Determining the Exposure of Chipper Operators to Wood Dust

Natascia Magagnotti[1*], Raffaele Spinelli[1], Cecilia Nannicini[2], Gianfranco Sciarra[3]
[1]CNR IVALSA, Via Madonna del Piano, 10; 50019 Sesto Fiorentino (FI), Italy
[2]Prevention and Work Protection Department, Tuscany Region
Via Taddeo Alderotti, 26; 50139 Florence, Italy
[3]Local Health Unit n. 7 Siena, Strada del Ruffolo, 4; 53100 Siena, Italy
magagnotti@ivalsa.cnr.it; spinelli@ivalsa.cnr.it

Abstract:
Chippers produce large amounts of wood dust, which is a recognized cancer agent. Hence the interest of determining the exposure of chipper operators to wood dust in order to evaluate the level of occupational hazard and suggest suitable countermeasures. This study surveyed both industrial and small-scale chipping operation in the Appenine mountains between of Northern Tuscany. During the survey 33 samples were collected using standardized methods. Operators were equipped with an active sampler connected to a suction pump. The sampler was placed as near as possible to the operator's face in order to sample the air he inhaled. When operators were seated inside an enclosed cab, samples were also collected outside the cab in order to gauge the dust abatement effect of the protected work station. Exposure to dust varied widely with wood conditions and operation type (industrial or small-scale), but it was always within the 5 mg/m^3 legal limit. Operators working inside a cab were at least 4 times less exposed than operators working outside. People working full-time as chipper operators should always be positioned inside an enclosed cab, for limiting their exposure to wood dust.

Keywords: biomass, occupational health, medicine, risk

1 Introduction

Chipping is one of the most popular biomass processing techniques, and since biomass sector is booming (Berndes et al., 2003, Linden, 2011, Coaloa, 2007, Krausmann et al., 2008, Magar et al., 2011) it is likely that the chipping business will expand and an increasingly larger number of operators will be involved.

Working environments in logging operations can be very dusty (Mitchell, 2011) but very few studies have addressed wood dust exposure, maybe because of the small quantity of operators working in forest sector (Martinotti et al., 2008). In fact, many of the epidemiological studies regarding the exposure to wood dust are focused on the furniture industry (Alwis, 1998). Based on these studies, the International Agency for Research on Cancer (IARC) has classified wood dust as a human carcinogen (IARC, 1995) and in the '90s the IARC estimated that at least 2 million people worldwide were exposure to wood dust.

Wood dust can be defined as solid airborne particles with variable dimensions generated after working process of the wood material. According to the dimension of component particles (ISO 7708: 1995), wood dust can be distinguished into:

⇒ inhalable dust: fraction of the total airborne particles that enters the body through the nose and/or mouth during breathing. This is relevant to health effects in the respiratory tract and it can trigger rhinitis, nasal and lung cancer. It can also have systemic effects;

⇒ thoracic fraction: sub fraction of the inhalable fraction composed of particles that can reach the tracheo-alveolar region of the lung, possibly triggering asthma, bronchitis, and lung cancer;

⇒ respirable fraction: sub-fraction of the inhaled particles that penetrates into the alveolar region of the lung (i.e., includes the respiratory bronchioles, the alveolar ducts and sacs) and can cause chronic diseases such as emphysema.

Determining the level of exposure to wood dust is extremely important because high exposure levels can trigger serious occupational diseases (Moscato et al., 2002). Besides, the irritant effects of wood dust on the skin and respiratory system are well documented (Senear, 1933; Woods and Calnan, 1976; ILO, 1983, Cirla, 2008, Innocenti, 2008). Respiratory, nasal and eye symptoms are the most common effects reported by woodworkers (Holness et al., 1985; Li et al., 1990; Pisaniello et al., 1991; Shamssain, 1992; Liou et al., 1996).

In 1714, the first Italian surgeon dealing with occupational diseases, doctor Ramazzini, reported that loggers during the manual processing of the trees suffered of eye irritation and pain due to wood dust (Cirla, 2008). The first observations on wood-related pathologies date back to the end of 1800, and come mostly from shipyards (Innocenti, 2008). Up to late '60s, skin pathologies represented the main recognized health problems deriving from exposure to wood dust (Hausen, 1981, Innocenti e Del Monaco, 1980). Later studies also addressed asthma and cancer of the paranasal sinuses. In Italy, asthma caused by beech dust was first reported in 1982 (Pisati et al., 1982)

In 1999, the European Union promulgated the European Directive 38/1999 CE, setting the legal limit for the exposure to wood dust at 5 mg/m^3, based on an 8-hours working day. This limit is valid for exposure to hardwood wood dust, or to any mix of hardwood and softwood dust. There is no legal limit to the exposure of pure conifer wood dust, which is not a yet a recognized noxious substance.

