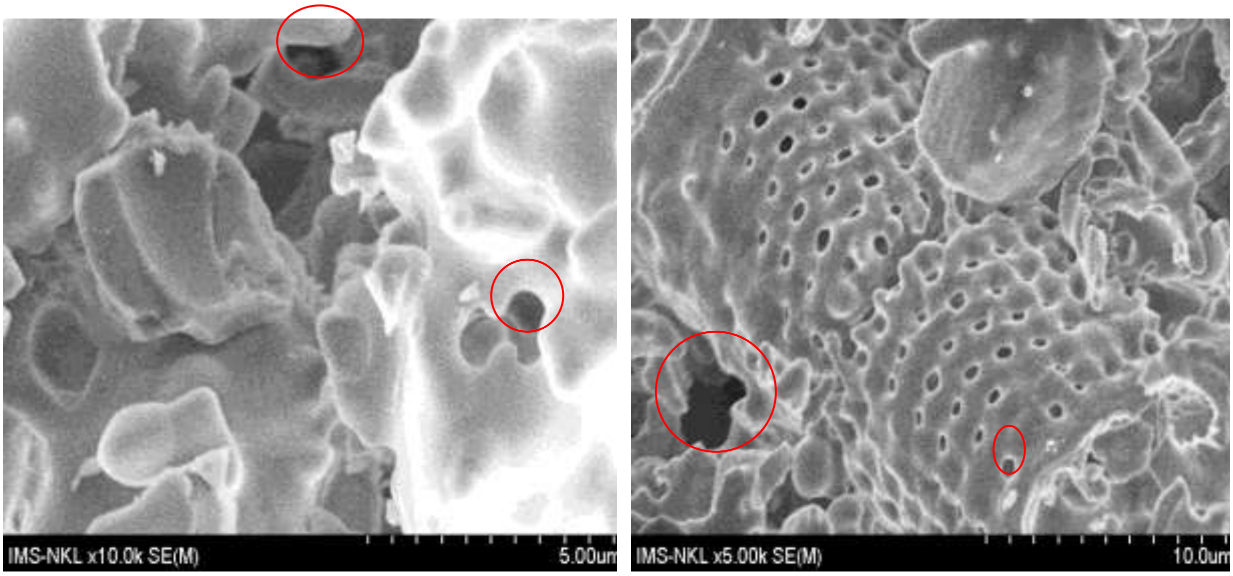
The surface morphology of collected samples was analyzed by the SEM method to image surfaces of ceramic candles. Both outer and inner surfaces of ceramic candles were scanned and according to SEM images below, most of the samples are porous with the main element being diatomite. This diatomite is in cylindrical crystals with pore size of 0.5 - 1µm and spaces between diatomite debris and crystals are in the range of 2 - 3µm




Outer surface　　　　　　　　Inner surface

**Figure 3-11. Surface morphology of BHCF**

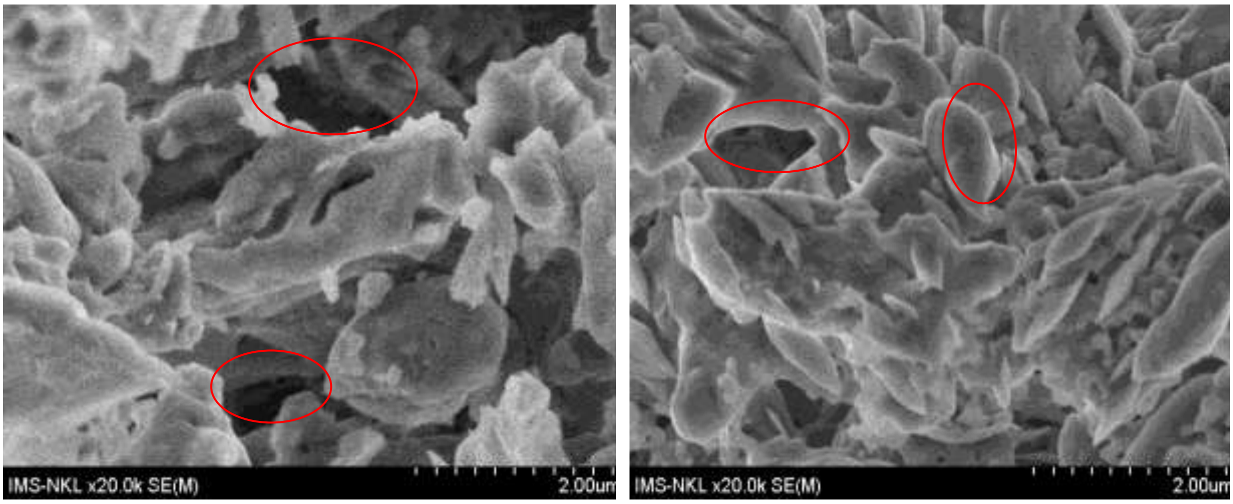
There is no significant difference between the outer and inner surfaces of the BHCF, spaces and pores have the size of 0.5 – 1.0 µm




Outer surface　　　　　　　　Inner surface

**Figure 3-12. Surface morphology of Vietnamese sample**

The pore size in Vietnamese sample is approximately 0.5 µm and spaces between diatomite debris and crystals are 1 - 2 µm




Outer surface Inner surface

**Figure 3-13. Surface morphology of Korean ceramic sample**

The space and debris size in Korean sample are approximately 1 – 1.5 µm

### 3.1.3.2 X-ray diffraction

According to the diagram of X-ray diffraction (Figures 4-14, 15, 16, 17, 18), the main element in samples was identified as $SiO_2$ with different crystal forms due to different burning temperatures.

Furthermore, there is the present of silver vanadate ($Ag_3VO_4$), an element necessary to sterilize water, in almost all samples except for sample number 5 imported from India. This means all samples were coated with a silver layer for sterilization purpose.

