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## Evolution of water purification methods

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### Abstract

**Introduction and Background:** Early humans believed that the purity of water was determined by taste and odour, if the water had a sweet and pleasant taste and good odour then it was considered as pure. As a result, the method of water purification in ancient era, as described in classical Unani literature, was to add herbs, flowers, honey or fruits to water to purify it as well as to make it pleasant in taste and odour. In the 3<sup>rd</sup> century BC the Father of Medicine, *Hippocrates* introduced “*Hippocratic Sleeve*” the first domestic filter. It was a simple cloth bag filter through which boiled water was filtered. The main purpose of this filter was to trap the particles and pollutants of water. Some Unani physicians also recommended use of silk cloth for water filtration. Other methods which are described by Unani physicians are Storage/ Sedimentation, Boiling, Vessels method, Distillation and Churning etc. Today, purification of water is more important due to the widespread of contamination and pollution. Numerous methods and techniques are invented but all these techniques are very expensive and out of reach of lower class and sometimes for middle class population also, while the old methods (which are mentioned in classical Unani literature) are more economical and easy to use for all at domestic level for potable drinking water.

**Methodology:** The present literary research is conducted through “input-processing-output” approach. The literature collected from primary and secondary sources, various libraries and online search engines. The result generated accordingly, then compiled, analyzed and evaluated.

**Objective:** To collect and compile the scattered literature related to water purification methods in Unani Medicine.

**Keywords:** Water, filtration, treatment, unani medicine, literature, techniques

### Introduction

Pure and safe water is a basic need of life because the health of all human beings may be affected by drinking of contaminated water, either directly or through food. Without safe and wholesome water there can be no state of positive health and wellbeing as well as it is a vital factor to all forms of life. It is the reason for that human has been working on the methods of water purification since the existence of life on earth. The importance of water, sanitation and hygiene for health and development has been reflected in the outcomes of a series of international policy forums. These have included health-oriented conferences such as the International Conference on Primary Health Care, held in Alma-Ata, Kazakhstan (former Soviet Union), in 1978. They have also included water-oriented conferences such as the 1977 World Water Conference in Mar del Plata, Argentina, which launched the water supply and sanitation decade of 1981–1990, as well as the Millennium Development Goal (MDG) adopted by the General Assembly of the United Nations (UN) in 2000 and the outcome of the Johannesburg World Summit for Sustainable Development in 2002. The UN General Assembly declared the period from 2005 to 2015 as the International Decade for Action, “Water for Life”.<sup>[1]</sup>

Alcmaeon of Croton (470 BC.) was the first Greek physician to state that the quality of water may influence the health of people. Hippocratic treatise: *Airs, Waters and Places* (around 400 BC.) deals with the different sources, qualities and health effects of water in length.<sup>2,3</sup> Various other Hippocratic treatises (mostly written around 400 BC.) contain short comments on the influence of water on the health of people.<sup>[2]</sup>

In the 3<sup>rd</sup> century the Father of Medicine, *Hippocrates* (460-370 BC) introduced the first domestic filter which is known as “*Hippocratic sleeve*”<sup>[2]</sup>, this was a simple cloth bag filter through which boiled water was filtered. The main purpose of this filter was to trap the particles and pollutants of water. Some Unani physicians also recommended use of silk cloth for water filtration to purify it<sup>[4]</sup>.

The importance of clean and wholesome drinking water became the subject of research in 19<sup>th</sup> century when an English epidemiologist John Snow studied the epidemiology of cholera

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in London from 1848 to 1854 and established the role of polluted drinking water in the spread of cholera<sup>[5]</sup>.

After John Snow, in 1856 another person William Budd, by careful observation of an outbreak of typhoid fever in the rural north of England concluded that the spread was by contaminated drinking water. These two studies prove that the contamination of water is a hazard for public health. The people became aware and demanded for clean water<sup>[5]</sup>.

### Review of Literature

**History of Water Purification:** Water is life – and every living thing on earth is dependent on water as God says in Holy Quran “We made everything live from water” (21: 30). Like this there are various verses in the Quran which are evident that water is a major theme in Islamic cosmogony and iconography as well as a recurrent topic in daily life. Description of Mā (water) in holy Quran occurs more than sixty times and several other words related to the semantics of water and hydrology, such as rivers, sea, fountains, springs, rainfall, clouds, and winds are frequently used. Water is thus described as a gift by God so that humanity can be benefit from it. This gift is the proof of the existence and uniqueness of Allah. Not only mankind, animals, plants and flowers need water as the basis for life but also to assure its continuation.

The purification of water is also mentioned in the Bible. Around the 9<sup>th</sup> century, Moses and the Israelites found that the water in *Marah* was bitter. Following instruction from the God, He cast a tree into the water, and the water was immediately sweetened. In another instance, the residents of Jericho complained to Elisha that the water in the city was “naught” and the prophet purified the water by casting salt in it<sup>[6]</sup>.

