

## **Safety of Working Conditions of Glyphosate Applicators on *Eucalyptus* Forests Using Knapsack and Tractor Powered Sprayers**

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Pesticides are highly selected chemical compounds to cause intoxication and death in target organism, but in a close contact they can be harmful to non target ones, including persons in charge of their application and manipulation. Thus, in the application of pesticides the risk of intoxication is always present requiring it the knowledge of the safety conditions of work.

Glyphosate is a herbicide recommended (Rodrigues and Almeida 1995) and used in the whole planting area of *Eucalyptus* in Brazil, applied with several types of equipment in post emergence, from the initial life cycle phases, and as desiccant agent in the whole area before planting, aiming to control weeds and sprouting branches arising from tree stumps. *Eucalyptus* was planted in seven million hectares around the whole brazilian territory in 1992, rendering 600,000 direct jobs and 1 million of indirect ones, and also an annual total income of 36 billions of dollars with exportations (Rezende et al 1996). The number of workers exposed to this pesticide is high and safety of working conditions were not determined yet.

The risk of intoxication with chemicals products depends on its toxicity and exposition (Turnbull 1985). Toxicity is inherent property of chemical products and it has to be completely evaluated before their liberation for sale. Working exposure is determined according to the type of work, how it is performed by the worker, kind of formulation (Turnbull 1985) and also by the application equipment used (Machado-Neto et al 1996).

In the same way, the distribution of dermal exposure along the body regions depends on the type and method of application, and also by the climatic conditions during applications (Turnbull 1985; van Hemmen 1992; and Machado-Neto 1996). During the operations of preparation of solutions, tank loading, and the use knapsack and tractor powered sprayers, hands were the most exposed body parts, receiving between 33 to 86% of the total exposure (Bonsall 1985). Hands of drivers of tractors equipped with spraying systems, received in average 65 to 75% of total dermal exposure, in comparison to legs with 10 a 25%. When knapsack

sprayers were used, hands presented only 10 to 25% and legs 25 to 85% (van Hemmen 1992).

Working conditions can be classified as safe or unsafe, considering the estimated margin of safety considering the toxicological data (van Hemmen et al. 1992) and working exposure (Kieczka 1993). The objective of this work was to evaluate the safety of working conditions of glyphosate applicators in *Eucalyptus* forests.

## MATERIALS AND METHODS

All this work was performed in the *Eucalyptus* forests of Aracruz Celulose S.A., where eleven application conditions of glyphosate were identified, using: knapsack sprayers and tractor trailer or mounted sprayers (Table 1).

**Table 1.** Working conditions in the application of glyphosate in *Eucalyptus* forests, Aracruz Celulose S.A. Espírito Santo State, Brazil.

| Working conditions   | Type of sprayer   | Target   |
|----------------------|---|--|
| 1. Applicator        | Lever operated knapsack   | Weeds  |
| 2. Applicator        | Pressurized knapsack  | Weeds  |
| 3. Tank loader       | Pressurized knapsack  | -  |
| 4. Tractor Driver    | Tractor trailed, with a boom at 2.3 m and six hoses.                  | Stumps   |
| 5. Applicator        | Tractor trailed, with a boom at 2.3 m and six hoses.                  | Stumps   |
| 6. Solution Mixer    | Tractor trailed, with a boom at 2.3 m and six hoses.                  | -  |
| 7. Tractor Driver    | Tractor trailed, with only the conventional application boom of 9.0 m | Total Area                                       |
| 8. Applicator        | Tractor trailed, using a single 70.0 m hose.                          | Total Area – Gorges                              |
| 9. Applicator Helper | Tractor trailed, using a single 70.0 m hose.                          | Total Area – Gorges                              |
| 10. Tractor Driver   | Tractor mounted, with protected small “Conceição” boom.               | Weeds - planting area 1 <sup>st</sup> year       |
| 11. Tractor Driver   | Tractor mounted, with unprotected small “Conceição” boom              | Weeds – planting area after 1 <sup>st</sup> year |

In order to evaluate the Potential Dermal Exposures (PDEs) on field workers, a copper fungicide (copper oxychloride 252g/100L of water) was added to the spraying solution of Roundup (glyphosate 480 g/L), being the Cu<sup>+2</sup> cation used as a tracer and applied together. Exposures to copper

fungicide were used as substitute (Jensen, 1984) to estimate exposures to glyphosate solutions.

