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RESEARCH ARTICLE

The Dynamics of DDT in Indoor Residual Sprayed Homes in South Africa

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ABSTRACT

An assessment of indoor air, indoor dust, and outdoor dust DDT concentration was conducted to assess the lefts of DDT residents in Indoor Residual Sprayed (IRS) areas were potentially exposed to. The study was carried out in Thohoyandou, Vhembe Limpopo at three villages, with one used as a control site. The results for DDT metabolites show that DDT concentrations increased during the spraying period and *o,p'*-DDE concentrations were highest compared to all other metabolites throughout the sampling period. There is a statistical difference in the mean concentrations of DDT isomers sampled at T0T and the other sampling intervals. *o,p'*-DDE concentrations also significantly dropped an hour after spraying. The concentrations remained also constant throughout the 84-day sampling period for all other metabolites. Dust concentration indoor were generally low at the two sampled sites, mainly because of the frequent sweeping of huts. Results show that the mean concentrations recorded an hour before sampling are significantly different from mean concentrations from sampling collected and hour and 24 hours after IRS. However outdoor dust recorded similar concentrations and both the sprayed and control site. Soil samples collected at TV and DV outside huts indicate the presence of DDT at both sites. *p,p'*-DDE concentrations were highest at both sites with concentrations of 16 µg/kg and 14 µg/kg respectively. *o,p'*-DDT concentrations were lowest at both sites. Samples from both sites displayed very similar results with very little difference in metabolite concentrations. A comparison of air and dust samples showed that air samples had higher levels of DDT and its metabolites with the most significant difference noted in *o,p'*-DDT and *p,p'*-DDT concentration. Indoor air recorded a concentration of 1.4 µg/m^3 with a concentration of 0.1 µg/m^2 being recorded for *o,p'*-DDT on the dust floor. *p,p'*-DDT concentration was 2.2 µg/m^3 in air and 1.1 µg/m^2 on floor dust.

1. Introduction

Indoor residual spraying or IRS is the process of spraying the inside of dwellings with an insecticide to kill mosquitoes that spread malaria. The insecticide is sprayed on the wall of dwellings. In 2008, 44 countries world over made use of IRS as a malaria control strategy. Southern African countries like South Africa, Zimbabwe, Mozambique and Swaziland have continuously employed IRS through the use of DDT for decades.

Several pesticides have historically been used for IRS, the first and most well-known being DDT. DDT use has generally been successful in fighting malaria (WHO, 2011), however concerns over its safety to the environment and human health has been raised. The books Silent Spring by Rachel Carson in 1962 highlighted the adverse health impacts of DDT on both human and environmental health. The book noted that DDT bio-accumulates and biomagnifies up the food chain and raised concerns that the pesticide may have long-lasting effects on wildlife and possibly on humans (Carson, 1962).

The type of DDT used in IRS is commonly known as technical-grade DDT. Technical-grade DDT contains two major isomers, the active ingredient, *p,p'*-DDT, and a by-product, *o,p'*-DDT. DDT and its primary breakdown product, dichlorodiphenyldichloro-ethylene (DDE), are highly lipophilic, persist in the environment, and bio-accumulate in humans because of their long half-lives (6 years and possibly up to 10 years, respectively) (Wolff et al. 2000a).

2. Materials and Method

2.1. Study site

A study to assess DDT spray dust deposition and air borne DDT residue monitoring during malaria vector control operations in Thohoyandou, Vhembe was conducted. Thirty huts were selected and monitored before and after DDT application for DDT dust deposition and air borne DDT residues. The DDT monitoring was conducted between 24 November 2007 and 1 December 2007. The objectives of the study were to determine the concentrations of DDT and its metabolites in air and dust after the administration of IRS. The second objective was to access concentrations of DDT at different sites.

2.2. Layout

A total of 30 huts x 7 sampling intervals i.e. 210 PUF air samples were collected from sprayed huts. Ninety GMF dust deposition samples (30 huts x 3) were collected over four sampling intervals (-1hour, 1 hour, 29 hour and 84 days after spraying). A total of 8 x huts x 1 sampling interval i.e. 8 dust samples were collected from control (non-sprayed, Tshakuma) huts.

