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Pesticide exposure and risk assessment of spraying with power sprayer: A review

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Abstract
VMD and NMD of droplets decide the droplet density, uniformity coefficient and relative span. Hence, in order to avoid air pollution may cause due to air floating droplets and soil pollution may be due to dripping droplets, it is very essential to have droplets of optimum size. The droplet parameters *viz*. size, density etc. are governed by nozzle and sprayer operating parameters. Hence, it is essential to optimize the spaying parameters, *viz* droplet size, droplet density, droplet deposition and uniformity coefficient. During the application of spraying due care is not taken particularly in spraying regarding pesticide handling and its application techniques. The harmful effects of pesticides spraying on human health without wearing any protective clothing or safety measures while spraying were resulted into headache 73.8%, skin irritation 62.3%, eye irritation 32.8%, weakness 22.4% and muscle pain 19.1% (Bhandari *et al.,* 2018) [20]. Five to ten lakh people around the world per year have experienced pesticide poisoning and about 500 to 1000 people per year experience fatal effects such as cancer, disability, infertility and liver disorders also dermal exposure accounts for 87 to 90% of total exposure of pesticides. Behind the reasons that mentioned prior latest 2017 poisoning and death report from Yavatmal in Maharashtra, farm laborers not taken precautions regarding any protective clothing, protective masks, goggle, hand gloves, cap, boot, apron etc while spraying pesticides on crops also in spite of this use of unscientifically own experience for rampantly spraying mixtures of various pesticide results new highly hazardous compound. At the time of pesticide application not following any safety provision, time of spraying, same person continuously spraying on large areas which keeps the person in constant touch of the poison therefore catalyzing the process of poisoning in the body. Use of improper pesticide application technique in view of volume of spray applied per unit area, use of ultra-low volume sprayer produce dense mist floating in air for long time gets in more quantity in body through inhalation. Hence considering above points of risk identification in mango spraying in Konkan region is essential. Farming without spraying pesticides unheard of, unless it is organic farming. 70 to 80 per cent people encountered health problems caused due to spraying without wearing protective aids but same was reduced after usage of protective clothing. The use of protective equipment against pesticides is indispensable and essential from the preparation/handling regulations of the pesticides spray to the application of diluted formulations. However, even with this protection, workers are not totally immune to the contamination of pesticides. There are several factors that contribute to the loss of efficiency of protective clothing against pesticides, such as field use of protective clothing, activity of application, type of material, seam presence, clothing model, type of formulation used in the application, the process of washing and the ironing of clothes after their use. Hence to assess the suitability of protective clothing, pesticide extraction which is deposited on user clothing during spraying is necessary.

Keywords: Agricultural sprayer, droplet size, personal protective equipments, pesticide exposure

Introduction
Under pesticide action network (PAN) India, draft pesticide management bill 2017 comprehensive not enough to address issues on pesticides in India. In its comments submitted to joint secretary (Plant Protection), PAN India presented a detailed deliberation on problems, concerns and challenges on the bill. It is a fact that about 50 year old insecticides act 1968, together with insecticides rules 1971, that govern pesticide registration is unable to respond to various hazardous situations, toxicity implications and socio economic issues thrown up by the harmful effects of the dangerous agro chemicals (Indian environment portal: the pesticide management bill, 2017). Lack of a 360 degree regulation of toxic pesticides had probably resulted in numerous pesticide poisoning incidents over the years, including the latest 2017 poisonings and deaths reported from Yavathmal in Maharashtra. As per special investigation team (SIT) report twenty two farmers/farm workers lost their lives in yavatmal district due to pesticide poisoning where as 503 cases were hospitalized during July to December 2017