Evaluations of PDE on tractor drivers and applicators were performed in time periods less than 70 minutes and extrapolated to a whole 7 hour working day of effective exposure. In the same way, for solution mixers and tank loaders of pressurized knapsack sprayers, their activities were also extrapolated to a whole day in order to evaluate PDE. All evaluations were performed in forests with plants spaced of 3.0 x 3.0 m, with 8 replications.

Female sanitary pads (Carefree) were used as samplers of PDE, distributed in 20 parts of workers body (Machado-Neto and Matuo 1989; Machado-Neto 1990; and Machado-Neto et al. 1992). They were distributed from the top of the head to the upper part of feet, on the drill overalls with long sleeves and hood, disposal semi-facial mask, and leather shoes (WHO 1975). PDE in hands were directly assayed in the cotton gloves used by workers. After the exposure periods, all samplers were taken to the laboratory, and the impregnated  $\text{Cu}^{+2}$  cation, was recovered and quantified in an atomical absorption spectrophotometer (Machado-Neto and Matuo 1989). PDE on the workers body parts were estimated through the collected  $\text{Cu}^{+2}$  from the female sanitary pads surface. Dermal exposures to solutions were estimated through the concentrations of  $\text{Cu}^{+2}$  present in the utilized solutions and the estimated quantities of  $\text{Cu}^{+2}$  for the body parts.

Dermal exposures to glyphosate were estimated through their recommended concentrations in the solutions, and the quantity of solution recovered from the sampler. The accepted variation in values of dermal exposures among repetitions of each body part, was equal to the mean  $\pm$  two times the calculated standard deviation (WHO 1975). The noncontrolled dermal exposures (NCDEs) by the personal protective equipments (PPEs) that workers use for these working conditions, were estimated by subtraction from the solution PDE, quantities of solution that could be retained by the equipments, they were: 80% for overalls and hoods, 95% for boots, 99% for rubber gloves and 99% for facial masks (Kiecicka 1993).

Safety of the eleven conditions of applications of glyphosate, was evaluated through the estimation of the Margin of Safety (MOS) by the following formula:  $\text{MOS} = [(\text{NOEL} \times 70) / (0,11 \times \text{Dermal Exposure} \times 10)]$  (Machado-Neto 1997), without taken into consideration the degradation of glyphosate. If it occurs, it will be added to the safety factor used in the MOS formula. In this formula, there were taken into consideration the following data: NOEL= 31 mg/kg/day (Worthing and Hance 1991); 2% absorption of PDE (mg/day) by dermal route (Wester et al. 1991, cited by Mensink & Janssen 1994) and 1% of PDE (mg/day) by respiratory route (Wolfe et al 1987 and 1972) body weight 70 kg, and the safety factor 10 (Brouwer et al 1990). Working condition was considered safe if  $\text{MOS} \geq 1$  and unsafe if  $\text{MOS} < 1$  (Machado-Neto 1997). For the unsafe conditions, in order to turn them safe, the need of

exposure control (NEC) was estimated by the formula  $NEC = [(1 - MOS) \times 1001]$  and expressed in percentage (Machado-Neto 1997).

