Wood Dust Production and VOC (Volatile Organic Compound) Emissions During Mechanical Pre-pruning in Vineyards

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ABSTRACT

During trials regarding the mechanization of vine pre-pruning, production of wood dust that could obstruct tractor filters was noticed. It was hence decided to investigate the production of chemical airborne pollutants during mechanical pre-pruning of vines, with the aim of assessing operators' exposure to wood dust and VOCs (*Volatile Organic Compounds*). Experiments were carried out in 4 different vineyards during mechanical pre-pruning using pre-pruning machinery with rotating components.

The dust was collected with active filter sampling, using an IOM sampler. The VOC emissions were recorded with a portable measuring device based on photo-ionisation technology. The data was processed with R software for variability distribution and to investigate the influence of the independent variables considered. The results show that the values found for wood dust were below the limits established by Italian regulations (5 mg/m^3). However, the daily exposure of 1.55 mg/m^3 that was found indicates the importance of risk assessment. The exposure to VOCs found leads to the conclusion that during mechanical pre-pruning quantities of airborne pollutants are released that could put the operator at risk if he/she is not suitably protected.

1. Introduction

During trials regarding the mechanization of pre-pruning, the production of wood dust that could obstruct tractor filters was noticed. The aim of this work was both to measure the concentration of wood dust and VOC (Volatile Organic Compound) emissions from the machines and to assess the exposure risk of the operator during pre-pruning.

The literature available and the methods used for sampling do not consider the agricultural sector but refer to industrial environments and, in just a few cases, to the forestry sector. Given the scarcity of information another aim of this research was to assess the measuring procedures adopted.

D. Lgs (Legislative decree) 66 of 25 February 2000, which modified article VII of *D.Lgs* 626/*94 "Protezione da agenti cancerogeni e mutageni*", ("Protection from carcinogenic and mutagenic agents"), subsequently absorbed into the Consolidating Act (Legislative decree 81/2008), added hard wood dust to the category of carcinogens affecting the nasal and paranasal sinuses, in accordance with the International Agency Cancer Research (I.A.R.C.) classification.

In Italy the maximum value for exposure to wood dust per workday (TLV-TWA) is 5 mg/m^3 for "hard wood" or without distinction if the hard wood is mixed with other wood dust (Legislative decree) 81/2008 - Title IX).

Hard wood dust sampling strategy meets the requirements of the regulations set out in Legislative decree 81/2008, technical regulations (UNI EN 481/94, UNI EN 689/97, UNI EN 482/98), methods (NIOSH 0500-0600 Methods) and guide lines (Arcuri *et al., 2001)*.
The research on occupational exposure to wood dust in Europe (WOODEX) indicates that in forestry sites there are low levels of exposure (0,12 mg/m^3 of inhalable fraction) because of the characteristics of the work (outdoors), the intermittency of exposure (use of chain saw) and the low inhalability of the dust produced by the saw (FIOH-INRS, 2005).
The variables affecting the concentrations present in the air are: the number of sources emitting the agents (tractors, operators, wood from pruning), the production speed in relation to the production capacity, the type and position of the source and the dispersal of the agents due to air movements **(**Aikten RJ et al, 1999; Marconi A. 2002, Campopiano A. et al, 2008). The variables connected with individual actions and behaviour are: closeness of the person to the sources and duration of the task (UNI EN 689/97).
As far as operator exposure to VOCs is concerned, the regulations in force are not specific and do not provide evaluation criteria and nor do they indicate the maximum concentrations that should be respected in the work place. The only research body expressing an opinion is OSHA, which gives a concentration of 0,5 ppm as a limit; while as regards petrol the Italian regulations in force (*T.U. D. Lgs 81/2008 allegato XLIII* [Consolidating Act Legislative decree 81/2008 attachment XLIII]) establishes an occupational exposure limit of 1 ppm, in contrast with the ACGHI limit of 0,5 ppm.

