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Commonly Available Commercial Insecticide Formulations and Their Applications in the Field

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Abstract

The objective of this article is to know the types of formulations, familiar with the major families of pesticides side by side their modes of action, what to consider in choosing the best formulation along with when to use various formulations and compatibility. Generally, the formulations are commercially produced for drugs, cosmetics, coatings, dyes, alloys, cleaning agents, foods, lubricants, fuels, fertilizers, pesticides and many others. Nevertheless, pesticides also come in various formulations and formulations enable the pesticide to be applied, but, insecticides specifically kill insects and are just one of many types of pesticides. An insecticide formulation can be principally a wettable powder (WP), soluble powder (SP), or emulsifiable concentrate (EC). These formulations are relatively easy to handle, transport, store, little agitation is required, do not settle out or separate when equipment is running, non-abrasive, cannot plug screens or nozzles, and leaves little visible residue on treated surfaces. Insecticide formulations are broken-down into active ingredients and inert ingredients. The active ingredients in insecticide are the chemicals that control the target pest upon application. Most insecticide products have inert (inactive) ingredients, which are used to dilute the pesticide or to make it safer, more effective, easier to measure, mix, or apply, and more convenient to handle. In that sense a formulation may be created according to the standard of the product for any of the purposes such as to achieve effects that cannot be obtained from its components when these are used singly, achieve a higher degree of effectiveness, facilitate any potential synergistic action of their components, and improve handling properties and often safety for the user. Some insecticides can be mixed together (i.e., these are compatible with each other); not all insecticides can be mixed together (incompatible) because these separate out of the solution, gel, curdle, or clog the equipment during application; and insecticides that are physically different (i.e., dust versus liquid) are typically incompatible. Consequently, the competently designed formulations for particular applications are safer, more effective and more economical than any of their components used singly.

Keywords

Formulation, Insecticide, Pesticide, Compatibility, Concentration

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1. Introduction

Formulation is a term used in various senses in various applications, and its fundamental meaning is the putting together of components in an appropriate relationships or structures, according to a formula. Pesticides are available in various formulations and a formulation is simply the form of a specific product that is used. The biological activity of a pesticide is based upon its chemical or biological nature and determined by its active ingredient (Ai also called the active substance). The Ai is usually formulated with other materials and this is the product as sold, but it may be further diluted for use. Formulation improves the properties of a chemical for handling, storage, application and may substantially influence effectiveness and safety (Burges, 1998).

By far, the most frequently used products are formulations

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for mixing with water and then applying as sprays. Water miscible, older formulations include EC-Emulsifiable concentrate, WP-Wettable powder, SL-Soluble (liquid) concentrate, SP-Soluble powder etc. Newer, non-powdery formulations with reduced or no use of hazardous solvents and improved stability include, SC-Suspension concentrate, CS-Capsule suspensions and WG-Water dispersible granules. Other common formulations include granules (GR) and dusts (D), although for improved safety the latter has been replaced by microgranules (MG) e.g., especially for rice. Specialist formulations are available for ultra-low volume spraying, fogging, fumigation, etc. Very occasionally, some pesticides (e.g., malathion) may be sold as technical material (TC), which is mostly Ai, but also contains small quantities of, usually non-active, by-products of the manufacturing process. A particularly efficient form of pesticide dose transfer is the seed treatment and specific formulations have been developed for this purpose. Further, a number of pesticide bait formulations are available for rodent pests control (Knowles, 1998; Sarwar, 2012).

Pesticides are derived in several diverse formulations owing to discrepancies in the solubility, capability to manage the pest, and easiness in handling and transporting of the active ingredients. A pesticide formulation is a mixture of chemicals which effectively controls a pest. Formulating a pesticide involves processing it to improve its storage, handling, safety, application, or effectiveness (Ware, 1994).

The pesticide formulation is a mixture of active and other ingredients (previously called inert ingredients). An active ingredient is a substance that prevents, kills, or repels a pest or acts as a plant regulator, desiccant, defoliant, synergist, or nitrogen stabilizer. Synergists are a type of active ingredient that are sometimes added to formulations. These enhance another active ingredient's ability to kill the pest while using the minimum amount of active ingredient, but do not possess pesticidal properties themselves (Label Review Manual, 1998). For reducing incompatibilities of flowable, wettable powder, and water-dispersible granule formulations, regular shaking is needed (University of Nebraska Cooperative Extension Service, 1992).

