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The Evolution of Safer and Smartest Pesticide Formulation and Delivery System

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Abstract: *This overview explores the major technological shift in the agrochemical industry, moving from simple, harsh chemicals to advanced, high-tech formulations. It explains that a pesticide is not just a 'killer ingredient" but a complex recipe that includes stabilizers and carriers to make the product usable and effective.*

The industry is currently replacing old, dusty powders and toxic, solvent- based sprays with safer alternatives. These modern solutions focus on water-based liquids (like Suspension Concentrates) and dust-free granules that are safer for farmers to handle and friendlier to the environment.

Furthermore, the text highlights the future of crop protection, which relies on nanotechnology (making particles ultra-small for better absorption) and controlled-release systems (microscopic shells that release the chemical slowly over time). Combined with precision tools like drones and seed coatings, these advancements allow farmers to use lower doses of chemicals while achieving better pest control and minimizing environmental impact.

Keywords: *agrochemical industry*

I. INTRODUCTION

- The Evolution of Crop Protection

• The history of protecting crops has changed dramatically. We have moved from using advanced organicanic chemicals to creating highly

However, the Active Ingredient (AI)— the actual chemical that kills the pest— is only a small part of the final product. A complete pesticide is a recipe (formulation) that mixes the AI with "inert ingredients" (helpers) like solvents, stabilizers, and emulsifiers.

- Why Are These "Helper" Ingredients Important?

- The AI often cannot work alone. These added ingredients are critical because they:

• take the AI Usable: Many active ingredients do not dissolve in water or break down easily. Formulation turns them into a stable liquid or powder that farmers can actually store and use.[2*

• Boost Performance: They help the chemical spread across leaves, stick to the pest, and stay active longer.[2*

• Improve Safety: Modern mixtures replace dangerous, flammable chemicals with safer options like water or vegetable oils.[2*

Help with Spraying: They ensure the mixture flows smoothly through spray nozzles without clogging or blowing away in the wind (drift).[2*

The Shift to Modern Technology For a long time, the market relied on Emulsifiable Concentrates (EC) and Wettable Powders (WP). However, these often used harsh solvents or created dangerous dust. To protect the environment and human health, the industry has shifted toward new technologies.[2*

- The Main Goals of Modern Formulations:

• Lower Dosage: Using less chemical to achieve the same result.[**

• Better Efficiency: Ensuring more of the chemical actually hits the target (bio-efficacy).[**

• Eco-Friendly: Reducing chemical runoff into soil and water.[**

• Safety: Protecting the farmer and the consumer.[**

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I] Modern Pesticide Formulations :-

The industry is moving away from dusty powders and chemical solvents. The focus is now on water-based liquids and dust-free solids.[°*

I. I Water-Based Li"qui"d Systems . - Water is the safest carrier for chemicals. These formulas use special stabilizers to keep the active ingredient mixed evenly.[°*

1.1.1 Suspension Concentrates (SC)

• What it is: Solid active ingredients are ground into tiny particles (1-10 microns) and suspended in water, similar to how medicines like liquid antibiotics are made.[°*

• Why it s better: It replaces old, dusty powders. It is non-flammable, easy to handle, and the small particles cover the plant surface better.[°*

1.1.2 Emulsions in Water (EW) and Microemulsions (ME)

• What it is: Instead of dissolving chemicals in harsh solvents, the active ingredient is dissolved in a small amount of oil and then mixed into water.[°*

• Microemulsions (BE): These are advanced versions where the oil droplets are incredibly small (less than 0.1 microns). This makes the liquid look clear like water rather than milky.[°*

• Why it s better: They eliminate dangerous fumes and solvents. The tiny droplet size helps the plant or pest absorb the chemical much faster.[°*

I.2. Improved Dry Products . - These are solid formulations designed to dissolve instantly in water without creating dust clouds.[5*

1.2.1 Water Dispersible Granules (WG) / Dry Flowables (DF) :

• What it is: The chemical is compacted into small, sand-like granules. When thrown into a water tank, they break apart immediately into fine particles.[**

• Why it s better: They are dust-free (safer for the far measure, and take up less storage space than bulkys),easy to

Solubility of Sugar

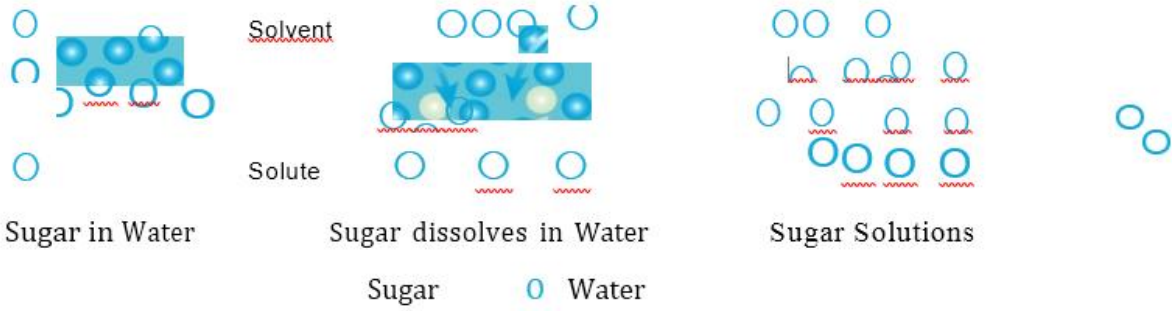

Figure 1.2.1

Tht tough pests, scientists mix two different active ingredients into one

• Example (Suspoemulsion - SE): This mixes a solid particle (SC) and an oil droplet (EW) in the same liquid.[