After 1500 BC and before *Hippocrates*, the Egyptians were very advance and civilized. They developed the water purification methods and first of all they discovered the principle of coagulation for water treatment. They applied the chemical alum for suspended particle settlement. Pictures of this purification technique were found on the wall of the tomb of *Amenophis II* and *Ramses II*<sup>[7]</sup>.

According to historical records of Unani Medicine (in chronological order), the water purification methods could be divided in to three periods as following.

1. Greek Period – Boiling, Straining and Filtration
2. Arabic Period – Distillation, Vesseles Method, and Others
3. Post Arabic Period – No New Method

**Greek Period: (500 BC to 500 AD):** Unani Medicine, originated in Greek and is primarily based on the principles propounded by the ancient Greek practitioners *Hippocrates* and his followers e.g. *Suqrāt*, *Aristotle*, *Aflātūn*, and *Galen etc.*

*Hippocrates* was the first person who established the basic concepts of health and disease. He defined clearly that disease is a natural process and that symptoms are the reactions of the body to disease. It employs the humoral theory which presupposes the presence of four *Akhlāṭ* (humours) in the body – *Dam* (blood), *Balgham* (phlegm), *Ṣafrā'* (yellow bile) and *Sawdā'* (black bile). Each humour has its own temperament: blood is hot and moist; phlegm is cold and moist; yellow bile is hot and dry; and black bile is cold and dry. According to Unani Medicine, if the four humours and the four primary temperaments (hot, cold, dry, moist) are all in a state of mutual equilibrium, the person is

considered healthy and if there will be any imbalance in four humors or temperaments, disease will appear. He also described the physical, social and environmental factors affecting health. In this concern his writings e.g. *Kitāb al Fuṣūl*, (Airs and Waters) and *Kitāb al Ahwiya wal Miyāh wal Buldān* (Airs, Waters and Places) have basic importance in preventive and social medicine. This is the first book written by *Hippocrates* on medical Geography, Metrology and Anthropology<sup>[8]</sup>. This is the first book on water purification methods as well as on description of various types of water and their uses. In concern of water treatment, *Hippocrates* recommended boiling, straining and filtration.<sup>3</sup> According to *Ibn Nadīm* Galen translated ten books of *Hippocrates*, in which two are related to water, its quality, characteristics and methods of its purification. These two books are 1- *Airs, Waters and Places*. 2- *Airs and Waters*<sup>[9]</sup>. These two books are translated in various languages of the world and are mile stones in water treatments as well as in preventive and community medicine because these three things (airs, waters and places) have basic importance in maintaining health as well as in epidemiology. Therefore, every writer of community and social medicine gives reference of this book compulsorily.

Two manuscripts of *Hippocrates* are present in Khuda Bakhsh Library Patna.

1. *Fuṣūl Buqrāt*-Manuscript No-HL 4093-A Manuscript of 11<sup>th</sup> AH It Is Translated By *Abdur Raḥmān Ibn 'Alī Abī Sādīque*<sup>[10]</sup>.
2. *Kitāb Al Fuṣū Al Buqrāt*-Manuscript No. 4099-A Manuscript of 12<sup>th</sup> AH It is translated by *Avicenna*<sup>[10]</sup>.

During Hippocratic period commonly, used methods of water purification were Boiling, Straining and Filtration. *Hippocrates* was the first person who invented these procedures (Boiling, Straining and Filtration) and commonly used them for their patients. After *Hippocrates* his followers also adopted these methods and used them for health and community wellbeing.

After the death of *Hippocrates*, Unani Medicine was scattered again. *Galen* (129-201 A.D.) was the person who again Re-emitted the fallen *Hippocratic* medicine in the Rome with his longstanding contribution to medicine. His writings influenced European medicine and accepted as standard text book for 14 centuries until his teaching challenged by the anatomist *Vesalius* in 1543 and the physiologist *William Harvey* in 1628, almost 1500 years after his death<sup>[5]</sup>.

**Arabic Period: (500 AD to 1500 AD):** After decline of Greek and other civilizations, Arab civilization became prominent. In this period, “known as DARK AGES for Europe and other European countries” Arabs were a milestone in all fields of sciences, e.g. medicine, philosophy, geography, mathematic, physics, chemistry, geology etc. Arabic period was the golden period in the history of medicine (5<sup>th</sup>-15<sup>th</sup> centuries). Arab physicians and scholars not only prevented the flicking torch of Greek medicine but also brightened its scope and handed it back after five centuries to the Europe<sup>[11]</sup>. They established the medical science as “*Greeko-Arabic Medicine*”. That is enshrining in books written in Arabic language, Greek in origin with Indian, Persian and Syrian accretions<sup>[11]</sup>. Arabs contributed a lot to the field of Unani medicine. Arabs not only favoured the previous knowledge of Greek by

translating it, moreover they included it as a constant component of their every writings and elaborated it with their personal efforts.