The pest needs to be identified and information on how the pest feeds, its reproductive habits, and its life cycle can help the manufacturer to determine which formulation would be the most effective (Farm Chemicals Handbook, 1997). The type of surface, training, equipment, runoff, drift, habits of the pest, and safety are all considered when a manufacturer designs a pesticide formulation (Oregon Pesticide Applicator's Manual, 1993). There are many types of other ingredients, solvents are liquids that dissolve the active ingredient, carriers are liquids or solid chemicals that are added to a pesticide product to aid in the delivery of the active ingredient, and adjuvants often help to make the pesticide stick to or spread out on the application surface i.e., leaves. A pesticide formulation typically consists of an active ingredient, plus several inactive materials called adjuvants or additives. The main purpose of additives is to increase the effectiveness of the active ingredient. Some common additives include spreaders, stickers, wetting agents, compatibility agents and foaming agents (Terms of the Environment, 1997).

2. How to Choose a Formulation

Any given active ingredient can often be purchased in more than one formulation, for example, the active ingredient Deltamethrin is available as a granule, a suspension concentrate, a dust and an aerosol, thus, the same active ingredient is available in four different products. The reason for this is that different formulations of the same active ingredient behave differently. Therefore, a deltamethrin dust is perfect for application into wall voids where it coats the inner wall and controls crawling pests, while deltamethrin aerosol is more suited towards contact control of flying pests. Knowing the characteristics of a given formulation can help to choose the right product for needs and use that product more effectively. Here are some points to consider when choosing a formulation and this information can usually be found on the product label. When choosing a formulation some points to consider are percent of active ingredient, ease in handling and mixing, personal safety risk, type of environment (agriculture, forest, urban, etc.), effectiveness against the pest, habits of the target pest, the crop to be protected, type of application equipment or machinery, danger of drift or runoff, possible injury to crop, and cost of product (Pimentel, 2005).

3. Formulation Process

This is usually accomplished by grinding the material to a powder or dissolving it in a petroleum solvent. The toxicant may then be diluted with other substances to make the desired formulation and is then known as the active ingredient (Ai). The other substances which are added to the formulation are called adjuvants. An adjuvant is anything that enhances the physical properties of an active ingredient or by itself it may have no killing properties. Some examples are xylene, talc, flour and bran. The preparation and use of pesticide formulations also involve the use of various accessory agents such as dusts, diluents, solvents, emulsifiers, wetting and dispersing agents, stickers, deodorants, and masking agents. Accessory agents are given

names that denote their specific actions or enhancement of the formulation, for example, a 'spreader' would help to spread the pesticide over a surface. The physical form in which insecticides are purchased may be either a dry or a liquid formulation. One of the most important components of a formulation is the carrier, and this is the substance which carries the active ingredient of the target surface. Carriers also may be either dry or liquid according to the formulation (Chloe et al., 2015).

4. Different Types of Insecticide Formulations

An insecticide can be manufactured in a variety of formulations, each tailored for specific applications. In the commercial development of insecticides, one of the first steps that a manufacturer employs is to chemically produce the compound in a form which is called the 'technical grade material'. This technical grade material or toxicant may be sold in forms such as crystals, or powder, or in a liquid or gas systems. Since it is not normally used in these forms for insect control, the technical grade material must be formulated (Rathburn, 1985). Here are some of the most common kinds of pesticide formulations available, along with a description to have a better understanding of what these are.

4.1. Dry Formulations

The commonly used dry formulations are dusts, granules, baits, wettable powders and soluble powders (Sarwar et al., 2007; Sarwar, 2013; Ahmad et al., 2011). Some of the more important information on common dry formulations include:-

