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Review

Gastro Retentive Floating Drug Delivery System

V.Bharath[1*], Mr. S. Naveenraj[2], C. Lalitha[3], A. Priya[4], R. Saru[5], R. Shanmuga Bairavi[6].

B. Pharm 8th Semester, Sree Bhavani College of Pharmacy, Kandappankurichi,

[*]Author for Correspondence: V.Bharath

Email: bharathbraren07@gmail.com

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Abstract

Gastro-retentive drug delivery systems (GRDDS) have emerged as an effective strategy to the therapeutic performance of drugs that exhibit narrow absorption windows, low solubility at intestinal pH, or preferential uptake in the upper gastrointestinal tract. By prolonging residence time, these systems improve drug dissolution, absorption, and overall while reducing dosing frequency and enhancing patient compliance. Floating drug delivery (FDDS), comprising effervescent and non-effervescent mechanisms, represent one of the most widely explored GRDDS approaches due to their ability to maintain buoyancy and sustained or controlled drug release. Various formulation techniques such as solvent evaporation, emulsion solvent diffusion, spray drying, and in-situ gel formation have enabled the development of single-unit and multiple-unit floating systems, hollow microspheres, beads, and raft-forming gels. The performance of these systems is influenced by multiple factors including selection, density, gastric physiology, meal pattern, and buoyancy characteristics. Evaluation parameters such as floating lag time, total floating duration, swelling behavior profiling, in-vivo imaging, mechanical strength, and physicochemical stability are critical in determining formulation efficiency. Despite limitations associated with drug stability in media and variability in gastric conditions, advancements in polymer technology and fabrication techniques continue to expand the applicability of GRDDS. Overall, floating delivery systems offer a promising platform for improving site-specific delivery, sustaining levels, and minimizing dose-related adverse effects, thereby contributing significantly to optimization of oral drug therapy.

Keywords: Gastro-retentive system, floating delivery, buoyancy, effervescent mechanism, non-effervescent system, raft-forming system, gastric retention, sustained release, bioavailability, patient gastric motility, density factor, fed state, polymers, HPMC, alginate, carbopol, Eudragit, chitosan, solvent evaporation, emulsion diffusion, spray drying, swelling index, dissolution, drug content, GERD, *H. pylori*, narrow absorption window, marketed formulations, Gaviscon, Madopar, Valrelease, Topalkan.

INTRODUCTION:

Oral drug delivery remains the most preferred route of administration due to its convenience, safety, and high patient acceptance. However, traditional oral dosage forms often face limitations such as short gastric residence time, variable gastric emptying, and incomplete drug absorption, particularly for molecules with a narrow absorption window in the upper gastrointestinal tract. These challenges led to the development of Gastro-Retentive Drug Delivery Systems (GRDDS), an advanced platform designed to prolong the residence of dosage forms in the stomach and enhance drug bioavailability.

GRDDS offer multiple therapeutic advantages, including improved solubility for drugs unstable or poorly soluble at intestinal pH, sustained and controlled release profiles, reduced dosing frequency, and targeted delivery to the upper gastrointestinal region. Among the various gastro- retentive strategies, Floating Drug Delivery Systems (FDDS) have received significant attention. These systems employ effervescent or non-effervescent mechanisms to maintain buoyancy, enabling the dosage form to remain afloat in gastric fluid for extended periods without being expelled by gastric motility.

Floating tablets, capsules, microspheres, beads, and in-situ gel systems have been explored extensively to improve therapeutic performance and overcome limitations of conventional oral formulations. Their effectiveness depends on factors such as density, polymer composition, gastric physiology, nutritional state, and motility patterns including the Migrating Myoelectric Complex (MMC). Advances in polymer science and fabrication techniques—such as solvent evaporation, emulsion diffusion, and spray drying—have further enhanced the design, stability, and performance of these systems.

Given the growing interest in gastro-retentive technologies, this review provides a comprehensive overview of floating dosage forms, their mechanisms, formulation strategies, evaluation parameters, advantages, limitations, and current applications in improving drug therapy.

Advantage of GRDDS

- Prolongs gastric residence time and enhances absorption of upper-GIT drugs.
- Improves bioavailability of drugs with narrow absorption windows.
- Enables sustained and controlled drug release for longer therapeutic action.
- Reduces dosing frequency and improves patient compliance.
- Useful for drugs that act locally in the stomach, such as antacids.
- Minimizes fluctuations in plasma drug levels and reduces side effects.

Disadvantages of GRDDS

- Not suitable for drugs unstable or degraded in acidic gastric conditions.
- Requires sufficient gastric fluid for proper floating and retention.
- Unsuitable for drugs absorbed mainly in the intestine or colon.
- Gastric retention may vary based on posture, fed state, and motility.
- Not ideal for patients with swallowing difficulties or paediatric use.
- High fluid volume is sometimes required to achieve buoyancy.
- First-pass metabolism drugs may show limited benefit from GRDDS.