The greatest physicians of the Eastern Caliphate (Abbasid) were the three, *Rhazes*, '*Alī ibn 'Abbās Majūsī* and *Avicenna* [12], and their writings were the previous resources of Unani medicine. A classical text book of *Rhazes*, preserved in the original Arabic with paralleled Latin translation in Channing's edition (London-1766) [12] and his great encyclopaedia of medicine "*Alhāwī*" (Continants) preserved in the Latin translation of Feragus [12]. '*Ali ibn Abbās* (D-994) author of "*Almalakī*" (Liber Regias or Royle Book) added also some specific and general books in the literature of Unani medicine. *Al-Qānūn fī Tib* of *Avicenna* is considered as one of masterpiece of Arab systemization representing the Islamic medicine. [13] in which he attempted to codify the medical knowledge of his time and square its facts with the system of *Galen* and *Aristotle* [12]. It is the book that superseded the work of their preceders and had a lot of editions, translations and commentaries. The fame of this book is due to its comprehensiveness and innovations [12].

It is said that *Ilm Tibb* was extinct, invented by the *Hippocrates*, dead re-emitted by the *Galen*, scattered compiled by *Rhazes*, imperfect completed by *Avicenna* [14].

In Arabic period *Jābir ibn Ḥayyān* known as *Geber*, is the most prominent personality in the field of science and medicine especially in chemistry. Due to his immense knowledge and experiments he is known as "Father of Chemistry [15]" and the development of chemistry in Europe can be traced directly to *Jābir ibn Ḥayyān* [16].

Except *Geber*, other philosophers and physicians of Arabic period for example *Avicenna*, *Muḥammad ibn Zakariyya Rāzī*, *Abū Sahl Masīhī* and many more, experimented themselves in water purification methods, resulting new ideas and techniques in this field, which became torch for other countries and civilizations. The water purification methods which were used by Arabs are distillation [17, 18, 19], filtration [2, 20, 21], boiling [17, 18, 21, 22], storage and sedimentation [17, 18], and churning etc [17, 21].

**After Arabic Period till Date:** After Arabs Unani medicine came to Asia, especially in India through Arabic and Persian literature. Indian hakims and philosophers translated some Unani literatures from Arabic and Persian into Urdu language. Their contribution to Unani medicine is very important. They added various Indian herbs and medicinal plants to Unani medicine. *Mughal* kings and their court physicians as well as other physicians certainly done distinguishable works for Unani medicine but unfortunately they could nothing in the field of water purification methods but followed the path of their ancestors philosophers of Greek and Arabs.

All the water purification methods used in Unani System of Medicine are as following

1. Boiling
2. Filtration / Straining
3. Storage / Sedimentation
4. Sun Light Exposure
5. Distillation/ Sublimation
6. Coagulation/Flocculation
7. Vessels Method
8. Churning

**Boiling:** [3, 17, 18, 19, 23, 24] *Rabban Tabari* says that, boiling kills all the bacteria (*جرثيم*) and water becomes rarefied and soft [24]. According to *Avicenna* and other physicians the best water treatment method is distillation. If that is not feasible, boiling will be sufficient, for boiled water, as the learned know, are less likely to cause inflammation and passes more rapidly through the body. Boiling removes the density which the quality of coldness produced, the particles of water are then forcibly rarefied and the substance of the water become more and more rare, until the heavy suspended particles burst loose and fall down and sink to the bottom. Nearly quite pure water remains behind [18]. Boiling water in regards to water purification or decontamination is something the majority of the people in the world encountered personally at some point in their lives. Of course water boiling for the purpose of cleaning the water and making it safe to drink is much more familiar issue for countries in the developing world, where in some regions this is a standard procedure that is performed daily.

Boiling water is an effective way to kill the microbes and other disease causing micro-organisms in it. WHO recommends that the water should be brought to a vigorous boil. This will kill or inactivate, most organisms causing diarrhea and other intestinal disease. High turbidity does not affect disinfection by boiling.

Boiling removes the temporary hardness of water by expelling carbon dioxide and precipitating the insoluble calcium carbonate. It is an expensive method to softening water on a large scale but suitable for domestic use. Boiling cannot remove chemical toxins or impurities. Boiling water is used as a method of making it potable by killing microbes that may be present in water. The sensitivity of different microorganism to heat varies, but if water is held at 70 °C (158 °F) for ten minutes, many organisms are killed, but some are more resistant to heat and require one minute at the boiling point of water. *Clostridium* spores can survive this treatment, but as the infection caused by this microbe is not water born, this is not a problem [25].