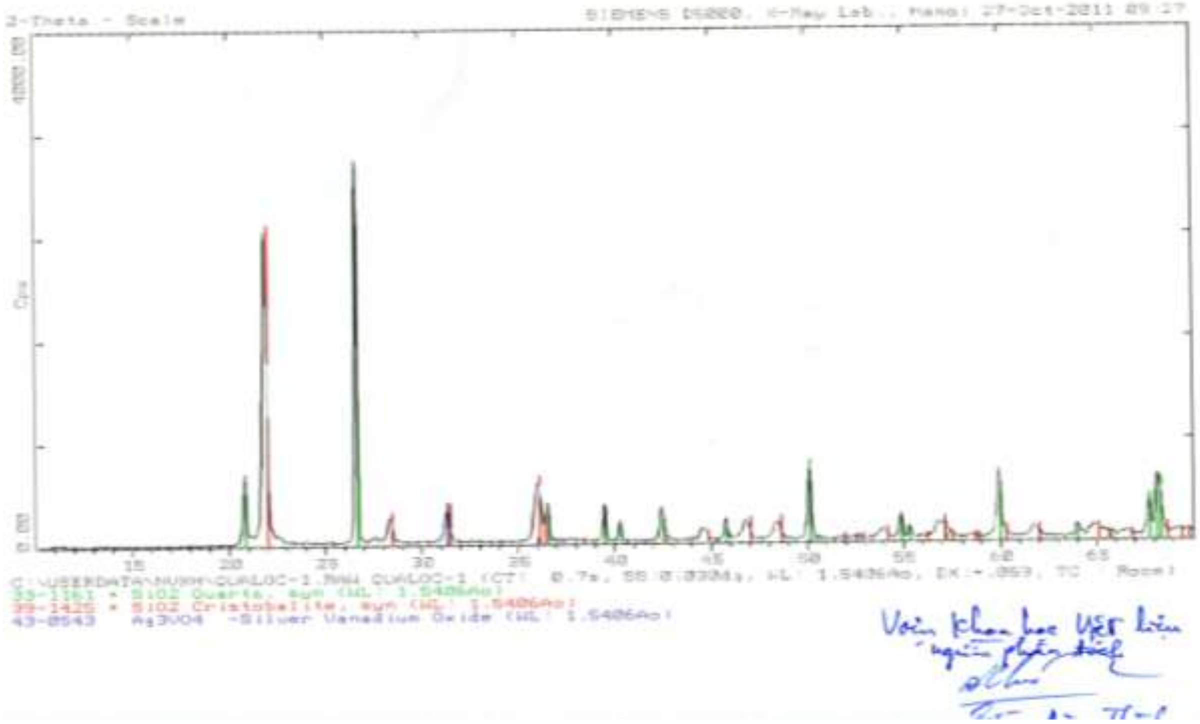



**Figure 3-14. Bo Huong sample**

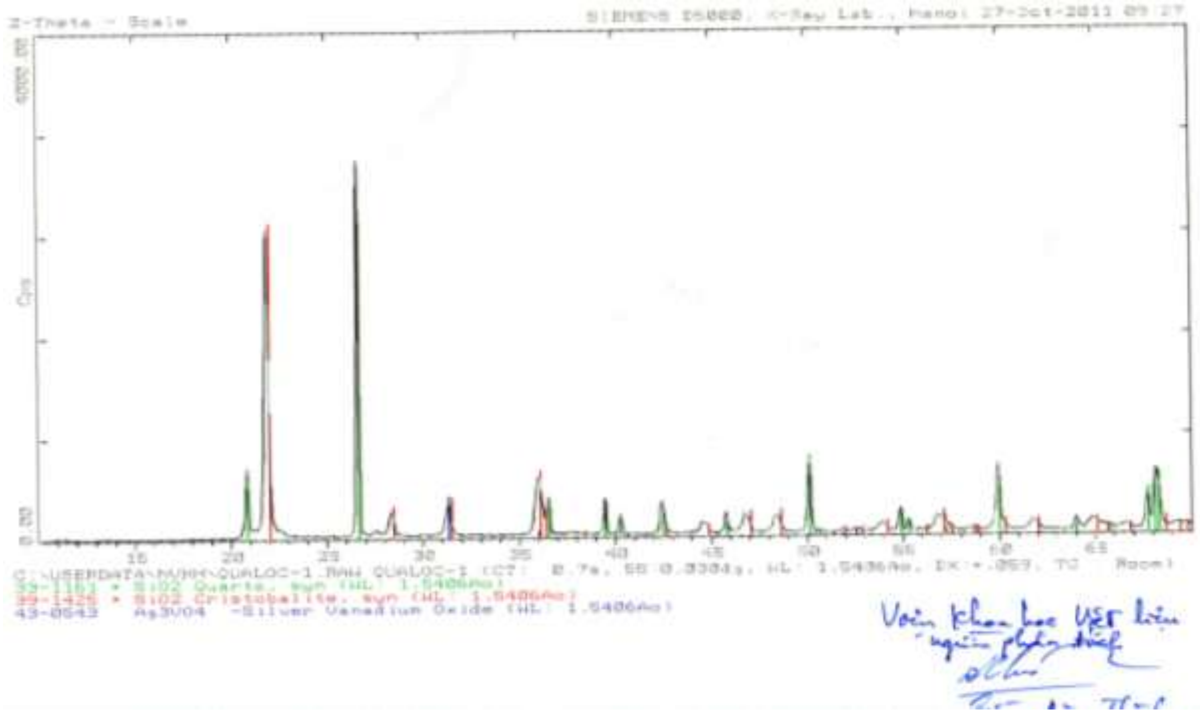



**Figure 3-15. Vietnamese ceramic sample**

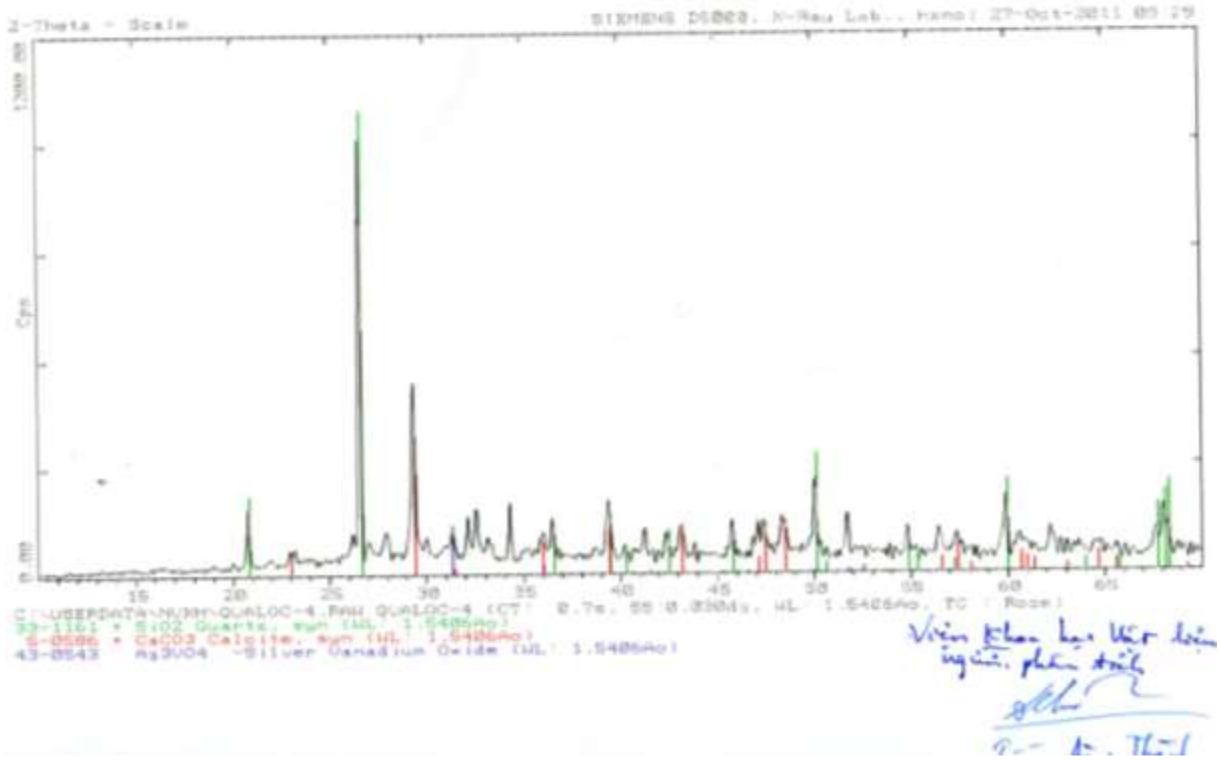


**Figure 3-16. Korean ceramic sample (1)**

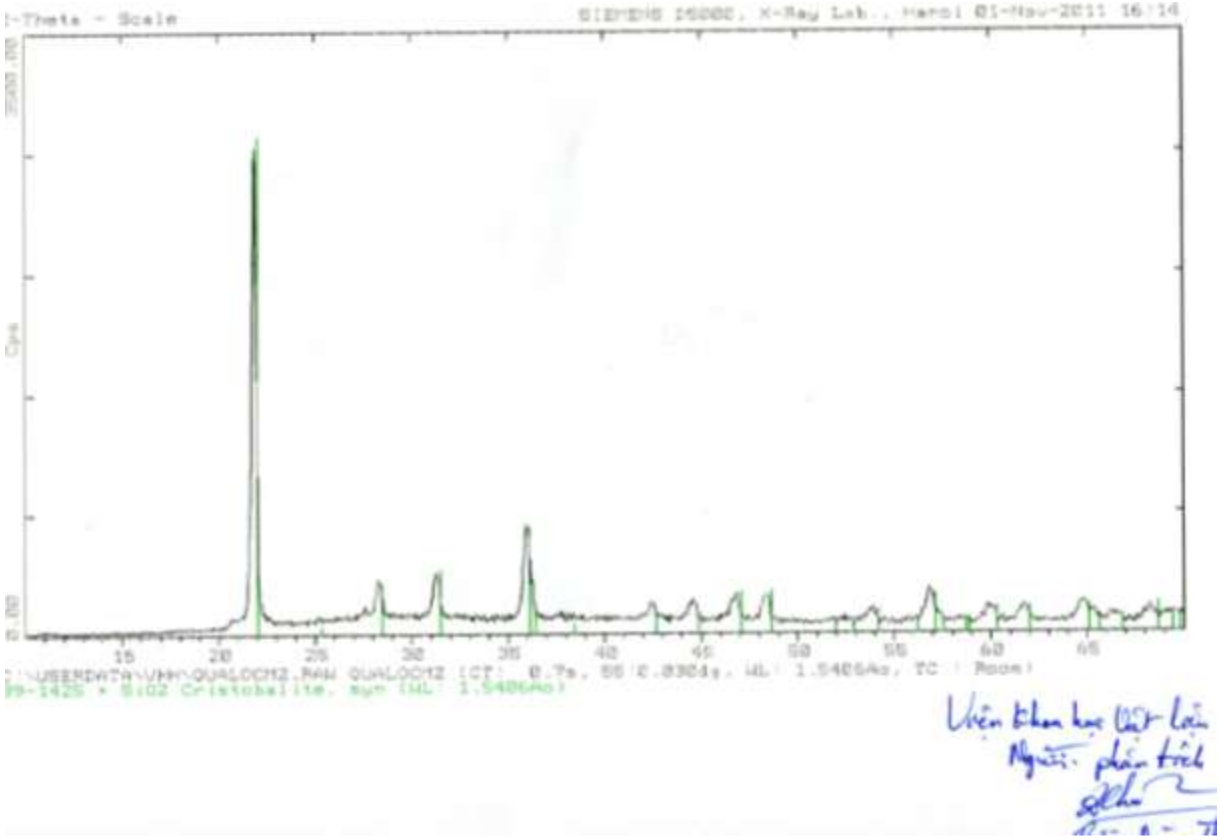


**Figure 3-17. Korean ceramic sample (2)**

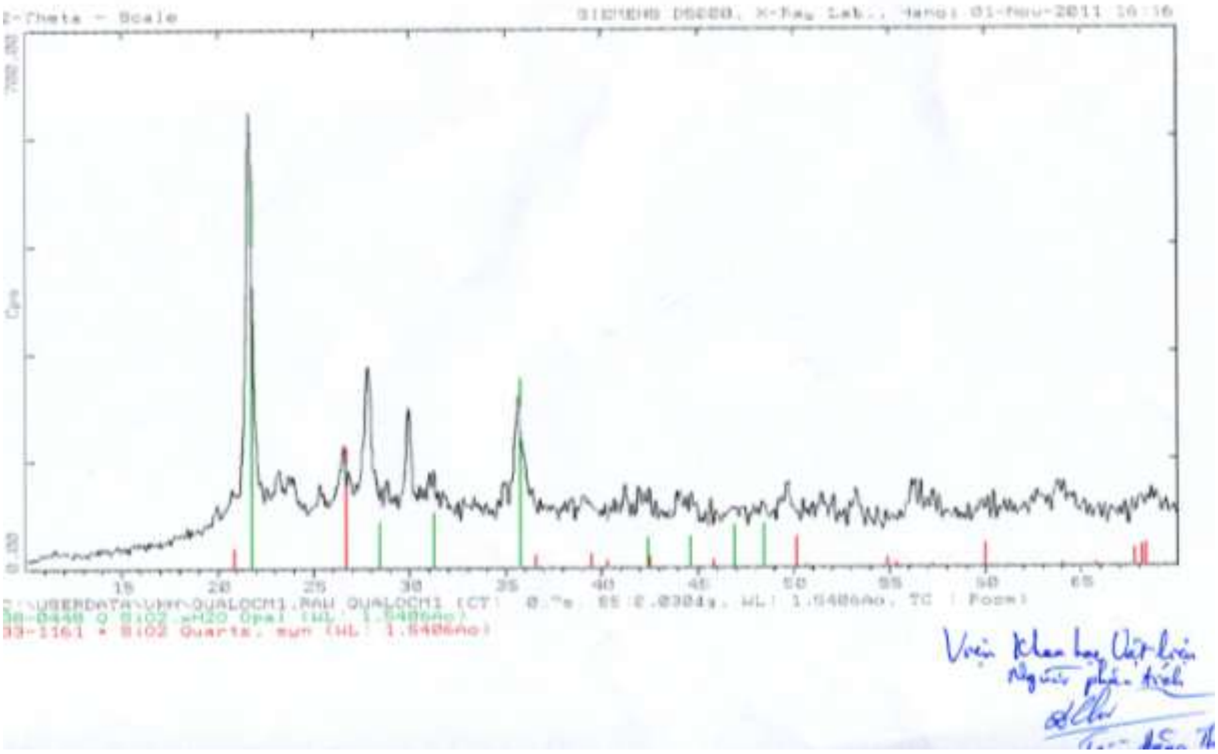



**Figure 3-18. English ceramic sample**

#### 3.1.3.3 Energy dispersive X-ray analysis

The results showed that, relative to results from X-ray diffraction analysis, major elements in all ceramic samples, including BHCF, are silica and oxygen which are equivalent to $SiO_2$. Elements and their masses in samples analyzed are similar to each other, which means that the primary ingredients used to make ceramic filter candles are quite similar. Besides, hazardous elements such as lead, mercury, arsenic, cadmium which negatively affect on human health were not found (Table 3-1). Thus these candles are safe for health and suitable for water filtering.

On the other hand, elements might be extracted from ceramic candles into water during filtering process were also analyzed. Results in Table 3-2 shows that there are no significant elements extracted from these samples. In other words, these ceramic candles were burned at the suitable temperatures.

**Table 3-1. Elements found in ceramic candle samples**

| Samples | C | O | Na | Mg | Al | Si | K | Ca | Ti | Fe | Mn | Zn | Sb | Zr | Ag | Cd, Pb, Hg, As | Mass (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BHCF | 4.17 | 49.16 | 0.41 | - | 0.65 | 45.36 | - | 0.11 | - | | 0.13 | - | - | - | + | - | 100 |
| Vietnamese candle | 2.19 | 48.11 | 1.56 | 0.04 | 1.00 | 45.44 | 0.16 | 0.3 | 0.16 | 1.03 | - | - | - | - | + | - | 100 |
| Korean candle 1 | 2.05 | 43.77 | 0.16 | 2.09 | 12.28 | 22.35 | 0.47 | 14.03 | 1.08 | 1.7 | - | - | - | - | + | - | 100 |
| Korean candle 2 | 4.04 | 49.74 | 1.61 | 0.03 | 1.11 | 42.58 | 0.08 | 0.25 | - | 0.5 | 0.04 | - | - | - | + | - | 100 |

**Table 3-2. Elements extractible into water from ceramic candles**

| Samples | TOC | SS | Na | Mg | Al | Si | K | Ca | Ti | Fe | Mn | Zn | Ag | Cd, Hg, Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BHCF | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| Vietnamese candle | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| Korean candle 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| Korean candle 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | |

### 3.1.3.4 Porosity and capillary structure analysis

Besides elements in ceramic candles, surface structure of the candle also plays an important role in the water filtering efficiency, thus the purpose of this part is to analyze the structure of material surfaces including pore size, capillary structure. Table below presents the results of basic parameters about surface structure of a ceramic candle

**Table 3-3. Specific surface structure parameters**

| Sample | $S_{BET}$ ($m^2/g$) | $V_t$ ($cm^3/g$) | $D_p$ ($A^0$) |
|---|---|---|---|
| **BHCF** | 0.5596 | 0.001319 | 149.218 |
| **Vietnamese ceramic candle** | 1.787 | 0.015425 | 358.475 |
| **Chinese ceramic candle** | 0.594 | 0.002607 | 125.977 |
| **Korean ceramic candle (1)** | 1.2181 | 0.002876 | 140.155 |
| **English ceramic candle** | 2.5524 | 0.009882 | 156.352 |
| **Korean ceramic candle (2)** | 1.4236 | 0.002231 | 120.384 |

*$S_{BET}$: BET[12] pore surface area*

*$V_t$: Total pore volume*

*$D_p$: Average pore diameter*

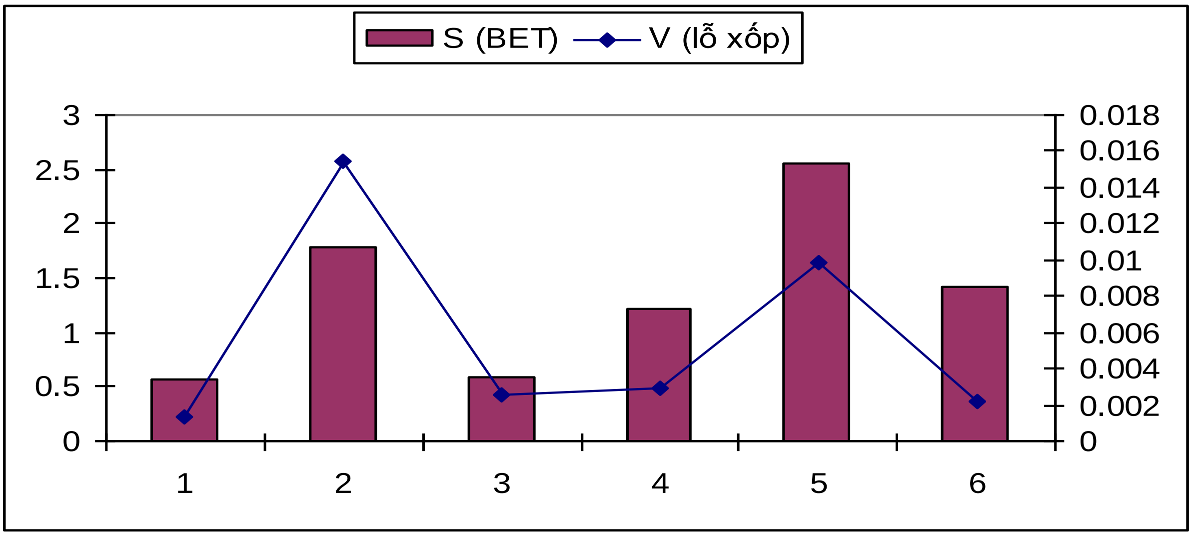



**Figure 3-19. Pore size distribution**

[12] BET: Brunauer, Emmett and Teller theory.

