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A REVIEW ON EXTRACTION A KEY TECHNIQUE IN PHARMACEUTICAL ANALYSIS

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ABSTRACT

Extraction is an essential process in pharmaceutical analysis that helps separate useful chemical compounds from plants, drugs, and other complex materials. It allows scientists to isolate, purify, and identify active ingredients that are responsible for the therapeutic effects of medicines. The process works by selecting a suitable solvent that can dissolve the desired compounds without affecting their quality or stability. Traditional extraction methods such as maceration, percolation, Soxhlet extraction, infusion, and decoction have been used for many years due to their simplicity and low cost. However, these methods often require more time and larger amounts of solvent. Modern extraction techniques like Ultrasound-Assisted Extraction (UAE), Microwave-Assisted Extraction (MAE), Supercritical Fluid Extraction (SFE), and Accelerated Solvent Extraction (ASE) provide faster, more efficient, and environmentally friendly alternatives. They help improve extraction yield, reduce processing time, and protect heat-sensitive compounds.

Extraction plays a major role in various pharmaceutical activities including drug discovery, herbal analysis, impurity removal, and sample preparation for analytical instruments like HPLC, GC, and LC-MS. It also ensures that medicines are safe, effective, and of high quality through proper standardization and quality control. Overall, extraction is a vital step in pharmaceutical science because it supports accurate analysis, reliable results, and the development of safe medicinal products.

KEYWORDS: *Extraction , Pharmaceutical Analysis , Maceration , Percolation , Soxhlet , UAE , MAE , SFE Sample Preparation , Solvent Selection , Bioactive Compounds , Green Extraction , Quality Control*

2. INTRODUCTION

Extraction is one of the most fundamental and widely applied operations in pharmaceutical analysis. It serves as a key preparatory step in the isolation, purification, and quantification of active pharmaceutical ingredients (APIs), excipients, and bioactive compounds from complex matrices such as plants, dosage forms, and biological samples. The primary purpose of extraction is to selectively transfer the desired constituents from a solid or liquid phase into a suitable solvent based on solubility differences, partition behavior, and chemical affinity. By doing so, it enables accurate qualitative and quantitative analysis while minimizing interferences from unwanted substances.

In the pharmaceutical industry, extraction is employed at every stage—from drug discovery and natural product isolation to formulation development, quality control, and impurity profiling. For example, in herbal drug analysis, extraction helps to isolate phytochemicals such as alkaloids, flavonoids, terpenoids, and glycosides, which contribute to therapeutic efficacy. In synthetic drug analysis, extraction is used to purify intermediates, remove degradation products, and prepare samples for chromatographic or spectroscopic examination. Thus, the extraction process directly influences the precision, reliability, and reproducibility of analytical results.

The efficiency of extraction depends on several factors, including the nature of the sample matrix, solvent polarity, temperature, pH, extraction time, and agitation. Selecting an appropriate solvent is especially critical, as it determines both the selectivity and recovery of the analyte. Traditional solvents such as water, ethanol, and chloroform have been used for decades, but recent advances have introduced greener alternatives like supercritical CO_2, ionic liquids, and deep eutectic solvents, aligning the process with sustainable and eco-friendly analytical practices.

Over the years, extraction techniques have evolved from conventional methods—such as maceration, percolation, and Soxhlet extraction—to advanced and automated systems including microwave-assisted extraction (MAE), ultrasound-assisted extraction (UAE), and supercritical fluid extraction (SFE). These modern techniques not only enhance extraction yield and reduce solvent consumption but also offer faster processing times and improved reproducibility. Integration of extraction with analytical instruments such as HPLC, GC, and LC-MS has further improved the sensitivity and selectivity of pharmaceutical assays.

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In summary, extraction is a cornerstone of pharmaceutical analysis, bridging raw material preparation and analytical quantification. Its scientific significance lies in its ability to isolate compounds in their purest form while maintaining chemical stability and analytical integrity. With continuous innovation and the adoption of green technologies, extraction continues to evolve as a sustainable, efficient, and indispensable process in modern pharmaceutical research and quality assurance

2.1 HISTORICAL BACKGROUND

The process of extraction has been practiced since ancient times, long before the formal establishment of pharmaceutical sciences. Early civilizations, including those of Egypt, Greece, China, and India, recognized the therapeutic potential of natural substances and developed simple extraction techniques to obtain active ingredients from plants and animal sources. Traditional systems of medicine such as Ayurveda, Traditional Chinese Medicine (TCM), and Unani relied heavily on crude extraction processes like boiling, soaking, and fermentation to isolate medicinal principles from herbs, roots, and minerals. These primitive methods, though basic, laid the foundation for modern extraction science by demonstrating the significance of solvent-mediated separation of bioactive compounds.

In the Middle Ages, the art of distillation and alchemy further refined extraction techniques. Alchemists used ethanol, oils, and water as solvents to prepare tinctures, elixirs, and essences, marking an early understanding of solubility and polarity. The development of distillation apparatus and percolation devices allowed better separation of volatile and non-volatile constituents. This period also witnessed the introduction of maceration and infusion, processes still employed today for the preparation of pharmaceutical and herbal extracts.

The 18th and 19th centuries saw significant progress in extraction methodology as chemistry became a formal scientific discipline. With the discovery and isolation of pure compounds such as morphine (1805), quinine (1820), caffeine (1821), and nicotine (1828), extraction transitioned from an art to a science. Scientists like Friedrich Sertürner and Joseph Pelletier demonstrated that precise solvent selection and control of temperature and pH were key to isolating pharmacologically active alkaloids. The invention of the Soxhlet extractor in 1879 by Franz von Soxhlet revolutionized solid–liquid extraction by allowing continuous solvent reflux, improving efficiency and reproducibility in analytical and preparative work.

During the 20th century, industrial-scale extraction techniques emerged with the advancement of chemical engineering and analytical instrumentation. Solvent extraction became widely used not only for natural product isolation but also for pharmaceutical purification, quality control, and metabolite analysis. With the advent of chromatography and spectroscopy, extraction became an integral step in sample preparation and analysis. The introduction of supercritical fluid extraction (SFE) in the 1980s and microwave-assisted extraction (MAE) and ultrasound-assisted extraction (UAE) in the late 20th century marked a major leap toward faster, cleaner, and more environmentally friendly processes.

In the 21st century, the focus of extraction research has shifted toward green chemistry, automation, and miniaturization. Novel solvents such as ionic liquids and deep eutectic solvents have been developed to reduce toxicity and improve selectivity. Modern pharmaceutical laboratories now use extraction techniques integrated with HPLC, GC-MS, and LC-MS/MS systems for efficient analyte separation and quantification. These innovations reflect the transformation of extraction from a manual, empirical procedure into a scientifically optimized, sustainable, and precision-driven process.