2. Methodology

The experiments to find and assess the risks from exposure to dust and VOCs during vineyard pre-pruning were carried out in four lots cultivated with vines (A,B) situated in south-east Sicily in the Pachino area and (C,D) in a vineyard in the Castiglione di Sicilia area on the north face of Mt Etna (CT). For each vineyard note was made of the type of plantation, the cultivation techniques adopted and the way the machines were used (Tab. 1). The physical characteristics of the soil were determined with granulometric analysis and the humidity was determined with gravimetric analysis. During the trials the air temperature, relative humidity and wind speed were recorded

Tab. 1 – Characteristics of the 4 vineyards

Vineyard	Variety	Year of planting	Spacing of vines (m)	Density (plants/ha)	Row Length (m)	Headland width (m)	Pruning type
A	Nero d'Avola	2001	2,1x0,9	5.000	216	4	Spurred cordon
B	Inzolia	2004	2,1x0,9	5.000	221	3	
C	Nerello mascalese	2006	2,2x1,0	4.545	190	5	
D	Merlot	2004	2,2x0,8	5.000	200	5	

2.1 Mechanical pre-pruning

Although mechanical pre-pruning does not eliminate manual work, it reduces the pruning time, particularly because of the efficient removal of the cut shoots, and for this reason it is a widespread practice in mechanised vine cultivation. The study focussed on two pruning machines with rotating cutting devices (Tab 2) installed on a tractor.

Tab.2 - Caratteristiche prepotatrici

Vineyard	Pre-pruning machine model (blades)	year	mass (kg)	Tractor
A	Pm (9)	2003	550	FIAT DT 7286, 4 RM, 55 kW
B				
C	Pe (9)	2004	605	FIAT DT 7286, 4 RM, 55 kW
D				

The pre-pruning machines (fig.1) used in the trials are straddling machines with a double stack of 9 blades (discs) joined to an inverted U-shaped carrying framework. Height and width regulation, as well as the opening of the two columns are controlled by oleodynamic cylinders commanded by electrovalves. The "P_e" machine is towed by a 55 kW double traction tractor – not a recent model. The pre-pruning machine "P_m" is used by a company that carries out work for third parties. It is the same make as the other machine but the rotating speed of the discs has been increased with respect to the factory version. The machine is towed by a double traction tractor, again with a power of 55 kW.

2.2 The measuring instruments

The dusts were measured by active filter sampling. As regards equipment the IOM (Institute of Occupational Medicine) sampler was chosen and as regards the filtering element, a fibreglass membrane with a diameter of 25mm and a porosity of 1 µm was used. The sampler was connected to a portable pump with an APEX Casella battery (*Fig. 2*), and there was electronic control of flow and automatic compensation for pressure variations, in compliance with regulation UNI –EN 1232. The sampling flow during the trials was regulated to 2 L/min.
The VOCs were detected using a portable measurer - *MiniRAE 3000* (*Fig. 2*), with a functioning principle based on photo-ionisation techniques – Detector PID. The values measured were visualised and elaborated with the specific *ProRAE Studio* software, which made it possible to draw up graphs of the VOC concentration against time and to save the data for further analysis (*Blandini G. et al*, 2009). The data was processed with software R for variability distribution and to investigate the influence of the independent variables considered.

2.3 Method

In each vineyard sampling was performed by placing the instruments in two pockets of the work jacket worn by the operator and carefully attaching the air and filter carrier samplers near the respiratory zone (*Fig. 3*).
In order to quantify the VOCs Isobutylene was used to calibrate the equipment.
Analysis of the wood dust deposited on the filter was carried out by gravimetric measurement using a Mettler Toledo XP56 analytical balance with 0.001mg sensitivity.
Before each weighing the filters were conditioned in a climatic room (dryer) for at least 24 hours.
The calculation of the airbourne dust in the air sample taken was obtained by dividing the difference between the weight before and after sampling by the volume of air sucked in during sampling, following the method contained in the HSE-MDHS 14/3 indications.
The calculation of occupational exposure both as regards dusts and VOCs was carried out over a reference period of 8 hours (weighted mean over 8 hours, TWA):

$C_{exp,g} = C_{tc} * T_e / T_0$ (C esp,g= daily exposure over 8 hours, C tc= polluting agent concentration durino sampling time, Te= t exposure = 6.40 hours, T0 = 8 hours)

Fig. 1 **–** *Pre-pruning machine working*

Fig. 2 – Apex Casella, sampler IOM, MiniRAE 3000

Fig. 3 **–** *Placing of instruments on operator*

3. Results and discussion

3.1 Soil characteristics

The mean relative humidity of the soil was found to be 19% in vineyards A and B and 24.8% in vineyards C and D. From the granulometric analysis it was found that the soil in A and B was of a medium consistency and made up of 16.9% clay, 26.3% lime and 56.8% sand. In C and D the soil was of medium consistency tending towards sandy with a composition of 6% clay, 26.2% lime and 67.8% sand. At the time of the trials the soil was not found to be particularly dry or dusty.