Physiology of Gastrointestinal tract:

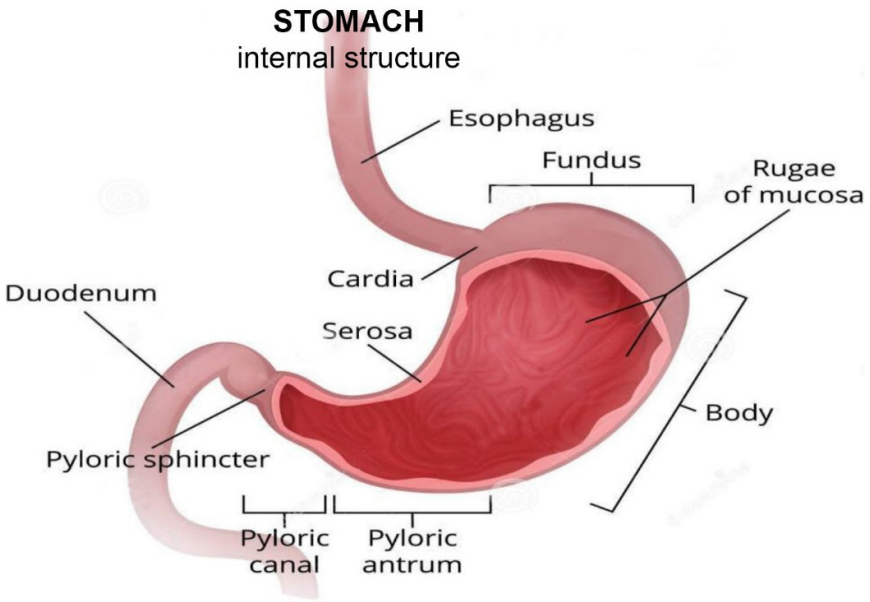

Figure 1: Anatomy of stomach.

The stomach motility is distinct in 2 states. During fasting state, inter digestive series of electrical events takes place, which cycles both through stomach and intestine every 2 to 3 hours. This is called the interdigestive myoelectric cycle or migrating myloelectric cycle (MMC), as described by Wilson and Washington (1989) it is further divided into following 4 phases. 1.Phase I (basal phase) with contractions 40 to 60 minutes. 2. Phase II (pre burst phase) with intermittent action potential and contractions it lasts for 40 to 60 minutes and the intensity and frequency also increase gradually during the phase progresses. 3. Phase III (burst phase) It includes intense and regular contractions for short period and stays up to 4 to 6 minutes. It is also known as the house keeper wave because this wave does all the undigested material is swept out of the stomach down to the small intestine. 4. Phase IV It is occurs between phases III and I of 2 consecutive cycles and last for 0 to 5 minutes. The pattern of contractions changes from fasted to that of fed state after taking mixed meal. This is also called as digestive motility pattern and bring out continuous contractions as in phase II of fasted state. These contractions reduce the size of food particles less than1mm, which are pushed toward the pylorus in a suspension form. During the fed state onset of migrating myoelectric cycle is delayed resulting in reduced gastric emptying rate.[4] Figure 2: Schematic representation of myoelectric cycle Needs for gastric retention 1) Drugs which are absorbed from the Upper part of the gastrointestinal tract (GIT). 2) Drugs which are less soluble in GIT or are degrades by the basic pH they administered at the Lower (distal) part of GIT. 3) Drugs which are absorbed during the variable gastric emptying time. To treat certain conditions Local or sustained drug delivery to the stomach and small intestine. 4) Mostly very useful for the treatment of peptic ulcers caused by Helicobacter Pylori Infections.

FLOATING DRUG DELIVERY SYSTEMS (FDDS)

Floating drug delivery system is also called the hydrodynamically balanced system (HBS). Floating drug delivery systems (FDDS) have a bulk density less than gastric fluids and so remain buoyant in the stomach without affecting gastric emptying rate for a prolonged period of time. While the system is floating on the gastric contents, the drug is released slowly at the desired rate from the system. After release of drug, the residual system is emptied from the stomach. This results in an increased GRT and a better control of the fluctuations in plasma drug concentration. This delivery system is further divided into in to) non-effervescent) Effervescent (Gas-generating system).

Gastric Motility and MMC Pattern

Gastric motility shows distinct patterns in the fasting and fed states. During fasting, the stomach and small intestine exhibit a repeating physiological cycle known as the Migrating Myoelectric Complex (MMC), which occurs every 2–3 hours. This cycle, described by Wilson and Washington, consists of four sequential phases:

1. **Phase I (Basal Phase):** A period of minimal or absent contractions lasting 40–60 minutes.
2. **Phase II (Pre-burst Phase):** Characterized by intermittent contractions and increasing electrical activity for another 40–60 minutes.

3. **Phase III (Burst Phase):** A short, intense contractile phase lasting 4–6 minutes, responsible for sweeping undigested material from the stomach into the small intestine; hence known as the *housekeeper wave*.
4. **Phase IV:** A brief transitional period (0–5 minutes) linking Phase III and the next Phase I.

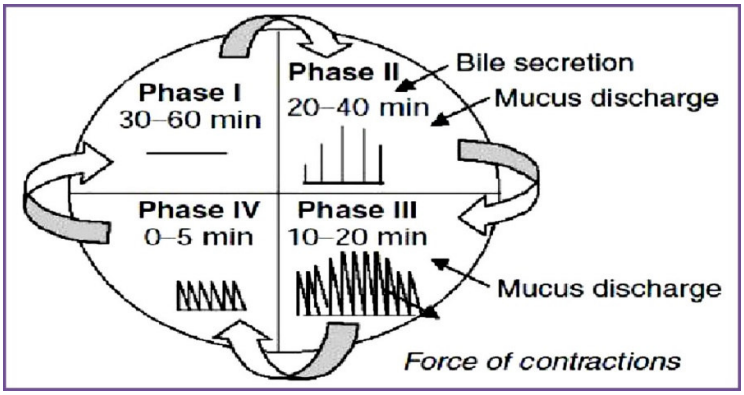

Figure 2: Motility Pattern in GIT.

