A health survey of 200 subjects occupationally exposed to mixture of pesticides and 100 control subjects similar in sex, age group and socio-economic status were selected from the rural areas of Lucknow district and urban area of adjoining District Barabanki of Uttar Pradesh, India to assess health risks associated with pesticide exposure in 2008-2011. The study was designed (i) to find out the health status of population occupationally exposed to pesticides (ii) to observe and studies work practices associated with pesticide exposure (iii) exposure assessment using cholinesterase levels and residual concentration of pesticide in blood (iv) effect of exposure on nerve conduction velocity and factors associated with nerve conduction deficits (v) Pre- and post-seasonal changes among pesticide sprayers (vi) to monitor the work environment for particulate matter and to find the presence of pesticides and their residues in air, water, soil, and fruits samples.

Studied subjects [pesticide sprayers (tractor-mounted sprayers and knapsack sprayers) and pesticide retail shopkeepers] were randomly selected on the basis of inclusion and exclusion criteria. Male subjects with aged 18-60 years and at least one year’s occupational exposure to pesticides were included. Subjects taking any medicines were excluded. Detailed information about personal habits, work practices, including use of personal protective equipment (PPE), awareness of pesticide toxicity and symptoms experienced from past month, was collected through questionnaires during face to face interview. Male subjects with no current and previous occupational exposed to pesticide and similar in age group and socio-economic status of exposed subjects were included in the study to compare the impact of occupational exposure of pesticides on the health of exposed workers.

**Part-I: Pesticide sprayers**

One hundred eighty of 250 (72%) eligible male pesticide sprayers and one hundred of 150 (67%) eligible control similar in age group and socio-economic status were included in this study. The Mean±SD of age (years), height (cm) and weight (Kg) of agricultural workers was 34±11, 164±7 and 52±8, respectively. The personal habits such as smoking (34%), tobacco
chewing (30%) and alcoholic (29%) were observed. About 19% of people were illiterate. Most of workers belong to upper lower to lower middle class of socioeconomic status. PPE such as apron, gloves, masks and long boots was not used by agricultural workers during handling, mixing and spraying. PPE was not provided by owners and sprayers could not afford to buy it themselves. One third sprayers also reported eating and smoking habits without previously washing their hands in the duration of spraying operation, although 78% of sprayers were aware that pesticide are harmful for them. Most of them reported the wetting of bare skin and clothes with pesticides during spraying operations and took baths at the end of spraying.

The overall morbidity rate on the basis of self reported symptoms was found to be 64 percent among pesticide sprayers. Pesticide sprayers reported higher percentage of health symptoms as compared to controls in systems viz., nervous (52), ocular (51), respiratory (47), cardiovascular (35), gastrointestinal (54), musculoskeletal (58), dermal (32), genito-urinary (5) and reproductive (4). The risk assessment of morbidity shows significantly higher odds ratio (OR) in sprayers for neurological (OR-9.62; 95% CI:4-21; P<0.001), ocular (OR-5.79; 95% CI:3-11; P<0.001), respiratory (OR-8.05; 95% CI:4-18, P<0.001), cardiovascular (OR-2.83; 95% CI:1-5; P<0.001), gastrointestinal (OR-4.14; 95% CI:2-7; P<0.001), musculoskeletal (OR-7.18; 95% CI:4-14; P<0.001), dermal (OR-5.47; 95% CI:2-13; P<0.001) symptoms.

Tractor-mounted sprayers reported higher percentage of health symptoms as compared to knapsack sprayers and controls including neurological (69), ocular (63), respiratory (47), cardiovascular (39), gastrointestinal (62), musculoskeletal (62), dermal (36), genito-urinary (7) and reproductive (4) symptoms. The risk assessment of morbidity shows significantly higher odds ration (OR) in tractor-mounted sprayers as compared to controls for neurological (OR-20.03; 95% CI:9-47; P<0.001), ocular (OR-9.65; 95% CI:5-20; P<0.001), respiratory (OR-7.98; 95% CI:4-18, P<0.001), cardiovascular (OR-5.17; 95% CI:2-12; P<0.001), gastrointestinal (OR-5.78; 95% CI:3-11; P<0.001), musculoskeletal (OR-8.57; 95% CI:4-18; P<0.001), dermal (OR-6.47; 95% CI:3-16; P<0.001) genito-
urinary (OR-7.45; 95%CI:0.92-339; P<0.05) symptoms. Knapsack sprayers also showed higher percentage of health symptoms as compared to controls in system viz., neurological (30), ocular (35), respiratory (48), cardiovascular (30), gastrointestinal (44), musculoskeletal (53), dermal (28), genito-urinary (3) and reproductive (4). The risk assessment of morbidity shows significantly higher odds ratio (OR) in knapsack sprayers as compared to controls for neurological (OR-3.86; 95%CI:2-9; P<0.01), ocular (OR-3.05; 95%CI:1-7; P<0.01), respiratory (OR-5.52; 95%CI:3-13, P<0.001), cardiovascular (OR-3.47; 95%CI:1-8; P<0.01), gastrointestinal (OR-3.92; 95%CI:2-8; P<0.001), musculoskeletal (OR-5.80; 95%CI:3-12; P<0.001), dermal (OR-4.36; 95%CI:2-11; P<0.01) system.