4.1.1. Granules (G) or Pellets (P)

Granule is a pesticide in the form of pellets, all of which are larger than dust particles. A granular formulation is dry and ready-to-use, and is made of small amount of pesticide and an inert carrier, and the active ingredient is mixed with, absorbed, adsorbed, or pressed on or into the inert carrier. Coarse particles (e.g., clay, ground corn cobs, or walnut shells) can serve as a carrier for certain types of insecticides. Various other types of inert clay pellets and peanut hulls are often used as the diluent or carrier. The toxicant is applied to it, and adheres to these granules. The toxicant slowly leaches out of the carrier, minimizing its movement within the ecosystem and maximizing its active life (persistence). Granular formulations are commonly used for controlling soil-dwelling insects and in systemic insecticides that are applied around the base of plants. Since, granular formulations do not blow or drift, so, these are considered relatively safe from the standpoint of accidental human exposure. Granules are large particles and dry formulations that usually contain two to twenty percent active ingredient. Granular formulations are easy to apply and do not drift as readily as other formulations. Granules are used widely for spot and broadcast soil applications and are often applied at planting time to protect the roots from soil insects.

4.1.2. Dusts (D)

These dry powders are usually formulated with inert particles of ash, chalk, talc, or clay. These are designed to be sprinkled or blown onto target surfaces. The powder sticks to feet, legs and other body parts of passing insects, and the toxicant is eventually ingested when the insect cleans itself. Insecticides that act as stomach poisons are often formulated as dusts. These formulations are not always suitable for outdoor applications because these have a tendency to drift away (blow with the wind). Dusts are in a dry, powdered form and usually contain from one-half to ten percent. Most of the material in this formulation is an inert clay diluent or carrier. Dusts do not always adhere well to plants or animals or structures; and these are extremely subjected to drift by the wind, therefore posing a greater toxic hazard to the applicator and the environment than many other types of formulations. For these reasons, dusts are usually recommended only for localized application, home control programs and storage system. Dilute dusts are used mainly as grain protectants, commonly used for interior wall void and perimeter treatments, as well as for crop-dusting.

4.1.3. Poison Baits (B)

Poisonous baits are food-like substances mixed with a pesticide specifically designed to attract and be eaten by insects or other pests and eventually poison them to death. The poison baits consist of a base or carrier material attractive to the pest species and a chemical toxicant in relatively small quantities. Baits contain a low percentage of active ingredient ranging from 1/4 to 5%. The toxicant is mixed with various carriers or attractants such as bran, orange pulp, corn cobs and sugars. Baits are commonly used for rodent control, including mice and rats, however, also used to control other insects. The poison baits are also used for the control of fruit flies, chewing insects, wireworms, white grubs in the soil, household pests like roaches, and slugs. Baits are also commonly used for subterranean soil pests such as ants, mole crickets and cutworms. Bait formulations can be used indoors or outdoors and are placed or scattered where these can be consumed by the target pests.

4.1.4. Wettable Powder (WP or W)

A dry (powder) preparation that is mixed with water to form a suspension is used for spraying. Unlike a soluble powder, it does not dissolve in water. Suspensions must be added to

tanks that have already been partially filled with water, and the mixture must be agitated in some way to avoid lumpy formulations that can clog nozzles and result in improper application. The Ai in a wettable powder usually ranges from 25 to 75%. The Ai is essentially a concentrated dust which has been finally ground to a powder mixed with a fine clay like diluent or carrier. While a WP is a dry formulation, it is mixed with water which acts as the secondary carrier. Most Ai of a WP formulation is immiscible with water and this incompatibility is overcomed by adding a bipolar compound such as a wetting agent. The wetting agent ties the Ai and diluents with the water carrier to form a suspension. However, this WP suspension is unstable and it must be constantly agitated to prevent settling and ensure its desired effectiveness.

4.1.5. Soluble Powder (SP)

This is a dry preparation of finely-ground powder containing a relatively high concentration (15%-95%) of active ingredient that dissolves in water (or another liquid) and forms a solution so that it can be applied. A soluble powder dissolves completely in water, whereas a wettable powder contains an emulsifier that produces a uniform suspension (colloid). Many foliar insecticides are formulated as wettable (or soluble) powders because these are easy to transport and generally have a long shelf life. These are finely ground, highly concentrated powders and the powder is soluble in water and needs no wetting agent. Simple mixing of powder with water forms the spray. The potentially hazardous concentrated material is packaged in a soluble bag, and the entire package is placed into spray tank with water.