After food intake, the MMC is replaced by a fed-state motility pattern, consisting of continuous contractions similar to Phase II, which help break food into particles smaller than 1 mm and slow gastric emptying.

Need for Gastric Retention Systems

Gastro-retentive formulations are particularly useful in the following situations:

- Drugs absorbed primarily in the upper gastrointestinal tract (stomach and proximal small intestine).
- Drugs unstable or poorly soluble at alkaline pH, which benefit from prolonged gastric exposure.
- Medications requiring controlled or site-specific release in the stomach or upper GIT.
- Therapies targeting gastric infections, such as *Helicobacter pylori*–induced ulcers.
- Drugs affected by variable gastric emptying, where maintaining a constant gastric residence time improves therapeutic outcomes.

Principle of Buoyancy for Floating Systems

To remain buoyant, a floating dosage form must generate enough upward force to counter its own weight. The floating force is expressed as:

$$F = (DF – DS) \times g \times v$$

Where:

- F = net upward force,
- DF = gastric fluid density,
- DS = dosage-form density,
- v = volume of the system,
- g = gravitational acceleration.

A positive value of F ensures the system floats efficiently atop gastric contents.

Importance of Gastro-Retentive Dosage Forms

Modern research increasingly focuses on developing gastro-retentive systems (tablets, capsules, microspheres) that remain in the stomach for prolonged and predictable durations. These systems enhance drug absorption, improve bioavailability, reduce dose frequency, and provide more consistent therapeutic activity

CLASSIFICATION OF FLOATING DRUG DELIVERY SYSTEM

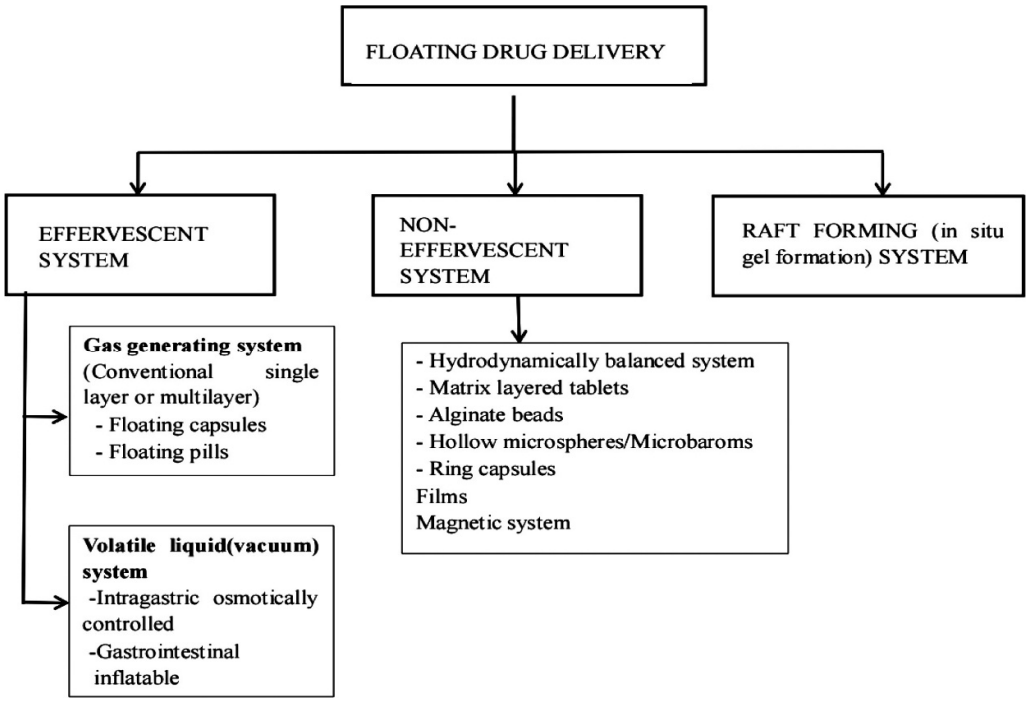

Figure 3: Classification of floating drug delivery system.

1. Floating Drug Delivery Systems (FDDS)

These systems remain buoyant on gastric fluid without affecting gastric emptying.

A. Effervescent Systems

Use gas-generating agents (e.g., sodium bicarbonate) to produce CO_2 for floatation.

Types:

Gas-Generating Systems

- Single-layer floating tablets
- Bilayer floating tablets
- Multiple-unit floating pills
- Floating capsules
- Floating beads (alginate- based)

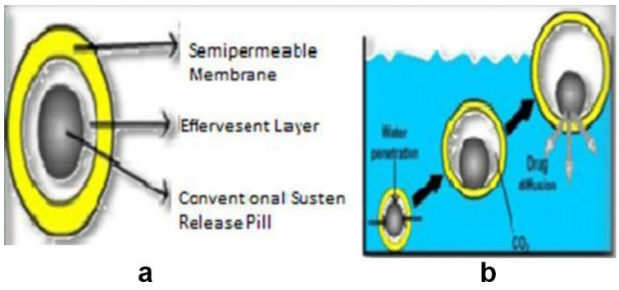

Figure 4: Effervescent Systems

Volatile Liquid/Vacuum Systems

- Intragastric Floating GI System
- Inflatable GI Delivery System
- Intragastric Osmotically Controlled System.