It can be seen that, porosities and pore surface areas in Vietnamese and English samples are the largest. Pore surface area of English sample is 1.41 times larger than that of Vietnamese one, however the porosity in Vietnamese candle is higher than that in English candle by 1.56 times. In other words, pores in Vietnamese candle are bigger than in English sample, this is corresponding to the average pore diameter results. The BHCF has the smallest surface area and pore volume which are 0.5596 $m^2/g$ and 0.001319 $cm^3/g$, respectively. These parameters are quite similar and small among other samples.

For the pore distribution, English and Vietnamese ceramic samples, pores are mainly at the areas of 1000 – 2000 Å, meanwhile in other samples, pores distribute in micro and medium capillary areas (20 – 500 Å).

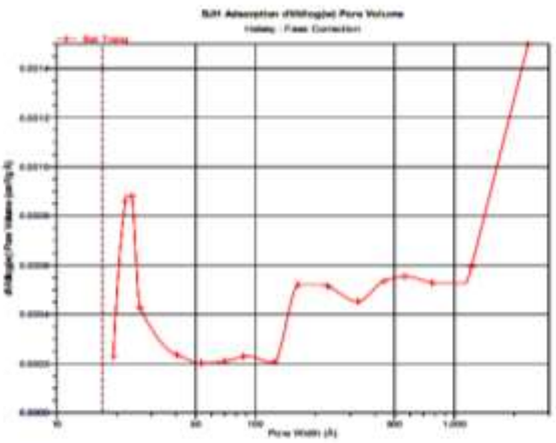


**Figure 3-20. Pore distribution in BHCF**

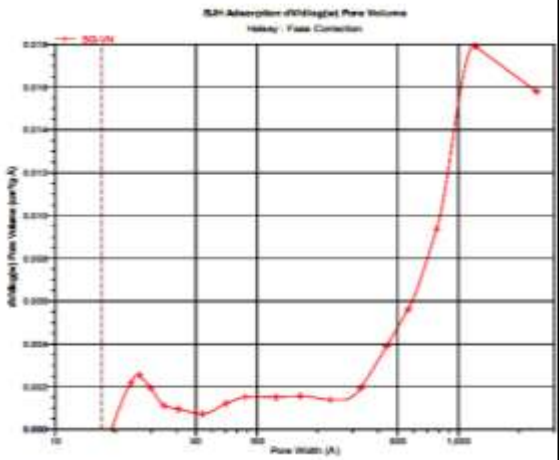


**Figure 3-21. Pore distribution in Vietnamese ceramic sample**

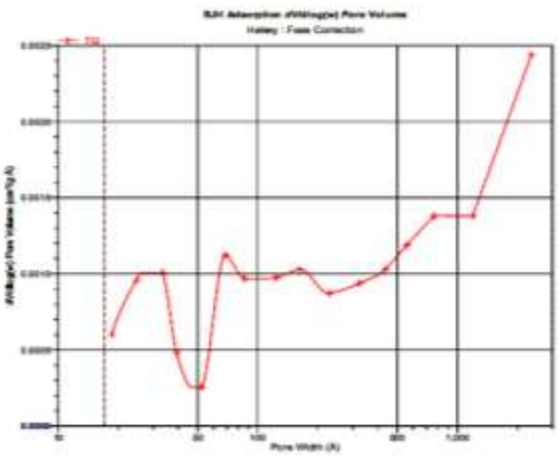


**Figure 3-22. Pore distribution in Chinese ceramic sample**

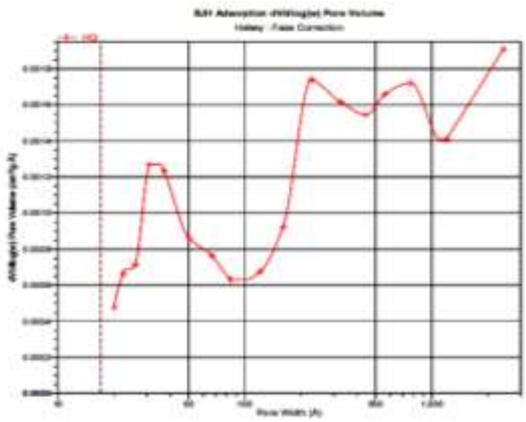


**Figure 3-23. Pore distribution in Korean ceramic sample (1)**

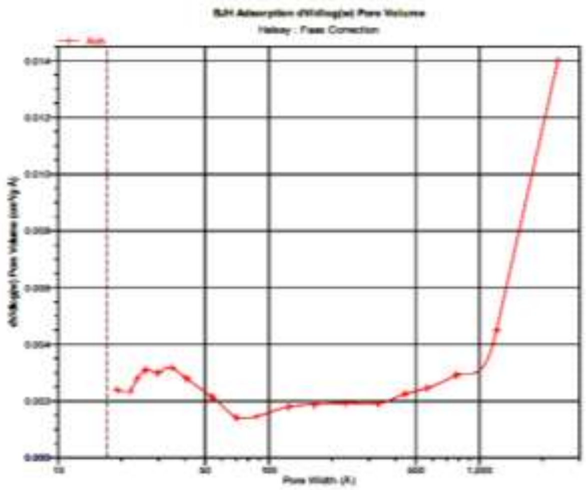


**Figure 3-24. Pore distribution in English ceramic sample**

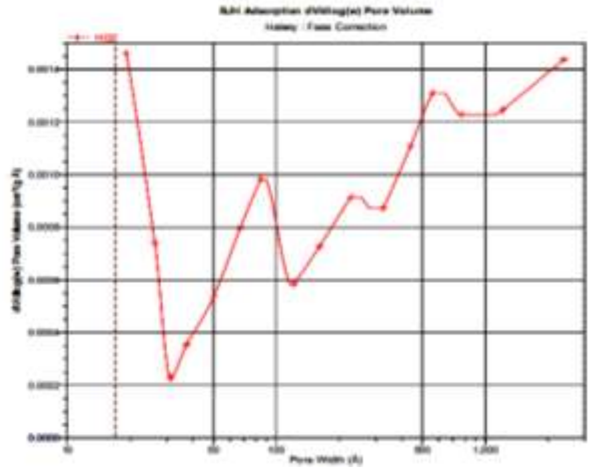


**Figure 3-25. Pore distribution in Korean ceramic filter (2)**

### 3.1.3.5 Discussion of ceramic filter structure and components

**Ceramic filter components**

Components and elements in the ceramic candles that were analyzed, including in the BHCF, are relatively similar. The main element is Silica oxide ($SiO_2$), besides there are other oxides in very small amounts, for instance Al, Mg, Zn, etc. and no detection of hazardous heavy metals like Pb, Cd, Hg, As which could have negative impacts on human health. Furthermore, there is a presence of of silver vanadate ($Ag_3VO_4$) in these samples; an element that can be used to sterilize water. This means, these candles were coated with a silver layer.

However, during the experiments, significant amount of manganese was detected in the Bo Huong ceramic filter, a toxic element which can have effects on the respiratory tract, the brains causing hallucinations, nerve damage, lung embolism or bronchitis, etc. Thus, the ability of extracting metals into filtered water was estimated and analyzed. As results showed in table above, there are no extractible metals including manganese and heavy metals in all ceramic samples.

In comparison, the BHCF has no significant difference in components in ceramic candle to other imported ceramic candles, though there is the present of manganese in BHCF, there are no extractible elements that could have bad effects on human health. This can give a prediction that the primary ingredients used to make candles were quite similar among samples and they were burned at suitable temperature and safe for health.

**Ceramic filter structure**

It can be seen through SEM images, most of the samples are porous with inhomogeneous surfaces. Pore size and spaces between cylindrical crystals and debris are approximately 0.5 - 1µm and 2 – 3 µm, respectively. These sizes are suitable in removing heavy metals and bacteria from water. In addition, most samples, including

BHCF sample, contain diatomite with cylindrical shapes. They provide high porosity, high surface area, inertness, high absorptive capacity and thus increase bacteria removal efficiency at high flow rate.

In comparison, English and Vietnamese samples have high surface areas and pore volumes with even pores distributions (Table 3-3). These characteristics give English and Vietnamese ceramic candles the highest filter efficiency. In contrast, smallest pore size, surface area and even pores distribution in the BHCF are suitable to remove bacteria, however, with low flow rate.

In conclusion, similar to imported ceramic filters, the Bo Huong ceramic filter contains the main element of $SiO_2$ in diatomite and no extracted hazardous elements in filtered water. Nevertheless, filtering efficiency might not be high due to the small pore sizes and low flow rate which can make porous pores stuck.

### 3.1.4 Water filtering efficiency between imported and Vietnamese ceramic filters

#### 3.1.4.1 Assessment of water filtering efficiency of ceramic filters

Parallel with the analysis of water samples collected in the field, this experiment was done in the laboratory of NIOEH as well. The water sample with concentrations of 24000 total coliform/100ml, 4600 tolerant thermo coliform/100ml, 0.75 mg total iron/l and with the turbidity of 5.45NTU was used as the input for filter pots. Outputs were collected and analyzed twice as a duplicate. The results showed that all ceramic candles reached maximum efficiency of removing physiochemical parameters (Table 3-4). However, removal efficiencies of total coliform (TC) and fecal coliform (FC) among these ceramic, though were similar, were above 99% (Figure 3-26, 27)

**Table 3-4. Removal efficiency results**

| Samples | Removal efficiency (%) ($E_o$) | | | |
|---|---|---|---|---|
| | **Total coliform** | **Fecal coliform** | **Turbidity** | **Total iron** |
| China filter candle | 99.45 | 99.89 | 100 | 100 |
| Vietnamese filter candle | 99.90 | 100 | 100 | 100 |
| Korean filter candle (1) | 99.66 | 99.98 | 100 | 100 |
| BHCF | 99.35 | 99.85 | 100 | 100 |
| Korean filter candle (2) | 99.74 | 99.87 | 100 | 100 |

