APPENDIX

Aerial contamination in the wine industry

In many wine industry taint cases, both in Australia and overseas, investigations have revealed that the taint occurred as the result of contamination due to airborne chemicals, including halogenated phenols, halogenated anisoles, ethylphenols, cresols and aromatic hydrocarbons including naphthalene and substituted naphthalenes (Chatonnet et al. 2004, Del Re et al. 1977, Strauss et al. 1985, Tanner and Sandoz 1973). In fact, the tainting of food and materials contacting food due to aerial contamination is a major source of concern to the food industry in general (Anon 2007a, Coulter et al. 2008, Whitfield 1983).

Volatile phenols, such as guaiacol, 4-methylguaiacol, cresol isomers and others have contributed to the tainting of grapes in Australia, and subsequent wines, due to exposure of vineyards to smoke from bushfires since 2003 (Coulter et al. 2022 and numerous references contained therein). The aerial contamination of grapes by bushfire smoke can lead to substantial costs for the wine industry. For example, the value of the loss of wine not produced in north-east Victoria due to the 2006/2007 fires was estimated to be between $75 to 90 million (Whiting and Krstic 2007).

Work conducted by the AWRI has shown that the 1,8-cineole (eucalyptol) found in grapes from vines in close proximity to Eucalyptus trees originates from those trees, with the mechanism being airborne transfer (Capone et al. 2012). Capone et al. (2012) indicated that the "concept of airborne transfer of volatile organic compounds is not surprising as it has been shown to occur in other studies, including those involving plants."

In one investigation conducted by the AWRI, all the wines and equipment within a small winery became tainted with 2,4,6-tribromoanisol (TBA) due to the accumulation of TBA vapors within the winery (Anon 2008). Chatonnet et al. (2004) investigated a large number of cases of wines polluted during storage in facilities where the atmosphere was contaminated with TBA. In some cases, even though the original source of TBA had been removed, residual pollution adsorbed on walls was considered to be sufficient to cause ongoing tainting. The researchers indicated that polyethylene- or polyester-based winemaking equipment, vulcanised rubber gaskets and silicone bungs readily absorb pollutants from the air and then release them into wine over time (Chatonnet et al. 2004).

Other investigations conducted by the AWRI have shown that oak barrels, wine and perlite (a clarifying agent) are capable of becoming contaminated with aromatic hydrocarbons (e.g. alkylbenzenes and naphthalene) after exposure during transport (Anon 2008). In the case of the perlite contamination, the clarifying agent became contaminated during a four-hour truck journey when exhaust fumes leaked into the

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storage compartment at the back of the truck. Testing showed that the perlite was clean (i.e. not contaminated) before the journey but was tainted after the journey.

In 1999 a study of Fluoride Monitoring in Grape Vine Leaves was conducted by HLA-Envirosciences Pty Limited, as reported by the New South Wales Government Hunter New England Area Health Service (Anon 2005). One particular vineyard in the study, which was 16 km from one of the Hunter Valley's power plants and that was aligned with a SE/NW wind axis, exhibited higher fluoride concentrations in grape leaves than other vineyards. Anon (2005) indicated that a study conducted by the Environmental Protection Authority (EPA) showed that the valley "tends to channel wind so that prevailing SE and NW winds carry pollutants along the valley in regional drainage flows that may be up to several hundred metres deep." The EPA study also indicated that episodes of local elevated concentrations of pollution occur with stable weather and light winds and with temperature inversions.

Moret et al. (2000) investigated the contamination of grapeseed oil with polyaromatic hydrocarbons (PAHs). These authors reported that the PAH contamination could be traced back to exposure of the pomace (containing grape seeds) to vehicle exhaust gases when the pomace was amassed in the open during the drying process.

Atmospheric emissions as sources of taint

Tanner and Sandoz (1973) conducted investigations into the cause of phenolic taints in wines from central Switzerland. These authors established a direct link between the proximity of vineyards to a copper wire insulating factory and the presence of phenolic taint compounds in the tainted wines. Air samples taken at 80 m and 300 m from the factory were determined to contain 50 µg of cresols (phenolic compounds) per m^3 and 25 µg of cresols/m^3, respectively. Both *m*-cresol and *p*-cresol were detected in the tainted wines. Note that Dietz and Traud (1978) indicated that the taste thresholds of *m*-cresol and *p*-cresol in water (18–22°C) were both 2 µg/L. Tanner and Sandoz (1973) obtained similar findings for other contaminated wines made from grapes sourced from vineyards in an industrial area near Veltlin, Switzerland. In these cases the vineyards were either near a railway sleeper processing factory or a bitumen factory. The authors concluded that wines could become tainted due to pollution of vineyards from nearby factories emitting phenolic compounds into the atmosphere.