B. Non-Effervescent Systems

Use swellable, gel-forming, or low-density polymers for buoyancy.

Types:

- Hydrodynamically Balanced Systems (HBS)
  - Single-layer matrix tablet
  - Bilayer tablet
  - Tri layer tablet
- Alginate beads
- Hollow microspheres / micro balloons
- Matrix tablets
- Ring capsules
- Magnetic floating systems

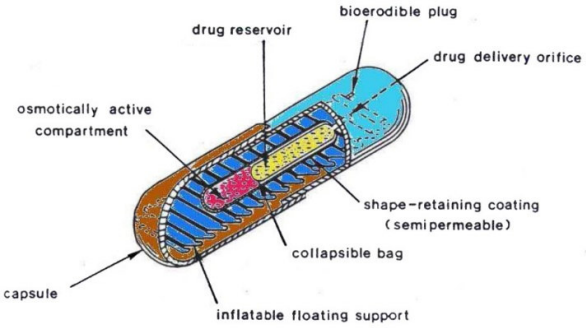

Figure 5: Non-Effervescent System.

2. Raft-Forming Systems

Generate a floating viscous gel "raft" when in contact with gastric fluid. Used mainly for **antacids** and **H. pylori** therapy.

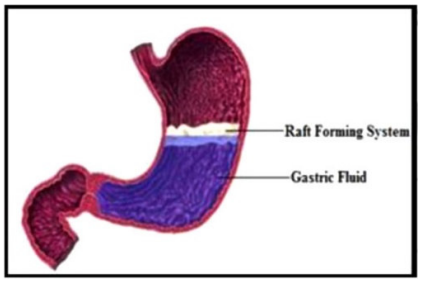

Figure 6: Raft-Forming Systems.

3. Other Gastro-Retentive Approaches Mentioned in Your File

Although the focus is on floating systems, your PDF also includes:

- **Magnetic Systems** – Retained by an external magnetic field.
- **Low-Density Systems** – Made from porous or foam-like materials.
- **Swelling / Expandable Systems** – (Briefly referenced under polymer hydration concepts.)

METHODS OF PREPARATION

1) Solvent evaporation method

The solvent evaporation method is one of the most common techniques used for preparing floating microspheres and multiarticulate gastro-retentive systems. In this process, the drug and polymer are dissolved in a suitable volatile organic solvent such as dichloromethane or acetone to form a uniform organic phase. This organic solution is then slowly introduced into an aqueous phase containing a stabilizer like polyvinyl alcohol (PVA), which helps maintain the dispersion.

Upon stirring, the mixture forms an oil-in-water (O/W) emulsion, where small droplets of the organic phase are dispersed throughout the aqueous medium. As stirring continues, the organic solvent gradually evaporates due to heat or continuous aeration, leading to polymer solidification around the drug. This results in

the formation of hollow or porous microspheres, which are low in density and capable of floating in gastric fluid.

After solvent removal, the formed microspheres are filtered, washed, and dried, yielding particles with good buoyancy, high drug entrapment efficiency, and controlled-release characteristics. This method is widely used because it is simple, economical, compatible with many polymers (e.g., Eudragit, cellulose derivatives, chitosan, carbopol), and suitable for formulating drugs that require prolonged gastric retention.

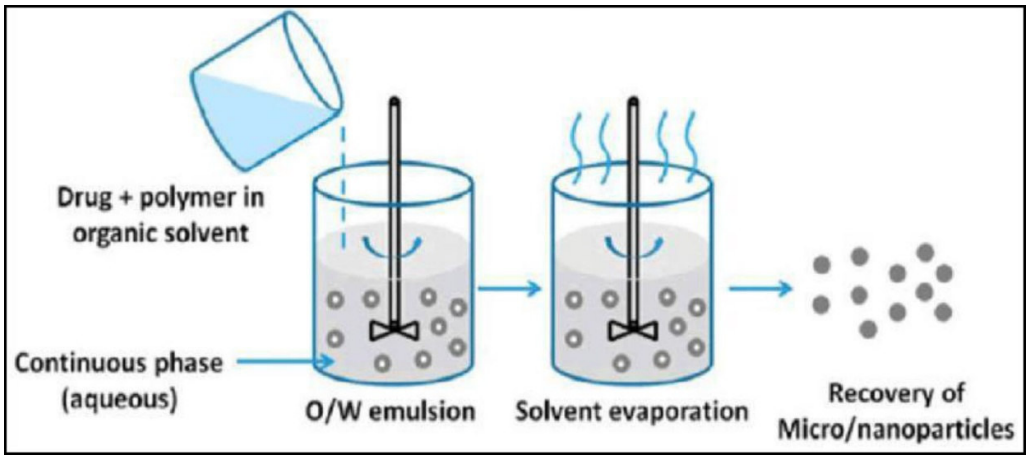

Figure 7: Solvent evaporation method.