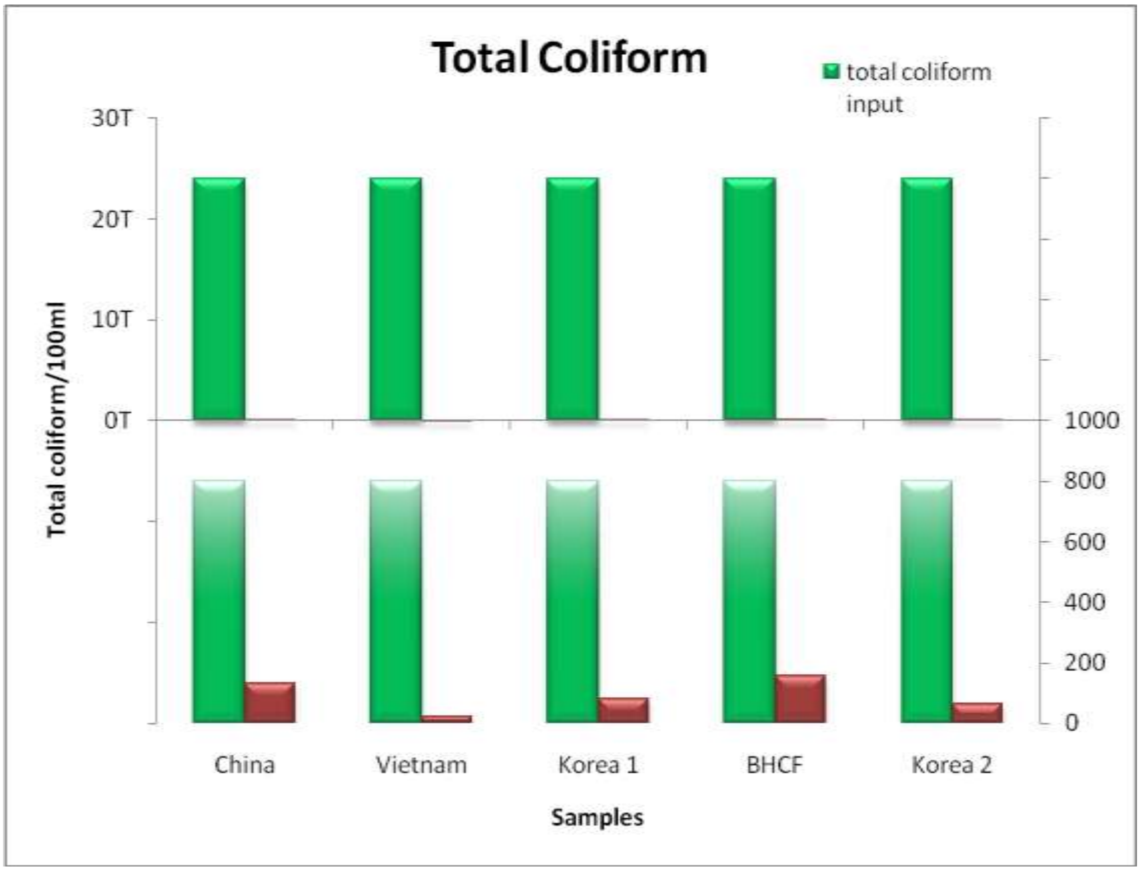



**Figure 3-26. Total coliform in water samples collected in the lab**

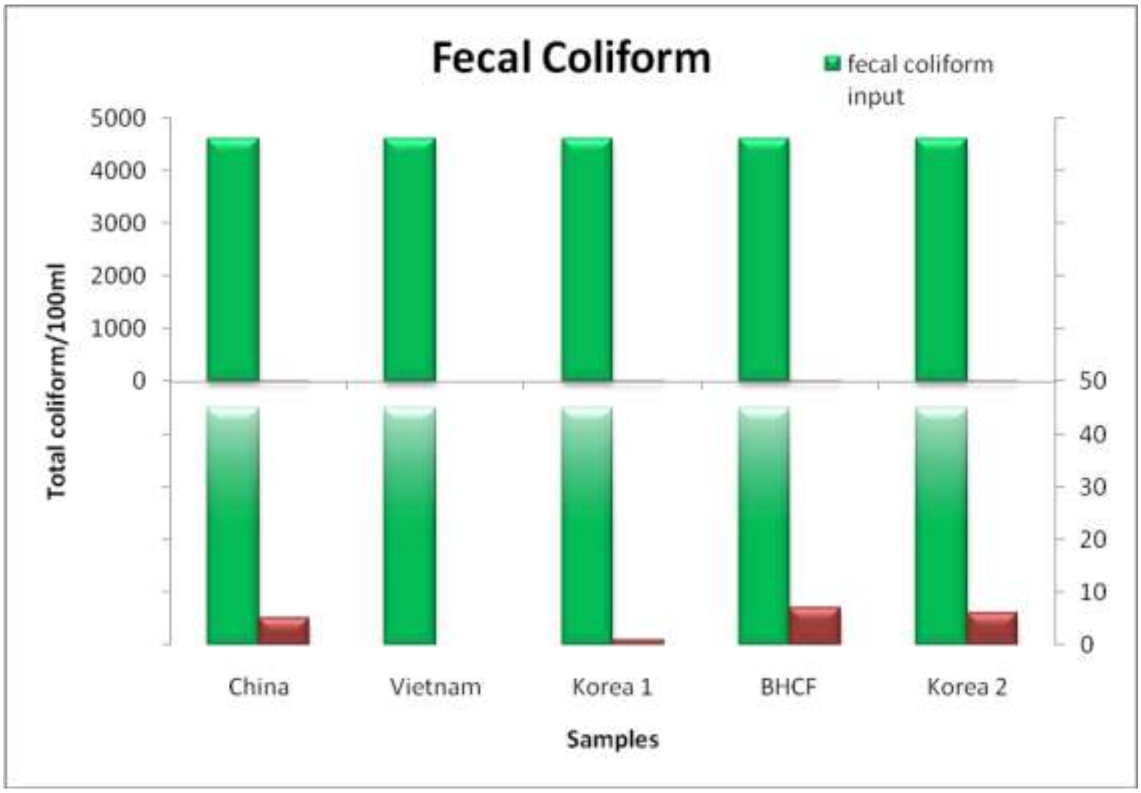



**Figure 3-27. Tolerant thermo coliform (Fecal coliform) in water samples collected in the lab**

#### 3.1.4.2 Discussion of water filtering efficiency

In terms of physiochemical parameters such as turbidity and total iron, all ceramic filters gave the outputs meeting National standards for drinking water[13]. However, due to to have an water input similar to the real, all input water samples collected from the field were mixed and used as the input for all imported ceramic filters and the BHCF. Thus, the concentration of total iron and turbidity were not high and the evaluation turbidity and total iron removal efficiencies were not representative.

For total coliform and fecal coliform, the results correspond to results and predictions from the previous chapter. The Vietnamese ceramic filter with high surface area, pore volume and even pore distribution has the highest efficiency in removing coliforms. Meanwhile, the BHCF has the lowest efficiency due to the small size of its pores.

In general, though the BHCF has the low coliforms removal efficiency in compared with imported ceramic filters, with above 99% efficiencies, the BHCF can be used to filter water effectively.

## 3.2 Piloting domestic ceramic filter pots for HWTS in Binh Nghia, Ha Nam

### 3.2.1 Households selection

Based on previous cooperative projects on water treatment and sanitation cooperated between NIOEH and WHO, which were conducted successfully, Binh Nghia is the studied location with the most active participations from not only from its inhabitants and medical staff but also from Binh Nghia authorities and local associations. Thus, Binh Nghia was chosen as the best site for this project.

Following site selection, together with great supports from medical staff in Binh Nghia medical station, 40 households in Cat Lai and Ngo Khe hamlets, Binh Nghia commune were selected (Annex) based on above criteria.

These households were provided 40 Bo Huong ceramic filters to use as a secondary water treatment method for drinking and cooking purposes. They committed themselves to using the pots regularly during and after the project period to filter groundwater that has already been treated by their sand-filters. Besides, Binh Nghia commune committees guaranteed (1) to create good conditions for NIOEH staff to conduct the project, (2) to participate actively in the project by (i) appointing experienced and responsible persons to monitor and help households if needed and (ii) encourage inhabitants to use and maintain their filters properly.

[13] QCVN 01-2009/BYT for drinking water and QCVN 02-2009/BYT for domestic water

**Figure 3-28. Images of the very first day**

### 3.2.2 Assessment of current situation of ceramic filter use in Binh Nghia

The interviews and observations were done together during the monitoring and water sampling trips. Most households in Binh Nghia commune use rain water for drinking and cooking purpose, especially during the rainy season – which corresponds to the time the project was implemented thus they do not need to use water filters to treat this water source before using. According to their explanations, reasons for not using imported water filters are (1) original rain water gives them sweeter and better taste than filtered rain water (2) tea made with filtered rain water has no taste or even has a strange taste that causes tea to taste not really good, (3) they have enough rain water for drinking and cooking, even for domestic use in some households and (4) water filters and purifiers are quite expensive for their incomes.

### 3.2.3 Water quality analysis

The purpose of this activity is to evaluate the actual water treatment efficiency of the BHFC thus Bo Huong ceramic filters were provided to selected households in Binh Nghia commune, Ha Nam province. Water samples were collected and analysed. Due to results in chapter 3.1.3, the pore size of the BHCF is the smallest among studied filters and it might be easily get stuck, so to avoid this issue from happening quickly the input was primarily treated by the sand-filter. Furthermore, the main target subject of this task is Bo Huong ceramic candles thus the output was collected directly after the candles not the storage tank

#### 3.2.3.1 Piloting Bo Huong ceramic filter in Binh Nghia commune

As mentioned above, 40 households were chosen to be involved in the project and provided 40 Bo Huong ceramic filters (BHCF). Water samples were collected in each household and analyzed in the laboratories. Parameters analyzed were given in below table.

**Table 3-5. Parameters analyzed in water samples**

| No | Parameters | Method for analysis | Reference |
|---|---|---|---|
| 1 | Total coliform | Membrane filter technique | Standard Methods for Examination of Water and Wastewater APHA 1998 |
| 2 | Thermo tolerant coliform (Fecal Coliform) | Membrane filter technique | Standard Methods for Examination of Water and Wastewater APHA 1998 |
| 3 | Total iron | Colorimetric method | Standard Methods for Examination of Water and Wastewater APHA 1998 |
| 4 | Turbidity | Nephelometric method | Standard Methods for Examination of Water and Wastewater APHA 1998 |

Besides, pH as the basic parameter of water sample was also measured for all samples collected. Together with other two physiochemical parameters: total iron, turbidity, pH values both input and output mainly in National standards for drinking water, approved by Ministry of Health (QCVN 01:2009/BYT) (Figures 4-29, 30, 31)