3.2 Wood dust

Table 3 shows the results of the analyses. The dust exposure values are much lower than the limit exposure value of 5 mg/m^3 (inhalable fraction) established by Legislative Decree 81/2008. The low values (between 0.57 and 1.55 mg/m^3,) are due to the characteristics of the work environment (open air), the intermittency of the exposure (suspended during the manoeuvres at the end of rows, to the work time (6 h 40' – less than 8 hours) and to the type of cut made by the pre-pruning machine – removal of portions of shoot and with the production of wood shavings and a limited amount of fine dust.
On site B a greater daily exposure to dust was found (1.55 mg/m^3). This site was characterised by the high work capacity of the machine, the average wind speed of 3,7 m/s and its direction - orthogonal with respect to the forward movement of the machine (Tab. 4).

Tab. 3 – Analysis results

Vineyard	**Dust concentration (mg/m^3)**	**C exp,g = daily exposure (mg/m^3)**
A	0.85	0.68
B	1.94	1.55
C	0.71	0.57
D	0.72	0.57
Mean	1.05	0.84
Standard deviation	0.59	0.47
Geometric mean	0.96	0.76
Q Dev	1.05	0.68

Tab. 4 – Work conditions

Vineyard	Soil humidity (%)	Mean relative humidity of air (%)	Mean external temp (°C)	Mean wind spead (m/s)	Pump aspiration duration (h)	Quantity of air aspirated (litri)	Actual time pre-pruning machine in field (h)	Speed of pre-pruning machine progress (km/h)	Cr (ha/h)
A	19,0	38,7	13,6	1,8	3,20	400	2,40	6,60	1.18
B	19,1	49,0	16,4	3,7	3,28	418	3,18	6,20	1.06
C	24,8	71,9	10,5	1,5	3,01	364	2,50	2,31	0.39
D	24,8	41,0	9,7	1,3	2,12	265	2,10	2,90	0.40

In the experimental conditions dictated by the use of the IOM sampler, as already pointed out by other authors (Biondi et al. 2002), there is the problem that large particles extraneous to the inhalable fraction to be sampled are captured. In these cases the problem was resolved by manually removing the small wood shavings before weighing the sample.

The data obtained was analysed for possible correlations between the factors observed. From the data elaboration it emerged that the duration of the trial did not affect the dust concentration and that neither did the pump aspiration duration or the relative air humidity percentage. The results show similar trends to those for aspired air and speed of progress of the machine. The soil humidity is inversely proportional to the concentration but not significantly so. The factors with marked correlation are the hours of the pre-pruning machine use in the field (93%), the external temperature (88%) and the wind speed (99%).