Boiling water is used as a method of disinfecting water, bringing it to its boiling point at 100 °C (212 °F). It is the oldest and most effective method since it does not affect the taste, it is effective despite contaminants or particles present in it and is a single step process which eliminates most microbes responsible for causing intestine related diseases [25].

The elimination of micro-organisms by boiling follows first-order kinetics- at high temperature it is achieved in less time and at lower temperature, in more time. The heat sensitivity of micro-organisms varies at 70°C (158°F). *Giardia* species (causing *Giardiasis*) can take ten minutes for complete inactivation, most intestine affecting microbes and *E coli* (causing *Gastroenteritis*) take less than one minute at boiling point. *Vibrios cholerae* take ten seconds and hepatitis A virus one minute. Boiling does not ensure the elimination of micro-organisms, the bacterial spore *clostridium* can survive at 100 °C (212 °F) but are not water born or intestine affecting. Thus for human health complete sterilization of water is not required [25].

The traditional advice of boiling water for ten minutes is mainly for additional safety, since microbes start getting eliminated at temperatures greater than 60 °C (140 °F) and bringing to its boiling point is also a useful indication that can be seen without the help of thermometer, and by this time, the water is disinfected. Though the boiling point

decreases with increasing altitude, it is not enough to affect the disinfecting process [25].

**Straining / Filtration:** [2, 18, 20, 21, 26] Straining / filtration means pouring any liquid containing solid matter through a filter, sieve or any other porous barrier which can hold back the solid and dense constituents of the liquid

The history of straining or filtration can be traced to the earliest civilization with written records. Water filter have been used throughout the history to improve the quality of water intended to be used for drinking and other domestic uses.

*Hippocrates* was the first person who conducted his own experiments in regards water purification. He believed that pure and clean water is necessary for life as well as for maintenance of health. He designed a crude water filter to purify the water which he used for his patients known as “*Hippocratic sleeve*” [2]. This filter was a cloth bag through which water could be poured after boiling.

Straining is the very simple method of filtration. In this method raw water is poured through a sieve, cloth or any other porous barrier, which removes the suspended particles, solid admixtures and some extent disease causing some pathogens also. After straining only, the water may not be perfectly safe for drinking, but it can be a drinking water improvement step for those people having no other treatment options. It is very effective and safe, if followed by boiling.

In this method any porous barrier can be used as filter, for example cotton, silk or any other cloth or any other material e.g. clay, sand, gravel or plants and herbs etc. Various materials through which water can be filtered are as following:

**Filtration through Winnowing Sieve:** [2] This type of filtration is used when the water source is polluted by wind-borne impurities such as dry leaves, stalks, and coarse particles. The raw water is passed through a winnowing sieve, and the impurities are filtered. This method cannot be used when the raw water is highly turbid or muddy, since the sieve cannot filter fine suspended particles in raw water.

**Filtration through Cloth:** [2, 4] Straining water through cloth is a very simple, economical, easy and widely used for house hold water treatment, in many cultures and civilizations for centuries. *Hippocrates* advised cotton cloth while *Abu'l Hasan Ahmad ibn Muhammad Tabari* recommended silk cloth for the filtration. Thin white cotton cloth or a discarded garment is used as the filter medium. This filter can filter raw water containing such impurities as plant debris, insects, dust particles or coarse mud particles. Filtration of suspended particles present in water can be achieved only to a very small extent. Therefore, this type of filtration is not suitable for highly turbid water. It is most suitable for filtration of well water. This practice of cloth filtration is quite common in rural areas, where the proper supply of potable water is not available. If the raw water is muddy and highly odorous, then various herbs are mixed with water and then filtered through cloth. It is very important to use a clean or sterilized cloth, as a dirty cloth may introduce additional impurities in to the water. The efficacy of straining depends upon the quality and weave of the cloth and the number of times; it has been folded, as well as number of straining. Cloth filters do not remove the

chemical contaminants or dissolved compounds from water. Therefore after straining, additional treatment methods can further improve the quality of drinking water.

**Filtration through Pure Soil:** [19, 26] *Rāzī* advised to add pure soil in bad water and filter it, the water will be cle

**Filtration through Clay Vessels** [18]: Clay vessels with a suitable pore size are sometimes used to filter highly turbid water. Turbid water is collected in a big clay jar and allowed to settle down. Then the water in the jar will trickle through the porous clay wall of the jar. This trickled water is collected in a vessel (usually a clay pot) by placing it at the bottom of the porous clay jar. This method of water treatment was common in Arabic period. In this method exactly like storage method, two pot methods or three pot methods are used.