3. FACTORS AFFECTING EXTRACTION

- **Solvent Selection**
  - The choice of solvent is the most important factor.
  - A suitable solvent must dissolve the desired component effectively.
  - According to the rule “like dissolves like”, polar solvents (water, ethanol, methanol) dissolve polar compounds, while non-polar solvents (hexane, benzene, chloroform) dissolve non-polar substances.
- **Temperature**
  - Temperature directly influences solubility and diffusion.
  - Increasing temperature reduces solvent viscosity and increases molecular movement, allowing faster penetration of solvent into the sample matrix.
  - Thus, moderate heating increases extraction efficiency.
  .
- **pH of Medium**
  - He pH of the extraction medium affects the ionization state of acidic and basic compounds.
  - Unionized forms are more soluble in organic solvents, while ionized forms prefer aqueous solvents.
  - Adjusting pH helps selectively extract specific classes of compounds.
  - Example: Alkaloids are extracted in their free base form by alkalizing the solution.

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- **Particle Size**
  - Particle size plays a major role in solvent penetration.
  - Smaller particles provide a larger surface area, allowing greater contact between solvent and analyte.
  - This enhances mass transfer and increases extraction rate.
- **Agitation and mixing**
  - Agitation helps maintain uniform contact between solvent and sample.
  - It increases mass transfer by reducing boundary layers around particles.
- **Extraction Time**
  - The duration of extraction determines how much analyte dissolves into the solvent.
  - Short extraction time leads to incomplete extraction.
  - Excessive time may extract unwanted materials such as pigments or tannins, lowering purity.
- **Solvent-to-Sample Ratio**
  - This ratio determines how much solvent is available to dissolve extractable compounds.
  - If the solvent quantity is too low, it becomes saturated quickly and extraction remains incomplete.
  - Too much solvent increases cost and time without benefit.

4. PRINCIPLE OF EXTRACTION

Extraction is a fundamental separation process widely used in pharmaceutical analysis to isolate bioactive constituents from plant or chemical materials. The core principle of extraction is based on the concept of differential solubility and partitioning of compounds between two phases. When a solid material containing drug constituents comes into contact with a suitable solvent, the molecules that possess higher solubility, affinity, and chemical compatibility with the solvent dissolve into it, leaving behind the insoluble or unwanted components. This behavior follows the Nernst Distribution (Partition) Law, which states that a solute distributes itself between two immiscible phases in a constant ratio depending on its solubility in each phase. Thus, extraction selectively pulls out the desired component without dissolving the whole matrix.

The movement of solute from plant cells into the solvent also depends on the concentration gradient, in which molecules diffuse from a region of high concentration inside the plant matrix to a lower concentration in the surrounding solvent until equilibrium is reached. The efficiency of this diffusion depends on various factors such as particle size reduction, which increases surface area and breaks the cell walls; temperature, which enhances solubility and diffusion rate; agitation, which accelerates mass transfer; and solvent-to-material ratio, which ensures maximum contact between solvent and solute. The polarity of the solvent is a key determinant in extraction: polar solvents (water, ethanol, methanol) extract polar compounds such as glycosides, tannins, and alkaloids, while non-polar solvents (hexane, petroleum ether) extract lipophilic components like oils, fats, and waxes.

In pharmaceutical analysis, the principle of extraction ensures selective and efficient isolation of active pharmaceutical ingredients (APIs), phytochemicals, or chemical markers required for identification, assay, or standardization. The ultimate aim is to obtain a purified, concentrated extract that represents the true chemical profile of the raw material. Whether applied in simple maceration, Soxhlet extraction, refluxing, ultrasound-assisted extraction, or supercritical fluid extraction, the basic principle remains constant: utilizing solvent properties and solubility differences to separate, concentrate, and recover target molecules. This principle forms the scientific basis for various industrial processes ranging from herbal drug preparation to modern analytical techniques.

5. METHOD OF EXTRACTION

Extraction techniques are generally classified into two broad categories:
1. Conventional (Classical) Extraction Method
2. Modern (Advanced or Instrumental) Extraction Methods

I. CONVENTIONAL EXTRACTION METHODS

Traditional extraction methods have been used for centuries in pharmaceutical and herbal industries. These are generally time-consuming, solvent-intensive, and operate under atmospheric conditions, but they remain useful for small-scale or preliminary studies.

1. Maceration

It is an old method used for medicinal preparation. It is consider as a widely and low-cost way to get natural products from plant material. The maceration is a method of solid–liquid extraction. In this process, the powdered solid materials is placed in a closed vessel and the solvent is added. It is allowed to stand for a long time (varying from hours to days) with occasional shaking. Sufficient time is allowed for the solvent to diffuse through the cell wall to solubilize the constituent present in plant. The process takes place only by molecular diffusion. After the desired time, the liquid is strained off; the solid residue is pressed to recover as much solvent as possible. When the solvent is water and the period of maceration is long, a small quantity of alcohol may be added to prevent microbial growth .

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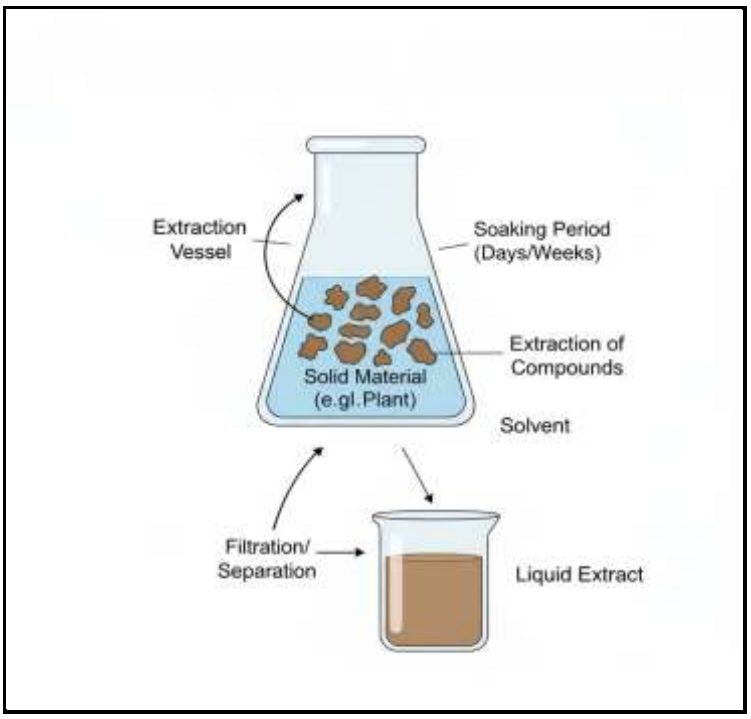


Fig.no 1: Maceration process

Advantages

1. Maceration is a simple method using non-complicated utensil and equipment.
2. Skilled operator not required.
3. Energy saving process.
4. For certain substances which are very less soluble in

Disadvantages

1. Unfortunately, the duration of extraction time is long and sometimes takes up to weeks.
2. Not exhaustively extract the drug.
3. It is very slow process and time consuming.
4. Solvent required is more

Applications

1. Maceration is used to extract bioactive compounds like alkaloids, flavonoids, glycosides, tannins, and phenolics**.**
2. Employed in extracting heat-sensitive compounds that may degrade during heating, e.g., flavonoids and glycosides.
3. Applied in preliminary phytochemical screening of medicinal plants in research laboratories.

2.Percolation

The percolation method is a process used to extract useful substances from plants or other solid materials by using a liquid solvent. In this method, the solvent is allowed to pass slowly through the powdered material, which is kept in a special container called a percolator. As the liquid moves down through the material, it dissolves the active or soluble parts, and the liquid that comes out at the bottom is called the percolate or extract.