Del Re et al. (1977) conducted an investigation into wines produced in Valtellina, a premium wine region of northern Italy that exhibited phenolic taints. These authors established a relationship between the contaminated wines and the activities of a chemical plant located in the proximity of the vineyards where the grapes were collected for winemaking. The compounds phenol, 3-ethylphenol, 4-ethylphenol, 3,4-dimethylphenol and 2,5-dimethylphenol were determined to be in the vapours generated from resins produced in the chemical plant, and in air samples collected in the area surrounding the plant. These compounds were also detected in the air at a vineyard located 700 m from the chemical plant. Commercial wines produced in Valtellina during the years 1970–1974 exhibited phenol concentrations of up to 156 µg/L, 2,5-dimethylphenol concentrations of up to 182 µg/L, and total ethylphenol concentrations of up to 743 µg/L. 'Sforzato' wines, made with grapes left on the vine to dry, were generally characterised by higher levels of these phenolic pollutants.
Del Re et al. (1977) concluded that the phenolic taints observed in the wines in the region were due to industrial air pollution.

In one particular food industry taint case, biscuits became aerially contaminated with the chlorophenol compound 2-chloro-6-methylphenol, commonly known as 6-Chloro-*o*-cresol (6CC). The taint was linked to the presence of two agrochemical plants within an 8 km radius of the biscuit factory where the 6CC was an impurity in a particular herbicide. It was found that trace quantities of 6CC were carried towards the biscuit factory when the wind was blowing in the right direction. The relatively high fat content of the biscuits acted as a solvent for the airborne 6CC contaminant as the biscuits emerged from the oven (Griffiths and Land 1973, Mottram 1998).

In another food industry taint case involving soft drink contamination, the taint (suspected to be mainly due to 6CC) was deduced to be due to the airborne contamination of the empty drink cans stored in a warehouse situated near an agrichemical plant. When the wind blew from the direction of the plant towards the warehouse, volatile impurities (chlorophenols) were blown into the warehouse where they were absorbed onto the surfaces of the exposed cans (Whitfield 1983).

Atmospheric exposure of plants to polyaromatic hydrocarbons (PAHs)
Edwards (1983) conducted a review of more than 30 papers that addressed the fate of PAHs in the terrestrial environment, and which investigated the concentrations of PAHs in more than 40 different types of plants. At the time, Edwards (1983) indicated the consensus was that PAHs can enter the food chain by contamination of vegetation. The results of subsequent investigations supported Edwards' statement with the investigators considering that the most important route of contamination of plants with PAHs is via atmospheric exposure of plants to those PAHs (Phillips 1999, Tao et al 2003, Wang et al. 2018, Wu et al 2004, Wild and Jones 1992). Whilst Edwards' (1983) review was on PAHs, he made a number of conclusions which could equally be applied to other types of atmospheric contaminants, for example:

- plants with broad leaves contained more of the contaminants than plants with narrow leaves, indicating a possible correlation between leaf surface area and direct absorption from the atmosphere [note that grapevine leaves are broad and have a large surface area];
- most contamination of vegetation is by direct deposition from the atmosphere;
- some terrestrial plants can take up contaminants through their roots and/or leaves and translocate them to various plant parts;
- contaminants may concentrate in certain plant parts more than in other parts; and
- emitted contaminants may be spread over long distances.

Edwards' (1983) conclusions are consistent with the cases briefly discussed above (Anon 1984, Anon 2003, Del Re et al. 1977, Coulter et al. 2022 and Tanner and Sandoz 1973), which showed that vineyards exposed to chemicals in the atmosphere resulted in the presence of those chemicals in wine produced form the vineyards.

References

Anon 2005. Power Stations. Hunter New England Area Health Service, New South Wales Government (http://www1.hnehealth.nsw.gov.au/hneph/EHM/PowerStations.htm)

Anon 2008. Australian Wine Research Institute Annual Report (2008): 26, 27. http://www.awri.com.au/wp-content/uploads/2008_AWRI_Annual_Report.pdf

Chatonnet, P., Bonnet, S., Boutou, S., Labadie. M. 2004. Identification and responsibility of 2,4,6-tribromoanisole in musty, corked odors in wine. *J. Agric. Food Chem*. 52:1255–1262.

