EVOLUTION OF DISTILLATION FROM ANCIENT ERA TO MODERN ERA

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The history of distillation has often been traced back to the Greeks and later to the Arabs for its origin according to the traditional belief. History of distillation is linked to the development of scientific and alchemical knowledge, playing a vital role in modern chemistry. The objective of this article is to re-examine the early history, origin of distillation by studying the various forms of stills in different regions across the world, including India, to study the influence of various alchemists on the advancement of distillation techniques, review the textual evidence, explore the evolution of distillation from ancient era to the modern era by focusing on its applications for the production of alcohol, extracting essential oils and others, based on historical records.

Keywords: Distillation, Alcohol, Mixtures, Fermentation, Flask, Sublimation

Introduction

Distillation is derived from the Latin word 'de-stillare', meaning 'drip down' or 'trickle down'. It is a widely used technique of physical separation of the components of a liquid mixture. This separation is realised by a way of heating the mixture to selective boiling of the volatile compounds followed by condensation of the vapours of the pure components using an apparatus called still (Kockmann, 2014). Distillation was not known in the ancient past of human civilisation in the same sense as we know it in present times. It must also be noted that the study of distillation is inseparably connected with the history of alcohol. Alcohol was known as the first product of scientific distillation used as medicine or a stimulant (Liebmann, 1956). It must also be noted that in the text of ancient times, the processes of sublimation and distillation are not much differentiated from one another. The range of purification and separation methods involved in distillation in the past were wider, including filtration, crystallisation, extraction, sublimation and mechanical pressing of oils (Kockmann, 2014). Early philosophers and scientists had made several observations but they did not fully understand or comprehend them. A few of them are addressed in this review article. It is conceivable that distinct cultures independently discovered distillation, given how simple the process is. Historians suggest that ancient seafarers in the eastern seas used it to obtain fresh water from seawater for drinking. Similarly, people in Asia have long used distillation to extract perfumes and essences from plants. Additionally, the practice of distilling fermented liquids has been present in various parts of the world since ancient times (Fairley, 1907).

Origin of Distillation Across Different Regions

The Greeks and Romans

The basic principle of distillation was known to early Greek scholars. Aristotle (384–322 BCE), in his book *Meterologica*, reported that boiling seawater in a vessel having large sponges covering its mouth to absorb what is evaporated and then squeezing the liquid from these sponges gave sweet water. Aristotle also attempted to describe the water cycle in nature as some sort of distillation by writing that the earth dried up when heated by sun's rays with the moisture rising up into the air in *Meterologica* (Aristotle, n.d.) The moisture in this air falls down as rain upon cooling (Koenig, 1950; Liebmann, 1956).

More than three hundred years later, the writings of the great Roman scholar, Pling the Elder, used the word 'destillare'or 'distillare' meaning 'to drop' or 'drip off'. His book, *Natural History* also describes the separation of mercury from mineral cinnabaris by the process of sublimation (Liebmann, 1956).

Again 300 years later, the Alexandrian alchemists, such as Zosimus of Panopolis, made significant advancements in alchemical processes, described some apparatus used for distillation (Schlosser, 2011). Although his writings do not explicitly mention alcohol distillation, they provide early evidence of experimental techniques involving heating and condensation (Liebmann, 1956). Encyclopedia by Zosimus also describes the work of two female alchemists, Cleopatra and Mary the Jewess, who wrote treatise on gold making and mercury, respectively. They described one of the earliest distilling apparatuses. Cleopatra, a Greek alchemist, is credited with one of the earliest known distillation apparatuses, consisting of a circular vessel and a vertical tube leading into an alembic (Liebmann, 1956). Mary the Jewess described a double-walled heating vessel, which evolved into the modern water bath. These devices indicate a sophisticated understanding of distillation principles, although their primary use was not for alcohol. The present-day water bath is also known as 'Bain Marie', after its original creator (Fairley, 1907). It is clear that, this group of alchemists had knowledge of distillation techniques, though their methods did not distinctly separate sublimation from true distillation. These early distillation devices, primarily made of materials such as clay and metal, were used for producing perfumes, essential oils and medicinal extracts (Kockmann, 2014).