This method is commonly used in pharmacies and herbal medicine to make tinctures and liquid extracts. It is more effective than simple soaking (maceration) because fresh solvent is always passing through the drug, giving better extraction. The main steps in percolation are grinding the material**,** moistening it**,** packing it into the percolator**,** adding solvent, and collecting the extract**.**

Percolation saves time and solvent, and gives a stronger product. A common example of percolation in daily life is brewing coffee, where hot water passes through coffee powder to extract its flavor and aroma.

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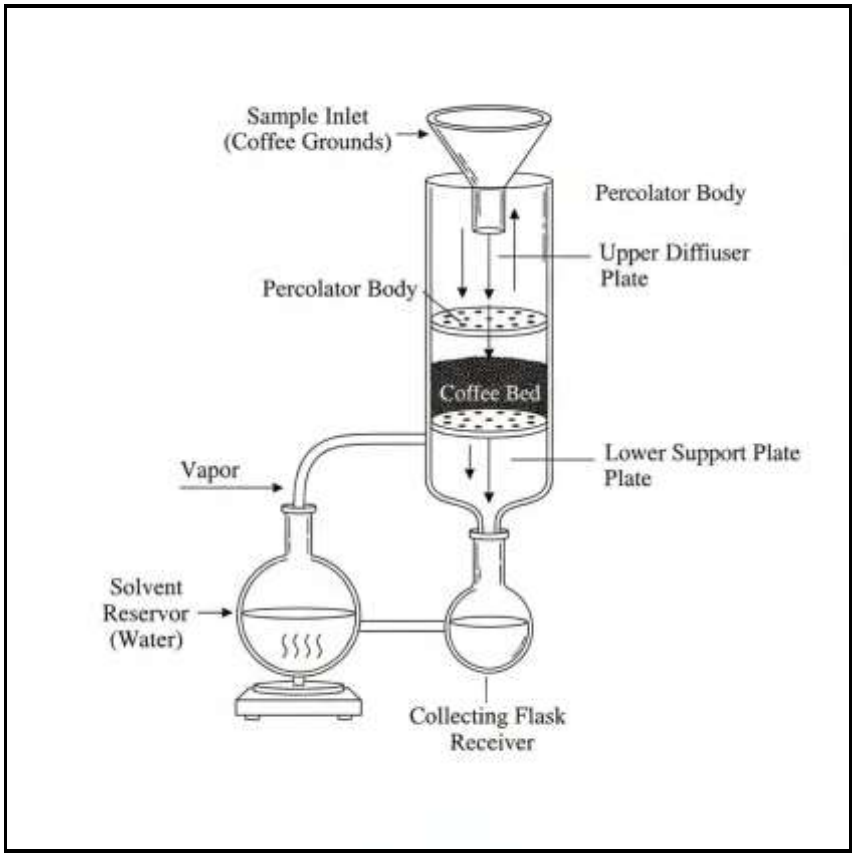


Fig.no 2: Percolation process

Advantages

1. It gives better and more complete extraction of active ingredients than simple soaking.
2. It requires less solvent because the same solvent passes continuously through the material.
3. The process also saves time compared to maceration and produces a stronger, more uniform extract.

Disadvantages

1. The flow of solvent must be carefully controlled, as too fast or too slow a rate can affect the extraction.
2. It is not suitable for materials that swell or form sticky masses, since they can block the percolator.
3. Very fine powders may cause clogging problems.

Applications

1. The percolation method is widely used in pharmacy to prepare tinctures, where medicinal plant materials are extracted with alcohol or other solvents to obtain concentrated solutions of active ingredients.
2. It is used to make fluid extracts from crude drugs, producing liquid forms of herbal or chemical substances that are easy to measure and use in medicine.
3. In herbal and Ayurvedic medicine, percolation helps extract useful plant compounds efficiently, ensuring that the medicinal properties of the herbs are preserved in the final product.

3. Soxhlet Extraction

Soxhlet extraction is a continuous hot-extraction method that is extensively utilized for the isolation of bioactive compounds, lipids, and various chemical constituents from solid materials. It was invented by Franz von Soxhlet in 1879, initially aimed at fat analysis in milk, but over time, it evolved into a standard procedure in pharmaceutical, food, and chemical laboratories.In this technique, a solid sample containing the target compound is placed within a porous thimble, which is then inserted into the Soxhlet extractor.

A suitable solvent is heated in a flask located below, and its vapors ascend through a side arm into a condenser, where they cool and subsequently drip onto the solid material.As the chamber fills, the solvent dissolves the extractable components and siphons back into the boiling flask, transporting the dissolved compounds along with it.This automatic siphoning cycle occurs repeatedly, ensuring that the sample is continuously washed with fresh hot solvent without the requirement for large volumes of solvent.

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The primary benefit of Soxhlet extraction is its ability to provide efficient and thorough extraction with minimal operator intervention.

The application of hot solvent enhances solubility and diffusion, resulting in a greater extraction yield.
Nevertheless, the technique does have certain limitations, including extended extraction times, significant solvent consumption, and the potential degradation of thermolabile compounds due to prolonged heating.
Despite these limitations, Soxhlet extraction continues to be a widely recognized reference method for the precise extraction of oils, fats, phytochemicals, and other analytes from complex solid matrices.

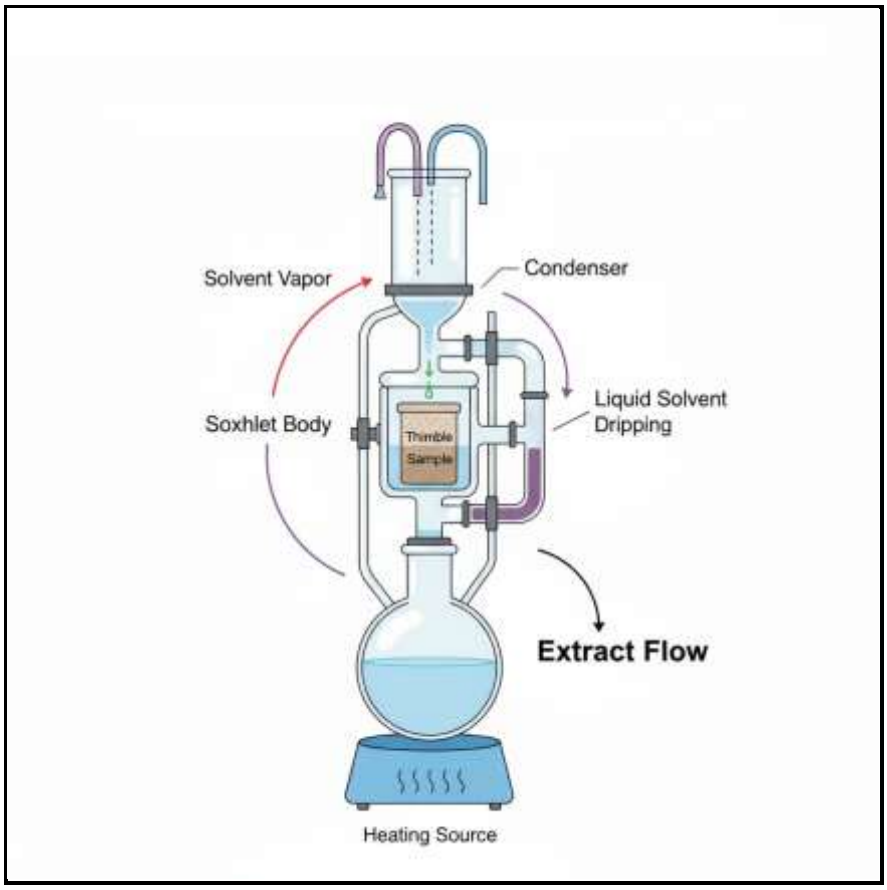


Fig.no 3: Soxhlet Extraction process

Advantages

1. It extracts all the desired substances from a solid material very efficiently.
2. It uses less solvent compared to other methods like simple soaking or maceration.
3. The process is continuous, so the solvent keeps washing the material without extra effort.