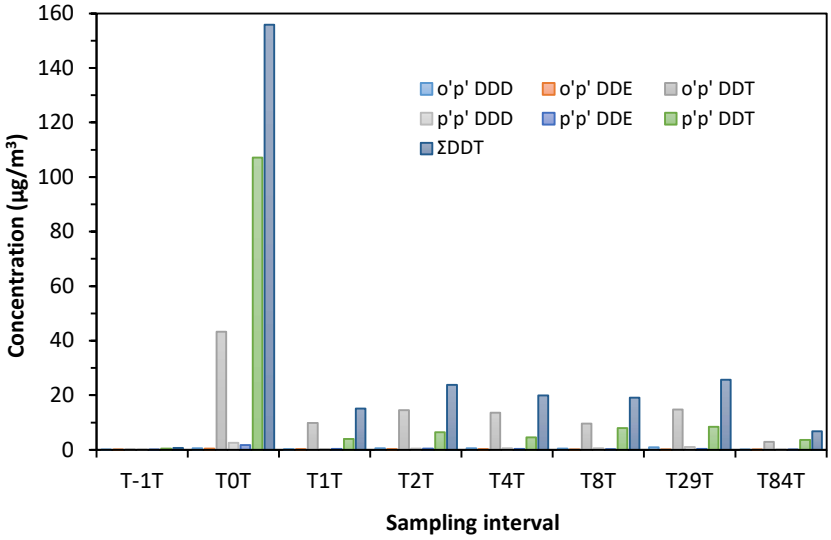

Fig. 1. Mean concentrations of DDT and its metabolites at different hut air sampling periods in Vhembe T-1T=-1 hour, T0T=0 hour after application, T1T=1 hour after application, T2T=2 hours after application, T4T=4 hours post application, T8T=8 hours post application and T29T=26 hours to 30 hours after, T84T=84 days after DDT application

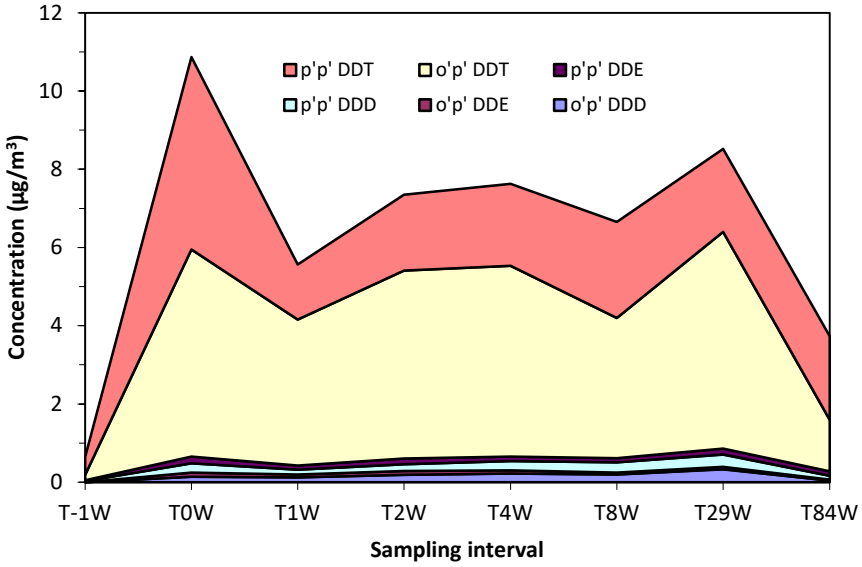

Fig. 2. Mean concentrations of DDT and its isomers in vapor different hut air sampling periods in Vhembe.T-1W=-1 hour, T0W=0 hour after application, T1W=1 hour after application, T2W=2 hours after application, T4W=4 hours post application, T8W=8 hours post application and T29W=26 hours to 30 hours after, T84W=84 days after DDT application

3.2. Grouping information using the Tukey Method and 95% confidence

Means that do not share a letter are significantly different. There is a statistical difference in the mean concentrations of DDT isomers sampled at T0T and the other sampling intervals (Fig. 1; Table 1). There are seven sampling intervals show no statistical differences in mean concentrations.

Table 1. One-way ANOVA: Vhembe air data

Time	N	Mean	Grouping
T0T	180	6.12	A
T29T	180	1.711	B
T2T	180	1.544	B
T4T	180	1.428	B
T8T	180	1.305	B
T1T	180	1.061	B
T84T	180	0.6106	B
T-1T	180	0.0939	B

Fig. 2 shows that *o,p'*-DDT dominated in vapor samples collected through-out the 84-day sampling period. The highest concentration of *o,p'*-DDT recorded was 5.296µg/m^3 *p,p'*-DDT concentrations are second highest after *o,p'*-DDT. Other DDT metabolites where generally low as compared to *o,p'*-DDT and *p,p'*-DDT.

Air samples with particulate matter indicate that *p,p'*-DDT mean concentrations were the highest during the spraying time T0M. The highest concentration of *p,p'*-DDT concentration recorded was above 100µg/m^3. *o,p'*-DDT concentrations were also high in comparison to the other DDT metabolites (Fig. 3).

o,p'-DDT constituted of the greatest percentage of the DDT metabolites analysed. *o,p-'*DDT constituted of about 50% of the metabolites is particulate matter. *p,p'*-DDT had the second highest concentrations. Other DDT metabolites had very small percentage contributions (Fig. 4).

Table 2. Monday air vs rest of the week (T-Test)

Day	N	Mean	StDev	SE Mean
Monday	282	4.5	19.3	1.1
Rest of the week	1440	1.73	8.88	0.23

Difference = µ (Monday) – µ (rest of the week)
Estimate for difference: 2.72
95% CI for difference: (0.41, 5.02)
T-Test of difference = 0 (vs ≠): T-Value = 2.32 P-Value = 0.021 DF = 304

Results show that there is significant difference between Monday and the rest of the week days. Monday mixture had a higher mean concentration of DDT metabolites as compared to mixtures applied on the other week days (Table 2).