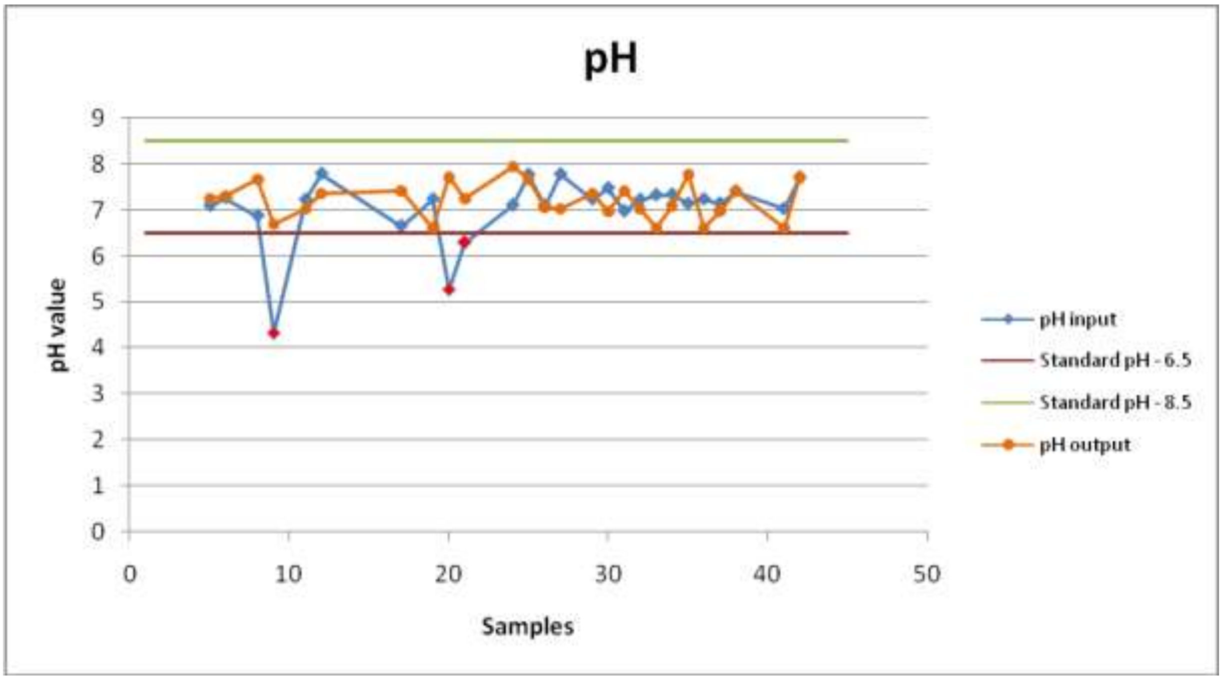



**Figure 3-29. pH value in water samples**

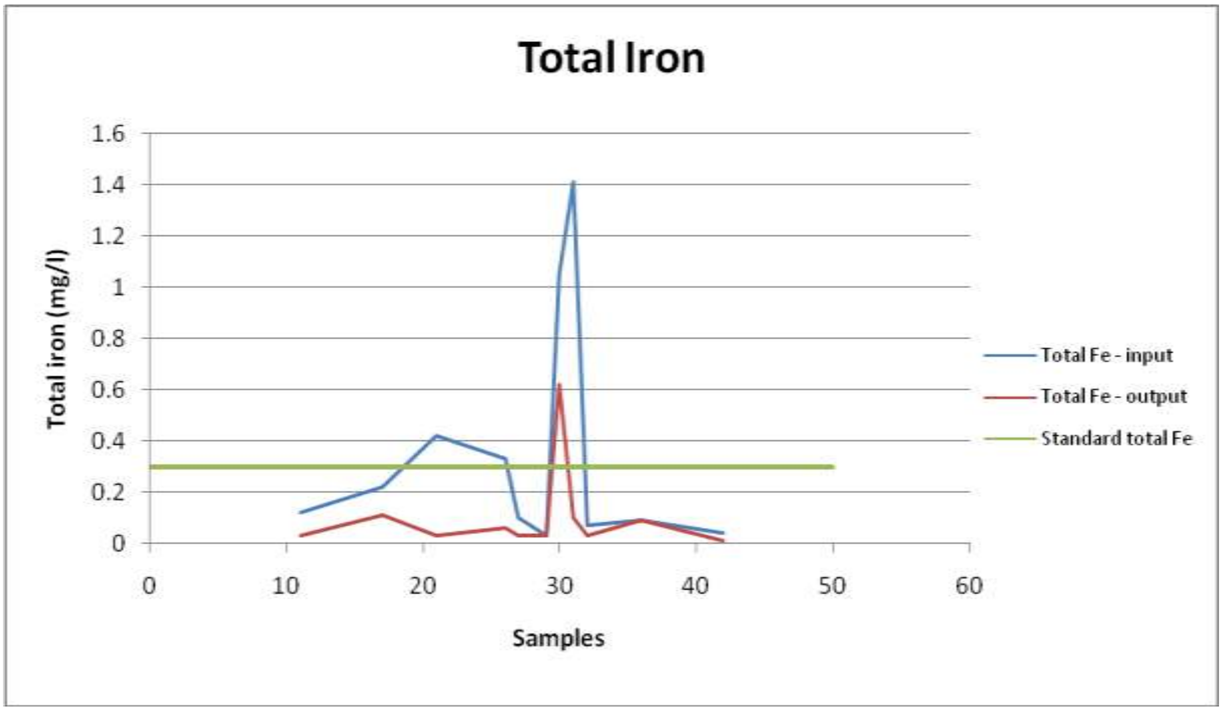



**Figure 3-30. Total iron in water samples**

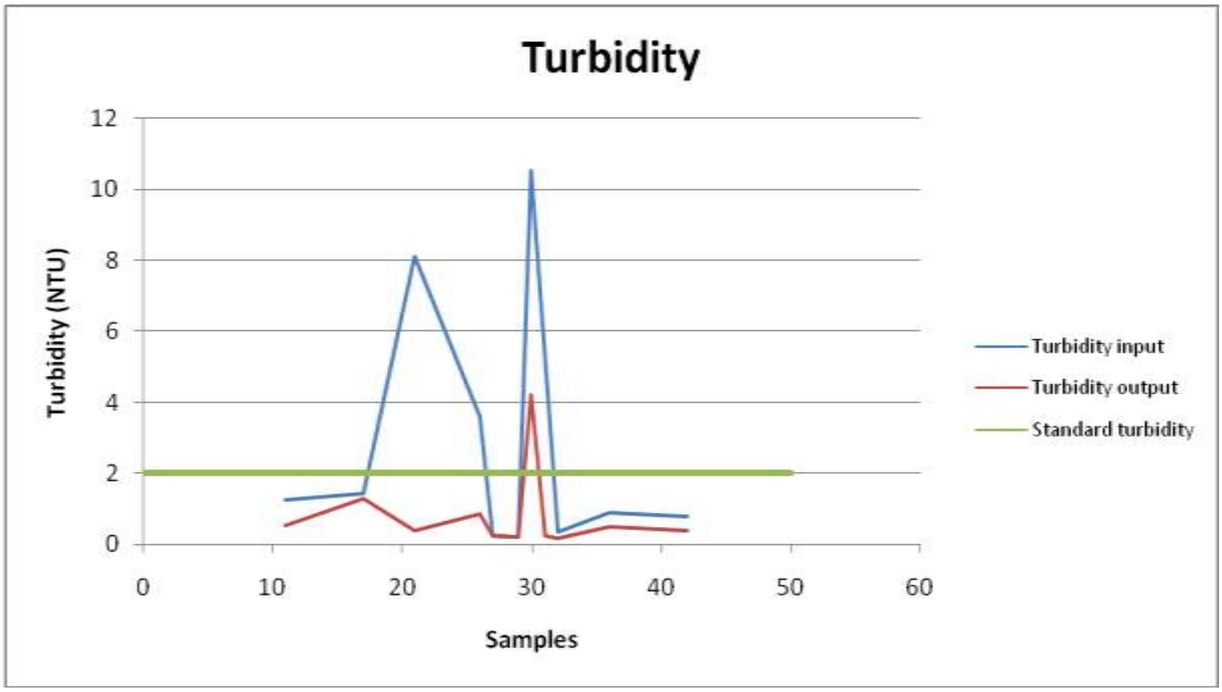



**Figure 3-31. Turbidity in water samples**

The ability of the BHCF in removing total iron and turbidity is not steady. The total iron and turbidity removing efficiencies fluctuated between 0 – 92.9% and 10 – 95.6%, respectively. Though efficiencies are not stable among samples, outputs mainly met National standards for drinking water.

For total coliform and fecal coliform, the filtering efficiencies are even in wider ranges, which are 4.53 – 99.76% for TC and 9.3 – 100% for TC (Figures 4-32, 33)

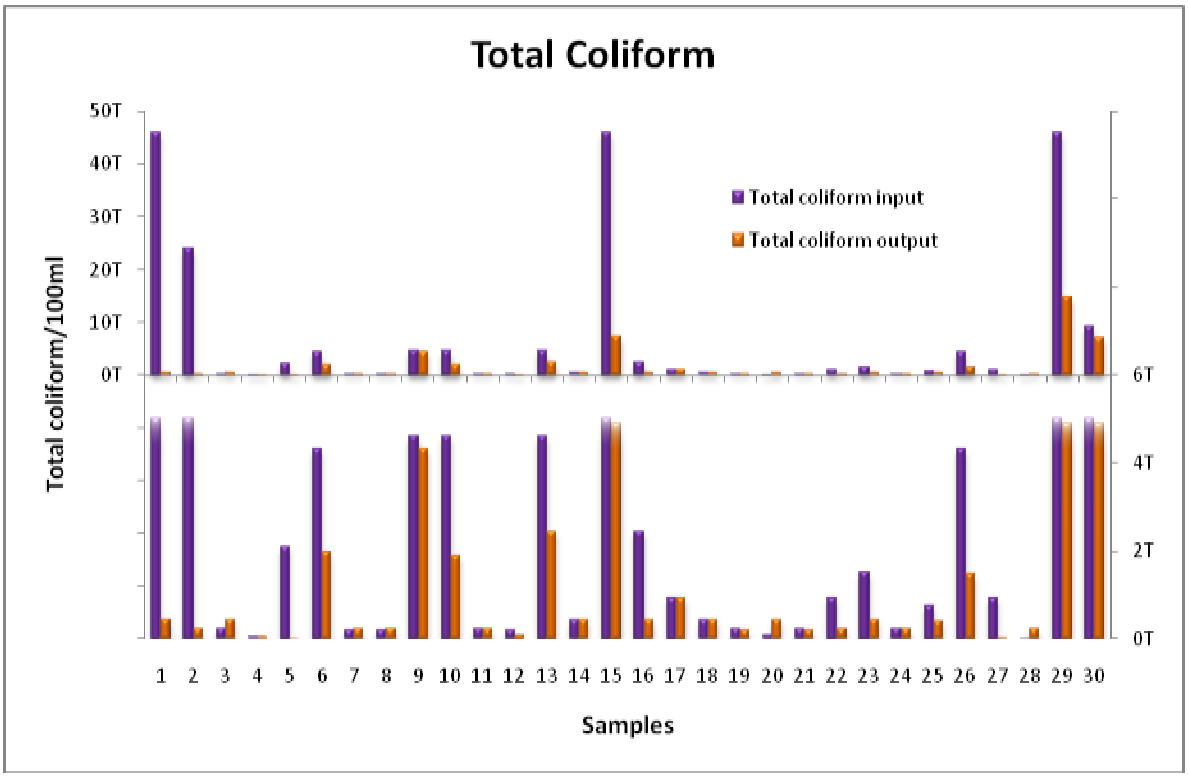



**Figure 3-32. Total coliform in water samples[14]**

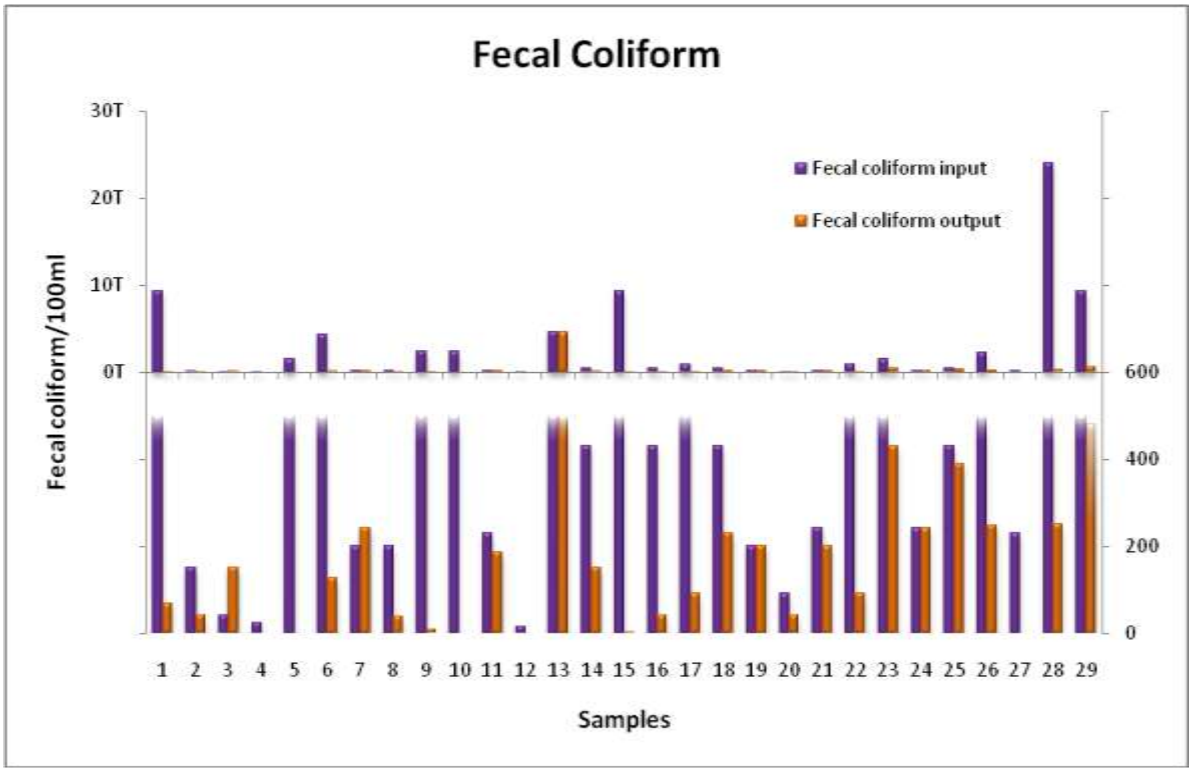



**Figure 3-33. Fecal coliform in water samples**

[14] T in y axis means Thousand

Thus, in order to assess the relation between the input concentrations and relative filtering efficiency of the BHCF (the output, in other words), all data were checked for the normal distributions and tested for the significant difference at the level of 0.05. In order to assess the relationship between input and output when data sets were not normal distribution, they were be transformed by using a logarithm function. Table 3-6 presents statistic results of all data sets.