Disadvantages

1. It is a time-consuming process, as several cycles of extraction are needed.
2. It can only be used for substances that are stable at the boiling point of the solvent.
3. The setup requires special apparatus like a Soxhlet extractor, condenser, and heating source.

Applications

1. It is used in laboratories to extract active compounds from plants for research or pharmaceutical use.
2. It is applied in the food industry to extract oils and flavors from seeds, nuts, and spices.
3. It is used in environmental studies to analyze pollutants, such as extracting pesticides or contaminants from soil and water samples.

4. Digestion (Warm Maceration)

Digestion is an extractive method similar to maceration and uses slight warming in the extraction process . Care is, however, exercised to avoid the temperature altering the bioactive phytochemicals of given plant material. Therefore, there is increased efficiency in using the extraction solvent due to warming. Mostly temperatures are kept in the range of 35 to 40 °C but may be

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increased to a maximum of 50 °C for tougher plant materials such as barks and materials containing dismally soluble phytochemicals. During extraction, desired plant parts are introduced in a container with the appropriate solvent pre-heated to the indicated temperatures. The optimum temperature is maintained for a period that may range from half an hour to 24 h with shaking the container at regular intervals.

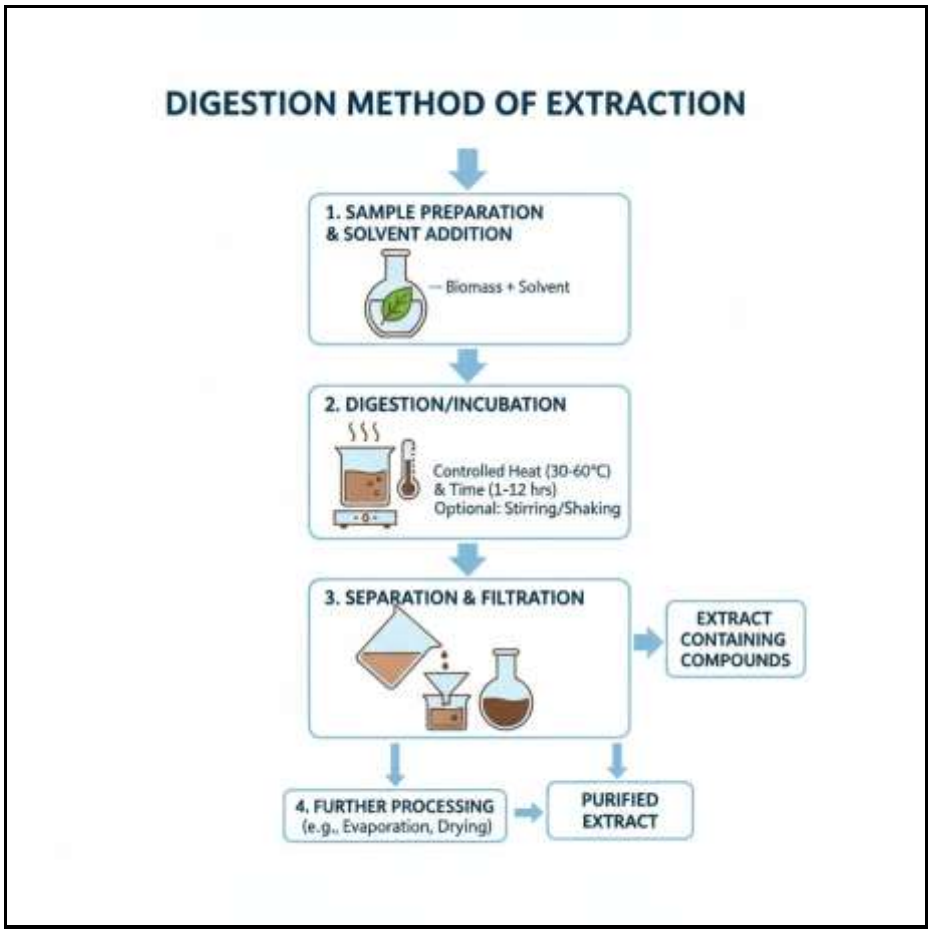


Fig.no 4 :- Digestion Process

Advantages

1. Faster extraction than maceration.
2. Increases solubility of certain compounds

Disadvantages

1. Possible degradation of heat-sensitive compounds.
2. Requires temperature control.

Applications

1. Extraction of resins and bitter principles from plant materials
2. Isolation of tannins and alkaloids that require mild heating for better solubility
3. Preparation of herbal extracts where slightly elevated temperatures improve yield without degrading heat-sensitive compounds.

5. Decoction

Decoction is one of the oldest and most widely used extraction methods in traditional medicine and pharmaceutical analysis. It is mainly used for hard and tough plant parts such as roots, bark, stems, rhizomes, and seeds, which need strong heating to release their active compounds. In this method, the crude plant material is first cleaned and coarsely powdered. This coarse powder allows better contact with water and improves extraction. The powdered drug is then placed in a boiling pot or suitable container, and a measured quantity of water is added. The mixture is boiled for a fixed time—usually between 15 to 60 minutes—depending on the hardness of the material and the nature of its constituents. Continuous boiling helps water penetrate deeply into the plant tissues,

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break the cell walls, and dissolve easily extractable compounds such as glycosides, alkaloids, tannins, flavonoids, saponins, and polysaccharides.

During the boiling process, water acts as the solvent (menstruum), and its high temperature increases the movement of molecules, helping more active components dissolve. The heating also softens the plant structure so the chemical constituents can move out more easily.

After boiling, the mixture is allowed to cool to room temperature. Cooling helps settle suspended particles and prevents evaporation of volatile components. Once cooled, the mixture is filtered through cloth or filter paper to remove solid residues (marc), and the liquid obtained is called the decoction. This decoction is used directly as a therapeutic preparation in traditional systems like Ayurveda or processed further in pharmaceutical analysis for testing extractive values, phytochemical screening, and preparation of herbal formulation

In modern pharmaceutical analysis, it is still used to prepare aqueous plant extracts, evaluate drug quality, determine extractive values, and compare different extraction methods. Its long history, simplicity, and effectiveness make decoction an important method for both traditional and scientific studies of medicinal plants.