**Filtration through Plants and Woods** [19, 27]: Highly turbid water with fine suspended and colloidal particles, are first coalesced and settled out using the leaves or roots of various plants, which are then, filtered using cloth filters. Raw water is poured into a vessel, and then the water is allowed to filter thorough this layer of leaves or roots. The water then trickles through the tiny holes at the bottom of next vessel. The filtered water is collected at the bottom of the vessel. Usually this filtered water is very clear and has a pleasant smell. *Abū Sahl Masīhī* recommended for this purpose grinded bitter almond, resins and soya and wood of *Sākhū* etc. If water is salty, *Rāzī* recommended adding vinegar and some herbs e.g. *Z'rūr* (thornapple/whitethorn), *Habbul Ās* (myratus), *Kharnūb* (*Ceratonia siliqua*) or pure soil then filter it.

**Filtration through Sand or Clay or Stones:** [22, 26, 27, 28] In this type of water filtration method, sand, pure soil or stones are used as the medium, through which raw water is passed very slowly, by which dissolved particles in water and other contaminants are filtered. Actually this ancient UNANI method is the base of modern slow sand and rapid sand filtration techniques.

*Masīhī* recommended coarse gravel, stony earth, new bricks, Armenian bole (*Gile Armani*) etc, while *Rāzī* advised with the reference of *Hunayn ibn Ishāque* filtration through stony earth.

**Filtration through Bread or Bakery items:** [19] *Muhammad ibn Zakariyya Rāzī* advised in his book “*Kitāb al Manşūrī*” that if the water will be dense and turbid could not be purified by vessels method, then homemade bread or bakery bread thoroughly soaked and mixed in water and then filter it, the water will be cleaned.

**Filtration through Alum:** [19, 26] *Rāzī* recommended that alum is dissolved in water and then filter it. By this method water will be cleaned rapidly.

**Filtration through Reservoirs:** [26, 28] *Rāzī* says that in any emergency condition when the clean water is not available. Three artificial reservoirs are dugged parallel and deeper gradual. Then fill the all three reservoirs with pure soil and contaminated water should be passed slowly through these reservoirs. Doing so all the impurities of water dissolved in soil and in the last reservoir the clean water will be collected.

**Storage / Sedimentation:** [4, 17, 18, 19, 23] FEMA (Federal Emergency Management Agency) and The Red Cross recommend that you store a minimum of one gallon (4.55 L) of water for per person per day, which will only cover your most basic needs: drinking, some cooking, and minimal hygiene (think sponge bath). For anything beyond that, you'll need to store additional water. Store as much water as possible; aim for two weeks of stored water. Start small-enough for just one day-then build up to three days, one week etc. [29]

Storage is very early and easy method of water purification, when the microbial and chemical contamination of water was unknown. Only physical admixtures e.g. mud, sand, plants, stones and wooden admixtures can be seen by naked eyes. To remove these admixtures and contaminants of water people store water and left it to settle down, by which the contaminants were settled down and water becomes pure and clear [4, 17, 18, 19, 23].

The microbial quality of water sometimes can be improved by holding or storing it without mixing long enough, for larger particles to settle by gravity. Storing water for few hours will allow settling of large, dense particles such as inorganic sands and silts, large microbes and any other microbes associated with larger, denser particles. However extended settling times for 1-2 hours or more will be required for comparatively large size microorganism. Therefore, microbial reduction by plain sedimentation or gravity settling is often low and inconsistent. Overall reduction of viruses and bacteria by sedimentation rarely exceed 90% but reduction of helminthes ova and some protozoa can exceed 90% especially with larger storage times of 1-2 days. The settled water then can be carefully removed without disturbing the settled particles [30].

Sedimentation of household water can be done in simple storage vessel, such as pots and buckets etc. Care must be taken to avoid disturbing the sediment particles when recovering the supernatant water by decanting or other methods. Typically, at least two containers are needed to settle water: one to act as the settling vessel and another to be the recipient of the supernatant water after the settling period. Water also can be settled in larger bulk storage system such as cisterns, basins and tanks etc. Regard less of the sedimentation vessel, it is essential that solids are removed and vessel cleaned on a regular basis. Hence plain sedimentation or gravity settling of highly turbid water for household use is recommended as a pretreatment for systems that disinfect water with solar radiation, chlorine or other chemical disinfectants. Furthermore sedimentation of particles improves the aesthetic qualities of the water and thereby increases its acceptance. Pre-treatment of turbid household water by sedimentation is recommended because is easy to perform and requires a minimum of materials and skill [30].