The Egyptians

Distillation, or rather sublimation, of mercury was known to ancient Egyptians at least one or two thousand years before Zosimus. The mercury thus, isolated from cinnabar was mixed with pigments in paints that adorned the funeral chambers of the rulers (Liebmann, 1956). Kohl (or *kajal*) from Arabic *Kuhl*, the black mascara powder, has been present from 3500–1100 BCE obtained by sublimation from mineral stibnite was worn by the ancient Egyptians for protection against eye ailments (Kreston, 2012).

Mesopotamia

Earliest evidence of primitive form of distillation describing perfumery operations have been found in Akkadian on clay tablets (dated 1200 BCE) in Mesopotamia (Levey, 1959). The first female perfumer in Mesopotamia 'Tapputi', used flowers and oil mixed with water before distilling and filtering

it multiple times. This method was used to extract essential oils and fragrances from herbs, as well as to produce alcohol from fermented substances (Kass-Simon, Farnes and Nash, 1993).

Persia

Many scholars believe that the roots of modern distillation technology began with the work of Persian alchemist, Abu Musa Jabir ibn Hayyan, born in 721 AD in modern-day Iran, he did extensive research on acids and alkalis (School of Physical and Chemical Sciences, Queen Mary University of London, n.d.). His name 'Jabir' was latinised to 'Geber' being ahead of his times, many European alchemists couldn't decipher his work and came up with the word 'gibberish'. His most important achievement was the alembic still (Fig. 1) made of glass or pottery.

An alembic is a container that is filled with a liquid and put over a heat source. It is connected by a tube to another vessel that allows vapours from heated substance to pass through, condense along, while flowing and drip into another container. The condensed substance became known as 'spirit'. Wine produces alcohol first because its boiling point is lower than that of water. So, alcohol is referred to as a 'spirit' (Al-Hassani, n.d.).

A century later, another Alchemist of Persia named, Zakariya al-Razi, isolated ethanol and formed wine using distillation, and named the product al'koh'l, which later became alcohol (Schlosser, 2011). (The word 'kohl' was then used for anything that had been sublimated or distilled). He reported his work in *The Secret* and may be regarded as the first true distiller (Anne Embank, 2018).

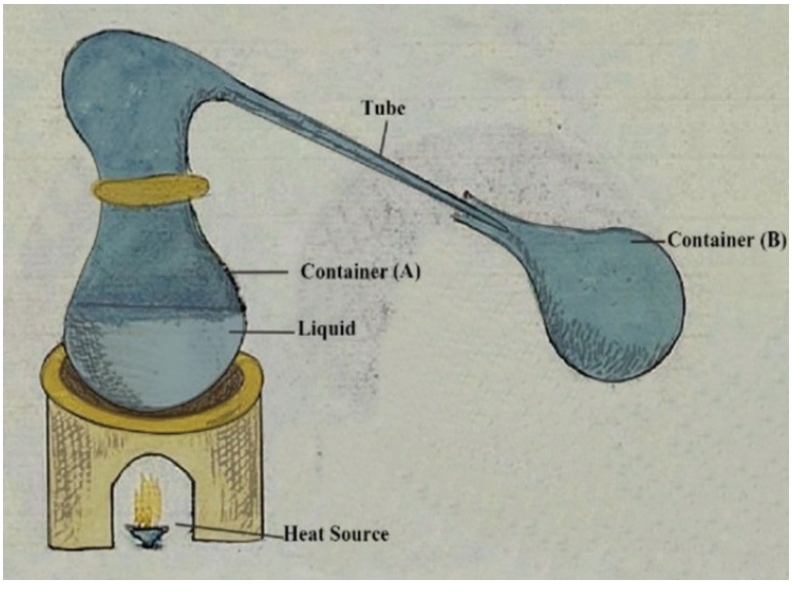

Fig. 1. Alembic still (Redrawn from Al-Hassani, S. T., *1001 Inventions: The Enduring Legacy of Muslim Civilisation*, Third edition, page no. 93)