2) Ionotropic Gelation Method:

The ionotropic gelation method is a simple and widely used technique for preparing floating beads and microspheres, especially when using natural polymers such as sodium alginate, pectin, or chitosan. In this process, the polymer is first dissolved in water to form a smooth viscous solution, and the drug is uniformly dispersed within this polymer mixture. The prepared solution is then dropped into a cross-linking solution containing multivalent cations such as calcium chloride (Ca^{2+}).

When the polymer droplets come in contact with the calcium ions, an immediate ionic cross- linking reaction occurs. Calcium ions replace sodium ions in the alginate chain, forming a three- dimensional gel network known as calcium alginate beads. This process is called *ionotropic gelation* because gel formation is triggered by ionic interactions.

The formed beads are allowed to harden for a specific time, then collected, washed, and dried. The resulting beads exhibit good structural integrity, controlled drug release, and in many cases, floatation properties when internal pores or gas-forming agents are included. Ionotropic gelation is preferred due to its mild conditions, no need for organic solvents, compatibility with sensitive drugs, and ability to produce uniform multiarticulate systems suitable for gastro- retentive delivery.

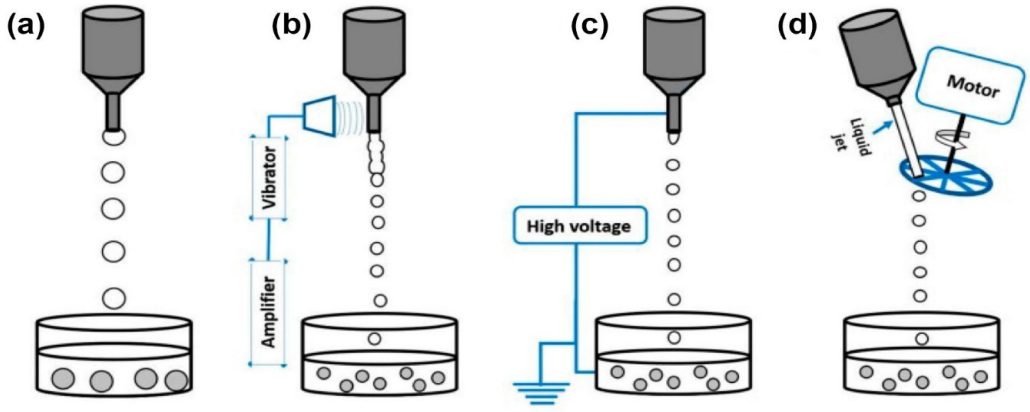

Figure 8:Illustration of dropping devices: (a) conventional dropping method influenced by gravity, surface tension, and viscosity; breaking up of liquid jets into droplets stimulated by (b) vibrating nozzle method, (c) electrostatic forces, and (d) a mechanical.

3) Emulsion solvent diffusion method:

The emulsion solvent diffusion method is a commonly used technique for preparing floating microspheres and hollow micro balloons. In this process, the drug and polymer are dissolved in a mixed solvent system containing both a volatile organic solvent and a partially water-miscible solvent (e.g., ethanol–dichloromethane or acetone–ethanol). This organic phase is then emulsified into an aqueous medium containing a stabilizer such as polyvinyl alcohol (PVA), forming a fine oil-in-water (O/W) emulsion.

When the emulsion is stirred, the water-miscible component of the organic solvent diffuses out into the aqueous phase, while the less miscible solvent slowly evaporates. This dual process of solvent diffusion and evaporation causes the polymer to precipitate at the droplet interface, gradually forming porous or hollow microspheres encapsulating the drug. These micro balloons typically exhibit low density, allowing them to float in gastric fluid for extended periods. After solidification, the particles are filtered, washed, and dried, yielding uniform microspheres with good buoyancy and controlled drug-release behaviour. The method is widely used because it allows precise control over particle size, porosity, and floatability, and works well with polymers such as cellulose acetate, Eudragit, polycarbonate, pectin, and alginate.

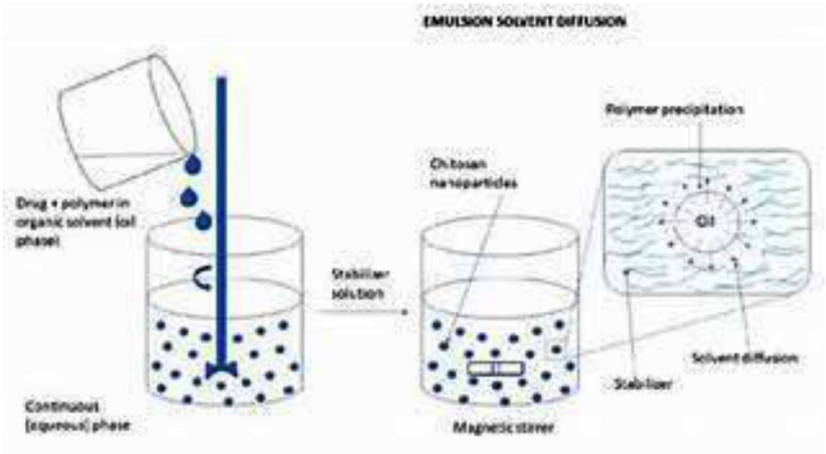

Figure 9: Emulsion solvent diffusion method.