*Avicenna* says explaining storage "If one should pour bad water every day from one vessel to another, one should see as much deposit on the last day as on the first. There is so little deposit during a day that it never clarifies properly. The reason is that the admixed earthy particles easily separate out from rarefied matter, for that is free of heaviness, viscosity or oiliness, but not so easily from dense matter. Boiling increases the rarefaction and so do the shaking-movements incident to ebullition" [4, 17, 18, 19, 23]. Storage provides a reserve of water from which further pollution is excluded and this natural purification process

has following benefits

- **Physical:** By mere storage the quality of water improves. About 90% of suspended impurities settle down in 24 hours by gravity. The water becomes clear and allows penetration of light and reduces the work of filtration [5].
- **Chemical:** Certain chemical changes also take place during storage. The aerobic bacteria oxidize the organic matter present in the water with the aid of dissolved oxygen. As a result the content of ammonia is reduced and a rise in nitrates occurs [5].
- **Biological:** A tremendous drop takes place in bacterial count during storage. The pathogenic organisms gradually die out. It is found that when river water is stored, the total bacterial count drops by as much as 90% in the first 5-7 days. This is one of the greatest benefits of storage [5].

The optimum period of storage of river water is considered to be about 10-14 days. If the water is stored for long periods, there will be development of vegetable growth such as algae which imparts a bad smell and colour to water [5].

According to *Abu'l Hasan Ahmad ibn Muhammad Tabari* any stored water must be discarded after 144 hours (6 days) and replaced by fresh water, because the fresh water is more tasty and suitable to the human body. *Tabari* also described the two pot method of storage in which suspended impurities and contaminants of water e.g. mud, sand, dust etc, are settled down and water become clear [4].

For Sedimentation, there are two methods as following:

**Two Pot Method:** [4] Fresh water should be taken in a clean pot or container and let it to settle down. When the maximum suspended impurities of this water are settled down, the supernatant clear water should be poured in the next clean pot or container and use it for drinking after cooling it by air.

The second method is that two pots or containers are kept one upon another; the raw water is filled in upper pot which bottom is porous and the next pot is kept just below the water filled pot. The cleaned water will poured in the next pot drop by drop and all suspended impurities will stop in first pot and clear water will be collected in the next pot.

**Three Pots Method:** [31] The three pots method is also like two pot method but more effective than two pot method. In this method, three pots or containers are used and every day the water is transferred from one to next container after settling down the water.

Each day when new water is brought to the house, do the following:

- A. Keep the drinking water in pot 3.
- B. Slowly pour water stored in pot 2 into pot 3.
- C. Wash out pot 2.
- D. Slowly pour water stored in pot 1 into pot 2.
- E. Wash out pot 1.
- F. Pour water collected from the source (bucket) into pot 1. Strain through a cloth if possible.

Allow the water to settle for a day and then repeat the process.

Only drink water from Pot 3. This water has been stored for at least 2 days, and the quality has improved. Periodically this pot should be washed out and may be sterilized by boiling water.

Using a flexible tube to siphon water from one pot to another disturbs the water less than pouring. This method can be improved by using a straining cloth when pouring into the pots. The three pots method is a good that can be adopted in an emergency until mass distribution of other methods is possible or the quality of the source is improved. In an emergency, people may not have three containers. Although it is likely to be less effective than the method described above, two containers can be utilized instead of three. More time should allow dirt to settle and germs, that cause disease, to die.

**Sunlight Exposure:** [18, 21, 28] This is very early and natural method of water purification. According to *Hippocrates* and all Unani philosophers, that the water upon which sunlight passes continuously is best, clear, fragrant and light. Exposing water to sunlight will destroy most germs that cause disease. This is even more effective at higher temperature (although the temperature of the water does not need to raise much above 50°C).

One easy method of treating the water is to expose plastic or glass bottles of water to the sun. In tropical regions, a safe exposure period is about five hours, centred on midday.

The amount of time the bottle is exposed to the sun will need to be doubled (two days instead of one) when the weather is cloudy. The exposure time also should be increased, if there is not sunny weather (rainy season). For greater efficacy, place the bottle on a corrugated-iron roof. The water also can be hold in a clean and clear plastic bag if a bottle is not available.

**Distillation/Sublimation:** [17, 18, 19, 23, 26, 27] The word Distill comes from Latin verb “Distillare” meaning to drop down.<sup>32</sup> Distillation involves boiling the water and then condensing the steam into a clean container.

Distillation is the technique of heating a liquid to create vapour which is collected when cooled separate from the original liquid [32].

**Examples:** Pure water can be separated from salt water through distillation. Salt water is boiled to create water steam, but the salt remains in the solution. The steam is collected and allowed to cool back into salt-free water.

**Sublimation:** The word “sublimate” comes from Latin verb “sublimare” which means “to lift up” or “raise” and which is also the ancestor of our sublime. “Sublimate” itself once meant “to elevate to a place of dignity or honor” or “to give a more elevated character to”, but these meanings are now obsolete [32].

To sublimate is to change the form, but not the essence. Physically speaking, it means to transform solid to vapour; psychologically, it means changing the outlet, or means, of expression from something base and inappropriate to something more positive or acceptable [32].