Distillation in Ancient India

Though much textual evidence is not available but evidence derived from primitive people and archaeology sites in north-west India around 1835, suggests that distillation was known to South Asia much earlier. Indian local cottage industries had already been distilling spirits using traditional methods. These methods involved simple apparatuses like simple pot or still and perforated pot still (Allchin, 1979). Additionally, early references to distillation in medical text are found in the *Bhaisajya Ratnavali* by Govinda Dasa (seventeenth century), which describes a medicinal spirit called *Mritasanjivani* (resurrection) *Sura* intended to revive the dead (O'Gorman, 1899; Allchin, 1979). Apparatus resembling the first type of still is described in the 12th century text, *Rasa ratna samuccaya* of 'vagbhata' under the name of Tiryak-Patana Yantra or the 'oblique falling' apparatus, a kind of patana yantra (Fig. 2), used for purification of mercury and for chemical purposes (Allchin, 1979). The paste of material is applied in big earthen pots and a hole is made at the neck of this pot to insert a tube in this hole and connect with the hole of other pot, which is kept at lower level in the transverse state. Lower pot is filled with water for condensing. The mouth of both the pots was sealed by earthen saucer. That large pot was heated, and due to which mercury, evaporated and collected through the tube in a small pot (Google Arts and Culture, n.d.).

Vedas

In ancient India, during the Vedic period, *Rig Vedas* (around 1200 BCE), alcoholic beverages, such as *sura* (an intoxicating drink) and *soma* (a stimulant) were noted for the use. Typically, *sura* was a ferment prepared from rice or barley (Allchin, 1979).

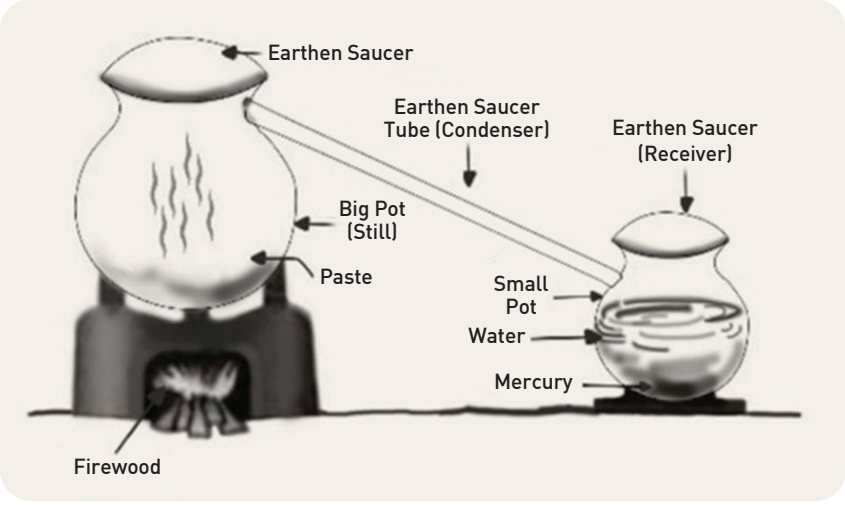

Fig. 2. Tiryak Patana Yantra
(Redrawn from https://artsandculture.google.com/asset/tiryakpatan-yantra-diagramme/_AHc0qjiEeaFwQ)

During the Arthashastra (around third century BCE), several recipes for fermented drinks were documented, including those made from rice, sugarcane juice, grapes and spices. Early medicinal texts from the early centuries also include discussions on intoxicants and their use in treatment, providing numerous recipes for various fermented drinks (O'Gorman, 1899; McHugh, 2021). These evidences showed that fermentation was well-established in early India but not distillation until the 12th century. The introduction of distillation is generally associated with the influence of Muslim invasions, marking a significant development in Indian beverage production. Thus, fermentation was common in ancient India but distillation appears to have been introduced much later. There is some reflection about this because, while historical texts don't mention distillation, some modern observations suggest that it might have been practiced earlier in certain regions (Allchin, 1979).

Taxila

During excavation at Taxila, a group of vessels found were reconstructed as apparatus for condensing water as part of a distillation apparatus in ancient India around the first century BCE or A.D. (Marshall, 1951). The apparatus includes an iron tripod and terracotta vessels—a globular pot, covered by an inverted bowl with a spout on one side and joined to a unique pot shape receiver through terracotta tube, completely closed except for a short wide spout on the domed top (Fig. 3).