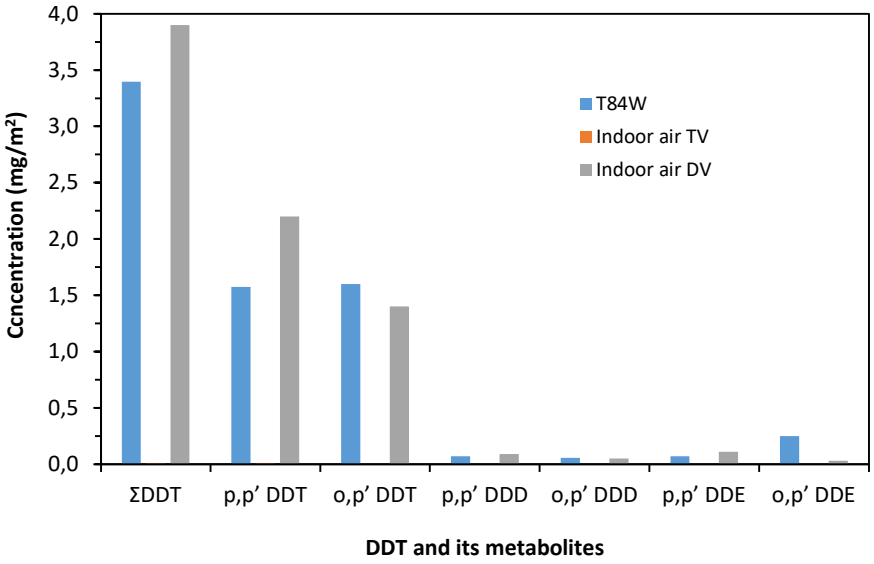

Fig. 6. Mean concentrations of DDT and its metabolites in air samples collected from three different sites two to three months after IRS in Vhembe.

Fig. 6 shows the mean concentrations of DDT and its metabolites from 3 different sampling areas. The samples collected from Vhembe and TV are much higher as compared to the DV. TV recorded limited concentrations of DDT and its metabolites in comparison to Vhembe and TV. The *p,p'*-DDT and the *o,p'*-DDT concentrations were much higher as compared to the other metabolites of DDT.

3.3. The trends and levels of DDT and its metabolite floor and outside dust

The results below show mean concentrations of DDT and its metabolites in dust samples collected from floors of huts under IRS in Vhembe, Limpopo. The mean concentrations of total of DDT (ΣDDT) and the metabolites are in mg/m^2. The metabolites are *o,p'*- DDT, *p,p'*-DDT, *o,p'*-DDD, *p,p'*-DDD, *o,p'*-DDE and *p,p'*-DDE. Samples were collected for a sampling period of 24 hours. This is largely due high frequency of sweeping by women in the homes. Dwellling are swept daily and hence the exposure is limited. Dust samples were collected before DDT application over a surface area of about 1200cm^2 near the inner walls of the huts. Vacuum suction was used.

Fig. 7 shows that the concentration of DDT and its metabolites generally increased from the start of the sampling period to the end. An initial concentration of 0.00 mg/m^2 was recorded an hour before IRS was conducted. Samples collected 24 hours after IRS had the highest ΣDDT concentration of 27.79 mg/m^2. There is a significant statistical difference between mean concentrations recorded F-1 and the other two sampling intervals.

Fig. 7 shows that dust sampled for *p,p'*-DDT an hour before IRS had no traces of the metabolite. However, after IRS application, the highest concentration of all DDT metabolites was recorded 24 hours after spraying. Mean concentrations were as high as 22.14 mg/m^2. *p,p'*-DDT mean concentration in dust an hour after DDT application was 20.74mg/m^2. The graph shows an upward trend of *p,p'*-DDT mean concentrations through-out the sampling period.

It also shows mean concentrations for *p,p'*-DDE. The graph shows an upward trend of mean concentrations within the 24-hour sampling period. Dust samples collected 24hours after IRS show the highest concentration of *p,p'*-DDE. The mean concentrations are generally low through-out the sampling period as compared to. *p,p'*-DDT. Dust samples collected and analysed for *p,p'*-DDD show very little quantities.

The highest measure was recorded 24 hours after IRS. There is however very little difference between mean concentrations recorded an hour after IRS and that recorded 24hours after. There was no trace of *p,p'*-DDD in samples collected an hour before IRS. *o,p'*-DDT concentrations were generally higher as compared to concentrations recorded for *o,p'*-DDD and *o,p'*-DDE. *o,p'*-DDT reached a high of almost 5mg/m^2 an hour after IRS. Mean concentrations 24 hours after IRS were also high, with limited change from concentrations recorded an hour after application.

