Pesticide Residues Contamination in Vegetable Crops

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Pesticides are a necessity for crop production whether they may be of chemical or natural origin. They aid farmers to grow more food on less land by protecting crops from pests, diseases, and weeds as well as increasing productivity. Without pesticides, more than half of the crops grown would be lost to pests and diseases. More than 600 kinds of agrochemicals are used around the world. Though, they boosted agricultural production, low amounts of some residues may persist in the food chain, air, water, and soil and could make up a significant exposure pathway for humans. Since the early part of the 1900s, the agricultural industry has been using chemical pesticides. An organochlorine insecticide, dichlorodiphenyltrichloroethane (DDT) was banned the publication of Silent Spring by the biologist Rache l Carson in 1962 (Carson, 1962). Other insecticides like ethylene dibromide in 1983, methyl bromide in 2005, and endosulfan in 2011. During Second World War, German chemists developed a new class of pesticides, organophosphorus (OP) compounds for agricultural use and chemical warfare agents. OP compounds are extensively used in plant protection. They represent up to one-third of world pesticide consumption. It has been reported that compounds which belong to OPs groups are dangerous to human life, owing to their toxic effects such as mutagenic, teratogenic, and carcinogenic effects. OPs exposure is linked to Leukemia, Lymphoma, and Parkinson's diseases. OPs were replacing the more persistent organochlorine compounds which were suspected to be bio-accumulated up the food chain. Due to direct and indirect exposure to pesticides, various forms of contamination in the environment may occur.

Contamination in air

Pesticides contaminate the atmosphere either by application drift, post-application vapor losses, or wind erosion of pesticide-treated soil. Liquid sprays drifted through nozzles from pesticide application providing metering, atomization, and uniform distribution of the pesticide mixture. Breaking the liquid into droplets with the use of hydraulic pressure as the energy source, droplet sizes are usually below 150 µm. It can be used as an indicator of drift potential because these small droplets are most prone to movement under windy conditions. Pesticides treated on the soil surface may be susceptible to transport through wind erosion of soil. Most organochlorine insecticides are found in the air. Atmospheric pesticides are the source of exposure to pesticides through inhalation and the source of contamination of surface/groundwater through dry deposition and precipitation. Atmospheric movement may cause the transportation of pesticides from application sites to sensitive areas and the accumulation of pesticides in the environment.

Effects of pesticides on water

Pesticides can contaminate water bodies via diffuse or point sources and pose a significant threat to aquatic ecosystems and drinking water resources. Surface outflow drain, baseflow seepage, surface and subsurface runoff and soil erosion from pesticide-treated fields, spray drift at application, and deposition after volatilization are the point sources of agricultural pesticides in aquatic systems (Cessna 2009). Even from atmospheric deposition, pesticides are subjected to transport over distances. At any point during transport, they are also subject to the removal processes of wet and dry deposition, both of which contaminate surface waters. Surface waters consist of streams, rivers, lakes, reservoirs, and oceans. Streams and reservoirs supply approximately 50% of the drinking water in the world. Surface waters receive a portion of their water from snow melt or rainfall runoff. Pesticides susceptible to surface runoff are those within the runoff-soil interaction zone or the top 0.5 to 1 cm of soil. Spray drift is the airborne movement of spray droplets of pesticides away from a treated site during application. It is affected by spray droplet size, wind speed, and distance between the nozzle and the

target. It can contaminate water in ponds, streams, and ditches and spoil aquatic life.

Fig 1: Vegetable Sample collection from Ima Market, Imphal, Manipur

Groundwater may be contaminated when pesticides leach from treated fields, mixing sites, washing sites, or waste disposal areas. Pesticides may move with runoff as compounds dissolved in the water or attached to soil particles. The amount of pesticide runoff may leach down or accumulate somewhere. Leaching can be increased when the pesticide is water soluble, the soil is sandy, a rain event occurs shortly after spraying, and the pesticide is not strongly adsorbed to the soil.

Effects of Pesticides on Soil

The adsorption of the number of pesticides in soil depends on the type of pesticide, soil, moisture, soil pH, and soil texture. Soils that are high in clay or organic matter content, adsorbed pesticides strongly. Most soil-bound pesticides are less likely to give off vapors or leach through the soil and are less easily taken up by plants.

Pesticides that are sorbed to soil particles are more likely to remain in the root zone where they may be available for plant uptake and microbial or chemical. Sorption describes the attraction between a chemical and soil, vegetation, or other surfaces. Soils high in clay and organic matter, have a high potential to sorb pesticides. Clay content is also important for holding organic matter degradation (Kerle et al. 2007).