Neurological symptoms like excessive salivation (P<0.001), excessive sweating (P<0.001), frequent severe headache (P<0.05), dizziness (P<0.01), tremor (P<0.05), headache (P<0.001), fatigue (P<0.01), severe irritability (P<0.05), convulsions (P<0.01), numbness (P<0.05), forgetfulness (P<0.05) and change in taste (P<0.05) symptoms were found to be more among sprayers as compare to controls. Among sprayers, tractor-mounted sprayers have reported higher prevalence of headache (49%), excessive sweating (37%), excessive salivation (34%), fatigue (21%), dizziness (18%), numbness (17%), convulsion (15%), frequent severe headache (14%), forgetfulness (13%), severe irritability (13%), change in taste (10%), tremor (10%), fainting (7%) and disorientation (2%). The knapsack sprayers reported headache (15%), excessive sweating (23%), excessive salivation (16%), fatigue (10%), dizziness (3%), convulsion (6%), frequent severe headache (1%), forgetfulness (6%), severe irritability (3%), change in taste (8%) and tremor (6%).

Besides neurological symptoms other pesticides related symptoms like blurred vision (P<0.001), itching in eyes (P<0.001), dry cough (P<0.001), stiffness in joints and muscle-pain (P<0.001), bodyache (P<0.001), dermal itching (P<0.001), hyperacidity (P<0.001), abdominal pain (P<0.001), pain in eyes (P<0.01), nausea/vomiting (P<0.01), red swollen eyes (P<0.01), difficulty in breathing (P<0.01), productive cough (P<0.01), dyspnoea (P<0.01), nose
secretion \((P<0.01)\), pain in chest \((P<0.01)\), lacrimation \((P<0.05)\), refractive error-near vision \((P<0.05)\), throat irritation \((P<0.05)\) and burning sensation of skin \((P<0.05)\) symptoms were found to be significant among sprayers as compare to controls.

Pesticide sprayers showed significant decline in cholinesterase (ACHE and BChE) enzyme activity \((P<0.001)\) as compared to controls. AChE level decline was 42\% \((P<0.001)\) and BChE activity decline was 49\% for sprayers compared to control \((P<0.001)\). AChE and BChE levels had significant depletion among tractor-mounted and knapsack sprayers as compared to mean values of control \((P<0.001)\). The inhibition in the AChE level was more pronounced in tractor-mounted sprayers than knapsack sprayers. Tractor-mounted sprayers had a AChE depletion of 51\% whereas knapsack sprayers had a decline of 26\% compared to mean of controls. The inhibition in the BChE activity was more pronounced in knapsack sprayers than tractor-mounted sprayers. Knapsack sprayers had a decline of 53\% whereas tractor-mounted sprayers showed a decline of 46\%.

Spirometric lung function studies in sprayers displayed decrement in lung function as compared to controls. The decline in FEV\(_1\) level was 4\% and 28\% in PEFR level in sprayers compared to controls. Lower FEV\(_1\) and PEFR levels was observed was among tractor-mounted and knapsack sprayers as compared to control. Knapsack sprayers had a FEV\(_1\) decrement of 7\% whereas tractor-mounted sprayers had a decrement of 1\% compared to mean of controls. Significant decrement in PEFR level was found in tractor-mounted sprayers and knapsack sprayers as compared to controls \((P<0.001)\). The decrement in the PEFR level was more pronounced in knapsack sprayers than tractor-mounted sprayers. Knapsack sprayers had a decline of 30\% whereas tractor-mounted show a decline of 27\%.

Pesticide sprayers showed significant decline in MNCV and SNCV as compared to controls \((P<0.001)\). Decline in MNCV was 36\% and decline of SNCV was 31\% \((P<0.001)\) in pesticide sprayers compared to controls. Odds ratio (OR) were significantly raised for slowing of MNCV (OR- 20.77; 95\%
Significant decrement in MNCV was found in tractor-mounted sprayers and knapsack sprayers as compared to control ($P<0.001$). Tractor-mounted sprayers show a reduction in MNCV of 34% whereas knapsack sprayers show 39% ($P<0.001$). Significant decrement in SNCV was found in tractor-mounted sprayers and knapsack sprayers as compared to control ($P<0.001$), but the slowing in the SNCV was more pronounced in tractor-mounted sprayers than knapsack sprayers. Knapsack sprayers showed a decline of 29% compared to 32% decrement in tractor-mounted sprayers. Knapsack sprayers showed higher odds ratio for slowing of MNCV (OR 36.50; 95% CI:8-193) as compared to tractor-mounted sprayers (OR- 16.66; 95% CI:5-72). Tractor-mounted sprayers showed higher odds ratios (OR) for slowing of SNCV (OR- 7.65; 95% CI: 2-34) as compared to knapsack sprayers (OR 7.02; 95% CI:1-39).