**Table 3-6. Statistic results**

| **Parameters** | **t-test** | | **Regression** | | | | |
|---|---|---|---|---|---|---|---|
| | **t(1,39)** | **p** | **Intercept** | **Output variables** | **R square** | **F(1,39)** | **p** |
| Total coliform | 2.3324 | < 0.05 | 525.6108 | 3.0337 | 0.8763 | 212.6002 | <0.001 |
| E.Coli | 3.4793 | < 0.001 | 198.2927 | 8.3271 | 0.6549 | 55.0156 | < 0.001 |
| Turbidity | 4.2563 | < 0.001 | 0.6143 | 2.2113 | 0.7738 | 130.0167 | < 0.001 |
| Total Iron | 4.9832 | < 0.001 | 0.1043 | 1.5518 | 0.7360 | 105.9416 | < 0.001 |

The results showed that there are significant differences between the input and output in all parameters analyzed. Figures 4-34, 35, 36, 37 show the correlations between the input and output with regards to TC, FC, total Fe and turbidity, respectively.

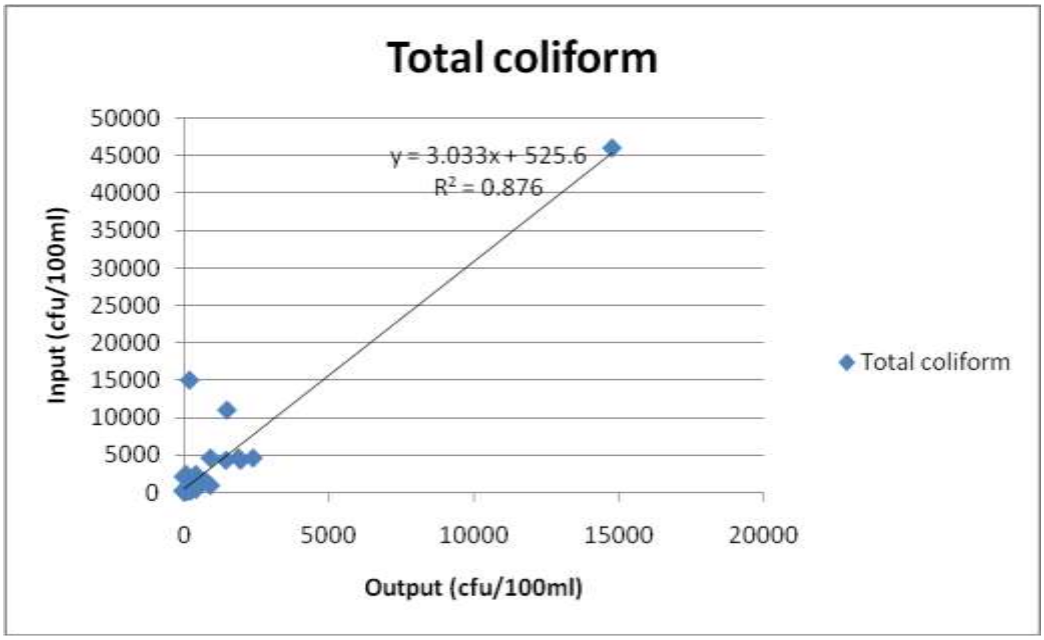



**Figure 3-34. Total coliform regression**

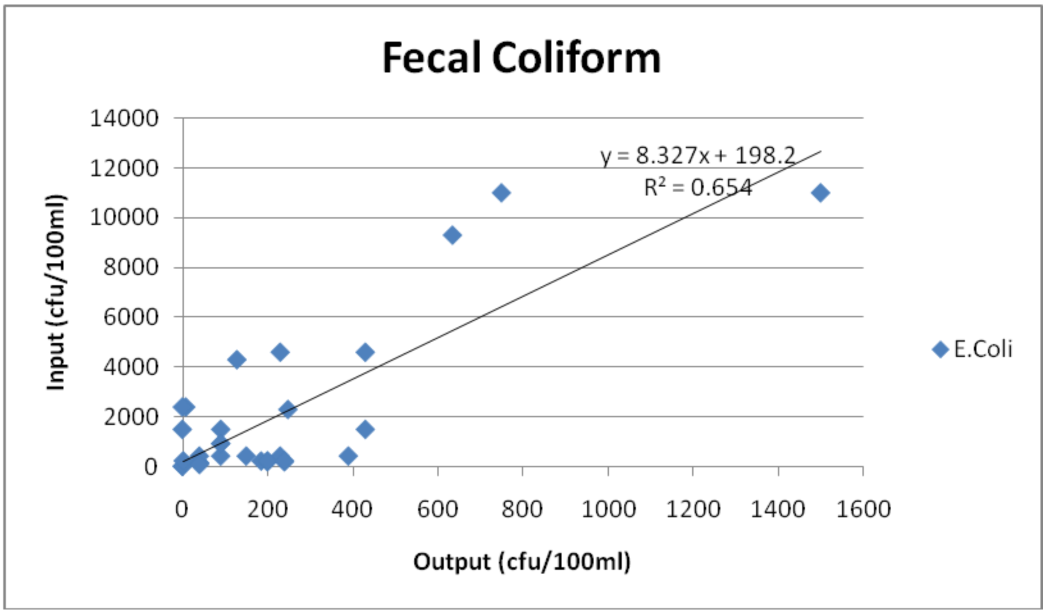



**Figure 3-35. Thermo tolerent coliform (Fecal coliform) regression**

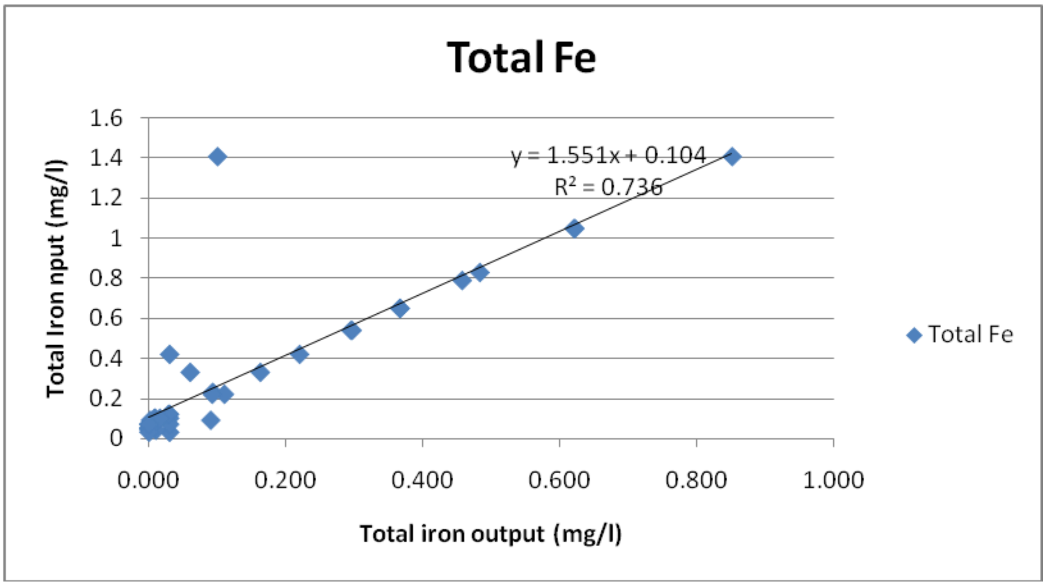



**Figure 3-36. Total Iron regression**

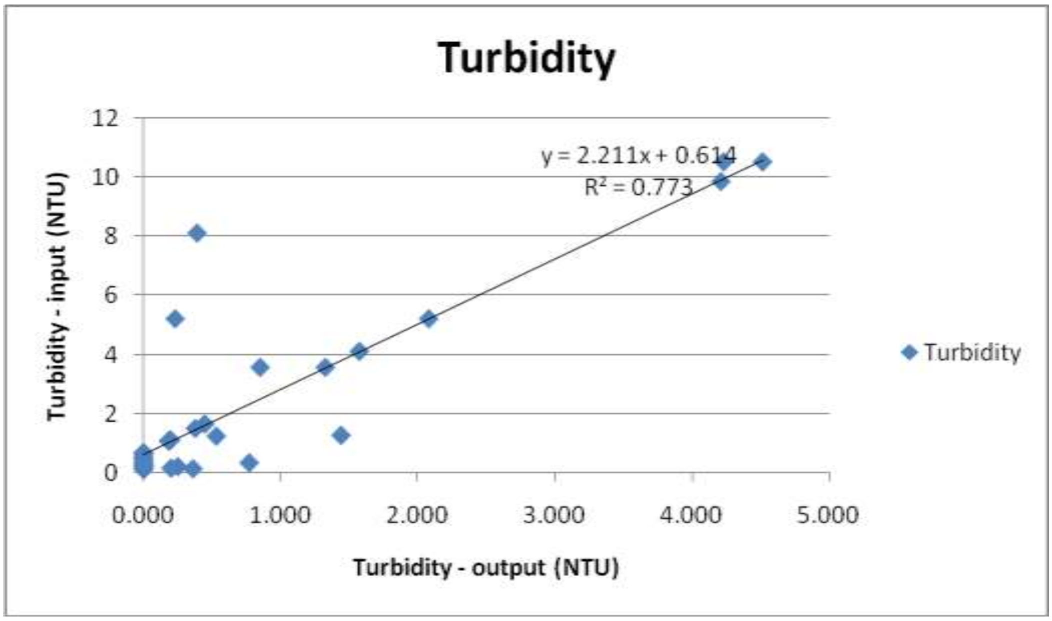



**Figure 3-37. Turbidity regression**

According to these correlations, for current BHCF, to have the filtering efficiency of 100% the input should have the maximum concentrations of approximately less than 550 TC/100ml; 200 FC/100ml; 0.1 mg total iron/l and 0.6 NTU for turbidity. However, to meet national standards, water input should have the maximum concentrations of 550 – 677 TC/100ml; less than 200 FC/100ml; 0.6 – 0.9 mg total iron/l and 5.0 – 11.7 NTU for turbidity.

**Table 3-7. Estimated inputs regarding to outputs**

| Parameters | Output 1[15] | Input 1 | Output 2[16] | Input 2 |
|---|---|---|---|---|
| Total coliform (colonies/100ml) | 0 | 550 | 50 | 677 |
| Fecal coliform (colonies/100ml) | 0 | 198 | 0 | 198 |
| Total iron (mg/l) | 0.3 | 0.6 | 0.5 | 0.9 |
| Turbidity (NTU) | 2 | 5 | 5 | 11.7 |

#### 3.2.3.2 Discussion of actual water filtering efficiency of the BHCF

The results demonstrate that turbidity and total iron reduction efficiencies (E) of BHCFs piloted in Binh Nghia commune are not steady and lower than those ($E_o$) assessed in NIOEH's laboratory (maximum total iron and turbidity removal efficiencies E of 92.9% and 95.6% compared to the efficiency $E_o$ of 100%). It can be explained that water inputs for physio-chemical analysis were not directly collected from the output of ceramic candles but from the storage tanks. These inputs could have therefore been re-contaminated during usage time in households. Despite the lower than 100% efficiency E, the quality of filtered water still meet standards for drinking water with regards to turbidity and total iron.

Similar to turbidity and total iron, efficiency of removing TC and FC out of water fluctuated in very wide ranges, which are 4.53 – 99.76% for TC and 9.3 – 100% for FC. The results achieved in this task are different to results from chapter 3.1.4, some BHCFs even give higher efficiencies and especially FC removal efficiency can reach 100% (18.5% of total output samples). For instance, BHCFs at Mr. Nguyễn Long Hưng and Ms. Ngô Thị Mai with inputs of 1500 and 2400 FC/100ml, respectively, gave 0 FC in output water. This means Bo Huong ceramic filter can remove bacteria at higher efficiencies (100% is possible). On the contrary, there are BHCFs have low bacteria removal efficiencies (48% and 25% of total BHCFs used in Binh Nghia have less-than 50% efficiency of removing TC and FC, respectively). In addition, 16.67% and 6.67% of BHCFs gave negative values to TC and FC removal efficiencies. Due to the lack of time, reasons for these errors have not been discovered and it is necessary to have further deeper research on this issue.

Compared to results from previous studies on ceramic filters in other countries such as Nicaragua, Cambodia, Nepal or Guatemala, BHCF gives similar efficiency in removing bacteria. For example, Robert W. Dies tested bacterial removal efficiencies of several ceramic filters with the input of 100 colonies/100ml water for both total

[15] National technical regulation on drinking water quality
[16] National technical regulation on domestic water quality

coliform and E.coli. The results showed that ceramic filters had 84 – 99.9% and 83 – 99.9% efficiencies in removing total coliform and E.coli, respectively[17]. In another study of Rebeca Eun Young Hwang (2002), point-of-use ceramic filters (Potters for Peace water filters) were applied and monitored in households in San Francisco, Nicaragua. The results showed that with the input of 16 or more than 16 colonies/100ml sample of both total coliform and E.coli, average removal rates of the PFP were 97.6% for E.coli and 89.3% for total coliform. Meanwhile, in this project, under the average input of approximately 5000 TC/100ml sample and 2000 FC/100ml sample, the BHCF could reach 99.76% and 100% efficiencies in removing total coliform and fecal coliform, respectively. This means, BHCF has the bacterial reduction efficiency as high as or even higher than other ceramic filters.