## RESULTS AND DISCUSSION

The distribution of PDE along applicator body regions is presented in Table 2. It can be verified that PDE concentration depends on the kind of activity performed and also by the equipment used, agreeing with the results presented by other authors (Bonsall 1985; van Hemmen 1992; and Machado-Neto et al 1996). When knapsack sprayers with hand lances (conditions 1 and 2) were used, values of PDE of 77 and 85,7 % were found only in two body regions: frontal part of thighs and legs and feet. For tank loaders and solution mixers in conditions 3 and 6, the most exposed regions were their hands (65,3 and 66,6% of PDE) and the frontal part of thighs and legs and feet. This data agrees with Bonsall (1985).

When tractor powered sprayers are used, with hand lances attached to a boom (condition 5) or a single pistol attached to 70 m hose (conditions 8 and 9) the most exposed body parts of workers were besides the frontal part of thighs and legs and feet, the arms and forearms, for all three conditions of work, and hands only for condition 9. The most exposed body parts for tractor drivers in working condition 7 (tractor trailed with a 9.0 m boom) regions as frontal part of thorax, arms and forearms, frontal part of thighs and legs, and hands; and for the case of the "Conceição" boom (condition 10 and 11) hands, frontal part of thighs and legs, and feet; these results are in agreement with those of other authors (Bonsall 1985; and van Hemmen 1992).

Estimated values of PDE and NCDE for the eleven working conditions, and their respective MOS values are presented in Table 3. It can be verified that only one (condition 5) applicator/ tractor trailed with boom at 2.3 m high and six hoses, can be classified as unsafe without the use of the PPEs (MOS = 0.78). However, considering NCDE with the use of PPEs, the estimated MOS was 5.18, rendering a safe activity in terms of working exposures. In this case the use of PPEs can reduce up to 82.52% of PDE values, which is highly superior to the need of the exposure control, that was estimated in 22.40% of PDE. It can also be verified, that the other working conditions can be classified as safe, with or without the use of PPEs.

Working conditions for application of glyphosate in *Eucalyptus* forests from Aracruz Celulose S.A., using knapsack and tractor powered sprayers, with or without the use of PPEs, can be considered safe, with the exception to that involving operators without protective clothes handling lances attached to boom at 2.3 m (MOS = 0.78) but with the use of this PPEs it became safe (MOS = 5.18).

**Table 2.** Distribution of PDEs in the body regions of glyphosate herbicide applicators in *Eucalyptus* forests.

| Working Conditions<br>(Operator/Type of<br>sprayer)                                  | % in<br>spray<br>sol. | Body regions |      |      |      |      |      |      |      |
|--|-----------------------|--------------|------|------|------|------|------|------|------|
|  |                       | A            | B    | C    | D    | E    | F    | G    | H    |
| 1. Applicator/ Lever<br>operated knapsack  | 0.48                  | 0.1          | 0.5  | 4.3  | 1.6  | 0.1  | 44.6 | 7.7  | 41.1 |
| 2. Applicator/<br>Pressurized knapsack   | 0.48                  | 4.3          | 0.7  | 0.2  | 3.9  | 10.2 | 33.6 | 3.7  | 43.4 |
| 3. Tank Loader/<br>Pressurized knapsack  | 0.48                  | 2.1          | 4.3  | 65.3 | 1.8  | 3.1  | 11.7 | 5.2  | 6.5  |
| 4. Tractor driver/<br>Tractor trailed with<br>boom at 2.3 m high<br>and six hoses    | 1.60                  | 9.4          | 20.1 | 7.0  | 18.9 | 6.8  | 19.4 | 11.4 | 7.0  |
| 5. Applicator/ Tractor<br>trailed with boom at<br>2.3 m high and six<br>hoses        | 1.60                  | 4.8          | 27.2 | 1.1  | 13.3 | 4.3  | 23.8 | 10.1 | 15.4 |
| 6. Solution Mixer/<br>Tractor trailed with<br>boom at 2.3 m high<br>and six hoses    | 48.00                 | 2.9          | 5.1  | 66.6 | 2.8  | 1.5  | 11.6 | 4.3  | 5.2  |
| 7. Tractor driver/<br>Tractor trailed with<br>only a boom of 9.0 m                   | 0.48                  | 7.4          | 20.5 | 10.9 | 28.4 | 4.5  | 12.6 | 9.8  | 5.9  |
| 8. Applicator/Tractor<br>trailed with only a<br>single 70.0 m long<br>hose           | 0.48                  | 2.4          | 24.1 | 2.2  | 5.1  | 4.5  | 35.7 | 14.9 | 11.1 |
| 9. Applicator Helper/<br>Tractor trailed with<br>only a single 70.0 m<br>long hose   | 0.48                  | 1.3          | 11.5 | 22.3 | 6.8  | 2.2  | 28.0 | 15.7 | 12.2 |
| 10. Tractor driver/<br>Tractor mounted with<br>protected small<br>"Conceição" boom   | 1.13                  | 6.2          | 8.8  | 27.8 | 5.2  | 3.7  | 13.5 | 5.9  | 28.9 |
| 11. Tractor driver/<br>Tractor mounted with<br>unprotected small<br>"Conceição" boom | 1.13                  | 1.5          | 4.0  | 50.0 | 2.0  | 1.2  | 18.1 | 3.4  | 19.8 |