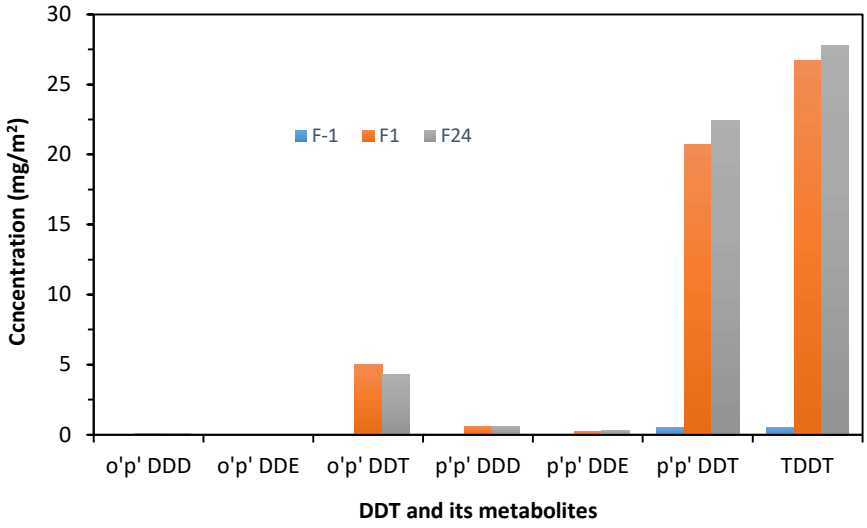

Fig. 7. Mean concentrations of DDT and its metabolites in dust at different sampling periods in Vhembe.T-1F=-1 hour, T1F=1 hour after application, T24W=24 hours after application.

Fig. 7 shows mean concentrations of *o,p'*-DDE in dust at different sampling periods in Vhembe. Mean concentrations were generally low in the sampling 24-hour period. Concentrations ranged between 0.00-0.05 mg/m^2. Dust samples collected an hour before sampling showed no traces of *o,p'* DDE. However, the highest mean concentration was recorded 24 hours after IRS. Dust samples collect an hour before IRS show no traces of *o,p'*-DDE. Mean concentrations of *o,p'*- DDD were also generally low, with the highest concentration being 0.12 mg/m^2 recorded and hour after IRS. Concentrations a 24 hour after IRS slightly dropped to 0.10 mg/m^2.

3.4. Grouping information using the Tukey Method and 95% confidence

Results show that the mean concentrations recorded an hour before sampling are significantly different from mean concentrations from sampling collected and hour and 24 hours after IRS (Table 3). Results show that there is significant difference between the dust samples collected

from the Monday mixture and the mixture applied on the rest of the week days. The other week days recorded a higher mean concentration of DDT isomers (Table 4).

Table 3: One-way ANOVA: Dust samples from Vhembe

Time	N	Mean	Grouping
T24T	180	4.63	A
T1T	180	4.455	A
T-1T	180	0.0914	B

Table 4: T-test: Monday vs rest of the week

Day	N	Mean	StDev	SE Mean
Monday	12	1.1	4.57	0.42
Rest of the week	540	3.1	11.4	0.49

Difference = μ (Monday) – μ (rest of the week)
Estimate for difference: -1.954
95% CI for difference: (-3.221, -0.687)
T-Test of difference = 0 (vs ≠): T-Value = -3.03 P-Value = 0.003 DF = 476

Dust samples collected in Vhembe indicated that the trend and concentrations of DDT metabolites in TV and DV were almost similar despite TV recording higher concentrations. *p,p'*-DDT recorded the highest concentration amongst all the metabolite. *o,p'*-DDE was the least concentrated metabolite (Fig. 8). Soil samples collected at TV and DV outside huts indicate the presence of DDT at both sites. *p,p'*-DDE concentrations were highest at both sites with concentrations of 16 μg/kg and 14 μg/kg respectively. *o,p'*-DDT concentrations were lowest at both sites (Fig. 9). Samples from both sites displayed very similar results with very little difference in metabolite concentrations.

3.5. A comparison of the trends and levels of DDT and its metabolites in air and dust samples

The results below gives an analyses and comparison of DDT concentrations between air samples and dust samples at the three sampling sites.

Fig. 10 shows that air samples had higher levels of DDT and its metabolites with the most significant difference noted in *o,p'*-DDT and *p,p'*-DDT concentration. Indoor air recorded a concentration of 1.4 μg/m^3 with a concentration of 0.1 μg/m^2 being recorded for o,*p'*-DDT on the dust floor. *p,p'*-DDT concentration was 2.2 μg/m^3 in air and 1.1 μg/m^2 on floor dust. The other DDT metabolites show very little concentration compared to *o,p'*-DDT and *p,p'*-DDT.

A comparison of DDT metabolite concentration between air and floor dust is given in the Fig. 11. Its shows that floor dust samples in TV recorded traces of DDT and its metabolites**.** However, in air samples collected, all DDT metabolites were detected except for *o,p'*-DDE.