Capone, D. L., Jeffery, D.W., Sefton, M.A. 2012. Vineyard and Fermentation Studies To Elucidate the Origin of 1,8-Cineole in Australian Red Wine. *J. Agric. Food Chem*. 60(9): 2281–2287.

Coulter, A., Baldock, G., Parker, M., Hayasaka, Y., Francis, I. L., Herderich, M. 2022. Concentration of smoke marker compounds in non-smoke-exposed grapes and wine in Australia. *Australian Journal of Grape and Wine Research*. 80, 459-474. https://doi.org/10.1111/ajgw.12543

Coulter, A.D., Capone, D.L., Baldock, G.A., Cowey, G.D., Francis, I.L., Hayasaka, Y., Holdstock, M.G., Sefton, M.A., Simos, C.A., Travis, B. 2008. Taints and off-flavours in wine – case studies of recent industry problems. Blair, R.J., Williams, P.J., Pretorius, I.S. (eds) *Proceedings of the thirteenth Australian wine industry technical conference, 29 July–2 August 2007, Adelaide, SA*: Australian Wine Industry Technical Conference Inc., Adelaide, SA., 73–80.

Del Re, A, Repetti, F., Ricci Oddi, F. 1977. Contaminazione da fenoli nei vini (Phenols contamination in wines). *Chim. Ind.* (Milan) 59: 82–84.

Dietz, F.; Traud, J. 1978. Taste and odour threshold concentrations of phenolic compounds. (Geruchs-und geschmacks schwellen-konzentrationen von phenolkorpern.) *Wasser, Abwasser* 119 (6): 318–325.

Edwards, N. T. 1983. Polycyclic aromatic hydrocarbons (PAHs) in the terrestrial environment—a review. *J. Environ. Qual*. 12:427–441

Griffiths, N.M., Land, D.G. 1973. 6-chloro-o-cresol taint in biscuits. *Chemistry and Industry*. 904.

Moret, S., Dudine, A., Conte, L.S. 2000. Processing Effects on the Polyaromatic Hydrocarbon Content of Grapeseed Oil. *JAOCS*. 77(12): 1289–1292.

Mottram, D.S. 1998. Chemical tainting of foods. *International Journal of Food Science and Technology*. 33: 19–29.

Strauss, C.R., Wilson, B., Williams, P.J. 1985. Taints and off-flavours resulting from contamination of wines: a review of some investigations. *Australian Grapegrower and Winemaker* 256, 20, 22, 24.

Tanner, H., Sandoz, M. 1973. Der Einfluss von atmosphärischen Umweltstoffen auf den Wein (The influence of atmospheric pollutants on wine). *Schweiz Z. Obst u. Weinbau*. 109: 585–591.

Tao, S.; Cui, Y.H. Xu, F., Li, B.G., Cao, J., Liu, W., Schmitt, G., Wang, X.J., Shen, W., Qing, B.P., Sun, R. 2004. Polycyclic aromatic hydrocarbons (PAHs) in agricultural soil and vegetables from Tianjin. *The Science of the Total Environment*. 320: 11–24.

Wang, C., Yang, Z., Zhang, Y., Zhang, Z., Cai, Z. 2018. PAHs and heavy metals in the surrounding soil of a cement plant Co-Processing hazardous waste. *Chemosphere*, 210, 247-256.

Whitfield, F.B. 1983. Some flavours which industry could well do without – Case studies of industrial problems. *CSIRO Food Research Quarterly* (43): 96–106.

Whiting, J., Krstic, M.P. 2007. Understanding the sensitivity to timing and management options to mitigate the negative impacts of bush fire smoke on grape and wine quality – scoping study (Department of Primary Industries: Knoxfield, Vic., Australia).

Wild, S.R., Jones, K.C. 1992. Organic chemicals in the environment. Polynuclear aromatic hydrocarbon uptake by carrots grown in sludge-amended soil. *J. Environ. Qual*. 21: 217–225.

Wu, S.P., Tao, S., Zhang, Z.H., Lan, T., Zuo, Q. 2007. Characterization of TSP-bound n-alkanes and polycyclic aromatic hydrocarbons at rural and urban sites of Tianjin, China. *Environmental Pollution* 147: 203–210.