In Italy, the European Directive was implemented the following year, with the Law 66/2000. This was incorporated into the current law on work safety (D.L 81/2008), which recognizes wood as dangerous material and a cancer agent. Therefore, the present legal limit in Italy is still 5 mg/m^3 , based on a 8-hours workday and referred to the inhalable fraction. However, symptoms to the upper respiratory system have also been reported for much lower exposure level, such as 1 mg/m^3 (Foà et al., 2008).

No published studies have yet determined the exposure levels characterizing wood chipping operations, although this information is crucial to assessing the risk for occupational disease. Without this information it is also very difficult to develop sensible and effective prevention measures. Furthermore, wood dust can contribute to fire risk, because it deposits on hot machine parts the chipper and ignites very easily (Spinelli and Hartsough 2001).

The goals of this study were: 1) to determine the exposure levels to wood dust for chipper operators; 2) to check whether these levels differed between industrial and small-scale operations and 3) to gauge the possible reduction of exposure levels obtained by placing the operator inside an enclosed cab, as available on modern industrial chippers.

2 Materials and methods

This study examined 16 commercial chipping operations in order to determine operator exposure to wood dust (Tab. 1). Operations were divided into industrial and small-scale operations, the former based on powerful chippers (300-400 kW) fitted with an enclosed cab, and the latter on smaller machines (100-150 kW) without enclosed cab.

Figure 1: Pump Gilian 5000 equipped with SKC button sampler

During the tests, chipper operators wore a SKC Button Sampler to collect the inhalable fraction of wood dust. This active filter sampler has a porous curved-surface inlet designed to improve the capacity to collect inhalable dust, and at the same time to avoid access to oversize “projectile” particles thrust into the sampler. Inclusion of these large particles would bias the sampling, because they are normally too heavy for being inhaled with the respiration act. Furthermore, this multi-orificed inlet mitigates electrostatic effects and reduces sensitivity to wind direction and velocity. The SKC Button Sampler operates at a flow rate of 4 L/min. Therefore, the samplers used for the study were connected by transparent flexible pipes to portable pumps, model Gilian 5000 (Fig. 1). All the pumps were set to the right flow rate using a flow meter. Flow rate was checked at the end of each test, and re-calibrated if necessary. The pumps were fitted with a meter, to record the total air flow and the duration of the test.

Table 1: Description of the chipping operations

Test n.	Site	Chipper type	Chipper model	Species	Chips (Mg)	Observation time (min)
1	Borgo San Lorenzo (FI)	Industrial	Pezzolato Hackertruck PTH1000/1000	Softwood	117,3	467
2	Borgo San Lorenzo (FI)	Industrial	Pezzolato Hackertruck PTH1000/1000	Softwood	74,86	365
3	San Piero a Sieve (FI)	Industrial	Pezzolato Hackertruck PTH1000/1000	Hardwood	42,54	248
4	San Piero a Sieve (FI)	Industrial	Pezzolato Hackertruck PTH1000/1000	Hardwood	70,88	387
5	Galliano (FI)	Small scale	Farmi 260	Softwood	9,12	248
6	Torsoli (FI)	Small-scale	Farmi 260	Hardwood	18,415	252
7	Case Geri (PT)	Small-scale	Pezzolato PTH 700/660	Hardwood	28,10	234
8	Vicchio (FI)	Small-scale	Pezzolato PTH400	Hardwood	11,180	243
9	Vicchio (FI)	Small-scale	Pezzolato PTH400	Hardwood	20,020	341
10	Pian del Voglio (BO)	Industrial	Pezzolato Hackertruck PTH1000/1000	Hardwood	99,600	399
11	Borgo San Lorenzo (FI)	Industrial	Pezzolato Hackertruck PTH1000/1000	Hardwood	60,020	417
12	Pian del Voglio (BO)	Industrial	Jenz HEM561	Softwood	149,580	600
13	Moscheta (FI)	Industrial	Jenz HEM561	Softwood	152,760	471
14	Scarperia (FI)	Industrial	Pezzolato Hackertruck PTH1000/1000	Hardwood	84,900	285
15	Scarperia (FI)	Industrial	Pezzolato Hackertruck PTH1000/1000	Softwood	90,560	220
16	Torsoli (FI)	Small-scale	Farmi 260	Hardwood	17,380	453
Total					1047,215	5630

Wood dust was collected on a glass fiber membrane placed inside the sampler. Before the tests, membranes were weighed in the laboratory with a precision scale accurate to the microgram and placed in sealed boxes identified with code numbers. Right before starting each chipping test, a membrane was carefully placed into the sampler using clean tweezers to avoid contamination.