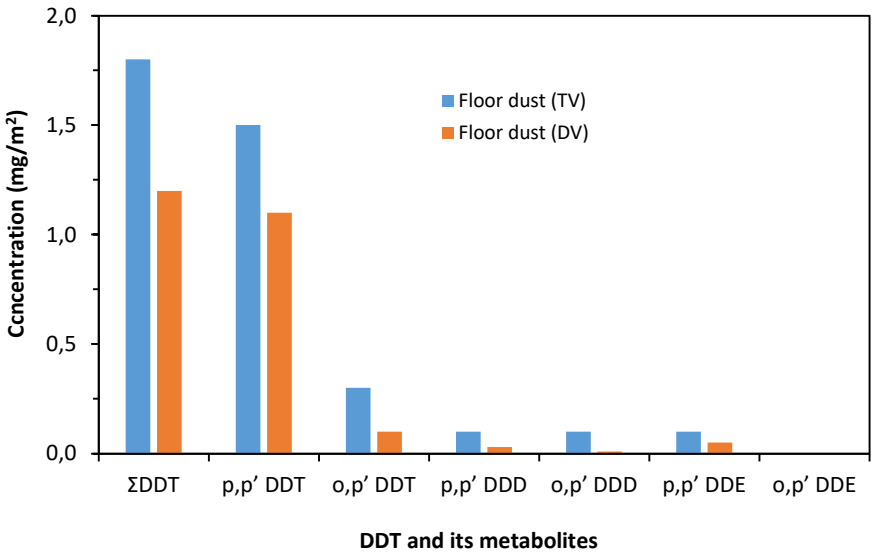

Fig. 8. Mean concentrations of DDT and its metabolites in hut dust samples collected from TV and DV sites two months after IRS

4. Discussion

4.1. Trends of DDT and its metabolites in air

Fig. 1 shows the concentration of DDT metabolites at an IRS site. An hour before IRS, traces of DDT metabolite were detected. DDT sprayed the previous year could have been present in air of the sampled hut based to historical use of DDT in the area. The prolonged use of the compound from the time of spraying the year before, and years before, dating as far back as 1945, may result in traces of DDT in air in areas with a history of IRS such as Vhembe. POPs are degraded through photolytic degradation (Berdowski et al., 1997). Blais et al. (1998) states that deposition of DDT maybe caused by the compound attaching to dust particles and is deposited on floors or land when the dust settles. DDT is

removed from the atmosphere and depositing them on the surface. This maybe the reason why they were limited DDT is area compared to DDT detected in air after spraying.

Fig. 1 also shows that the greatest concentration of DDT isomers was recorded during the spraying period. The most dominate metabolites were *p,p'* DDT and *o,p'* DDT. The results reveal that a significant difference in concentrations during spraying compared to other sampling periods. Traditional dwellings are sprayed on the inside walls with two grams (g) per square meter of technical DDT (Gyalpo et al., 2012). According to Bouwman et al. (2011), 2 g of 75% water wettable technical DDT are applied per m^2 to the inner walls of all dwellings in malaria-endemic areas, resulting in 64 -128 g of DDT applied per dwelling. The commercial mixture is made up of 77% and 15% of *p-p'* and *o-p'* isomers commercial DDT respectively. *p,p'*-DDT and its primary breakdown product *p,p'*-DDE have long half-lives of six years and possibly up to 10 years, respectively (Longnecker, 2005; Wolff et al., 2000a). *p,p'*-DDT is predominant at 75% in the IRS formulation (WHO, 2001; Bouwman., 2004; Bouwman et al., 2006), hence it's consistently detectable presence in air. This could therefore explain the high levels of the compounds during spraying. The persistent nature of *p-p'* and *o-p'* isomers could also explain their high presence throughout the sampling intervals at sites.

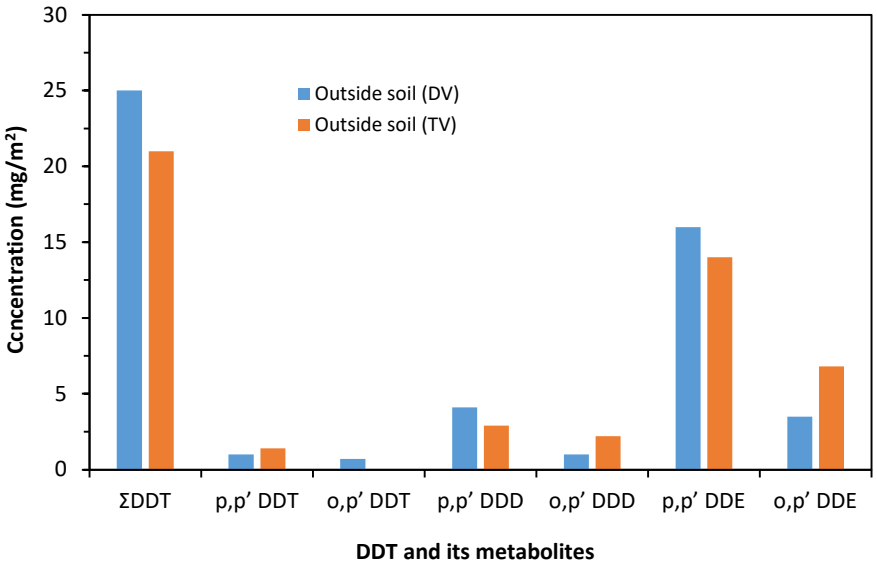

Fig. 9. Mean concentrations of DDT and its metabolites in outside dust samples collected from TV and DV sites two months after IRS in Vhembe