(Anonymous, 2018) [12]. The main reasons behind this trajery were human factor, crop factor, environmental factor and machine factor. The human factor includes non use of proper personal protective equipments (Apron, mask, hand gloves, caps and goggles etc), improper time of pesticide application (pesticides should be sprayed in the morning or evening), use of mixture of pesticides or insecticides instead of mixing it separately (Which may form the new compound) and not following the proper personal cleaning habit (i.e. hand washing after mixing the insecticides or pesticides with water, taking proper bath after spraying, chewing tobacco during spraying without properly cleaning hands). The crop factor includes the density and height of crop. It was reported that crop was so dense that workers may hardly go through the rows of crop. The crop plants were tall about 6 feet, carrying the spraying nozzle to keep above the shoulder height resulting in handling of pesticides by worker and also their body was completely drenched. Environmental factor included temperature, humidity and rainfall. During June to october 2017, the average temperature was raised by l.1 degree, the rain fall was reduced by 77 mm and humidity was increased by 10 percent as compared to same period during the year 2016. It resulted more sweating and facilitates the entry of pesticide in the body. The machine factor included the use of spray pump. It was reported that high volume and ultra low volume pumps used for pesticide spraying. The droplet size of the high volume sprayer was larger to fall quickly on plant but the droplet size of spray fluid ejected through ultra low volume spray were extremely small and these droplets keeps floating in the air which might have inhaled by the operator during operation due to absence of protective measures. In Perambalur in Tamil Nadu the outbreak of the diseases on cotton resulted in the heavy application of chemical herbicides and manures, more often than not, without the use of proper safety gear results three farmers die due to chemical poisoning. Apart from this poisonous gas leak near Tughlaqabad depot affected innocent school children in Delhi. There is an urgent need of an improved pesticide regulatory framework with stricter implementation in India. Several studies had been conducted on insecticides in protective clothing but almost all based on whole body dosimetry method documented by the organization for economic cooperation and development, patch method for investigating dermal exposure of pesticides in different parts of the workers exposure level can be expressed as ml of spray deposited on each body part per hour of application or using absorbent patch on protective clothing of artificial operator, pesticide exposure on clothing quantified in mg/kg . Proper use and maintenance of protective clothing are considered important behaviors associated with reduced chemical exposures. Furthermore, the frequency and duration of pesticide handling both on a seasonal and lifetime basis affects the exposure (Christos *et al.,* 2011) [23]. The pesticide deposited on garments can be approximated on time intensity basis in mg/kg with help of a standard dye. The pesticides deposited on garments during spraying can be estimated by active agent extraction in a suitable solvent and followed by quantification by gas chromatography. This process is useful for determination of pesticides exposure level on human body during spraying.

Methodology: Initially their need to survey of farmer spraying with power sprayer for 'risk identification in spraying' by selecting a group farmers from particular region having well experience in the activity. The survey for 'risk identification in spraying' consists of description of workplace, worker description, spraying related checklist advisory and farmers comments (yes/no). It also consists of occupational hazards, description of pesticide sprayer, aspect of pesticide spraying equipment, ergonomics aspects and technical aspects on workers answer/rating basis (0-5).

Selection of spraying equipment: The functional Components of sprayer consist of; a) Pump, b) Air chamber e) Pressure gauge f) Pressure regulator g) *Valves*h) Strainer i) Suction line and j) Delivery line. Generally HTP (horizontal triplex piston) pump operated with petrol engine used for spraying chemicals in orchards operating at a pressure of 9 to 18 kg/sq.cm and operated at forward speed of 1.20 km/h (0.33 m/s) to 1.50 km/h (0.41 m/s) (Anonymous, 2017) [8]. In hand operated tractor, operator working speed varied from 0.30 to 0.63 m/s for rota tilling and rota puddling operation. The optimum working speed of operator was considered as 0.45 m/s or 1.62 kmph (Dewangan and Tewari, 2008) [34].

Selection of nozzle: Cone nozzles are used primarily when plant foliage penetration is essential for effective insect or disease control and when drift is not a major concern. These nozzles produce small droplets that readily penetrate plant canopies and cover the underside of the leaves more effectively than any other nozzle type. They are also very difficult to arrange along a boom for uniform distribution. The lever operated knapsack sprayer and tractor operated gun sprayer performs better at nozzle height of 53 and 54.5 cm respectively (Kumar *et al.,* 2020) [41]. The hollow cone nozzles produce a cone shaped pattern with the spray concentrated in a ring around the outer edge of the pattern. The complete coverage of an area will be obtained using solid cone at a close range. In which the breaking of droplets formed due to impact action.