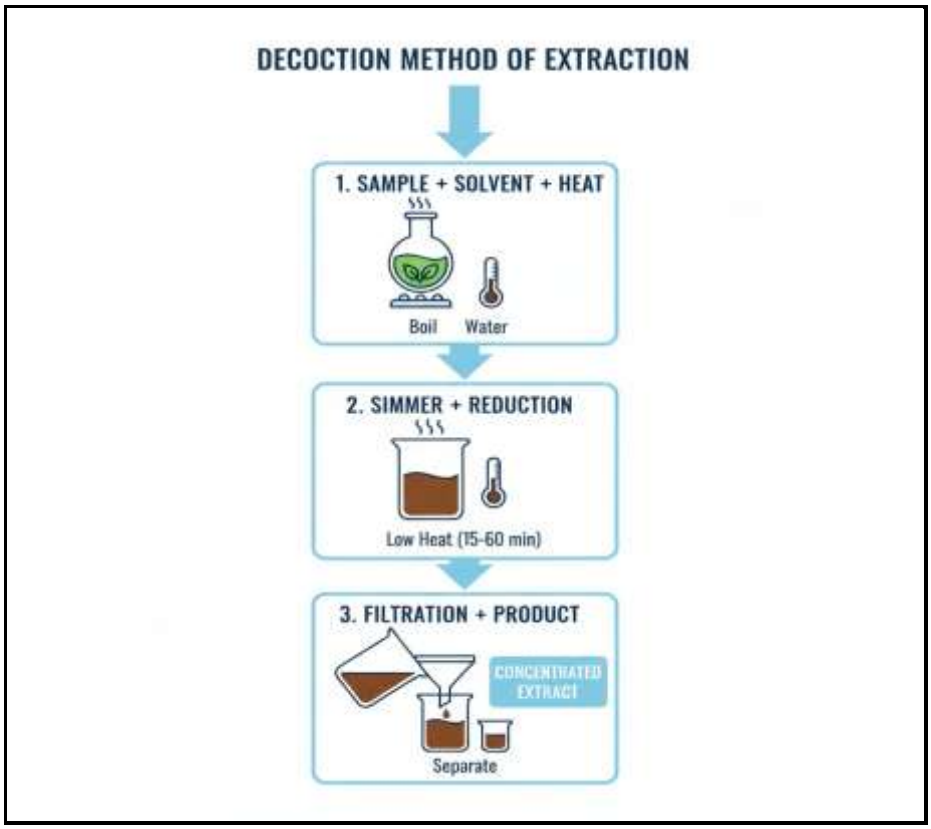


Fig. no 5 :- Decoction Process

Advantages

1. Simple and safe.
2. Water used as solvent (eco-friendly).

Disadvantages

1. Short shelf life of extracts.
2. Only suitable for water-soluble compounds.

Applications

1. Preparation of herbal teas and tonic drinks from leaves and flowers.
2. Extraction of water-soluble phytochemicals like glycosides, tannins, and polyphenols.
3. Use in mild pharmaceutical and nutraceutical formulations such as syrups and mouthwashes.
4. Used in traditional medicine for extracting water-soluble active ingredients from hard plant parts like roots and bark.
5. Employed for formulation of ayurvedic preparations such as kadha or herbal teas.

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6.Infusion

Infusion is a simple and widely used extraction technique in which plant material is treated with boiling water to obtain a dilute solution of its easily soluble constituents. In this method, the plant material—such as leaves, flowers, or finely divided herbal parts—is immersed in hot water and allowed to steep in a covered container for a short period, typically around 10–15 minutes. After steeping, the liquid extract is separated from the marc by decanting or filtration. Infusions are commonly used in the preparation of herbal teas, where compounds such as caffeine, phenols, flavonoids, and other antioxidants are efficiently extracted. This method is valued for its simplicity, rapid extraction, and suitability for heat-stable constituents, and is often employed in traditional medicine for preparing remedies for conditions like digestive discomfort, respiratory issues, and inflammation.

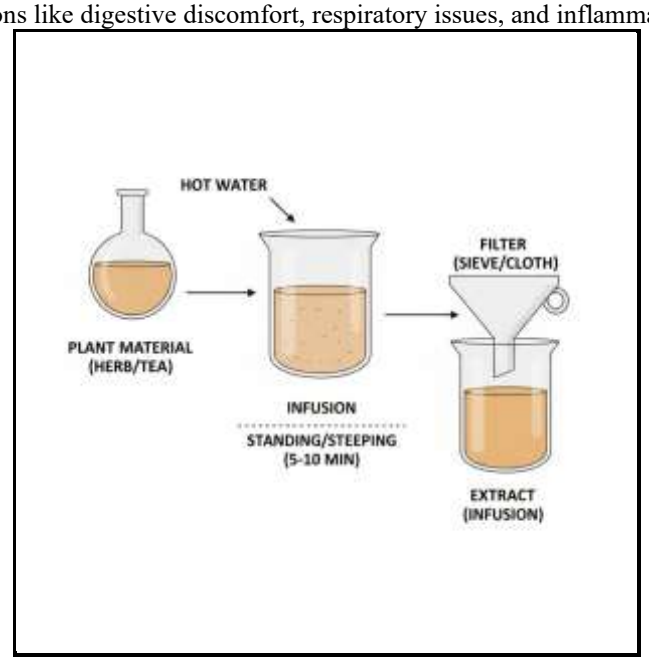


Fig.no 6 :- Infusion process

Advantages:

1. It is a simple and quick extraction method.
2. It effectively extracts water-soluble, heat-stable compounds.
3. It preserves volatile constituents due to short steeping time.
4. It is convenient for preparing medicinal and household herbal remedies.

Disadvantages:

1. It is unsuitable for extracting poorly water-soluble compounds.
2. Heat-sensitive constituents may degrade during boiling.
3. The extract has a short shelf life and may spoil quickly.

Applications:

1. Used to prepare herbal teas for daily consumption.
2. Employed in traditional medicine to extract therapeutic compounds.
3. Used to obtain caffeine, phenols, and flavonoids from plant materials.
4. Applied in food and cosmetic industries for producing natural extracts and flavors.

II. MODERN EXTRACTION METHODS

Modern techniques were developed to overcome the drawbacks of conventional methods. These methods are faster, eco-friendly, and energy-efficient, often integrating with analytical instruments for quantitative and qualitative analysis.

1. Ultrasound-Assisted Extraction (UAE)

Ultrasound-Assisted Extraction (UAE) is a modern method used in pharmaceutical analysis to extract important compounds from plants and other natural materials. It works by using high-frequency sound waves that create tiny bubbles in the solvent. When these bubbles burst, they gently break open the cells of the material, allowing the useful chemicals inside to dissolve more easily into the solvent. This makes the extraction process faster and more effective compared to traditional techniques like soaking or boiling.