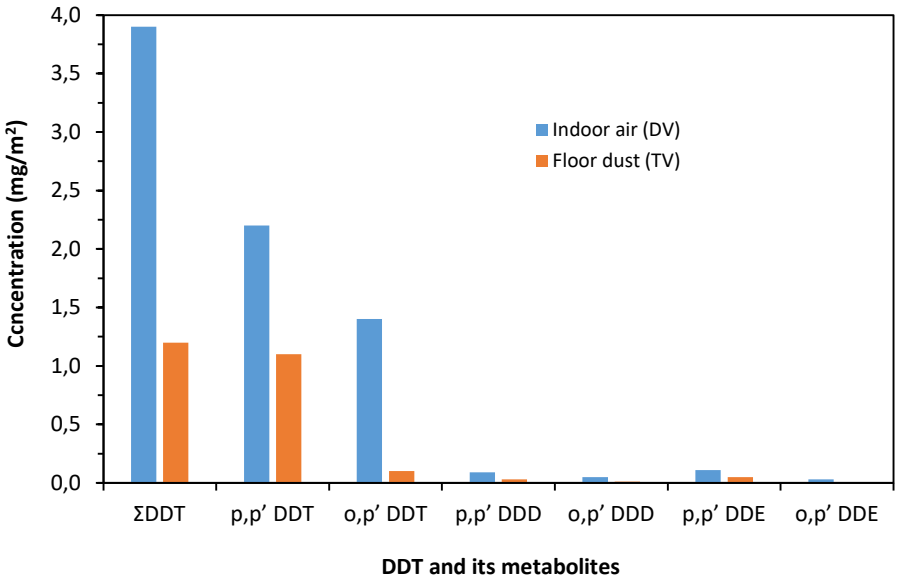

Fig. 10. Mean concentrations of DDT and its metabolites in indoor air samples collected DV site two months after IRS in Vhembe compared to floor dust mean concentrations over the same period

The high presence of *p,p'*-DDE can be further explained by the difference in thermal decomposition parameters for *p-p'* and *o-p'* isomers. The primary step in the thermal decomposition of *p,p'*-DDT is elimination of HCl, resulting in formation of *p,p'*-DDE at 152°C (Lubkowski et al., 1988). DDE starts to volatilize at the onset of the process. The decomposition temperature is dependent on the type of DDT, for *o,p'*-DDT the decomposition starts at some higher temperatures.

Concentrations of all the other metabolites show concentrations with limited change from samples collected an hour after spraying to samples collected 84 days after the initial spraying day. Due to its persistence, DDT continues to cycle between compartments and also to be primary emitted (Qiu et al., 2005). The compounds take years to broken down and hence their continued presence months after IRS. Through their nature to processes of evaporate and deposit frequently, DDT, DDE, and DDD on the sprayed walls may volatilise into the atmosphere and hence continue to be detected months after IRS.

Figs. 3 and 5 show the percentage concentrations of DDT isomers. *o,p'* DDT had a higher % concentration in air compared to *p,p'* DDT despite *p,p'* DDT's higher concentration is the sprayed DDT solution. According to Spencer and Cliath (1972), different isomers have different levels of volatility. Spencer and Cliath (1972), report the vapour pressure of *o,p'*-DDT is 7.5 times greater than that of *p,p'*-DDT. At 30 °C, the atmosphere above a surface deposit of technical grade DDT contains approximately 62 % *o,p'*-DDT, 16% *o,p'*-DDE, 14% *p,p'*-DDE, and only 8% *p,p'*-DDT.

Table 2 shows a significant difference in concentration recorded hut sprayed on Monday and the rest of the week. This may be due to the fact that the sprayed mix on Monday was mixed differently as compared to the mix sprayed during the rest of the week. Incorrect and careless handling of commercial DDT is of high concern as it puts both IRS sprayers and residences of the applied households at great risk of DDT contamination. Instead, the possible human health risk of DDT, especially to the applicators, could outweigh its use. Applicators have the greatest exposure because of the very nature of the work and their exposure dates back to the early 50s (Wolfe et al., 1959; Wassie et al., 2012).

Studies provide evidence that there are higher plasma levels of DDT and DDE among workers who apply DDT during indoor residual spraying (IRS), and among residents in areas where IRS takes place, compared with levels from the general population (Bouwman et al., 1990; de Jager et al., 2006; de Jager et al., 2009; Ritter et al., 2011; Channa et al., 2012). Great care therefore needs to be taken when handling chemicals and preparing the mixtures for application.