The earliest recorded wine distilling is traced by some scholar to Anaxilous of Thessaly, who was expelled from Rome in 28 BC for practicing magic. Philosopher-chemist in Alexandria, Egypt practiced distilling from around the second century. They employed three or four different still types by the 1<sup>st</sup> century AD, including one with bronze outlet tubes, invented by Maria the Jews, a leading figure among their cohort [33].

Distilling itself is based on the concept that the different

substances turn to vapour at different temperature. This was known to Greeks for centuries before the sophisticated stills of the Egyptians philosopher-chemists. For example, ancient Greek sailors evaporated drinkable water from sea water. They also learned that if wine was boiled in an open container, the fiery alcohol vapour escaped first. How to capture this elusive substance? The Greek learned that if wine was heated slowly in a vessel with a small mouth covered by a bowl, alcohol would collect as condensed vapour inside the bowl, much as a pot lid collects droplets of condensed steam. The addition of a downward-slanted tube to the apparatus facilitated the cooling and condensation of the vapour and its collection in a handy receiving vessel [33].

An Arabic philosopher and chemist Jābir ibn Ḥayyān or Geber (721-815 AD) was a prominent polymath; al-chemist, astronomer, astrologer, engineer, geographer, philosopher, physicist, pharmacist and physician, born and educated in Tus, later traveled to Kūfa. He is referred to as the “Father of early chemistry” [14, 15]. He invented another “Distillation Apparatus” which is known as Qar‘Ambīque (Alembic Still) [14, 15].

The still was developed in 800 AD by the Arab alchemist Jābir ibn Ḥayyān. The word ‘alembic’ is derived from the metaphoric meaning of ‘that which refines; which transmutes’, through distillation [34].

The first documented scientific studies on distillation date back to the Middle Ages, to around the year 800 and the alchemist *Jābir ibn Ḥayyān* (Geber). It was he, too, who invented the alembic, which has been used ever since to distil alcoholic drinks [34].

Alchemy has its origins in Greece, and around the year 300 BC it is referred to in Egyptian and Babylonian records. In antiquity it seems to have been at its height in Alexandria in between 200-300 AD. We have documentary evidence that the work of these alchemists came to the Arabs and the apparatus they used for distilling was described by Marco Graco in the 8<sup>th</sup> century. This may be regarded as the first historic document on the distillation of wine, though it does not say anything about the characteristics of the distillation product. The middle of the 9<sup>th</sup> century, the beginnings of the development of Arab alchemy, under the influence of the Alexandrian school, in this period the Arabs compiled all the chemical knowledge so far available in a volume entitled the Book of Crates. But it was Geber’s work, published in 850 and translated into Latin as *De Summa Perfectionis*, which led Europe to the thinking and methods of chemistry [34].

The use of the distillation process made it possible to produce remedies, for both the official pharmacopoeia and household use.

**Coagulation/Flocculation:** [19, 24, 27] Coagulation and Flocculation are used to separate the suspended solid parts of water. Suspended particles may vary in source, charge, size, shape and density.

Flocculation means, when microscopic particles bind together to form larger particles in a liquids. It occurs naturally or artificially in water as well as in other solutions. The coagulation process involves adding salts, such as alum, ferric sulphate, ferric chloride or poly electrolytes to water. These chemicals are called coagulants and have a positive charge. The positive charge of the coagulant neutralizes the negative charge of dissolved and suspended particles in the

water. When this reaction occurs, the particles bind together or coagulate (sometimes this process is called flocculation). The large particles or flocs are heavy and quickly settle to the bottom. This settling process is called clarification or sedimentation<sup>[30]</sup>.

In water treatment facility, the coagulant is added to the water and it is rapidly mixed, so that the coagulant is circulated throughout the water. The coagulated water is moved to settling tank. In a settling tank or clarifier, the heavy particles settle to bottom and are removed and the water moves on to the filtration step of the treatment process<sup>[30]</sup>. Coagulation can successfully remove a large amount of organic compounds, including some dissolved organic material, which is referred to as Natural Organic Matter (NOM) or Dissolved Organic Carbon (DOC). Coagulation can also remove suspended particles, including inorganic precipitates such as iron hydroxides. A large amount of DOC can give water an unpleasant taste and odor, as well as a brown discoloration. While coagulation can remove particles and some dissolved matter, the water may still contain pathogens. Coagulation and Sedimentation can only remove between 27% and 84% of viruses and between 32 and 87 percent of bacteria. Usually, the pathogens that are removed as they get attached to the dissolved substances that are removed by coagulation<sup>[30]</sup>.