However, microbial degradation of pesticides is the breakdown of pesticides by microorganisms such as fungi, bacteria, and other soil microorganisms. Microbial activity usually is greatest in warm, moist, well-aerated soils with a neutral pH. As the pH of the soil becomes too acidic or alkaline, microbial activity usually decreases. Some portion of the pesticides

Effects of pesticides on plant

Different factors like physicochemical behavior, formulation, droplet size and application technique, precipitation or rainfall and relative humidity, temperature, sunlight, plant species, and physiological differences, e.g. stomata, upper/lower leaf surface, hairs, waxes, and time of application influence leaf uptake and metabolism of pesticides. The degree of plant uptake is determined partially by the pesticide's water solubility. Plant uptake of pesticides prevents runoff or leaching. After treatment, pesticide residues may be broken down or remain inside the plant or animal and be released back into the environment when the animal dies or as the plant decays. Some organochlorine pesticides may remain in the soil long enough to be absorbed by plants grown in a field years later.

Effects of pesticides on human health

All chemical pesticides are toxic when not used in recommended doses in respect of their appropriate crops and pests. Most of organochlorine (OC) is carcinogenic and neurotoxic. They act as endocrine-disrupting chemicals by interfering with molecular circuitry and the function of the endocrine system. The OC, Dichlorodiphenyltrichloroethane (DDT) is still found to be present and it is believed that every living organism on earth has a DDT body burden, mainly stored in the fat cells. The residues of DDT and its highly toxic metabolites, dichlorodiphenyldichloroethylene (DDE) have been associated with neurodevelopmental effects in children. The hazardous nature of organochlorines like endosulfan, which remains in the environment for longer periods and bio-accumulates in plants and animals leads to contamination of food consumed by humans. It affects mainly the central nervous system,

the disproportion of thyroid hormones, etc. OCs were also reported to increase the risk of hormone-related cancers including breast, prostate, stomach, and lung cancer.

Organophosphorous (OPs) compounds have also harmful effects on the nervous system of the affected organisms where they inhibit acetylcholinesterase. OPs compounds or their metabolites are related to cardiovascular diseases and the reduction of the fertility of human beings, which is often linked to a decrease in the level of testosterone.

Carbamate pesticides, such as aldicarb, carbofuran, carbaryl, etc. are also associated with endocrine-disrupting activity which possibly affects reproductive disorders, effects on cellular metabolic mechanisms, and mitochondrial function. It has the ability to cause neurobehavioral effects, increased risk for dementia, and non-Hodgkin's lymphoma.

Synthetic pyrethroids, such as fenvalerate, permethrin, cypermethrin, etc. have also the ability to display endocrine-disrupting activity and affect the reproductive behavior in experimental animals. The insecticides are also associated with DNA damage in human sperm. Neonicotinoid pesticides, such as imidacloprid, thiacloprid, and thiamethoxam, have possible effects on the endocrine and reproductive systems of animals. There are various reports affecting the bee population. The increased expression of the enzyme aromatase, which is engaged in breast cancer was also reported from neonicotinoids.

Acceptable Daily Intake (ADI)

Acceptable daily intake (ADI) is a measure of the amount of a specific substance (originally applied for a food additive, later also for a residue of a veterinary drug or pesticide) to which a person can be exposed on a daily basis over an extended period of time (usually a lifetime) without suffering any detrimental effect. It is expressed in milligrams (of the substance) per kilogram of body weight per day. It relates to daily ingestion because accepted additives should not accumulate in the body. It is based upon the scientific judgment of all facts known at the time of assessment in order to define a limit, below which no harmful effects would be expected. More simply, it may be defined as an intake that is believed to be "without appreciable risk". The higher the ADI, the larger amounts of a compound are harmless for regular ingestion. The ADI does not take into account allergic reactions that are individual responses rather than dose-dependent phenomena. The ADI value can be measured from long-term studies on animals and humans.

No-observed-adverse-effect level (NOAEL) is the highest dose at which there was not an observed toxic or adverse effect. Usually, the studies are performed with several doses including high doses. However, the lowest NOAEL is usually taken. The NOAEL is then divided by a safety factor, conventionally 100, to account for the differences between test animals and humans (factor of 10) and possible differences in sensitivity between humans (another factor of 10).

Maximum Residue Limit (MRL)

MRLs are defined as the maximum concentration of pesticide residue (expressed as milligrams of residue per kilogram of food/animal feeding stuff) that is expected to remain in or on food when the pesticides are used according to good agricultural practice (GAP), i.e. when the pesticide has been applied in line with the product label recommendations and in keeping with local environmental and other conditions. The MRL is generally set at a value determined from supervised field trials. The trial field crop has to be treated with a pesticide. Samples of the crop have to be analyzed to determine pesticide residue levels. If there is no detection of residue as expected, a residue level can be set at the limit of determination (LOD). It is the lowest level at which reliable quantitative analysis can be performed.

Present status of chemical Pesticide Residues in Vegetable Crops

Vegetables like tomato, cabbage, and cauliflower, brinjal, pea, broad beans, French beans, and cowpea were collected from major local markets of Manipur. It has been found that the pesticide residues of chemical insecticides like imidacloprid, fipronil, and chlorantraniliprole above MRL (FSSAI) were detected in vegetable samples. There is a need of creating awareness among the public for the safe use and consumption of raw vegetables by following the available on-farm decontamination techniques. Time has also come forward to apply only the recommended doses at the right time of application by identifying the specific insect pests and their related host crop.

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