DRUGS FORMULATED AS SINGLE AND MULTIPLE UNIT FORMS OF FLOATING DRUG DELIVERY SYSTEM:

Table 1:

Product Name	Drug / Active Ingredient	Type of Floating System	Therapeutic Use
Madopar® HBS	Levodopa Benserzide	Hydrodynamically balanced capsule	Parkinson's disease; prolonged drug release
Valrelease®	Diazepam	Floating capsule	Anxiety, insomnia; extended overnight effect
Topalkan®	Aluminium–Magnesium antacid	Low-density floating Suspension	Gastric acidity, reflux
Gaviscon®	Alginate-based antacid	Raft-forming floating gel	GERD and reflux management
Cifran OD®	Ciprofloxacin ER	Gastric-retentive / floating matrix	Bacterial infections;
Almagate Flatcoat®	Almagate	Floating suspension	Antacid for gastric discomfort
Cytotec®	Misoprostol	Floating /gastro-retentive system	Gastriculcer prevention
Liquid Foaming Antacids	Alginate or foam-forming agents	Raft-forming floatation	Hyperacidity, GERD

POLYMERS UESD IN FLOATING DRUG DELIVERY SYSTEM:

Table 2. List of polymers

Category	Polymer Examples	Functional Role in FDDS
1. Hydrophilic Polymers	HPMC (K4M, K15M, K100M), Hydroxypropyl cellulose (HPC), Sodium CMC	Swelling, gel formation, extend drug release
2. Natural Polymers	Sodium alginate, Pectin, Chitosan, Guar gum, Xanthan gum	Gelation, buoyancy improvement, biodegradable matrix
3. Synthetic Polymers	Eudragit RS/RL, Polycarbonate, Polyvinyl acetate, Polyacrylates, Ethyl cellulose	Matrix formation, sustained release, structural stability
4. Effervescent Agents	Sodium bicarbonate, Citric acid, Tartaric acid	CO_2 generation for floating effect
5. Low-Density Polymers	Polypropylene foam powder, Ethyl cellulose	Formation of hollow/porous particles, enhance buoyancy
6. Mucoadhesive Polymers	Carbopol, Polycarbophil, Chitosan	Improve gastric retention through adhesion
7. Coating Polymers	Polyvinyl alcohol (PVA), Eudragit coatings, Shellac	Surface protection, modified release coating
8. Raft-Forming Polymers	Alginate, Sodium alginate + bicarbonate mixtures	Formation of floating raft systems for GERD treatment

EVALUATION PARAMETERS:

The performance and efficiency of Floating Drug Delivery Systems (FDDS) are determined through various in-vitro and in-vivo evaluation parameters. These tests help to assess buoyancy, drug release, and other physicochemical properties essential for the formulation's stability and effectiveness.

Floating Behaviour (Buoyancy Study)

The buoyancy of FDDS is evaluated by measuring the floating lag time (FLT) and total floating time (TFT).

- FLT: The time taken by the dosage form to rise to the surface of the medium after introduction.
- TFT: The total duration for which the dosage form remains buoyant.
- These studies are conducted using 0.1 N HCl (simulated gastric fluid) at 37 ± 0.5 °C.

Swelling Index (SI)

The swelling index indicates the water uptake capacity of the polymer used in FDDS. The dosage form is weighed before and after immersion in 0.1 N HCl at 37 °C.

Swelling Index (SI) =

□□− □ 0

□ 0

× 100

Where:

= weight of the swollen tablet at time *t*

= initial weight of the tablet

Drug Content Uniformity

To ensure uniform drug distribution, the dosage form is powdered, dissolved in a suitable solvent, and analyzed spectrophotometrically (UV or HPLC). The content should be within 90– 110% of the labelled amount.

In-vitro Dissolution Study

Dissolution studies are carried out using the USP Type II (Paddle) apparatus with 0.1 HCl (pH 1.2) as the dissolution medium at 37 ± 0.5 °C. Samples are withdrawn at specified intervals, filtered, and analyzed spectrophotometrically to determine the drug release profile.29

In-vitro Buoyancy Test

This test determines the floating ability under physiological conditions. The dosage form is placed in 900 mL of 0.1 N HCl at 37 °C. The floating time and integrity of the dosage form are visually observed.

In-vivo Evaluation

In-vivo studies confirm gastric retention and bioavailability using: X-ray or Gamma scintigraphy (using $BaSO_4$ as a marker)

Pharmacokinetic studies in animals or humans

These tests evaluate the gastric residence time, drug absorption, and plasma concentration profiles.

Hardness and Friability

These tests assess mechanical strength:

- Hardness: Measured using a Monsanto or Pfizer hardness tester.
- Friability: Determined using a Roche Friabilator; acceptable loss is < 1% of total weight.

Weight Variation

A sample of 20 tablets is weighed individually and compared to the average weight. The percentage deviation should be within ±5% for tablets weighing more than 250 mg.

Thickness and Diameter

Measured using a Vernier calliper, ensuring uniform dimensions and compression during tablet formulation.

Moisture Content

Moisture can affect floating ability and drug release. It is measured using a Karl Fischer titrator or infrared moisture analyser.

APPLICATIONS OF FLOATING DRUG DELIVERY SYSTEMS

Enhanced Drug Absorption

Floating drug delivery systems are widely used to improve the absorption of drugs that are preferentially absorbed in the stomach or upper small intestine. By prolonging gastric residence, these systems allow the drug to remain in its optimal absorption window for a longer duration.This leads to higher bioavailability and better therapeutic effectiveness. Drugs with narrow absorption windows particularly benefit from this approach. Such systems help overcome the limitations of rapid gastric emptying.