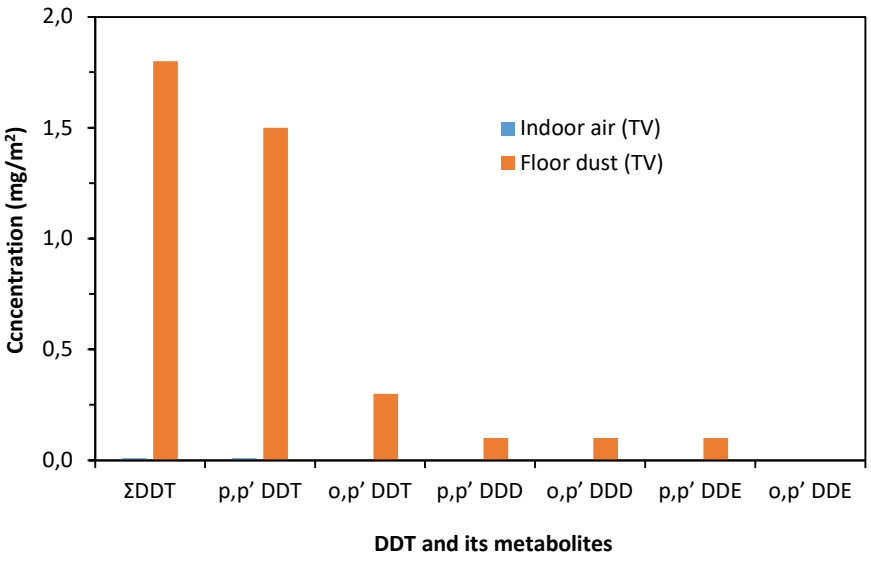

Fig. 11. Mean concentrations of DDT and its metabolites in indoor air samples collected DV site two months after IRS in Vhembe compared to floor dust mean concentrations over the same period

Furthermore, the applicators are likely to be exposed to DDT through ingestion of DDT and contact of applicators with treated surfaces. Ingestion of DDT during hand-to-mouth contact is also highly likely if the workers are not careful (Ross et al., 2008). The applicators' houses were also treated with DDT that can expose them to the residue of DDT through inhalation and contact with treated surfaces and floor dust (Bouviera et al., 2006; Van Dyk et al., 2010).

Fig. 6 shows the mean concentrations of DDT and its metabolites from Vhembe and published data from two sites TV and DV. Samples collected from Vhembe and TV are much higher as compared to DV. The difference in concentrations is mainly because the Vhembe and TV were under IRS and DV was not. However, traces of DDT metabolites were detected in TV. DDT can migrate long distances via air. The continuous evaporation and deposition

may be repeated many times. This is known as the grasshopper effect. Because of the grasshopper effect, DDT metabolites, DDE, and DDD can be transported for long distances in the atmosphere, even to areas that have need had DDT use (Wania and Mackay 1996; Ritter et al., 2005).

High levels of DDT during spraying is of great concern to health worker that conduct the IRS. It is critical to ensure that the workers have adequate personal protective clothing to avoid exposing themselves to DDT. Proper training on how the handle, mix and dispose DDT is of the most importance. Compression sprayer fitted with a fan-type nozzle and a constant flow valve are used in most IRS programs. The World Health Organization (WHO) specification for compression sprayers for IRS is detailed in its specification guidelines on equipment for vector control (WHO, 2006). Procedures for IRS are contained in a separate manual (WHO, 2007). These guidelines and procedures and set to protect workers and prevent also prevent environmental contamination. Studies by Bouwman et al., 1991, show that sprayers that worked in Natal without protective clothing were seriously exposed to DDE.

Levels of DDT detected in air samples collected in Vhembe and DV were higher than the Environmental Protection Agency inhalation limit of 0.097 ng m-3 published by the ATSDR in 2002. Though the inhalation exposure may be limited by particle size, accumulation of DDT in the upper tract of the respiratory system eventually swallowed. This may lead to great exposure to dwellers in sprayed huts. Exposure to such high levels of DDT poses a risk of a number of health complications to the residences. DDT and DDE mainly affect the nervous system when ingested in large amounts (ATSDR, 2001). ATSDR (2002) report on DDT discusses in detail acute exposure effects on the nervous system, effects of chronic exposure to small amounts of DDT being mostly limited to changes in liver enzymes. People exposed to DDT for a long time had changes in liver enzymes (ATSDR, 2003). Considering that DDT has used for IRS in Limpopo for over 40 years, with the general population having not migrated and having living in the province for a lifetime, the bio-accumulative nature and persistence of DDT rising a high alarm on the cumulative effect of IRS on human health.

4.2. The trends and levels of DDT and its metabolite in floor and outside dust

Samples of *o,p'*- DDT, *p,p'*-DDT, *o,p'*-DDD, *p,p'*-DDD, *o,p'*-DDE and *p,p'*-DDE were collected for a sampling period of 24 hours. The first sample was collected and hour before IRS, the second, an hour after and the last sample was collected 24 hours after IRS.