Charsada

In Charsada excavations at Shaikhan Dheri (a city founded by Indo-Greeks after 200 BCE and occupied till 4th–5th century A.D. having the ancient name Pushkalavati, capital of Gandhara region) (Dani, 1966), a large number of receivers were found along with shallow drinking bowls and globular pots with sooty exteriors, which could have been a part of the distilling apparatus. This

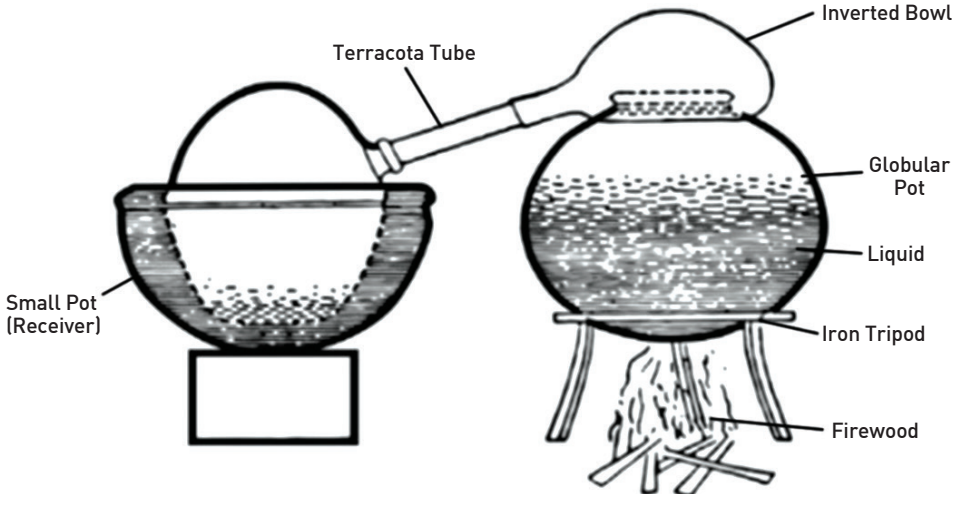

Fig. 3. Still for distillation (Redrawn from Allchin, F.R. (1979) *India: The Ancient Home of Distillation*)

apparatus is called as the Gandharan still (Allchin, 1979).

A couple of words, originating from 500 BCE derived from Sanskrit word '*sunda*' (elephant's trunk) are connected with production and addiction to strong drinks. These *Sunda–Saundika* (elephant's trunk and beauty) words derives from the elephantine appearance of the still and were in particular associated with the fermenters and distillers of alcohol. Gandharan still's shape helps to identify the 'elephant's trunk' associations with drinking in literature from 500 BCE. The same still can be seen as the direct ancestor of the village stills used in villages of the Indian sub-continent (Allchin, 1979).

With the progression of technology, scientific understanding and industrial need, distillation has evolved remarkably from ancient era to modern era. Ancient distillation apparatuses were basic and made up of clay and metal pots on a small scale for extracting perfumes and essential oils (Kockmann, 2014). Nowadays, modern distillation like vacuum, fractional, membrane, solar distillation has become highly developed for large scale to meet the demand of various industries, including pharmaceuticals, alcohol production, petrochemicals, food and beverages, and in biotechnology. Ancient distillation was inefficient, consumed plenty of heat and mostly relied on manual labour whereas modern distillation is highly efficient, accurate and reduces energy consumption (Saidur et al., 2011).

Distillation in Modern Era

Distillation Apparatus and Process

Modern distillation apparatus consists of a distillation flask, primary vessel that holds the liquid mixtures. It is heated so that, its mixture is vapourised by boiling. Two miscible liquids are separated by a simple distillation method having a minimum difference of 25 K in their boiling points and this difference is because of the interaction between the particles. The liquid that has lower boiling point evaporates before and more quickly than the liquid which has a higher boiling point. As the mixture heats up, more volatile compound gets converted into vapours and are passing into the condenser. A condenser is present at the top of this flask that cools and condenses the vapours back into liquid form as cold water is flowing in its outer section. This condensed liquid having more volatile components, distillate, then flows into a receiving flask. For accurate measurement of vapour temperature and for error free distillation process, a thermometer is positioned just below, where the condenser joins to the flask, required for determining the temperature when different components of the mixture are separating (Fig. 4) (Stichlmair, Klein and Rehfeldt, 2021).