Improved Bioavailability of Poorly Soluble Drugs

FDDS are especially valuable for drugs that have low solubility or degrade rapidly in the alkaline environment of the intestine. By retaining the dosage form in the stomach, the drug can dissolve more effectively in acidic gastric fluids. This enhances dissolution and improves overall bioavailability. Sustained exposure to acidic pH helps stabilize drug molecules. The result is more predictable and efficient drug absorption.

Localized Gastric Delivery

Floating systems are commonly used for the localized treatment of gastric diseases such as gastritis, peptic ulcers, and *Helicobacter pylori* infections. By remaining in the stomach for extended periods, these formulations ensure that therapeutic agents act directly at the site of pathology. This localized action reduces systemic drug exposure and minimizes side effects. Improved drug concentration at the affected site enhances healing. Such systems are essential for effective treatment of chronic gastric conditions.

Sustained and Controlled Drug Release

FDDS assist in delivering drugs at a controlled rate over several hours by remaining in the stomach for prolonged periods. This helps maintain stable plasma concentrations and avoids fluctuations associated with immediate-release formulations. Controlled delivery reduces toxicity and enhances therapeutic outcomes. It is particularly beneficial for medications that require long-term dosing.

These systems contribute to better management of chronic conditions.

Reduced Dosing Frequency & Better Compliance

Since floating systems provide prolonged drug release, patients often require fewer doses throughout the day. This simplifies treatment regimens and improves compliance, especially for elderly or chronically ill patients. Reduced dosing frequency helps minimize missed doses. Patients experience more consistent symptom control with fewer interruptions. Ultimately, this improves overall treatment satisfaction and adherence.

INNOVATIVE TECHNOLOGIES FOR FLOATING DRUG DELIVERY SYSTEMS (FDDS):

1. Micro balloon and Hollow Microsphere Technology

Micro balloons, also known as hollow microspheres, are one of the most advanced FDDS approaches. These systems are prepared using solvent evaporation or solvent diffusion techniques, producing particles with an internal hollow cavity. Their low density ensures excellent buoyancy for more than 12 hours. They provide uniform distribution in the stomach and exhibit consistent drug-release patterns. This technology is suitable for drugs requiring extended gastric retention and sustained delivery.

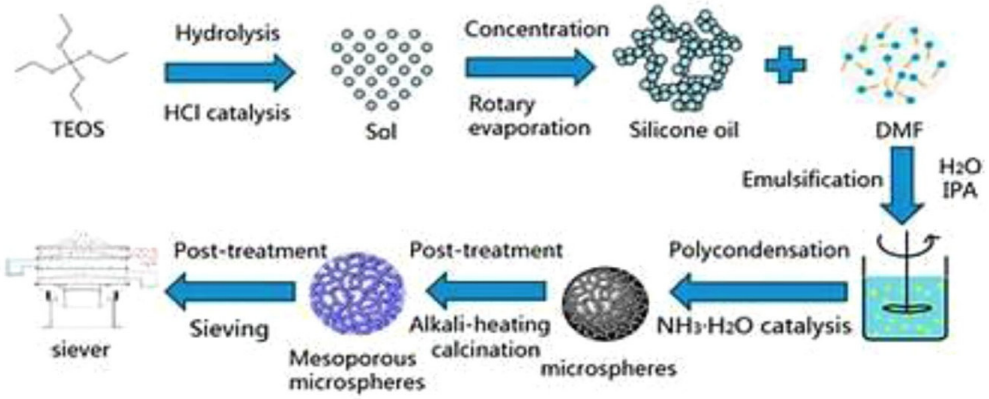

Figure 10: Micro balloon and hollow microsphere technology.

2. Oleotec™ and Soctec™ leotec™ Technology

Oleotec™ is an advanced lipid-based delivery technology designed to enhance the solubility and absorption of poorly water-soluble drugs. It uses optimized oil–lipid matrices that improve drug dissolution in the gastrointestinal environment, resulting in higher bioavailability. Oleotec™ systems offer smooth dispersion in gastric fluids and can be adapted for gastro-retentive formulations by incorporating low-density carriers. This technology is particularly useful for lipophilic drugs that show limited absorption in conventional oral dosage forms.

Soctec™ Technology

Soctec™ is a solid-oil-core technology that stabilizes lipophilic drugs within a solid matrix, allowing controlled release and improved stability. The system contains a solidified lipid core surrounded by polymeric or protective excipients, enabling predictable release kinetics. Because of its low density and structured matrix, Soctec™ can be incorporated into floating drug delivery systems. It enhances drug loading, protects sensitive molecules, and supports sustained release profiles ideal for prolonged gastric retention.