In the industrial operations, two sampling units were used: one was worn by the operator inside the cab, and the other was placed outside the cab near the place where the operator would station if the machine was not fitted with a cab (Fig. 2). This was done in order to determine the protection offered by the cab. In the small scale operations, all the operator involved in the chipping operation wore a sampling unit (Fig. 3). The portable pump was attached to the worker's belt and the sampler was placed to a distance of 10 cm from the operator's face, to the right or to the left depending on whether the operator was right-handed or left-handed.

Figure 2: One of the industrial chipping operations

Figure 3: Two different small-scale operations

At the end of the tests, membranes were removed with the tweezers and placed back into their respective coded boxes. These were sent to the laboratory, where used membranes were weighed again with the same precision scale used earlier for determining their original weights.. Before weighing, membranes were reconditioned to the initial temperature and humidity. To achieve the highest possible accuracy, the weight of the membranes was corrected by the average weight of 3 field blanks. Finally, the concentration of wood dust was measured using the following formula:

$$C= (P2-P1)/V \quad (mg/m^3)$$

C= wood dust concentration

P2-P1= difference in weight of the filter after (P2) and before (P1) the chipping test

V= air volume in cubic meters, calculated as V=T*F, where T is the duration of the trial in minutes and F is the effective air flow in L/min.

The duration of each sampling session ranged between 3 and 8 hours. At each worksite, dust monitoring was personally supervised by the researchers, who also checked the proper running of the pumps and the correct position of the devices. The researchers also determined machine productivity and utilization with suitable time studies. They also collected chip samples, in order to determine moisture content and particle size distribution.

3 Results and discussion

In all sampled operations the concentration of wood dust was within the 5 mg/m^3 legal limit (Fig. 4 and Tab. 2).

Table 2: Descriptive statistics: minimum, mean and maximum values for exposure to wood dust in small-scale and industrial operations (inside and outside the cab)

	Industrial outside mg/m^3	Industrial inside mg/m^3	Small-scale mg/m^3
Mean	0,898	0,204	1,354
Minimum	0,19	0,07	0,38
Maximum	1,43	0,50	3,66
Standard Dev	0,413	0,14	1,059

In the industrial operations, the recorded average value inside the cab (personal exposure) was 0.204 mg/m^3 while the average value outside the cab was 0.898 mg/m^3, i.e. over 4 times higher. If we take the maximum values as a reference the difference is smaller, with 0.5 mg/m^3 and 1.43 mg/m^3 inside and outside the cab, respectively. Exposure was higher in small-scale operations, with an average value of 1.35 mg/m^3 that was similar to the maximum value recorded in the industrial operations. The minimum exposure level recorded for small-scale operations was 0.38 mg/m^3. In the industrial operations the minimum exposure value recorded inside the cab was 0.07 mg/m^3. That corresponded to a minimum value outside the cab of 0.19 mg/m^3, almost the half of the minimum value recorded in the small-scale operations. The highest exposure level in this study was recorded in a small-scale operation during summer (29 August), when handling exceedingly dry material (chestnut poles with a moisture content of 25 %).

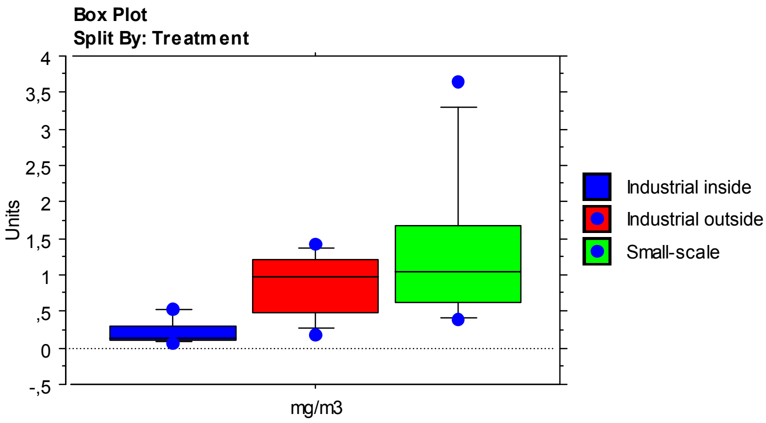

Figure 4: Exposure to wood dust for small scale and industrial operations (inside and outside the enclosed cab)