4.1.6. Water-Dispersible Granules or Dry Flowables (WDG or DF)

Water-dispersible granular formulations are like wettable powder formulations, except the active ingredient is prepared as granule-sized particles. Dry flowables are very similar to granules in appearance, but behave in the same way as wettable powders. Dry flowables have several advantages over WPs because of their shape: these can be easily ‘poured’ and measured just like liquid, and are safer to use because very little dust is released into the air when they are mixed and measured. This very finely ground solid material which is suspended in a liquid; usually contains a high concentration or large amount of the active ingredient and must be mixed with water when applied.

4.1.7. Insecticides Fertilizers Mixtures

The mixture generally constitutes addition of a granular insecticide to chemical fertilizer or spreading of insecticide directly on to the fertilizer. These are applied at the regular fertilizing time and provide both plant nutrients and control of soil insects. Urea 2% solution is mixed with compatible insecticidal emulsions and sprayed for supply of nitrogen to the plant and for realizing effective pest control. Many pesticides are rapidly broken down when mixed with fertilizers.

4.2. Liquid Formulations

Most insecticides that are applied as liquid or spray use water as the carrier (Akbar et al., 2011; Sarwar et al., 2011). Primarily, the following liquid formulations will be discussed;-

4.2.1. Emulsifiable Concentrates (EC)

These liquid formulations contain the toxicant (s) and an emulsifier dissolved in organic solvent. The concentrate is diluted with a large volume of water to produce the final spray mixture. Some foliar insecticides are formulated as emulsifiable concentrates. Unlike most wettable powders, these do not leave a visible residue on fruits and vegetables. Sensitive plants, however, may be injured by organic solvents in the mixture. Emulsifiable concentrates are also commonly used in sprays for urban and industrial pests. The Ai is dissolved in a petroleum solvent such as xylene and an emulsifier which allows the material to mix with water. The percentage of the emulsifying agent which is present in the insecticide is indicated by the inert ingredients. Emulsifers and wetting agents are bipolar in that one end is hydrophobic and other end is hydrophilic. The EC when mixed with water, forms a milky colored emulsion, this is generally stable for a period of several hours without agitation and should only be mixed in quantities that will be used immediately. The EC are used for treating storage structure or fabric, external bag surfaces and disinfecting transport facilities.

4.2.2. Ultralow Volume Concentrates (ULV)

These are both a formulation and an application technique, and are highly concentrated formulations (more than 8 pounds of active ingredient per gallon) designed to be used in specialized spray equipment that atomizes the concentrate droplets. The ULV spray equipment is used by most aerial applicators (airplane sprayers) that treat forested lands or large agricultural acreages. These kill the pest directly, usually by exposing it to lethal substances or unsuitable environmental conditions. These reduce the reproductive potential of a pest population often by modifying its environment (biotic or abiotic) or by restricting its movement. These modify the pest's behavior to make it less troublesome (attract, repel, confuse, exclude and mislead it). These are usually sold as technical grade materials and not further diluted before application by special spray equipment. The extremely fine spray is applied at rates as low as one-half pint to one-half gallon per acre.

4.2.3. Oils

These are sprays in which oil itself is the ingredient. The oil may be refined to reduce phytotoxity to plants and is usually mixed with an emulsifier so water may be used as the carrier. The percentage of oil in this type of formulation may range from 1 to 99%.

4.2.4. Flowable Suspensions (F)

Flowable suspensions are an ingenious solution to a formulation problem. Earlier, it is stated that some insecticides are soluble in neither oil nor water, but are soluble in one of the exotic solvents, making the formulation quite expensive. To handle the problem, the technical material is blended with one of the dust diluents and a small quantity of water, leaving the insecticide-diluent mixture finely ground but in wet form. This 'wet blend' mixes well with water and can be sprayed with the same tank settling characteristic as wettable powder.

4.2.5. Solutions and Water Soluble Concentrates (S)

These are liquids in their original state and are fully soluble in water and any other solvent. Solutions that are prepared in the right way will not leave unsightly residues or clog spray nozzles. It is a concentrated liquid pesticide formulation that may be used directly or require diluting. Many of the synthetic organic insecticides are water insoluble but soluble in organic solvents such as amyl acetate, carbon tetrachloride, ethylene dichloride, kerosene, xylene, pine oil etc., which themselves possess some insecticidal properties of their own.