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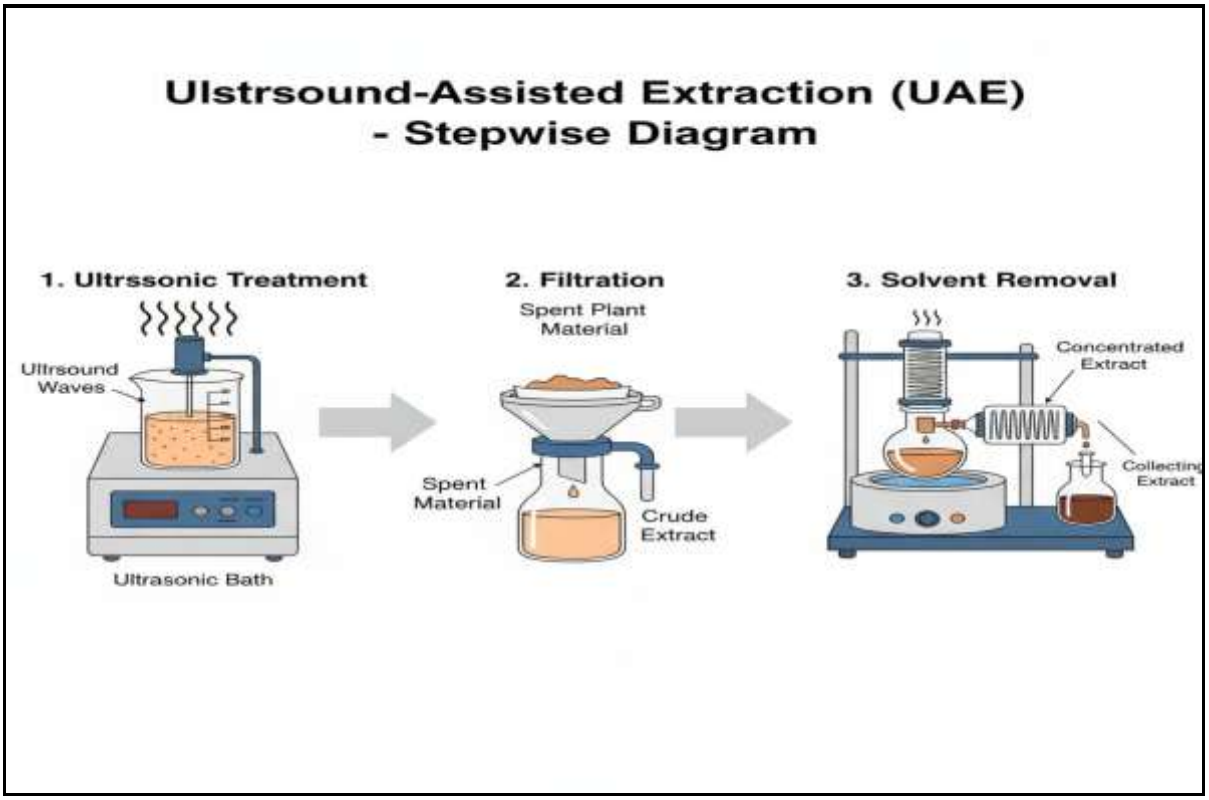


Fig.no 7 :- Ultrasound Assisted Extraction

Advantages

1. Short extraction time.
2. Lower solvent and energy use.
3. Suitable for thermolabile compounds.

Disadvantages

1. Limited scalability for industrial use.
2. Excessive ultrasound can degrade compounds.

Applications

1. Extraction of antioxidants, polyphenols, and flavonoids from herbal materials.
2. Used for rapid sample preparation before chromatographic analysis (HPLC, GC).
3. Applied in green extraction due to reduced solvent and energy consumption.

2. Microwave-Assisted Extraction (MAE)

Microwave-assisted extraction (MAE) is a modern extraction technique that utilizes microwave energy to enhance the extraction process. It is widely used in various industries, including pharmaceuticals, food, and natural product extraction. In Microwave-assisted extraction, the sample material is mixed with a suitable solvent in an extraction vessel.

Microwave energy is then applied, which rapidly heats the mixture, causing the solvent to boil and creating internal pressure within the sample. This pressure helps to rupture the cell walls and facilitate the extraction of target compounds.

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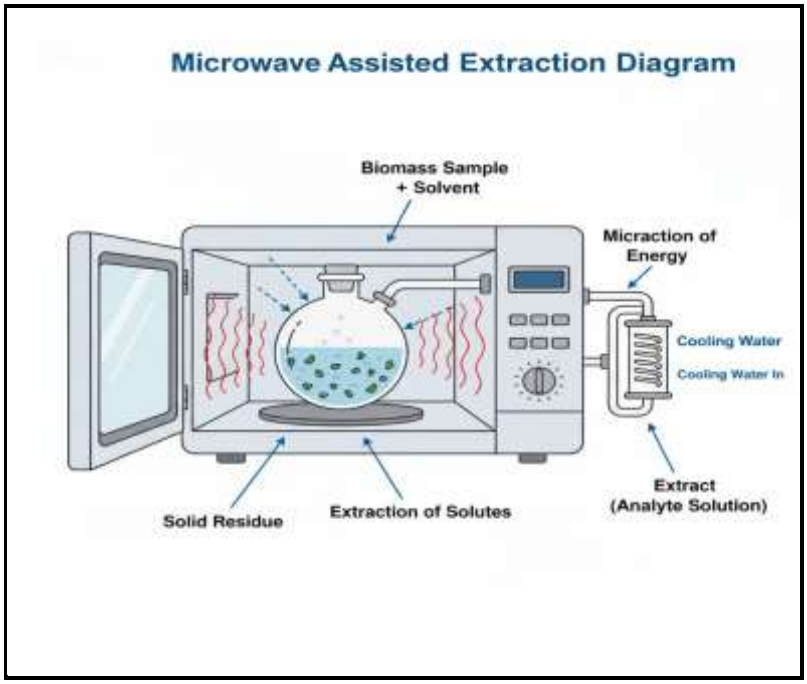


Fig.no 8 :-Microwave Assisted Extraction Diagram

Advantages

1. Rapid extraction (minutes).
2. High reproducibility and efficiency.
3. Low solvent consumption.

Disadvantages

1. Expensive equipment.
2. Not suitable for highly volatile compounds.

Applications:

1. Extraction of essential oils and bioactive compounds from plant materials.
2. Used in pharmaceutical quality control for rapid analyte recovery.
3. Applied in isolation of natural colorants and alkaloids with minimal solvent use.

3. Supercritical Fluid Extraction (SFE)

Supercritical fluid extraction (SFE) is a technique used to extract desired compounds from a variety of materials using supercritical fluids as the solvent. A supercritical fluid refers to a substance that is at a temperature and pressure above its critical point, where it exhibits properties of both a liquid and a gas SFE, the most commonly used supercritical fluid is carbon dioxide (CO2) due to its favorable properties, such as low toxicity, availability, and relatively low critical point. However, other supercritical fluids like ethane, propane, and water can also be used depending on the application. SFE involves the use of a specialized extraction system. The extraction vessel is a high pressure chamber where the sample to be extracted is placed.