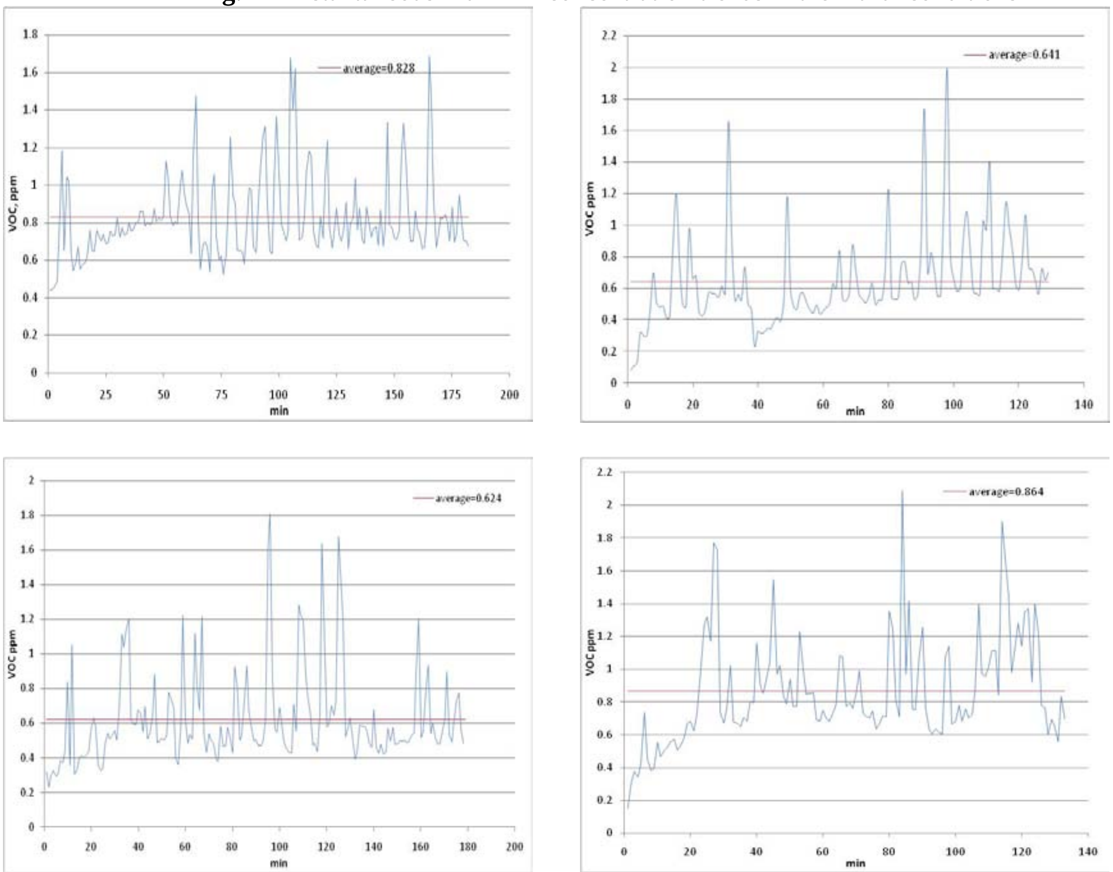
3.3 Volatile organic compound VOCs

If the exposure values found in this preliminary evaluation are compared with the limit value for benzene, it would seem that pre-pruning represents an immoderate chemical risk for the operator and that consequently further periodic tests should be organised.
The graphs in figure 4 shows the maximum concentration values found in the four trial conditions plotted against time. It is possible to see that there are concentration peaks corresponding to the turns at the end of the rows. These are probably due to the wind direction, which was often orthogonal with respect to the advance of the machine.

Tab. 5 – Analysis results

Vineyard	**VOC (ppm)**		
	MIN PID	PID AVG	MAX PID
A	0,68	0,73	0,83
B	0,41	0,49	0,65
C	0,40	0,48	0,66
D	0,63	0,72	0,90

Fig. 4 – Instantaneous Max PID concentration trends in the 4 trial conditions



Elaboration of the data obtained revealed an inverse correlation (-80%) between the VOCs and the air humidity, which could indicate that when the air is dry there is a greater quantity of volatile compounds.

It emerged that the VOCs were influenced in a statistically significant way by the trial vineyard conditions. On the other hand, the time of sampling and trial repetition had no influence on the final result. This indicates a high repeatability of the trial as regards both time and previous results.

From the variance breakdown carried out with R software there would appear to be a first order interaction between the VINEYARD factor and the TIME factor indicating that the final result is certainly influenced by the VINEYARD factor but not by the TIME factor, but that in some vineyards the time influenced the response value.

The Tukey test was applied to the mean obtained from the elaborated data (Tab. 6).

In general the VOC values were influenced by the conditions prevailing on the day the vineyards were studied. The correlations seem to show that the vineyard factor to have most influenced the final result was the low humidity present on the day of the trial

Tab. 6 – Tukey test on vineyard means.

1 0.67763 a	Vineyard A
2 0.40670 c	Vineyard B
3 0.51562 b	Vineyards C, D
DMS	0.06474