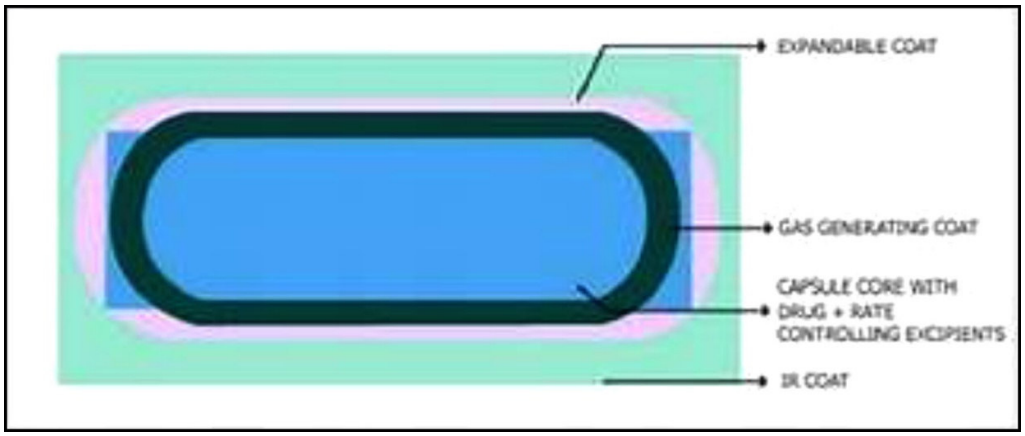

Figure 11: Soctec™ Gastro retentive capsule.

3. Accordion Pill™ Technology:

This is a versatile gastro adhesive formulation composed of the biodegradable polymers. It is a multi-layer, planar structure, folded to an accordion shape into regular standard size capsule. When capsule reaches to the stomach, it dissolves, the folded pill unfolds and is sustained in the stomach last up to 12 hours. During it is in the stomach, the pill releases the drug in a controlled manner towards the proximal part of the GI tract which gives prolonged and continuous absorption phase of the drug in the upper part of the GI tract, resulting in increased efficacy and safety profiling, as well as reducing frequency dosing. The drug release mechanism is not dependent on the Accordion pill™ retention mechanism. After the Accordion Pill™ is expelled from the stomach, it is get degraded in the intestinal media. Drugs which are belonging to the BCS Class II and BCS Class IV are more preferable for this system.

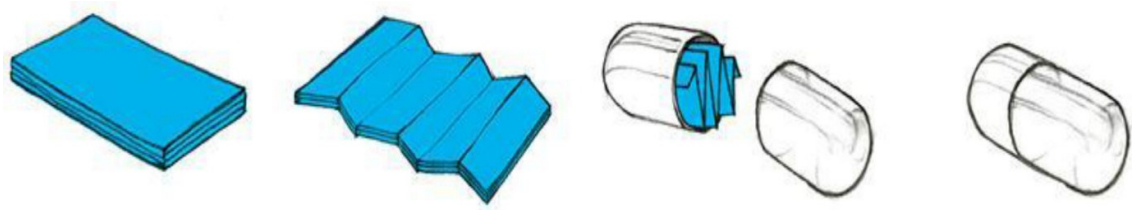

Figure 12: Accordion Pill™ Technology.

4. Multiple Polymers Hydrophilic

Matrix Technology: Multiple polymer hydrophilic matrix technology is a sustained gastro drug delivery system. Cetapin XR is a formulation of this system patented by Sanofi which contain Metformin XR as a drug, to achieve extended release of Metformin hydrochloride. The polymers are made by combining nonionic and ionic hydrophilic polymers. The drug release from the matrix pore occurs through a process of dissolution of the drug and undergoing diffusion through the gel matrix in a sustained manner. This technology gives consistent and reproducible results with good optimal absorption, minimum irritation, increased plasma drug levels and good bioavailability.

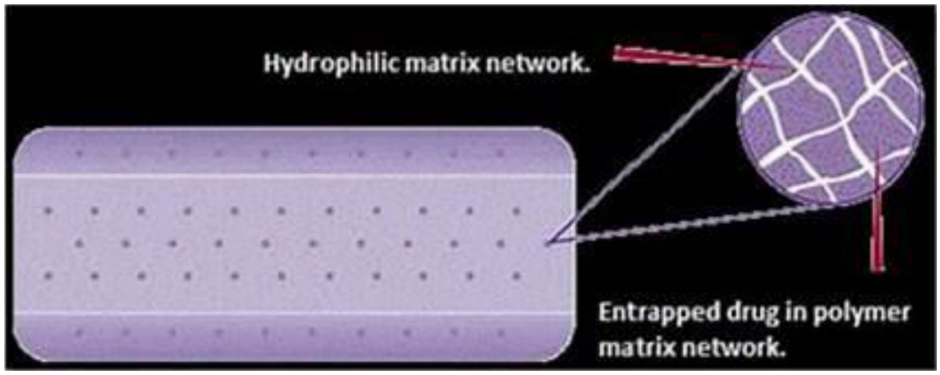

Figure 13: Multiple Polymers Hydrophilic Matrix Technology.

CONCLUSION:

Floating drug delivery systems represent a significant advancement in oral controlled-release technology, offering improved gastric retention and enhanced therapeutic effectiveness for drugs requiring prolonged residence in the stomach. By utilizing innovative polymers, buoyancy mechanisms, and modern formulation techniques, FDDS overcome challenges associated with variable gastric emptying and limited absorption windows. These systems not only enhance bioavailability but also provide site-specific action, reduced dosing frequency, and better patient compliance. Continued research in novel technologies such as micro balloons, 3D-printed systems, lipid-based platforms, and expandable devices further strengthens the potential of FDDS in

modern pharmacotherapy. Overall, floating drug delivery systems provide a promising approach for achieving sustained and targeted drug delivery within the upper gastrointestinal tract.

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