It is interesting to notice the sharp reduction of dust exposure obtained by placing the operator inside an enclosed cab (Tab. 3). The enclosed environment allowed capping exposure to a constant level near to 0.2 mg/m^3 independent from the dust concentration in the outside environment. The difference in dust exposure between the inside and outside environment resulted statistically significant to the standard t-test ($p=0,0050$). Dust concentration inside the cab seemed to be stable and was not affected by the dust concentration outside the cab. This is witnessed by the absence of any significant correlation between the two dust concentration levels (Fig. 5). Therefore, the higher the outside dust concentration, the stronger the abatement effect of the cab (Fig. 6). That may also imply a shorter service life for the air filters in the cab consequent to higher outside dust concentrations, but the study was not long enough to test this assumption.

Table 3: Wood dust concentration inside and outside the enclosed cab

Test n.	Type	Inside cab mg/m^3	Outside cab mg/m^3	Ratio
1	Hackertruck	0,10	1,20	12,00
2	Hackertruck	0,34	0,54	1,59
3	Hackertruck	0,13	0,19	1,46
4	Hackertruck	0,50	0,84	1,68
10	Hackertruck	0,26	1,12	4,31
11	Hackertruck	0,11	1,34	12,18
12	Lifting cab	0,30	1,16	3,87
13	Lifting cab	0,07	0,67	9,57
14	Hackertruck	0,11	1,43	13,00
15	Hackertruck	0,12	0,49	4,08

Current bibliography offers very few similar studies. Mitchell (2011) measured the concentration of dust in chipping operations in Alabama, and the levels recorded in his study were very similar to those reported here. For instance, Mitchell reported an average concentration of 1.3 mg/m^3, with minimum and maximum values equal to 0 and 4 3 mg/m^3, respectively. Alwis (1998) recorded an average concentration of 1.9 mg/m^3 for chipping operations in Australia, and this figure is also very close to those reported in our study.

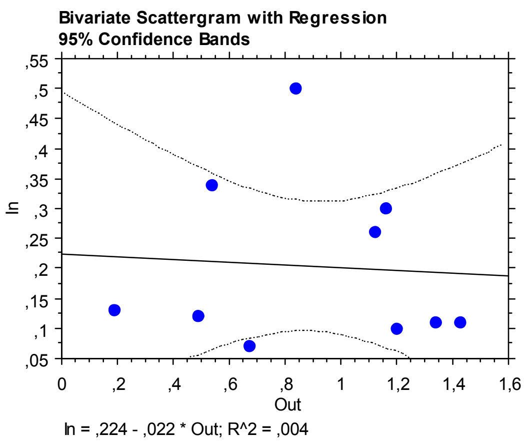

Figure 5: Relationship between dust concentration inside (in) and outside (out) the cab

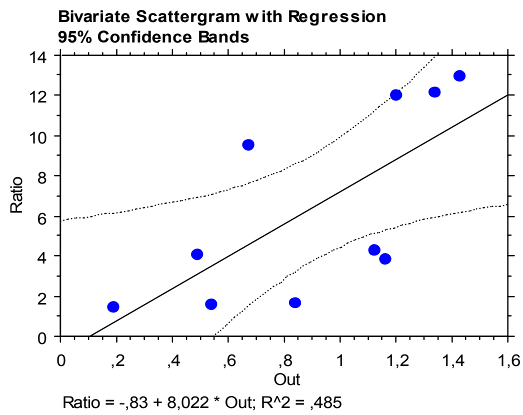

Figure 6: Relationship between the dust concentration outside the cab (out) and the dust abatement ratio (out/in)

Most of the other studies deal with sawmill and furniture industries, not with logging operations. Scarselli et al (2008) report of a large survey of 1181 woodworking industries in Italy, and estimate the average exposure to wood dust to 1.44 mg/m^3. In Australia, Mandryk et al (2000) compared the sawmilling of fresh and dry eucalypt wood, finding very similar exposure values: i.e. 1.52 mg/m^3 and 1.71 mg/m^3 for the fresh and dry wood, respectively. However, it is most interesting to notice that while the concentration levels were similar, the exposure to endotoxins was higher when dealing with fresh wood, compared to dry wood. This may have a direct bearing on our study. If further sampling will confirm the apparent inverse relationship between dust concentration and wood moisture content, one will need to carefully weigh whether it is advisable to chip fresh wood or dry wood, since the former may result in a lower exposure but higher toxicity, and the latter to a higher exposure but lower toxicity.