Furthermore, due to the unstable and not really high efficiency in removing bacteria and physiochemical parameters, all data were checked for normal distribution and tested for the significant difference at the level of 0.05. The results show that there are significant differences between inputs and outputs for all parameters and equations To demonstrate the relation between inputs and outputs, results were built based on regression results. The equations allow us to estimate inputs with maximum concentrations in the range of 550 – 677 TC/100ml, less than 200 FC/100ml, 0.6 – 0.9 mg total Fe/l and 5.0 – 11.7 NTU for turbidity to have outputs meet National standards.

### 3.2.4 The acceptance of the community with Bo Huong ceramic filter

After 3 months of piloting the usage of the BHCF in Binh Nghia commune and assessing its effectiveness, interviews were carried out inquiring about the acceptance of Bo Huong ceramic filters in the community. A questionnaire was developed which focused on how residents use the BHCF, which purposes they use filtered water for, how they feel of the BHCF (see Annex).

Interviews were carried out with representatives of 40 households involved in the project and an additional 20 households that didn’t participate in the pilot.

Among 40 households using BHCFs, 100% use filtered water for drinking and cooking purposes. For drinking purposes, 30% of them drank water directly without any other treatment methods and 97.5% boiled filtered water before drinking. When asked for reasons why they use water these ways, persons who drank water directly said “After working in the rice fields, I was very tired and thirsty. All I could do that time was wash my hands, grab a glass, take water and drink” or “It is somehow my habit, before I also usually drank un-boiled rain water” and “Thinking my opinion, filtered water is of course of better in quality and as I see it is clearer without any strange smell and taste”. Meanwhile, answers from 97.5% are mainly “We normally drink tea, thus to make tea we have to boil the water no matter how good it is treated”, “My family has never drank un-boiled water” and “Though water after being filtered looks better, I still am not sure about the real efficiency so it is safer to use boiled water”.

[17] Robert W. Dies, Development of a ceramic water filter for Nepal, Massachusetts Institute of Technology, 2003, MA

In addition, when asked about their feelings about water quality after the BHCF, on the one hand, 100% of 40 households said that water quality after the BHCF makes water filtered by the sand-filter much better because “This water is clean and clearer”, “There is no iron smell in the water” and “I checked by using filtered water to make tea, and there are no black dregs on the bottom of the tea pot and tea cup like when I use groundwater after the sand-filter”. On the other hand, only 97.5% felt that water quality after the BHCF is good and the other 2.5% felt that it is not good enough because “this water is not as good as rain water”. In other words, residents have accepted this filter and believe that it provides them with better and safer water for drinking. However, they said “this water is still not as palatable as rain water”. Despite this, they are willing to buy new filter or new ceramic candles at the price of 250,000VND/filter or 30,000VND/three candles. However, about 15% of them said “the price is still high for them to afford”. This is understandable for their incomes are mainly from agricultural work or from their pensions (less than 1million/family/month).

In general, 40 interviewees in 40 households involved in the project are satisfied with Bo Huong filters (97.5%) and they do want to continue using this product (100%), they even introduced this product to other people (95%). However, this product needs to improve the aesthetics, the structure and the flow rate, and the material of the containers should be changed because according to them the whole BHCF “is not really beautiful” with “a bulky and fragile container” and “a tray that carries three ceramic candles does not match the tank underneath it” and “the filtering speed is very slow”.

**Figure 3-38. Mr. Ngô Ngọc Sơn answering the interviewer**

Besides the 40 households involved in the pilot, 20 other households were randomly interviewed about their familiarity with the BHCF and whether they would consider using it. The results illustrate that through observation and word-of-mouth, they are aware of this product (100%) and feel that water quality after the BHCF is good (40%), easy to use (48%) and reasonably priced (12%). When asked why they think water quality is good, they said “I can see that water is clearer” and “I asked my neighbor and they said it is good” or even “I came to witness with my own eyes and I tasted the filtered water to check if it is good. Yes it is good”.

It can be said that the Bo Huong ceramic filter receives not only the acceptance of 40 households in the project but also attention of other households due to the perceptible effectiveness of the BHCF.

### 3.2.5 Other activities

**Monitoring**

Besides collecting water samples and interviewing local people, monitoring trips were done by NIOEH's specialists. These specialists spent time and went to Binh Nghia commune to check whether the studied 40 households used filters properly and whether there were unexpected issues that had occurred during the use. These visits were also a good occasion for the households to ask questions about the product and how to use it effectively.

In the first monitoring trip (a few days after 40 BHCFs were distributed), there were some households that had not yet made use of the product and the reason for that was "we want to save it for later". Some households made use of the Bo Huong filters to treat rainwater and not groundwater which is primarily filtered by the sand-filter. NIOEH's staff not only asked them to use BHCFs and but requested them to use it to treat the right target water source (groundwater). Furthermore, NIOEH's staff requested Binh Nghia medical staff and administrative to be more active in supervising and encouraging local people to use BHCFs properly.

In addition, during the first monitoring trip, one issue which was observed was that after being used, there were cracks on surfaces of the first batch of Bo Huong ceramic candles. This issue was then reported to producer in time and another batch was produced to replace the faulty one.

**Figure 3-39. Ceramic candles with cracks on the surface**

**Figure 3-40. New ceramic candles**

Aside from the unexpected issues mentioned above, inhabitants were very happy with the product and the water quality after being filtered. They made use of the filters everyday for drinking and cooking. They expressed that they expect this product to become an affordable method for them to keep their water clean and safe.

Furthermore, the 40 households mainly kept BHCFs in a dry and high place, usually in the kitchen where they can use the water for cooking. Others kept it in the corner of a common space where they and their children could take water for drinking. They are satisfied because this product is not bulky and steady like the sand-filter, it is easier to clean. However, still some households placed filters outdoor, near the pigpen. They were advised to keep their filters at a cleaner place.

**Figure 3-41. BHCF kept indoor**

**Figure 3-42. BHCF kept outdoor**

### Ceramic water filter instructional brochure

As part of the project, an instructional brochure was designed with simple but detailed information on how to use the filters properly and safely.


**Figure 3-43. Ceramic filter instruction brochure**

## Seminar

A seminar was organized to report project results, share experience and lessons learnt from project implementation and hearing experiences, suggestions from other researchers and stakeholders with regards to HWTS. The seminar entitled "**Piloting**

**Ceramic Filter as One Household Water Treatment and Safe Storage Option**" was held at Vietnam Trade Union Hotel for 25 participants (Annex)

Comments on Project results mainly are

- The project is very necessary since it will be the initial for further studies on not only the improvement of Bo Huong ceramic filter but also the ceramic filters suitable for HWTS in rural areas.
- Basically, BHCF helps users to treat water sources common in Vietnam (groundwater) and gives clear, iron free outputs.
- Primarily, BHCF gained the acceptance of the community in Binh Nghia province due to the reasonable price and the convenience in use. This is a good sign of being successfully applied in households.

However, there are recommendations on improving the BHFC and on continuing with this project, which mainly are

- It is necessary to test more parameters in both input and output to evaluate in detail the water treatment efficiency of the BHCF.
- It is required to have more studies on improving the aesthetics, flow rate, material structure aspects of the filter.
- Research on the market for the BHCF is also very important
- WHO, NIOEH and the producer need to cooperate closely to research and produced better quality products.
- In addition to having detailed studies on this issue, IEC programme also need to be implemented to raise people's awareness on environmental hygiene and safety.


**Figure 3-44. Images in the seminar**

# 4 Conclusion and Recommendations

## 4.1 Conclusion

There is no significant difference in the physical elements in between the Bo Huong ceramic filter and other imported ones. The Bo Huong ceramic filter contains the main element of silica oxide ($SiO_2$) from diatomite, which inertness provides its products with high absorptive capacity.

In terms of structural aspect, the Bo Huong ceramic filter has the smaller pore size, surface area and even pore distribution. It can be said that Bo Huong ceramic filter is suitable to remove bacteria, however, it can easily get stuck and subsequently the efficiency is lower than other candles. Moreover, smaller pore size gives the low flow rate of the BHCF and this is one weakness need to be improved to gain be successful in the market.

The results achieved from experiments in the laboratory proved that Bo Huong ceramic candles hves lower bacteria reduction efficiency than others, however, the efficiency is still more than 99% and filtered water quality meet National standards for drinking water.

When applied in Binh Nghia commune, water filtering efficiency of Bo Huong ceramic filter with regards to 4 parameters fluctuated in a wide range, however, according to results, Bo Huong ceramic filters can achieve high efficiency (100% is possible).

Bo Huong ceramic filters were highly accepted in the community in Binh Nghia commune, not only by the 40 households taking part in the project but also by other households when they witnessed the perceptible results of the product. Most of them agree that BHCF makes water, which is primarily treated by the sand-filter, better. Thus besides rainwater, the BHCF can help them to have better water to use for drinking and cooking purposes.

In conclusion, it is possible to explore option to distribute the Bo Huong ceramic filters more widely as a successful Household Water Treatment and Safe Storage method although it still need undergo some structural and aesthetic improvements of the candle.

## 4.2 Recommendations

In order to successfully provide an effective method for water treatment and storage in the community, the Bo Huong ceramic filter needs to be improved both the aesthetics and filtering efficiency which means that it is necessary to carry out further research on this product, for instance, increase the pore size and the porosity of ceramic material.

For households who are using Bo Huong ceramic filter or who want to use Bo Huong ceramic filter, it is recommended that the filtered water should be boiled before drinking.

In order to allow a higher success rate of future projects, as well as to allow extra time to test and improve the tools (in this case, ceramic filters), it would be recommended that future planning and transfer of funds be carried out much in advance of project implementation to allow for proper completion of the project in question. Another option might be to allow longer funding periods (such as 12-18 months) which would provide more leeway to deal with unexpected events as well as enough time to perfect the technologies being studied.

# 5 Follow-up actions

Based on results achieved from the project, we would like to propose and continue further research on "Improvement of the Bo Huong Ceramic Filter to meet the demand of Vietnamese peasants".

The main objectives of this activity are

- To continue to research on water treatment efficiency of the Bo Huong ceramic filter.
- Technically support the producer to improve the filter with regards to the structure of the filter, water treatment and aesthetic effectiveness.

Main tasks would be in the activity including

- Laboratory work to evaluate the ability of the Bo Huong cereamic filter to remove bacteria and other physio-chemical factors.
- Identification of factors that affect water filtration of the ceramic filter, such as the flow rate, pore size, inputs, etc.
- Research on improving the Bo Huong ceramic filter, for instance, improving production process, changing the pore size or the porosity, etc. to increase the effectiveness of the candle.
- Design of aesthetic supplements.

For this proposed activity, expected results would be

- Evaluation of the ability of removing bacteria and physio-chemical elements of the Bo Huong ceramic filter to different water inputs.
- Identification of factors that affect the effectiveness of the Bo Huong ceramic filter.
- Improved ceramic filter to provide treated water meet National standards for drinking water.