Residual analysis showed $\alpha$-hexachlorocyclohexane (HCH) and total HCH were found significantly higher in blood of sprayers as compared to controls. Urine samples collected from sprayers showed no detection of OP urinary metabolites (dialkylphosphates:DAPs). Suspended particulate matter (SPM) and respirable suspended particulate matter (RSPM) at study locations exceed National Ambient Air Quality Standards (NAAQS) limit. Hand pump water samples collected from the Malihabad and Bakhshi Ka Talab were monitored for OC and OP pesticides showed no detection for pesticides. Soil samples collected from mango plantations showed $\alpha$-endosulfan and gamma-HCH contamination.

This study demonstrated lower cholinesterase levels, decrement in lung function, slowing nerve conduction velocity and significant adverse health problems in pesticide sprayers compared to controls. Tractor-mounted sprayers are at greater risk of cholinesterase inhibition and adverse health symptoms than knapsack sprayers. Occupational exposure in pesticide sprayers in North India needs better control, perhaps through redesign of spraying equipment and proper usage of personal protective equipment.
Part-II: Sub-clinical alterations among sprayers before and after a spraying season

Eighteen of 27 (67%) eligible male sprayers consented to participate in this study. The Mean±SD of age (years), height (cm) and weight (Kg) of sprayers was 44±9, 161±8 and 53±9, respectively. Among them, 33% were smokers, 22% were tobacco chewers and 22% occasionally consume alcohol. PPE such as apron, gloves masks and long boots was not used by sprayers during handling, mixing and spraying of pesticides. Wetting of bare skin and clothes with pesticides during spraying operations were reported and they take bath after their spraying work for the day.

AChE activity declined in sprayers from pre-exposure level of 551.62±235.99 to post exposure level 249.02±85.34 (IU/L), showing a significant reduction of 55% (P<0.01). BChE activity declined from a pre-exposure level 279.21±232.84 to post-exposure level 254.59±120.61 (IU/L) showing reduction of 9%. Sprayers showed significant decrement of 20% in FEV\textsubscript{1} level from a pre-exposure level of 1.74±0.54 to post-exposure level 1.39±0.43 (L/sec) [P<0.05]. One percent decrement in mean value of PEFR was observed among sprayers in relation to pre-post exposure assessment (308.5 Vs 306 L/min). MNCV declined from a pre exposure level of 29.77±9.43 to 28.19±9.96 (m/s), showing a reduction of 5% and no reduction in SNCV was observed.

In future more studies with large sample size and prolonged exposure are needed to explore the mechanism of neurophysiologic changes in pre- and post-exposure assessment. There is need to implement regular monitoring of subclinical prevalence in the pesticide exposed agrarian communities. The regular use of PPE should be implemented in farm practices to reduce the burden of pesticide toxicity.
Part-III: Pesticide retail shopkeepers

Twenty out of 32 pesticide retailers were randomly selected to assess risks associated with pesticide selling from urban areas of Lucknow District and adjoining District Barabanki of Uttar Pradesh, India. In this study, the pesticide shopkeepers were at a higher risk for sickness including ocular problems (RR-2.16; 95%CI:0.83-5.62; \(P>0.05\)), cardiovascular problems (RR-3.36; 95% CI:1.13-9.99;\(P<0.05\)), gastro-intestinal problems (RR-1.92; 95% CI:0.94-3.93; \(P>0.05\)), genito-urinary problems (RR-8.64; 95%CI:1.23-60.61; \(P<0.01\)), musculo-skeletal problems (RR-2.88; 95% CI:0.95-8.74; \(P>0.05\)), respiratory problems (RR-8.64; 95% CI:1.23-60.61; \(P<0.01\)), nervous system related problems (RR-2.88; 95% CI:1.16-7.18; \(P<0.05\)), problems related to reproductive system (RR -4.32; 95% CI:0.57-32.84; \(P>0.05\)) and dermal (RR-4.32; 95% CI:1.34-15.24; \(P<0.01\)).

Lower mean value of MNCV (32.88 ± 15.72 m/s) was observed in retail shopkeepers as compared to control (50.24 ± 10.74 m/s). To the best of our knowledge, this is the first report of adverse effects by multiple pesticide exposure among subjects employed in retail pesticide outlets. Significant relative risk for sickness related to systems viz., cardio-vascular, genito-urinary, respiratory, nervous and dermal was observed among exposed subjects. The nerve conduction among the exposed subjects was also found to be impaired. This was reflected in low values of MNCV among shopkeepers as compared to control subjects. These findings are in consonance with earlier reports on pesticide toxicity.

Sound national policies are needed to effectively articulate appropriate guidelines for reducing pesticide exposure at work place. It is recommended that detailed studies to formulate an action plan for promoting the health of this group should be urgently undertaken.

Finally in this study, pesticide toxicity results in sub-clinical conditions such as cholinesterase inhibition, airway narrowing and slowing of nerve conduction among population occupationally exposed to mixture of pesticides due to exposure of pesticides which belongs to extreme, high or moderate hazardous
class of pesticides categorized by WHO, without using correct protective measurements during mixing, handling, spraying or selling. The proposed toxicity related to sub-clinical variations is given in the Fig.5.1.

Fig. 5.1 Proposed pesticide toxicity related to sub-clinical variations