• Benefit: The farmer doesn't have to mix different bottles manually ("tank-mixing"), making the job easier and faster.[1'*

2] Advanced Delivery SYstems:-

The next generation of technology focuses on "smart" delivery—putting the chemical exactly where it is needed and releasing it slowly.[11*

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2. I. Controlled-Release (CR) Systems :- These systems release the chemical slowly over time, rather than all at once.[12*

2.1.1. Microencapsulation (CS):

• How it works: The active ingredient is trapped inside a tiny microscopic shell (a capsule).[12* The shell breaks down slowly or lets the chemical seep out over days or weeks.[12*

• Benefits:

o Lasts Longer: One spray does the work of several because the chemical is protected from the sun and rain.[13*

o Safer: The toxic chemical is sealed inside the shell, reducing the smell and danger to the person spraying it.[1°*

Microencapsulation

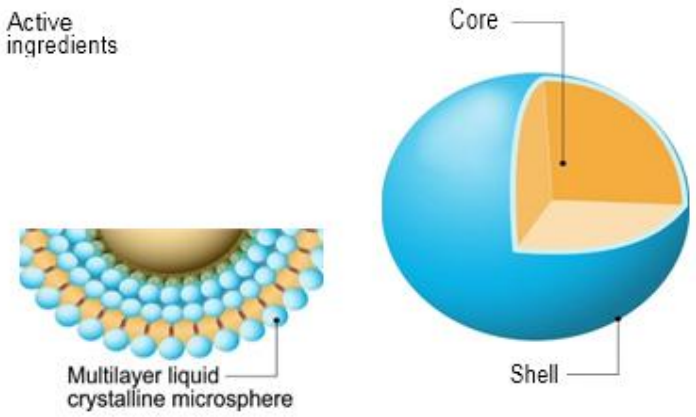

Figure 2.1.1

2. 2 Nano technology .“- This involves shrinking particles down to the nanometer scale (extremely tiny).[15*

2.2.1 Nano-emulsions and Nano-suspensions

• How it works: By making particles super-small, the total surface area increases massively.[1**

• Benefits: The chemical sticks better and penetrates deep into the plant or insect, meaning you can use far less chemical for the same effect.[1’*

2.2.2 Nanocarriers

• How it works: The chemical is loaded onto tiny nanoparticles that act like delivery trucks.[1®*

• Targeted Delivery: Scientists hope to program these carriers to stick only to a specific pest or weed, leaving harmless bugs and plants alone.[1’*

2.S Smarter Application Methods .“- It isn't just about the chemical: it's about how we apply it.[2’*

2.3.1 Drone Application

• How it works: Drones use GPS and maps to find exactly where the pests are.[21*They spray only the infected spots, not the whole field.[22*

• Benefit: This is known as "Precision Agriculture." It drastically reduces the amount of chemical used.[2**

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Figure 2.3.1

2.3.2 Seed Treatments

• How it works: The pesticide is coated directly onto the seed before planting using special polymers.[2°*

• Benefit: The baby plant is protected from the moment it starts to grow.[25*Because the chemical is on the seed, it doesn't get sprayed into the air or soil unnecessarily.[2**

Conclusion: -

6 The Future of Pesticides is Safer and Smarter

6 The world of crop protection is undergoing a major revolution. The basic function of pesticides—killing pests—hasn't changed, but how we deliver them has.

6 The key takeaway is a dramatic shift away from old, harsh formulas that relied on dusty powders and toxic solvents, toward safer, smarter, and more efficient systems.

Here's the summary of this transformation:

• From Toxic Solvents to Water: Modern formulations primarily use water (like Suspension Concentrates - SC) or replace harsh solvents with tiny, safe oil droplets (Emulsions in Water - EW). This is safer for the environment and the people who apply the chemicals.

• From Dust to Granules: Dusty powders have been replaced by Water Dispersible Granules (WG), which are safer to handle and measure because they dissolve quickly in water without creating dust.

• The Power of Precision Delivery: The most advanced step is using Controlled-Release (CR) systems like Microencapsulation . This works like a time-release medicine, protecting the chemical and releasing it slowly so one application lasts much longer.

• The Nanotech Edge: Making particles incredibly small (Nanotechnology) ensures the chemical is absorbed better and you need less of it to do the job.

• Smart Application: Technologies like drones and seed coatings ensure the pesticide is only used exactly where and when it is needed, drastically reducing overall chemical use and minimizing environmental impact

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