*Ha Noi, December 9th, 2011*

**The National Institute of Occupational and Environmental Health**

**Director General**

## Annex

### Annex 1

### Selected households involved in the project

| No | Houlsehold | Address |
|---|---|---|
| 1 | Trần Văn Quyền | Hamlet 1 Cát Lại, Binh Nghia, Ha Nam |
| 2 | Đặng Trung Thành | Hamlet 1 Cát Lại, Binh Nghia, Ha Nam |
| 3 | Nguyễn Thị Lan | Hamlet 2 Cát Lại, Binh Nghia, Ha Nam |
| 5 | Trần Xuân Thiện | Hamlet 3 Cát Lại, Binh Nghia, Ha Nam |
| 6 | Trần Thị Lịch | Hamlet 3 Cát Lại, Binh Nghia, Ha Nam |
| 7 | Phạm Thi Loan | Hamlet 3 Cát Lại, Binh Nghia, Ha Nam |
| 8 | Nguyễn Thị Minh | Hamlet 4 Cát Lại, Binh Nghia, Ha Nam |
| 9 | Đặng Thị Yến | Hamlet 4 Cát Lại, Binh Nghia, Ha Nam |
| 10 | Nguyễn Thị Loan | Hamlet 4 Cát Lại, Binh Nghia, Ha Nam |
| 11 | Trần Thị Nga | Hamlet 4 Cát Lại, Binh Nghia, Ha Nam |
| 12 | Nguyễn Thị Nga | Hamlet 4 Cát Lại, Binh Nghia, Ha Nam |
| 13 | Phạm Quang Thực | Hamlet 5 Cát Lại, Binh Nghia, Ha Nam |
| 14 | Nguyễn Văn Thắng | Hamlet 5 Cát Lại, Binh Nghia, Ha Nam |
| 15 | Trần Văn Chuyên | Hamlet 5 Cát Lại, Binh Nghia, Ha Nam |
| 16 | Trần Cao Quát | Hamlet 7 Cát Lại, Binh Nghia, Ha Nam |
| 17 | Nguyễn Long Hưng | Hamlet 7 Cát Lại, Binh Nghia, Ha Nam |
| 18 | Trần Hữu Hưng | Hamlet 8 Cát Lại, Binh Nghia, Ha Nam |
| 19 | Nguyễn Văn Tuyến | Hamlet 9 Cát Lại, Binh Nghia, Ha Nam |
| 20 | Trần Văn Tuấn | Hamlet 9 Cát Lại, Binh Nghia, Ha Nam |
| 21 | Trần Thanh Bình | Hamlet 3 Cát Lại, Binh Nghia, Ha Nam |

| | | |
|---|---|---|
| 22 | Trần Văn Hiếu | Hamlet 3 Cát Lại, Binh Nghia, Ha Nam |
| 24 | Ngô Thị Mai | Hamlet 3 Ngô Khê, Binh Nghia, Ha Nam |
| 25 | Trần Thị Huyền | Hamlet 1 Ngô Khê, Binh Nghia, Ha Nam |
| 26 | Lê Thị Hà | Hamlet 1 Ngô Khê, Binh Nghia, Ha Nam |
| 27 | Lương Mạnh Lễ | Hamlet 2 Ngô Khê, Binh Nghia, Ha Nam |
| 28 | Phạm Quang Thắng | Hamlet 2 Ngô Khê, Binh Nghia, Ha Nam |
| 29 | Trần Văn Hùng | Hamlet 3 Ngô Khê, Binh Nghia, Ha Nam |
| 30 | Ngô Văn Hải | Hamlet 4 Ngô Khê, Binh Nghia, Ha Nam |
| 31 | Nguyễn Văn Bột | Hamlet 4 Ngô Khê, Binh Nghia, Ha Nam |
| 32 | Phạm Thị Hải | Hamlet 5 Ngô Khê, Binh Nghia, Ha Nam |
| 33 | Vũ Ngọc Khải | Hamlet 5 Ngô Khê, Binh Nghia, Ha Nam |
| 34 | Đào Ngọc Lũ | Hamlet 5 Ngô Khê, Binh Nghia, Ha Nam |
| 35 | Nguyễn Thị Quyên | Hamlet 6 Ngô Khê, Binh Nghia, Ha Nam |
| 36 | Nguyễn Văn Bốn | Hamlet 7 Ngô Khê, Binh Nghia, Ha Nam |
| 37 | Hoàng Văn Hảo | Hamlet 8 Ngô Khê, Binh Nghia, Ha Nam |
| 38 | Hoàng Văn Hùng | Hamlet 8 Ngô Khê, Binh Nghia, Ha Nam |
| 39 | Trần Văn Thư | Hamlet 5 Ngô Khê, Binh Nghia, Ha Nam |
| 41 | Trần Thị Tính | Hamlet 6 Ngô Khê, Binh Nghia, Ha Nam |
| 42 | Ngô Văn Minh | Hamlet 6 Ngô Khê, Binh Nghia, Ha Nam |
| 43 | Ngô Ngọc Sơn | Teacher |

## Annex 2

**QUESTIONNAIRE ON THE ACCEPTANCE OF**
**BO HUONG CERAMIC FILTERS IN THE COMMUNITY**

## I. GENERAL INFORMATION

1. Full name:
2. Age: Sex:
3. Address:
4. Occupation:
5. Income: VND/month
6. How many people are there in your family?
7. How many children do you have?

Now I would like to ask you questions about Bo Huong ceramic filter and how you use water for your normal life.

## II. ACCEPTANCE OF CERAMIC FILTERS

| STT | QUESTION | ANSWER |
|---|---|---|
| 1 | Which water resources do you use for everyday life (including: drinking and cooking activities) | a. Tube well<br>b. Dug well<br>c. Tap water<br>d. Ponds, Lakes or rivers<br>e. Rainwater<br>f. Others: …………………………….. |
| 2 | Which water resources do you use for drinking and cooking purposes? | a. Tube well<br>b. Dug well<br>c. Tap water<br>d. Ponds, lakes or rivers<br>e. Rainwater<br>f. Others: …………………………….... |
| 3 | Do you treat water before using? | a. Yes<br>b. No (Move to Question 25) |
| 4 | Which methods do you apply to treat your water for drinking purpose? | a. Sand-filter by NIOEH (or based on NIOEH's filter)<br>b. Bo Huong filter<br>c. Chemicals: ………………………….. |

| | | |
|---|---|---|
| | | d. Solar energy<br>e. Others: ……………………………........... |
| 5 | Are you now using Bo Huong filter? | a. Yes<br>b. No (Move to Question 25) |
| 6 | Which purposes do you use Bo Huong filter for? | a. Drinking only<br>b. Cooking only<br>c. Both |
| 7 | Can Bo Huong filter provide enough water for your family to use in a day? | a. Yes (Move to Question 9)<br>b. No |
| 8 | If No, which other water sources you use for drinking? | a. Rainwater<br>b. Filtered groundwater<br>c. Tap water<br>d. Others: ………………………….. ……………………………………… |
| 9 | How do you use water after Bo Huong filter? | a. Drink directly<br>b. Boil<br>c. Filter another time<br>d. Others: ………………………….. ……………………………………… |
| 10 | Why? | ………………………………………<br>……………………………………… |
| 11 | According to you, is water quality after this filter good enough to use? | a. Yes (Move to Question 13)<br>b. No |
| 12 | Why the water quality is not good? | ………………………………………<br>……………………………………… |
| 13 | Is water quality after Bo Huong filter better than that after other treatment method you applied/are applying? | a. Yes (Move to Question 15)<br>b. No |
| 14 | Why it is not better? | a. More turbid<br>b. Strange smell/taste<br>c. Colored<br>d. Others: …..………………………….. ……………………………………… |
| 15 | Is it convenient to use? | a. Yes (Move to Question 17)<br>b. No |
| 16 | Why it is inconvenient? | ………………………………………<br>……………………………………… |
| 17 | What do you think of the aesthetic of Bo Huong filter | a. Very nice<br>b. Normal<br>c. Ugly |

| | | |
|---|---|---|
| 18 | Now you are provided the Bo Huong filter which is sold with the price of 250,000VND/set, are you willing to buy the new one? | a. Yes (Move to Question 20)<br>b. No |
| 19 | Why not? | a. More expensive than other filters<br>b. The filter water quality is not good<br>c. Others ………………………………<br>............................................................... |
| 20 | In general, are you satisfied with this filter? | a. Yes (Move to Question 21)<br>b. No |
| | Why No? | ………………………………………<br>……………………………………… |
| 21 | Do you like to continue using this filter | a. Yes (Move to Question 23)<br>b. No (End) |
| 22 | Why no? (and Move to Question 30) | ………………………………………<br>……………………………………… |
| 23 | Would you like to introduce this filter to your friends and neighbors? | a. Yes<br>b. No |
| 24 | Why? | ………………………………………..<br>………………………………………..<br>………………………………………..<br>……………………………………….. |
| 25 | Do you know about Bo Huong filter? | a. Yes<br>b. No (End) |
| 26 | How do you know about this filter? | a. Friends<br>b. Neighbors are using it<br>c. Advertisement<br>d. Others: …………………………..<br>……………………………………........ |
| 27 | Do you like to use Bo Huong filter? | a. Yes<br>b. No (End) |
| 28 | Why Yes? | a. Cheap<br>b. Looks nice<br>c. Easy to use<br>d. Water quality is good<br>e. Others: …………………………..<br>……………………………………........ |

| | | |
|---|---|---|
| 29 | Why No? | a. Expensive<br>b. Not nice<br>c. Inconvenient to use<br>d. Water quality is not good<br>e. Others: ………………………….. ……………………………………........ |
| 30 | Do you have any suggestions on improving this filter? | ……………………………………….<br>………………………………………. |

Thank you very much for your cooperation.

, 2011

**Interviewee** **Interviewer**

**Annex 3**

**Seminar Agenda**

***Piloting ceramic filters as one Household Water Treatment and Safe Storage (HWTS) option***

*Hà Nội, 30th November, 2011*

*at Công Đoàn Hotel, 14 Trần Bình Trọng, Hai Bà Trưng, Hà Nội*

| Time | Activities | Person |
|---|---|---|
| 8.30 - 9.00 | Registrtation | |
| ***Opening speech*** | | |
| 9.00 - 9.15 | Welcome and introduction of objectives of the workshop, participants | Dr. Nguyễn Duy Bảo<br>Director of NIOEH |
| | WHO representative | |
| | MoH representative | Dr. Trần Đắc Phu<br>Vice Director of HEMA |
| ***Presentations*** | | |
| 9.15 - 10.15 | Project report | Ms. Đỗ Phương Hiền<br>NIOEH |
| ***10. 15 – 10.30*** | ***Coffee break*** | |
| 10.30 – 11.30 | Overview of water filters and purifiers in Vietnam | Dr. Từ Hải Bằng<br>NIOEH |
| | ***Lunch at Hotel*** | |
| 13.30 - 14.30 | Introduction about Bo Huong ceramic filter | Mr. Phạm Tiến Bộ<br>Bát Tràng, Hà Nội |
| ***14.30 – 14.45*** | ***Coffee break*** | |

| | | |
|---|---|---|
| 14.45 - 15.45 | Evaluation of ceramic material for water filtering on the market and recommendations for domestic producers | Ms. Phạm Thanh Thảo<br><br>Institute of Natural Products Chemistry |
| 15.45 – 16.30 | ***Discussion*** | All participants |
| | ***Closing the Seminar*** | NIOEH representative |
| | | WHO representative |

## Annex 4

## List of Seminar Participants

| No. | Participants | Address |
|---|---|---|
| 1 | Dr. Tran Dac Phu | Vice Director of HEMA, MOH |
| 2 | Dr. Nguyen Duy Bao | Director of NIOEH |
| 3 | Ms. Viktoria Dijakovic | WHO |
| 4 | Dr. Nguyen Bich Diep | Vice Director of NIOEH |
| 5 | Mr. Bui Van Chung | Vice Director of NIOEH |
| 6 | Mr. Pham Tien Bo | Producer of the BHCF |
| 7 | Mrs. Vu Thi Nhung | Producer of the BHCF |
| 8 | Ms. Pham Thi Minh Thao | Institute of Chemistry and Natural Products |
| 9 | Mr. Nguyen Xuan Dung | |
| 10 | Ms. Tran Thi Minh Tam | Thua Thien Hue Water Supply and Construction State One Member Company Limited |
| 11 | Mr. Hoang Van Hung | Vice Head of Binh Nghia people's committee |
| 12 | Mrs. Nguyen Thi Nga | Head of Binh Nghia medical station |
| 13 | Mr. Pham Quang Thuc | Binh Nghia medical station |
| 14 | Mr. Dao Van Trong | Binh Nghia commune |
| 15 | Mr. Tran Van Quyen | Binh Nghia commune |
| 16 | Mr. Dao Ngoc Lu | Binh Nghia commune |
| 17 | Mr. Ngo Van Hai | Binh Nghia commune |
| 18 | Ms. Pham Thi Hai | Binh Nghia commune |
| 19 | Mr. Tran Van Chuyen | Binh Nghia commune |
| 20 | Mr. Nguyen Van Tuyen | Binh Nghia commune |
| 21 | Mr. Bui Van Truong | NIOEH |

| | | |
|---|---|---|
| 22 | Mrs. Le Thai Ha | NIOEH |
| 23 | Ms. Nguyen Huyen Trang | NIOEH |
| 24 | Mr. Pham Hong Quang | NIOEH |
| 25 | Mr. Tu Hai Bang | NIOEH |