4.2.6. Ready-to-Use (RTU)

These solutions contain the correct amount of solvent when buy and no further dilution is required before application. These formulations, usually in petroleum-based solvents, contain small amounts (often 1% or less) of active ingredient per gallon.

4.2.7. Concentrate Solutions (C or LC)

These must be further diluted with a liquid solvent before to apply, occasionally the solvent is water, but more often the solvent is a specially refined oil or petroleum-based solvent. Some uses include livestock and poultry pest control, space sprays in barns and warehouses, shade tree pest control, as well as mosquito control.

4.2.8. Encapsulated Pesticides

These are a new kind of formulation in which the active ingredient is held in a very small capsule and these capsules are then suspended in a liquid. This formulation of suspended capsules is then mixed with water and maybe applied with a sprayer. Encapsulated pesticides are safe and easy to use, but may pose a threat to bees when these carry the capsules back to their hive.

4.3. Liquefied Gas

These include poisons applied as liquids that turn to gas. Insecticides that are formulated together with a solvent may be pre-packaged in pressurized spray cans or sold unpressurized for use in special fogging machines. Spray cans are relatively expensive (per pound of active ingredient) but these are convenient, easy to store and have a long shelf life. Commercial foggers are typically used indoors (e.g., greenhouses and warehouses) or for control of biting flies in community-wide pest control operations (Rajput et al., 2003; Sarwar et al., 2003).

4.3.1. Insecticides Aerosols (A)

In insecticide aerosol, the toxicant is suspended as minute particles having size ranging from 0.1 to 50 microns in air as a fog or mist. This is achieved by burning the toxicant or vaporizing it with heat. The toxicant dissolved in a liquefied gas, if released through small hole may cause the toxicant particles to float in air with the rapid evaporation of the released gas. Liquefied gas aerosols or bombs are the common method for producing small amounts of aerosols for indoor use. The aerosol is formed by the release of a solution of insecticide in a liquefied gas through a capillary tube with very small diameter. When the nozzle valve is triggered, the pesticide is driven through a fine opening by an inert gas under pressure, creating fine droplets. These products are used in greenhouses, in small areas inside buildings, or in localized outdoor areas.

4.3.2. Formulations for Smoke or Fog Generators

These aerosol formulations are not under pressure and are used in machines that break the liquid formulation into a fine mist or fog (aerosol) using a rapidly whirling disk or heated surface. These formulations are used mainly to control insect pests in structures such as greenhouses and warehouses, and to control mosquitoes and biting flies outdoors.

4.3.3. Fumigant

A chemical compound, which is volatile at ordinary temperatures and sufficiently toxic, is known as fumigant or it is a volatile insecticide that enters an insect via tracheal system. It is a pesticide that enters the pest in the form of a gas and kills it. The fumigant may be a liquid that changes to a gas when it is applied. Methyl bromide, phostoxin, chloropicrin, and carbon bisulfide are examples, and these are gaseous poisons which boil at room temperature. Application is generally limited to plants or products in tight

enclosures or those that can be enclosed in gas-tight tents. Most are highly toxic and must be applied by trained, certified applicator. New formulations of phosphine-generating products have been developed and approved, and phosphine may become the principal fumigant gas. Fumigants are pesticides that form gases or vapors toxic to plants, insects, and microorganisms. Some active ingredients are formulated, packaged, and released as gases; others are liquids when packaged under high pressure and change to gases when they are released. Other active ingredients are volatile liquids when enclosed in an ordinary container and therefore are not formulated under pressure. Some others are solids that release gases when applied under conditions of high humidity or in the presence of water vapor. Fumigants are used for structural pest control, in food and grain storage facilities, and in regulatory pest control at ports of entry and at state and national borders. In agricultural pest control, fumigants are used in soil, greenhouses, granaries, and grain bins.