4. Conclusions

As concern dust production, the bibliography available and methodology adopted in the past do not consider the agricultural sector but refer to industrial environments and, in just a few cases, the forestry sector. This work represents the first results regarding exposure to wood dust and VOC emissions during mechanical pre-pruning, a widespread operation in mechanised vineyards. In order to monitor the production of dust in the open field it is necessary to refer to what is rigidly foreseen for closed environments (sawmills, artisan workshops). It can be said that as regards the wood dust, the mean values found were far below the limits established by the current regulations in Italy (5 mg/m^3). However, machine P_m with higher speedy blades presents more dust than the other one. In fact, in case B, the daily exposure values were found to be 1,55 mg/m^3. Although this is well under the limit mentioned above, the EU Scientific Committee for Occupational Exposure Limits (SCOEL) claims that exposure to wood dust above a 0,5 mg/m^3 of total dust (equal to 1-1,5 mg/m^3 inhalable fraction) can have an effect on the lungs and should, therefore, be avoided in order to protect workers (*Martinotti*, 2008). Also the situation regarding VOCs seems worrying, in that preliminary analyses of the exposure would seem to indicate that during mechanical pre-pruning airbourne pollutants are produced in a quantity that places the operator at risk if he is not adequately protected. Analysis of the results showed the influence of environmental factors, particularly that of the air humidity. Also aspects connected to the production of exhaust fumes and the correctness of the tractor - pre-pruning machine relationship are linked to VOC emissions and this should be studied further. Given these considerations, the investigation should be extended, focussing on the influence of air currents (intensity, constancy and direction) and on the main climatic considerations that can be found in an open environment.

5.**Bibliography**

ARCURI C., BIANCHI A., BOSI A., CACCHI F., CERVINO D., DI STEFANO S., FERRI F., GOVONI C., GUGLIELMIN A., PASSERA G., POLETTI R., VENERI L. 2001. *Problemi applicativi ed interpretativi del titolo VII del D. Lgs. 626/94 per le polveri di legno duro.* In Govoni C., Ferrari D. - Rischio Prevenzione e protezione da agenti cancerogeni e mutageni. Modena. 171-212.

BIONDI P., MONARCA D., CECCHINI M. 2002. *La valutazione del rischio da esposizione a polveri di legno duro: indagine sperimentale e metodologica*. Proc. Convegno nazionale AIIA Alghero-Sassari, 11-15 settembre, 377-390.

BLANDINI G., CERRUTO E., MANETTO G. 2009. *Rischi da polvere e da VOC per gli addetti alle operazioni colturali negli agrumeti.* Atti su CD-rom del IX Convegno Nazionale AIIA, 12-16 settembre, Ischia Porto (NA).

Decreto legislativo 9 aprile 2008 n. 81. Attuazione dell'articolo 1 della legge 3 agosto 2007, n. 123, in materia di tutela della salute e della sicurezza nei luoghi di lavoro – Titolo IX, Allegato XLII –XLIII. Suppl. ord. n.108, G.U. n. 101 del 30 aprile 2008.

FIOH, INRS. 2005. *Exposure measurements of wood dust in the European Union.* WOODEX report UE. 1-201.

IARC. 1995. Monographs on the evaluation of carcinogenic risks to humans:*Wood dust and Formaldehyde.* Lyon (France), 9-215.

SCHILLACI G., BALLONI S., CAMILLIERI D., CONTI A., TIRRÒ G., CARUSO L. 2009. *Determinazione di residui sospesi in aria dopo trattamenti in serra con agrofarmaci.* Atti su CD rom del IX Convegno Nazionale AIIA 12-16 settembre, Ischia Porto (NA).

SCHILLACI G., CARUSO L., CAMILLIERI D., BONSIGNORE R. 2009. *Macchine e tecniche di potatura invernale nella vite allevata a cordone speronato.* Atti su CD rom del IX Convegno Nazionale AIIA 12-16 settembre, Ischia Porto (NA).

SCHILLACI G., CARUSO L., BONSIGNORE R., CAMILLIERI D., EMMA G., TIRRÒ G., RAPISARDA V. - 2010. *Produzione di polveri di legno e emissione di VOC durante la prepotatura delle viti.* Third International Congress on Mountain Viticulture CERVIM, Castiglione di Sicilia (Italy), May 12/14.SCOEL. 2003.

Recommendation from Scientific Committee on Occupational Exposure Limits for Wood dust. SCOEL/SUM/102 final.

UNI CEN, 1994. Norma UNI EN 481 *"Atmosfera nell'ambiente di lavoro. Definizione delle frazioni granulometriche per la misurazione delle particelle aerodisperse".* Ed. Ottobre 1994.

UNI ISO, 1998. Norma UNI ISO 7708 *Qualità dell'aria. Definizioni delle frazioni granulometriche per il campionamento relativo agli effetti sanitari.* Ed. settembre 1998.