Items related to droplet spectrum: The spray depositions will be taken at different locations of mango tree on glossy papers size (44x44 mm). The droplet size spectrum will be analyzed using 'deposit scan' software which is available for free download. For evaluation of power sprayer parameters i.e. droplet size, droplet density, uniformity coefficient and spray depositions, 'Image J' analysis software was used (Zhu *et al.,* 2001 and Panneton, 2002) [56, 57]. 'Image J' very capable image analysis software was used for analysis of glossy paper. The advanced 'Image J' processing features of the program are provided through MAC, OS X, Linux, and Windows for upgrade newer version. 'Image J' allows multiple images to be displayed on the screen at one time. All operations were performed on active image. So scanning glossy paper in scanner the images were processed in a software program which directly gave volume mean diameter, number mean diameter, droplet density and spray deposition. The following parameters will be studied.

a) Volume median diameter (VMD), µm
b) Uniformity coefficient (UC)
c) Droplet density (DD), Nos./sq.cm
d) Spray deposition, µl/sq.cm

a) Volume median diameter ($V_{0.5}$): It is the volume median diameter (VMD) which is representative sample

of droplets of spray which divide spray into equal parts so that one half of the volume contains droplets smaller than a droplet whose diameter is the VMD and the other half of the volume contains larger droplets. It is droplet diameters at the 50th percentiles from the volume cumulative distribution curve.

b) NMD: It is the number median diameter, which divides the spray volume into two equal parts by number without reference to volume, thus emphasizing the smaller droplets.

c) Uniformity Coefficient (UC): It is the ratio of VMD to NMD, which gives the uniformity of spray. More uniform size of the droplet, the ratio is nearer to one.

d) Droplet Density (DD): It is the number of droplets per unit area of the surface usually expressed in number of drop per sq.cm.

e) Spray deposition (SP): It is quantity of spray fluid received by target in µl per sq.cm.

Spraying characteristics of nozzle for orchard spraying: The spray generated by agricultural nozzles play an important role in application of plant protection products. Spray droplets are produced from nozzles in different ways. A flat fan nozzle forces the liquid under pressure through an elliptical orifice and the liquid spreads out into a thin sheet that breaks up into different sized droplets. A flood nozzle deflects a liquid stream off a plate that causes droplets to form. A whirl chamber nozzle swirls the liquid out of an orifice with a circular motion and aids the droplet formation with a spinning force. The nozzle or atomizer chosen for any particular application is probably the single most influential component of the sprayer in determining the success or failure of the application. Nozzles break the liquid into droplets form the spray pattern and propel the droplets in the proper direction. The nozzle spray pattern is made up of many droplets of varying sizes. Patterns are commonly described in terms of the spray angle and the shape of the pattern. The three general categories are fan, hollow cone, and solid cone. Angles will vary with nozzle design and pressure used. Sprayer performance can be optimized by selecting the proper nozzle for the task, based upon total flow rate, desired range of droplet sizes emitted, and pattern desired. Various combinations of nozzle type, operating pressure, spacing, height above the target and travel speed are available for use in pesticide application. To minimize drift a fine or medium spray is required. The classification of spray droplet size by ASABE is presented in Table 1.

Table 1: Optimum droplet size classification for selected target

Sr. No	Classification category	VMD of droplets (µm)	Selected Target
1.	Extremely fine	<60	Exceptions
2.	Very fine	61-144	Exceptions
3.	fine	145-235	Fungicides & insecticides
4.	Medium	236-340	Fungicides, insecticides, contact herbicides
5.	Coarse	341-403	Systemic herbicides
6.	Very Coarse	404-502	Soil herbicides
7.	Extremely Coarse	203-665	Liquid fertilizer
8.	Ultra Coarse	>665	Liquid fertilizer with good coverage

Procedure for pesticide application using optimized method and conventional method of spraying