A = head + face + neck

B = arms + forearms

C = hands

D = thorax front

E = thorax back

F = legs + thigh front

G = legs + thigh back

H = feet

**Table 3.** Potential dermal exposure (PDE) and not controlled dermal exposure (NCDE) by personal protective equipments (PPEs) and margin of safety (MOS) from glyphosate herbicide applicators in *Eucalyptus* forests.

| Working Conditions<br>(Operator/Type of<br>sprayer)                                  | % in<br>spray<br>sol. | Dermal Exposure<br>(mg/day) |          | Margin of Safety |          |
|--|-----------------------|-----------------------------|----------|------------------|----------|
|  |                       | Potential                   | NCDE     | PDE              | NCDE     |
| 1. Applicator/ Lever<br>operated knapsack  | 0.48                  | 1,945.83                    | 253.90   | 3.72             | 30.89    |
| 2. Applicator/<br>Pressurized knapsack   | 0.48                  | 1,448.73                    | 194.75   | 4.99             | 40.61    |
| 3. Tank Loader/<br>Pressurized knapsack  | 0.48                  | 1,764.08                    | 127.59   | 4.10             | 50.28    |
| 4. Tractor driver/ Tractor<br>trailed with boom at<br>2.3 m high and six<br>hoses    | 1.60                  | 1,077.42                    | 189.98   | 6.71             | 44.49    |
| 5. Applicator/ Tractor<br>trailed with boom at<br>2.3 m high and six<br>hoses        | 1.60                  | 9,320.64                    | 1,629.30 | 0.78             | 5.18     |
| 6. Solution Mixer/<br>Tractor trailed with<br>boom at 2.3 m high<br>and six hoses    | 48.00                 | 88.47                       | 5.83     | 81.89            | 1,057.70 |
| 7. Tractor driver/ Tractor<br>trailed with only a<br>boom of 9.0 m                   | 0.48                  | 196.69                      | 33.52    | 36.77            | 250.24   |
| 8. Applicator/Tractor<br>trailed with only a<br>single 70.0 m long<br>hose           | 0.48                  | 6,540.28                    | 1,171.80 | 1.11             | 7.24     |
| 9. Applicator Helper/<br>Tractor trailed with only<br>a single 70.0 m long<br>hose   | 0.48                  | 6,347.66                    | 883.46   | 1.14             | 9.04     |
| 10. Tractor driver/ Tractor<br>mounted with<br>protected small<br>"Conceição" boom   | 1.13                  | 70.60                       | 7.33     | 102.3<br>6       | 999.00   |
| 11. Tractor driver/ Tractor<br>mounted with<br>unprotected small<br>"Conceição" boom | 1.13                  | 838.88                      | 63.15    | 8.62             | 103.24   |

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