5. Common Adjuvants

Insecticides contain one or more active ingredients that serve as toxicants (poisons). In their purest form (technical grade), these chemicals may be too toxic, too unstable, or too volatile to be handled or applied safely. Therefore, technical grade insecticide is always mixed with other compounds, known as adjuvants, in order to improve the performance, safety, or handling characteristics of a commercial product. These mixtures (technical grade insecticide plus adjuvants) are known as formulations and may represent 90-95% of the total volume of a commercial formulation. An adjuvant is a chemical added to a pesticide formulation or tank mixed to increase its effectiveness or safety. Most pesticide formulations contain at least a small percentage of adjuvants. Some of the most common adjuvants are surfactants, surface active ingredients that alter the dispersing, spreading, and wetting properties of spray droplets. Adjuvants include wetting agents (allow wettable powders to mix with water), emulsifiers (allow petroleum-based pesticides to mix with water), invert emulsifiers (allow water-based pesticides to mix with petroleum carrier), spreaders (allow pesticide to form a uniform coating layer over the treated surface), stickers (allow pesticide to stay on the treated surface), penetrants (allow the pesticide to get through the outer surface to the inside of the treated area), foaming agents (reduce drift, thickeners, reduce drift by increasing droplet size), safeners (reduce the toxicity of a pesticide formulation to the pesticide handler or to the treated surface, compatibility agents (aid in combining pesticides effectively), buffers (allow pesticides to be mixed with diluents or other pesticides of different acidity or alkalinity), and anti-foaming agents (reduce foaming of spray mixtures that require vigorous agitation).

6. Combining Different Formulations

Compatibility is an ability of two compounds to mix without affecting each other's chemical properties. Sometimes two different insecticide formulations are combined to create a more effective application; however, not all pesticides can be combined safely (Sarwar, 2014; Hina et al., 2015). Insecticides should be mixed in small quantities to test for compatibility problems and check or verify incompatibility using a jar test. The procedure is wearing label-prescribed protective clothing, measuring a pint of intended spray water into a quart glass jar, adding ingredients (in the order, surfactant, compatibility agents and activators, wettable powders and dry flowable formulations, water soluble concentrations and solutions, emulsifiable concentrations and flowable formulations, soluble powders, any adjuvants) and stirring well. For each ingredient (e.g., wettable powder), add 1 teaspoon per unit (pint or pound) per 100 gallons of final spray mixture; after mixing, let stand it for 15 minutes; and stir and observe the results. In case of compatible, smooth mixture combines well after stirring, but, incompatible mixture separates out, contains clumps, and is grainy in appearance (The University of Arizona, 2000).

Before combining various formulations, always check the label and other literature for possible solutions to incompatible mixtures or consult a pest control professional to find out whether the two formulations are compatible. The mixing of two incompatible insecticide formulations may be fatal. Incompatibility can be either chemical or physical and these incompatibilities may be clearly indicated on the product label. However, the pesticide product label can list any chemicals that should not be mixed with (i.e., incompatible with) or containers that should not be mixed in. For example, wettable sulfur should not be mixed with Lorsban or Morestan because these are incompatible (Bohmont, 1990; Khan et al., 2010).

7. Conclusion

This review paper contains a brief discussion of the composition, preparation and use of the various types of insecticide formulations and presents an aid to persons presently engaged in pests control. Formulation involves processing the technical grade material by any method that will improve its effectiveness, storage, handling, safety and ease of application. The composite comprising of the toxic ingredient might be framed in a treatment that is appropriate for consumption in the form of a spray, dust, granule as well

as fumigant. The common formulations of insecticides are detailed in manuscript and some insecticide formulations include dusts, gels, granules, liquids, aerosols, wettable powders, concentrates, and pre-mixed solutions. A single active ingredient is often sold in several different kinds of formulations. To choose the best available formulation for pest control situation, the interrogations about each formulation should base on availability of the necessary application equipment, can the formulation be applied safely under the conditions in the application area (e.g., drift, runoff, wind, rain), can the formulation reach to target and stay in place long enough to control the pest, and is the formulation likely to harm the surface to which it is applied. To answer these kinds of questions, it needs to know something about the characteristics of different types of formulations (liquid, dry, or fumigant) and the general advantages and disadvantages of each type. The rain soon after the application may cause the pesticide or insecticide to run off and contaminate lakes, rivers, streams, or ponds. The wind may carry or drift the insecticide during the application onto adjacent property, bodies of water, peoples, or animals. The specific environmental precautionary statements may be present on the label describing how to avoid runoff or drift of insecticide in the vicinity. This document is intended to be educational in nature and might be helpful to manufacturers or consumers for making decisions about pesticide uses.

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