Optimizing the droplet size spectra of spraying application equipment, sprayer will be utilized in orchard crop for both optimized and conventional method using selected pesticide in pesticide risk assessment study; fabric type and method of spraying are two independent parameters should be considered in risk assessment study. Thus each operator were utilized for conventional and also for optimized method of spraying using C_1 and C_2 levels fabric clothes. The nonwoven and impermeable materials commonly used for PPE's are unsuitable for the tropics. The use of a cotton shirt and pants as a protective clothing for pesticide application in tropical countries is suitable (Chester *et al.*, 1990) [29]. Also results indicated that cotton and cotton polyester fabrics treated with the finish performed well compared to untreated fabrics (Shaw *et al.*, 1994) [55]. So based on the findings penetration property of fabrics and commercially available PPE's as per ISO 22608, two fabrics confirming to protective clothing as per ISO 27065:2017 was selected for field study.

Quantification of pesticides deposited on users clothes: As per the ISO 27065:2017 for protective clothing, performance requirements for protective clothing worn by operators applying pesticides is to establish the minimum pesticide spraying safety requirements that the customer must comply with in order to design and construct the PPE's. As per the ISO 27065, Level C_1 protective clothing including partial body is suitable when the potential risk is relatively low. Level C_1 protective clothing provides the least protection. Level C_2 protective clothing, including partial body is suitable when it has been determined that the protection required is higher than that provided by Level C_1 protective clothing. Level C_2 protective clothing typically provides a balance between comfort and protection. As per ISO 27065, materials for protective clothing classified as Level C_1, when the upper limit for percent penetration shall be 40% that is highly absorbent fabric. For materials classified as Level C_2, the upper limit for percent penetration shall be 5% that is highly repellent fabric. Materials for Level C_1 and Level C_2 protective clothing are tested in accordance with ISO: 22608. After optimizing the operating parameters of the sprayer, the study on quantification of pesticides deposited on users clothes will be carried out with two fabrics (level C1 and level C2) as per ISO 27065: 2017.

Selection of pesticides: The study on quantification of pesticide deposited on users clothing will be carried out with different types of pesticide which should be recommended throughout season for fruit, crop in particular region (Burondkar *et al.*, 2018) [25]. The physiochemical properties of selected pesticides includes common name of chemical, molecular formula, form of appearance, percent purity, melting point of chemical for know for quantification of pesticides.

Gas chromatography for Chemical analysis: Gas chromatography is a type of chromatography used in analytical chemistry for separating and analyzing chemical compound from ethyl acetate which was vaporized without decomposition. The ethyl acetate diluted sample solution injected into the instrument enters a gas stream which transports the sample into a separation tube known as the column. The chemical compound from ethyl acetate components are separated inside the column. The detector measures the quantity of the both components that exit the column. To measure a chemical sample with an unknown concentration, a standard chemical sample with a known concentration is injected into the instrument. The standard sample peak retention time and area are compared to the test sample to calculate the concentration in mg/kg.

Conclusion

It is noted that, there are still several gaps need to be studied regarding exposure to insecticides and other pesticides. The means of exposure to insecticides can occur without the use of clothing, but the exposure also occurs with the use of protective clothing. The loss of efficiency of clothing can be due to wear by insecticide applicators, washing, the use of soap at the time of washing, the presence of seams, and improperly made openings. In addition, the factor discussed is the quality of the clothes that are put up for sale; even the certified clothing used in the application of insecticides does not present adequate exposure to the worker throughout the workday. There are differences in results between the penetration tests carried out with the clothes in the laboratory and in the actual pesticide deposition on body part in the field, mainly due to wear factor by the use and contamination with other types of formulations that interact with the fabric or material of the dress. It is important to emphasize that many insecticides with high toxicity are still commercialized in the world, although many countries already prohibit their commercialization, as some organophosphorus insecticides This way, it is important to evaluate protective clothing as per ISO 27065:2017 with these types of pesticides for detect pesticide exposure and evaluate risk of spraying with power sprayer.

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