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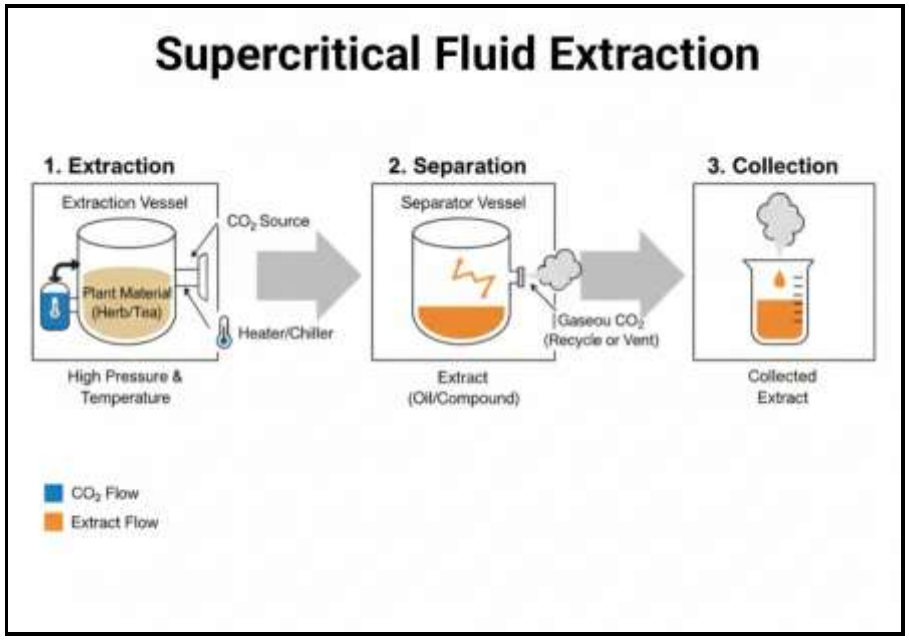


Fig.No 9 :- SFE Process

Advantages

1. Non-toxic, residue-free, and eco-friendly.
2. Selectivity controlled by pressure and temperature.
3. Suitable for thermo-sensitive compounds.

Disadvantages

1. High initial setup cost.
2. Requires skilled operation.

Applications

1. Extraction of caffeine from coffee and tea using supercritical CO_2.
2. Used in purification of heat-sensitive pharmaceutical compounds
3. Employed in isolation of lipophilic drugs and essential oils on an industrial scale.

4. Accelerated Solvent Extraction (ASE) / Pressurized Liquid Extraction (PLE)

Accelerated Solvent Extraction (ASE)**,** also known as Pressurized Liquid Extraction (PLE), is an advanced extraction technique used to efficiently isolate bioactive compounds from plant and other natural materials. In this method, the sample is mixed with a solvent and subjected to high temperature and pressure inside a closed system. The high pressure keeps the solvent in liquid form even above its normal boiling point, which increases its ability to dissolve target compounds and speeds up the extraction process.

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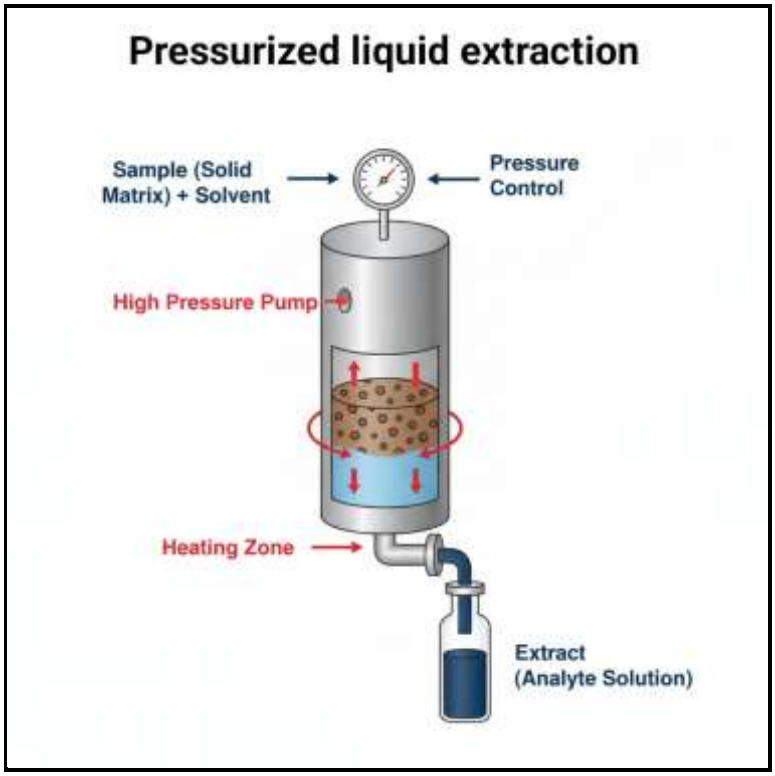


Fig.no 10 :- Diagram PLE/ASE

Advantages

1. Automated, reproducible, and efficient.
2. Reduced solvent use and time.
3. Compatible with various solvents and analytes.

Disadvantages

1. High cost of equipment.
2. Not suitable for volatile compounds.

Applications

1. Extraction of antibiotics, vitamins, and pesticides from pharmaceutical or biological samples.
2. Used in pharmaceutical residue and impurity analysis.
3. Efficient recovery of bioactives from plant or microbial sources under controlled temperature and pressure.

5. Solid Phase Extraction (SPE)

Solid Phase Extraction (SPE) is a modern sample preparation technique used in pharmaceutical analysis to isolate, concentrate, and purify compounds from complex mixtures. In this method, the sample is passed through a solid adsorbent material (the stationary phase) that selectively retains the target compounds while other unwanted components are washed away. The retained compounds are then eluted using a suitable solvent for further analysis.

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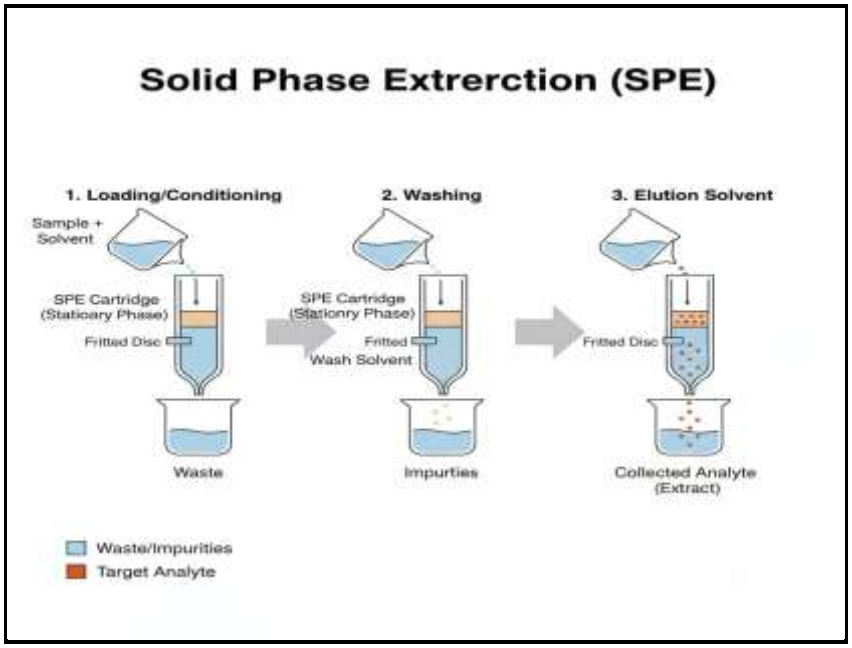


Fig no 11 :- SPE Process

Advantages

1. High selectivity and precision.
2. Requires minimal solvent.
3. Ideal for sample cleanup before analysis.

Disadvantages

1. Limited sample capacity.
2. Requires optimization of sorbent and solvent.

Applications

1. Cleanup and concentration of biological samples like plasma and urine before chromatographic analysis.
2. Isolation and purification of drug residues and impurities in pharmaceutical formulations.
3. Extraction of specific analytes from complex matrices for HPLC, GC, or LC-MS studies.