Applications

Distillation is a versatile technique, widely used in numerous fields for its efficiency in concentrating, purifying and separating various substances like chemicals. Some types of modern distillation techniques are mentioned below:

- **Simple traditional distillation:** It is the oldest and most appropriate method of water treatment, that is used for domestic purposes and in chemical laboratories. It can remove contaminants like organic and inorganic compounds from drinking water. But this is the most expensive

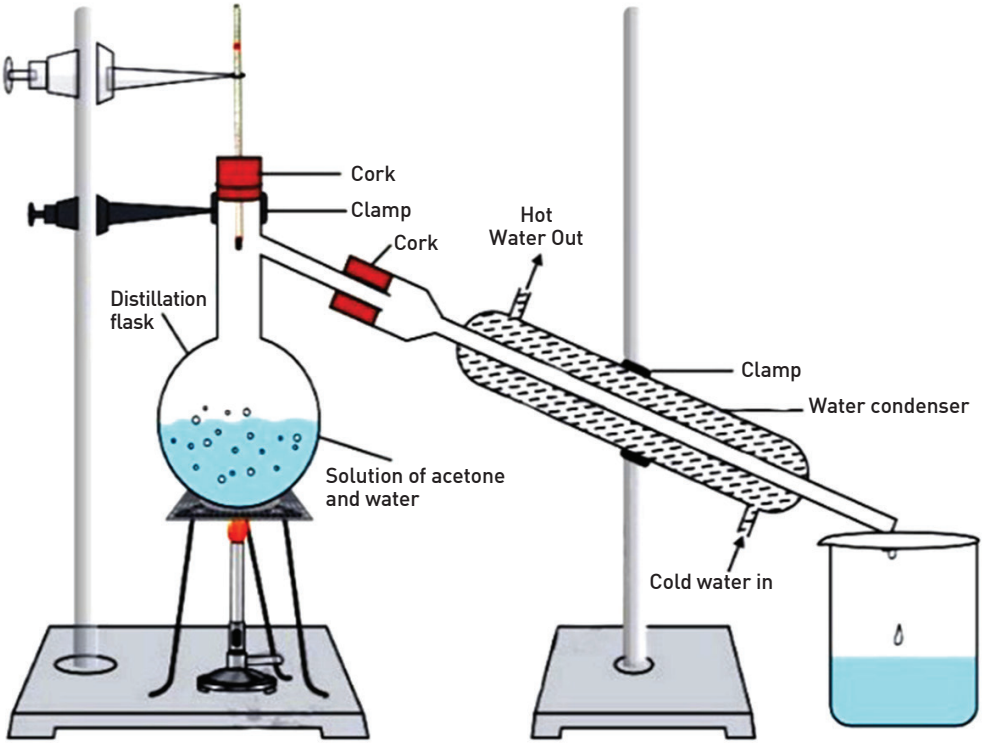

Fig. 4. Laboratory apparatus for simple distillation
(From NCERT (2014) Science Laboratory Manuals Class 9, Page no. 61)

type in terms of energy consumption (Saha and Bhattacharjee, 2019).

- **Multiple-effect and multi-stage flash distillation:** They are the advanced distillation techniques used in modern water treatment plants to get high-quality water from contaminated groundwater and seawater. The aim of this distillation is to utilise the same amount of heat to evaporate more amounts of saline water, increase water distillation plant efficiency and reduce the energy costs (Saidur et al., 2011).
- **Solar distillation:** Solar distillation looks very attractive due to utilising the heat of the sun, since it is a free source of energy and also used for saline water treatment (Saha and Bhattacharjee, 2019).
- **Retro-distiller:** This is a new method that reduces the heat loss than simple traditional distillation method for water desalination and a low-pressure condition to decrease the boiling temperature (Saidur et al., 2011).
- **Fractional distillation:** It is used in petroleum refining (for removal of

heavy aromatic compounds from lubricating oils), oil refineries (for breaking down the crude oil into its components, such as petrol, diesel, aviation fuel and heating oil) and for purifying chemicals and solvents in both lab and industries when boiling points of components are close to each other (Carey, 1935).

- **Steam distillation:** It is used in the extraction of essential oils and in pharmaceutical industries for medicinal spirits and in the food industries (Akdağ and Öztürk, 2019). For extraction of essential oils from plant material, plant materials are placed in a still and through steam generator steam is passed, volatile compounds from steam are condensed and collected through decantation (Fig. 5) (eOil, n.d.).
- **Microwave-assisted water distillation:** It is used as an alternative method of steam distillation for the extraction of essential oils to get more efficiency at lower cost (Akdağ and Öztürk, 2019).
- **Vacuum distillation:** It is used for heat sensitive and high boiling point substances. For the production of spirits and liquors, the alcohol industry uses vacuum distillation, which separates alcohol from fermentation mixtures based on their different boiling points and in petroleum refineries to efficiently separate and purify hydrocarbons from crude oil, such as gasoline, diesel, kerosene and lubricants (Fig. 6) (Saidur et al., 2011).
- **Molecular distillation:** It plays a crucial role in the pharmaceutical industry for medicinal spirits and also in the food industry for producing healthy products by removing excess cholesterol and organic pollutants (Ketenoglu and Tekin, 2015). Laboratories and research institutions use distillation for precise separation and analysis of chemical compounds using gas chromatography and fractional distillation, and in material science. Additionally, distillation is used for production and formulation of drugs (Saha and Bhattacharjee, 2019).