A few wood dust exposure studies were also conducted for the motor-manual felling and processing of trees in the forest. None reports of exposure levels above the 5 mg/m^3 legal limit. Poggi (2011) remarked that exposure to wood dust increases with working time and that it is higher in thinning operations, possibly for the lower wind velocity inside a thick stand which results in a longer permanence of the wood dust in the air. Horvat et al. (2005) also recorded an average exposure value of 0.6 mg/m^3 for similar motor-manual felling operations.

The protective effect of the cab with respect to dust exposure is specifically reported by Blandini et al. (2009) in their study of cultural operations in Citrus orchards.

4 Conclusions

Exposure to wood dust varied widely, depending on wood conditions and operation type (industrial or small-scale), but it was always below the prescribed legal limit. Operators working inside a cab were at least 4 times less exposed to wood dust than operators working outside. If future legislation will reduce the maximum allowed exposure limit to the expected 1 or 3 mg/m^3, then manual chipping operations may only be conducted under specific wood and weather conditions. However, most small-scale chipping operators are part-timers, and it is likely that their average 8-hour exposure will still be within limits, regardless of momentary activity peaks. Professional chipper operators should always be positioned inside an enclosed cab, for limiting their exposure to wood dust. Protection from wood dust should be a priority because wood dust is a recognized cancer agent and it can trigger a number of occupational diseases. Further studies are in progress, in order to increase the accuracy of our current estimates.

5 References

Alwis, K.U., 1998: Occupational exposure to wood dust. PhD Thesis. Faculty of Medicine. University of Sydney, New South Wales Australia

Berndes, G., Hoogwijk, M., van den Broek, R., 2003: The contribution of biomass in the future global Energy supply: a review of 17 studies. Biomass and Bioenergy, 25, 1-28

Blandini, G., Cerruto, E., Emma, G., Manetto, G., 2009: Dust and VOC risks during cultural operations in Citrus orchards. In "XXXIII CIOSTA-CIGR V Conference 2009, Reggio Calabria (Italy) "Technology and management to ensure sustainable agriculture, agro-system, forestry and safety" vol 2, 1457-1461

Cirla, A.M., 2008: Polveri di legno ad effetti sensibilizzanti. In "Polveri di legno: salute e sicurezza" Edizioni CIMAL ISBN 978-88-902124-3-7, 36-53

Coaloa, D., 2007: Biomasse per energia e mercato del legno. Sherwood 138, 39-43

Decreto Legislativo 25 febbraio 200, n. 66. Attuazione delle direttive 97/42/CE e 1999/38/CE, che modificano la direttiva 90/394/CEE, in materia di protezione dei lavoratori contro i rischi derivanti da esposizione ad agenti cancerogeni o mutageni durante il lavoro

Foà, V., Cila P.E., Martinotti, I., Bertazzi, P.A., 2008: Esposizione a polveri di legno: la valutazione delle SCOEL (Scientific Committee on Occupational Exposure Limits). In "Polveri di legno: salute e sicurezza" Edizioni CIMAL ISBN 978-88-902124-3-7, 63-68

Hausen, B., 1981: Woods injurious to human health. A manual Ed. Walter de Gruiter Berlin

Holness, D.L., Sass-Kortsak, A.M., Pilger, C.W., Nethercott, J.R., 1985: Respiratory function and exposure-effect relationships in wood dust-exposed and control workers. J. Occup. Med. 27: 501-506.

Horvat, D., Čavlović, A., Zečić, Ž., Šušnjar, M., Bešlić, I., Madunić-Zečić, V., 2005: Research of fir-wood dust concentration in the working environment of cutters. Croatian Journal of Forest Engineering 26, 85-90

IARC, 1995: IARC Monographs on the Evaluation of Carcinogenic Risks to Human, vol 62 Wood dust and formaldehyde. Lyon:IARC

ILO, 1983: Woods. In: Encyclopaedia of Occupational Health and Safety. vol. II, pp. 2308-2316. International Labour Organization, Geneva.