As coagulation does not remove all of the viruses and bacteria in the water, it cannot produce safe drinking water, It is however, an important primary step in water treatment process, because coagulation removes many of suspended particles, and colloidal and dissolved organic carbon, that make water difficult to disinfect. Because coagulation removes some of the dissolved substances, less chlorine will be required to disinfect the water. A water treatment plant can save money by using less chlorine, and the water will be safer, because Trihalomethanes (THMs) are harmful by-product that results from the reaction of chlorine with NOM.<sup>30</sup> With accurate dosage and proper application, the residuals of the added chemicals do not pose a problem. Residuals are the by-products that remain in water after substances are added and reactions occur while treating water. The particular residuals depend on the coagulant that is used. If ferric sulphate is used, iron and sulphate are added to the water. If ferric chloride is used, iron and chloride are added. If aluminium sulphate is used, aluminium and sulphate are added. The majority of water treatment plants use aluminium sulphate as the coagulation chemical. Generally, water treatment facilities have the coagulation process set up so that the coagulant chemicals are removed with the floc<sup>[30]</sup>.

**Vessels Method:**<sup>[18, 19, 22, 35]</sup> This is also a simple method of water treatment resembling storage and filtration method in which two or three clay pots or containers are used. First pot is filled with water and kept some above height from the next and a wick of cotton or wool is inserted in the first water filled pot while the other end of wick is kept in second empty pot. The water slowly drops from the first pot into the next empty pot slowly and thus becomes pure. According to *Avicenna*, this method is better than distillation and sublimation, especially when it is repeated again and again<sup>[22]</sup>.

*Avicenna* says “If one should pour bad water every day from one vessel to another, one should see as much deposit on the last day as on the first. There is so little deposit during a day that it never clarifies properly. The reason is that the admixed earthy particles easily separate out from rarefied matter, for that is free of heaviness, viscosity or oiliness, but not so easily from dense matter. Boiling increases the rarefaction and so do the shaking-movements incident to ebullition”<sup>[22]</sup>.

Another method is that the first water filled pot is kept above and the second empty pot kept just below the first. The bottom of the first pot is porous or open and covered with any porous barrier. Thus the raw water slowly comes down from the pores of first pot into the below empty pot slowly.

At least two containers are needed to settle water: one to act as the settling vessel and another to be the recipient of the supernatant water after the settling period. Regard less of the sedimentation vessel, it is essential that solids are removed and vessel cleaned on a regular basis.

The process of water purification in this method is same as in storage and sedimentation system and the techniques are also same. The same *two pot* method and *three pot* methods are used in vessels method as discussed in storage and sedimentation method.

**Churning:**<sup>[17, 21, 26, 35]</sup> Meaning of Churning is the moving of water around violently<sup>[36]</sup>.

In churning method, water is taken in any container and agitated violently either manually with a stirrer or by a machine and left it to settle down. After sometime all the impurities will be settled down and water will be clear and sweet.

## Results and Discussion

### Water purification methods

S No.	Methods	Access	Cost	Effects		
				Physical	Chemical	Biological
1	Boiling	Easy but slow/ time taking	Economical	No effect	Most effective	Kills all pathogens
2	Filtration/ Straining	Easy and fast	No cast	Most effective with boiling	No effect	Most effective with boiling
3	Storage/ Sedimentation	Easy but slow/ time taking	No cast	Most effective	No effect	Kills most pathogens in 5-7 days
4	Sunlight Exposure	Easy but slow/ time taking	No cast	Most effective	No effect	Effective as Boiling
5	Distillation/ Sublimation	Rapid and fast but not easy	Costly and technical skill required	Most effective	Most effective	Most effective
6	Coagulation/ Flocculation	Easy but time taking	Low cost	Most effective	Removes pesticides and heavy metals	Reduces virus, bacteria and protozoa
7	Vessels Method	Easy but time taking	Low cast	Effective	No effect	No effect
8	Churning	Easy but time taking	Low cost	Effective	No effect	No effect

All methods of water purification described in classical literature of Unani system of Medicine tested by renowned Unani physicians are found effective till date and some of these methods are used today in various parts of the world especially in those areas where potable drinking water is not available. Some methods are most effective, economical and easy to access e.g. boiling and filtration while some are effective but for their use man power and technical skill is required e.g. distillation. Some methods are less effective but most economical without any technical skill and equipment requirement e.g. simple filtration and vessels methods. In spite this, these methods are used in various slum areas and poor population.

In all these methods boiling, filtration and distillation methods are most popular and effective methods till date. These old techniques paved the modern techniques of water treatment e.g. modern techniques of slow sand filtration and rapid sand filtration techniques are based on the idea of old filtration method, while distilled water and bottling technique is based on the old distillation method. Modern science developed these methods using on large scale while old methods are limited to small and domestic use. For poor countries and populations old methods are more beneficial, easy, economical according their economy and resources.

There is no doubt that these old methods are more effective and more economical than modern techniques for domestic use therefore these methods should be adopted for the benefit of health as well as to save money and time. These methods can be modified to make them most effective and accessible to the all population.

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