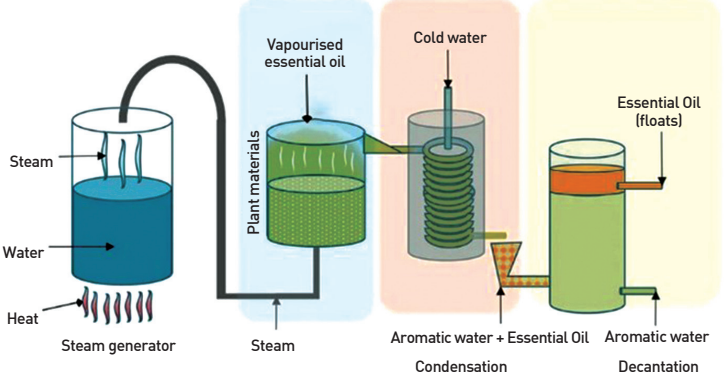

Fig. 5. Steam Distillation to Produce Essential Oil
(Redrawn from https://eoil.co.za/pages/steam-distillation-process-for-essential-oils-and-hydrosols)

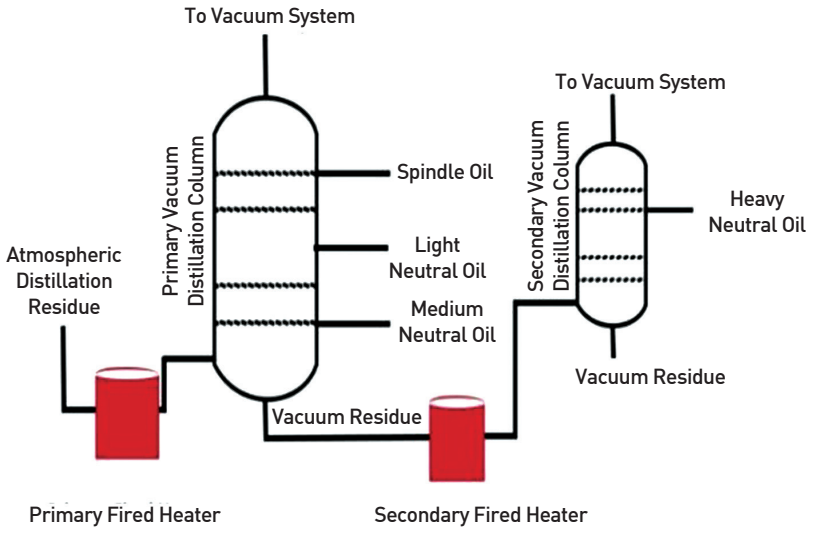

Fig. 6. Vacuum Distillation

Conclusion

Distillation has evolved from its origin into a most advanced technique, with contributions from various cultures, including many alchemists that established the foundational understanding of vapourisation and condensation. All these textual evidences from ancient Indian literature for the early development of distillation, suggests that India may have been a vast culture that made a significant contribution and utilise distillation for alcoholic beverages. Increasing demands for purity, efficiency and technological advancements, unroll and amplify the role of distillation. Overall, distillation remains a backbone of many modern industrial processes and fulfils the current application demands.

This paper is highly relevant for students as it provides a historical perspective on the development of distillation, connecting theoretical knowledge with real-world application. By studying its evolution, students gain a deeper understanding of scientific progress, appreciate the cultural past of our country and to link with present cultural practices, helpful in developing pride and sense of appreciation for India's culture and heritage, and historical significance of distillation. The paper fosters curiosity and inspires inquiry-based learning, helping students to learn science as a dynamic and collaborative process. Additionally, it promotes interdisciplinary learning, enriching students' understanding of chemistry, history and cultural heritage, while motivating them to explore new areas of research and innovation (National Council of Educational Research and Training, 2020).

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