Innocenti, A., Del Monaco, S., 1980: Patologi dovuta a polveri di legno. Contributi scientifico pratici per una migliore conoscenza del legno n .27 CNR Istituto del Legno, Firenze 64pp

Innocenti, A., 2008: Effetti sulla salute delle polveri di legno: la funzione respiratoria. In “Polveri di legno: salute e sicurezza” Edizioni CIMAL ISBN 978-88-902124-3-7, 27-35

Krausmann, F., Erb, K.H. Gingrich, S., Lauk, C., Haberl, H., 2008: Global patterns of socioeconomic biomass flows in the year 2000: A comprehensive assessment of supply, consumption and constraints. Ecological Economics 65, 471-487

Li, D., Yuan, L., Yi, S., Jiang, Z., 1990: Effects of wood dust exposure on respiratory health: cross-sectional study among farmers exposed to wood dust. Am. J. Ind. Med. 17: 84-85.

Linden, M., 2011: Forecasting forest chip energy production in Finland 2008-2014. Biomass and Bioenergy 35, 590-599

Liou, S.H., Cheng, S.Y., Lai, F.M., Yang, J.L., 1996: Respiratory symptoms and pulmonary function in mill workers exposed to wood dust. Am. J. Ind. Med. 30: 293-299

Magar, S.B., Pelkonen, P., Tahvanainen, L., Toivonen, R., Toppinen, A., 2011: Growing trade of bioenergy in the Eu: Public acceptability, policy harmonizatioin, European standards and certification needs. Biomass and Bioenergy 35, 3318-3327

Mandryk, J., Alwis, U.K., Hocking, A.D., 2000: Effects of personal exposures on pulmonary function and work-related symptoms among sawmill workers. Ann occup. Hyg. 44 (4) 281-289

Mitchell D., 2011 – Air quality on biomass harvesting operations. Proceedings of the 34th Council on Forest Engineering annual meeting, Quebec City, Quebec, Canada, June 2011. 9pp (http://www.srs.fs.usda.gov/pubs/ja/2011/ja_2011_mitchell_001.pdf)

Moscato, G., Della Bianca, A., Maestrelli, P., Paggiaro, P., Romano, C., De Zotti, R. Marabini, A., Voltolini, S., Crippa, M., Previdi, M., Bramé, B., Benzon, R., Siracusa, A., 2002: Features and severity of occupational asthma upon diagnosis: an Italian multicnetric review. Allergy 57, 236-242

Pisaniello, D.L., Connell, K.E., Muriale, L., 1991: Wood dust exposure during furniture manufacture - results From an Australian survey and considerations for threshold limit value development. Am. Ind. Hyg. Assoc. J. 52(11): 485-492

Pisati, G., Cirla, A.M., Zedda, S., 1982: Asma allergologico da esposizione professionale a polveri di legno non esotico (Faggio). Considerazioni di un caso clinico. Proceedings of the conference “Infortuni e malattie professionali nel settore del legno e del mobile” OECE Edizioni, 472-478

Poggi, L., 2011: Prime indagini sull’esposizione a polveri di legno e gas di scarico per operatori addetti all’uso della motosega. Thesis Università degli Studi di Firenze 78 pp

Regione Toscana, 2009: La salute e la sicurezza sul lavoro. Decreto Legislativo 9 aprile 2008 n. 81 e successive modifiche. Felici Editore Pisa ISBN 978-88-6019-316-2,431pp

Shamssain, M.H., 1992: Pulmonary function and symptoms in workers exposed to wood dust. Thorax 47: 84-87

SAS Institute Inc., 1999: StatView Reference. SAS Publishing, cary, NC. ISBN-1-58025-162-5, 84-93

Scarselli, A., Binazzi, A., Ferrante, P., Marinaccio, A., 2008: Occupational exposure levels to wood dust in Italy, 1996-2006. Occup Environ Med 65, 567-574.

Senear, FE, 1933: Dermatitis due to woods. J. Am. Med. Assoc. 101: 1527-1532.

Spinelli, R., Hartsough, B.R., 2001: A survey of Italian chipping operations. Biomass and Bioenergy 21, 433-444

Woods, B., Calnan, C.D., 1976: Toxic Woods. Br. J. Dermatol. 95 (Suppl. 13) 1-97.