The results in Fig. 7 show that DDT metabolite *p,p'*-DDE and *p,p'*-DDT were present in floor dust samples collected an hour before DDT s was sprayed for IRS. This could be residual DDT from previous IRS operations. DDT spraying was introduced in 1945 for malarial vector control, and since 1966 DDT has been sprayed annually (P. Kruger, Limpopo Malaria Control Programme). DDT is hydrophobic and absorbed by soil. These qualities allow DDT, DDE and DDD to last in soils for long periods (Spencer and Cliath, 1972). These maybe explain the DDT metabolites detected an hour before IRS. Volatilisation of DDT from soil is controlled by the evaporation half-life in soil, which may be set to 2 years. Length of time and chemical remains in the soil is dependent on type of soil, temperature, and moisture. DDT remains in soil for a much shorter time in the tropics where the chemical volatilises faster and micro-organisms degrade it faster (Brouwer, 2010). It therefore follows that in an environment like hut floors, the degrading will take long and hence the presence of DDT. DDT is degraded faster when the soil is flooded or wet than when it is dry. The stability of WHO approved insecticides for IRS is affected by the pH of the environment (Wolfe, 1977; Wolff et al., 1993; WHO, 2007; WHO, 2010a; WHO, 2010b), temperature exposure to ultraviolet (UV) light and the availability of degrading bacteria (Singh and Walker 2006).

p,p'-DDT is predominant at 75% in the IRS formulation (WHO, 2001; Bouwman et al., 2006), and therefore most likely to be present in higher concentrations than other DDT metabolites. *p,p*'-DDT recorded the highest concentration followed by *p,p'*-DDE. The primary step in the thermal decomposition of *p, p'*-DDT is elimination of HCl, resulting in formation of *p, p'*-DDE at 152°C (Longnecker 2005; Wolff et al., 2000b).

Table 3 shows that samples collected an hour and 24 hours after IRS indicate levels of all the metabolites of DDT with *o,p'* isomers being lower than the *p,p'* isomers. This may be largely due to the composition of and *p,p'*-DDT. Commercial mixture used in IRS is made up of 77% and 15% of *p-p*' and *o-p*' isomers commercial DDT respectively. *p,p*'-DDT and its primary breakdown product *p,p*' -DDE have long half-lives of six years and possibly up to 10 years, respectively (Longnecker 2005; Wolff et al., 2000a).

Results also show a significant difference in DDT concentrations based on sampling times. Samples collected and hour before spraying are significantly different from those collected after. This may be due to DDT degradation from the last spraying period and a result of sweeping. The huts are swept daily and hence DDT maybe swept together with the dust particles.

Table 4 shows that there is significant difference between the dust samples collected from the Monday mixture and that collected from the mixture applied on the rest of the week days. The results collected show that dust samples collected during the rest of the week had significantly higher concentrations of DDT compared to Monday samples.

Fig. 8 shows that *p,p*'-DDT was again the dominate isomer, largely due to it high composition in commercial grade DDT. DDT is a highly volatile compound that has a potential to undergo long range transportation. POPs can be transported by wind, water, and biota, and therefore POPs generated in one country can and do affect people and environments further away from where they were used or released (AMAP, 1997; Ritter et al., 2005; Holoubek et al., 2007). In warmer climatic environments the DDT may evaporate after

application and be spread long distances by the atmosphere as a gas. Tests carried out in Arizona indicated that six months after application, DDT was detected in the air above a field and up to 50% of the DDT evaporated out of the soil within 5 months. (WHO, 2009). This may explain the high presence of DDT in TV, as Limpopo is considered to have high temperatures in South Africa, hence the presence of DDT in TV even though no IRS was conducted in that area.

p,p'-DDE had the highest concentration of metabolite detected in outside soil at both DV and TV sites. This was largely due the high decomposition from *p,p*'-DDT to *p,p'*-DDE which may have been greatly influenced by the high temperatures is Limpopo. Most DDT breaks down slowly into DDE and DDD, generally by the action of microorganisms in soil take a long time to breakdown DDT into DDE and DDD (ATSDR, 1994; Wania and Mackay, 1996). DDT is hydrophobic and absorbed by soil. These qualities allow DDT, DDE and DDD to last in soils for long periods. Their half-lives in soil range between as little as 22 days to as much as 30 years (Spencer and Cliath, 1972). A number of researchers, namely, South Africa, Sharp et al. (1988), le Sueur et al. (1993), le Sueur et al. (1996), and Sharp and le Sueur (1996) documented that the history of malarial control in South Africa dates back from the early 1930s to the 1990s. The current source of DDT in the environment is mainly as a result of its past use. Bouwman et al. (2011) concur that continued use of DDT in Africa has contributed to DDT ending up in the environment, hence its presence in TV.

5. Conclusion

DDT exposure poses great health risks the people in and around areas where IRS is conducted. It is there for very important to minimize the risk of exposure in both its frequency and time. Due to the ability of DDT to undergo long range transportation through air and other mediums, caution should therefore be taken to minimize the amount of DDT sprayed to avoid introducing higher concentrations or excess DDT into the environment.

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Conflicts of Interest

The authors declare no conflict of interest.

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