6. Liquid–Liquid Extraction (LLE)

Liquid–Liquid Extraction (LLE) is a widely used technique in pharmaceutical analysis to separate and isolate compounds based on their solubility in two immiscible liquids, usually water and an organic solvent.

In this method, the sample is mixed with both solvents, and the compound of interest moves from one liquid phase to the other depending on its chemical properties. The two layers are then separated, allowing the desired compound to be collected in the solvent where it is more soluble.

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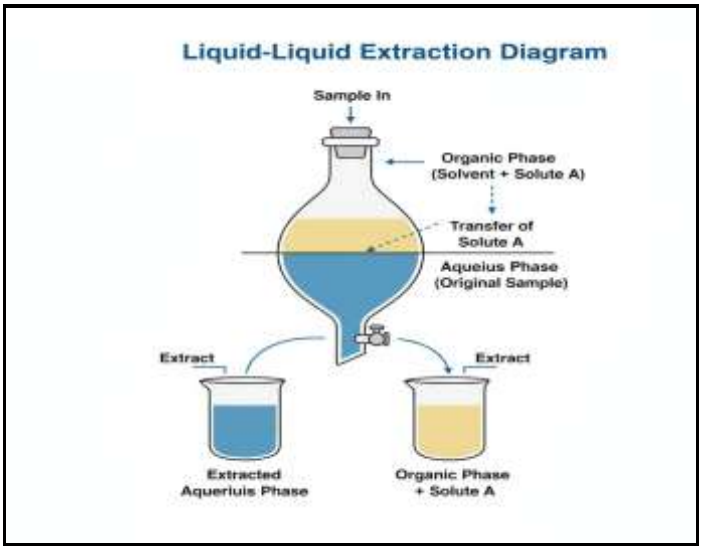


Fig.no 12 :- Liquid Liquid Extraction

Advantages

1. Simple and effective.
2. Applicable to a wide range of compounds.

Disadvantages

1. Large solvent requirement.
2. Possible emulsion formation.

Applications

1. Separation of alkaloids, antibiotics, and other organic compounds from aqueous solutions.
2. Isolation of drug intermediates and active pharmaceutical ingredients during formulation.
3. Sample preparation for chromatographic analysis in pharmaceutical and biochemical studie

6. COMPARISON OF CONVENTIONAL AND MODERN EXTRACTION METHODS

Parameter	Conventional Methods	Modern Methods
1. Principle	Based on solvent diffusion and mass transfer by soaking or heating	Based on enhanced mass transfer using energy (ultrasound, microwave, pressure, or supercritical fluids)
2. Temperature Requirement	Usually moderate to high; may cause degradation of thermolabile compounds	Controlled or lower temperatures; minimizes thermal degradation
3. Solvent Consumption	High solvent usage	Low solvent consumption (eco-friendly)
4. Time Required	Long (hours to days)	Short (minutes to hours)
5. Extraction Efficiency	Moderate; incomplete extraction sometimes	High; enhanced yield and purity
6. Automation	Mostly manual or semi-manual	Fully or semi-automated systems available
7. Energy Requirement	Generally low to moderate	Moderate to high (microwave or pressure-based systems)
8. Selectivity	Low selectivity; co-extraction of impurities common	High selectivity for specific analytes
9. Reproducibility	Variable; depends on operator	High; standardized conditions and control
10. Cost	Low initial cost; simple setup	Higher cost; requires specialized equipment
11. Safety & Environmental Impact	Uses large volumes of toxic solvents; disposal issues	Green techniques with minimal solvent waste
12. Scalability	Suitable for laboratory and small-scale production	Suitable for industrial and analytical applications
13. Examples	Maceration, Percolation, Soxhlet, Decoction	Ultrasound-Assisted Extraction (UAE), Microwave-Assisted Extraction (MAE), Supercritical Fluid Extraction (SFE).

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7. ROLE OF EXTRACTION IN PHARMACEUTICAL ANALYSIS

1. Isolation of Active Compounds
- Separates bioactive constituents like alkaloids, flavonoids, glycosides, and terpenoids from complex matrices.
- Essential for research, drug development, and production of standardized herbal and synthetic formulations.

2. Purification of Drugs and Intermediates
- Removes impurities, degradation products, and residual solvents.
- Ensures chemical purity, stability, and safety of pharmaceutical products.

3. Sample Preparation for Analytical Testing
- Prepares samples for HPLC, GC, LC-MS, and other analytical methods.
- Concentrates analytes and eliminates interfering substances for accurate, reproducible results.

4. Pharmacokinetic and Bioavailability Studie
- Isolates drugs from biological fluids such as plasma, urine, and tissues.
- Enables accurate measurement of drug concentrations and monitoring of absorption, distribution, and metabolism.

5. Quality Control and Standardization
- Ensures consistent quantification of active ingredients in raw materials, formulations, and finished products.
- Supports product efficacy, safety, and regulatory compliance.

6. Environmental and Green Chemistry Benefits
- Modern extraction techniques reduce solvent use and energy consumption.
- Promotes sustainable and eco-friendly pharmaceutical practices.

8. CONCLUSION

Extraction is one of the most important processes in pharmaceutical analysis because it helps us separate useful chemicals from plants, drugs, and other complex materials. Without extraction, it would be very difficult to study medicines, check their quality, or prepare samples for testing. Extraction works by choosing a suitable solvent that can dissolve the required compounds without damaging them. This makes it possible to isolate active ingredients like alkaloids, flavonoids, glycosides, oils, vitamins, and many more substances that are used in medicines.

Both traditional and modern extraction methods are used today. Conventional methods like maceration, percolation, Soxhlet extraction, infusion, and decoction are simple, low-cost techniques that have been used for many years. These methods are easy to perform but take more time and require more solvent. On the other hand, modern methods such as Ultrasound-Assisted Extraction (UAE), Microwave-Assisted Extraction (MAE), Supercritical Fluid Extraction (SFE), and Accelerated Solvent Extraction (ASE) offer faster and more efficient extraction. These techniques use advanced technology to improve extraction speed, reduce solvent use, and protect heat-sensitive compounds. They also support green chemistry by minimizing waste and environmental pollution.

Extraction has a major role in almost every step of pharmaceutical work. It is used in drug discovery to isolate new molecules from natural sources. It is used in sample preparation before tests like HPLC, GC, and LC-MS to make sure the results are accurate. It also helps in quality control by ensuring that medicines contain the correct amount of active ingredients and are free from impurities. In pharmacokinetic studies, extraction helps in isolating drugs from blood, urine, and tissues, making it possible to study how medicines move inside the body.

Overall, extraction is a backbone of pharmaceutical analysis. As technology improves, extraction techniques are becoming faster, safer, and more environment-friendly. Whether in herbal medicine, synthetic drug analysis, research laboratories, or pharmaceutical industries, extraction ensures purity, safety, and effectiveness of medicines. This makes extraction an essential and irreplaceable process in modern pharmaceutical science.

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