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AIR POLLUTION EFFECTS ON DIAMETER INCREMENT OF FOREST TREES

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Abstract. In Turkey, negative effects of air pollution on forests have been known since 1950's. However, the biggest forest decline due to air pollution was noted in Yatagan district of Mugla city in Turkey after the foundation of a thermal power plant using lignite coal in 1982. After the foundation of power plant (1984), all calabrian pine (*Pinus brutia* T e n.) forests under the effects of funnel gases declined severely. Even if some pine trees remained healthy around power plant, these trees had just one year old needles. All older needles of them shed. By loosing of needles and partial damage of chlorophyll, it was determined that annual tree diameter increment decreased significantly. Similar results occurred in different regions under intensive air pollution effect in Turkey.

Keywords: annual tree ring width, diameter increment, thermal power plant, air pollution.

AIMS AND BACKGROUND

Many research results brought up that air pollution has several negative effects on organisms. It is known that especially on areas where extreme industrial activities are present, increase of NO_x and SO_2 concentrations in air has mortal effects on organisms, including human beings. Air pollution also causes extremely harmful effects on forests. These effects might become directly when the leaves take the harmful gases through their stomas, or indirectly by changing ecological conditions due to increased soil acidity. Particularly coniferous tree species are affected much more from air pollution because they have not shed leaves and their leaves remain on tree for a long time. Air pollution effects on tree can be clearly seen as yellowish spots on their leaves (acid burns). Then harmful gases taken by leaves through their stomas change the normal chlorophyll structure, also damages are seen on epidermis, cuticle layers, stomas and resin ducts. Needles turn yellow or red by loosing their healthy green colour. As a result of these effects, decreasing leave mass of tree and then collective forest declines are being noted due to increasing harmful effect.

If the trees do not die because of air pollution, there is a decreasing of tree growth due to some causes such as damages on leaves, especially chlorophyll, and increase of soil acidity. Annual tree growth decreases can be determined by measuring of annual tree ring widths.

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Site characteristics are very influential on annual tree ring width and they might change the growing rate of trees by affecting water and nutrient capability of the site. In other words, the better the site characteristics, the more increase of annual tree ring width, and vice versa. Site characteristics that influence the annual ring width include climate (precipitation, humidity, temperature, wind, vegetation period), soil properties (depth, structure, texture, etc.), tree species, stand age and density, relief, relationships with other organisms (insect, fungi, other plants, etc.), and improvement cuttings in forest. There is a close relationship between climate and annual ring width[1]. Another factor, in addition to these factors, that affects annual ring width and diameter increment, is air pollution causing losses of tree leaves. However, it is difficult to determine which factors are effective on decreasing the annual ring width.

Depending on air pollution, decreases of annual tree ring widths are more prominent on conifers. A number of investigations about this subject verified that air pollution is effective on annual tree ring width on coniferous trees[2-7]. However, there are different results from the studies carried on deciduous tree species. According to As[8] attributing to Fuhwald[9], there is no tree ring contraction on European beech by air pollution effect, yet attributing to Kurjatko et al.[10], tree rings contraction was found on the same species.

In this study, examples are given on decrease of tree rings of trees via taking samples from forest areas in different parts of Turkey under intensive air pollution effect.

EXAMPLES OF INCREMENT LOSSES ON FOREST TREES DEPENDING ON AIR POLLUTION IN TURKEY

Yatagan Thermal Power Plant – Mugla. Yatagan Thermal Power plant is located on the boundaries of Mugla city neighbouring both the Aegean Sea and the Mediterranean sea in the southwest part of Turkey.

The plant has a 3×210 MW power and consists of 3 units. These units began to operate in November 1982, June 1983 and December 1984, respectively. Lignite coal with 2.35-3.65 % burning sulphur content is being used in power plant and this coal gives 3800 mg/m^3/h SO_2 to the atmosphere when the power plant works at 210 MW power[11]. Funnel waste gases affect forests at south-east parts of plant via north-east prevailing winds of this location. As a matter of fact, collective forest declines emerged after several years after the power plant began to operate, and then 2271 ha forest area were clearcut. However, diameter increments and annual tree ring width of living trees near Yatagan decreased extremely (Fig. 1, Picture 1). By setting a regression equation between monthly precipitation values and annual tree ring widths before 1982 (before air pollution effect), estimates are made as to the annual ring widths that should normally occur with-

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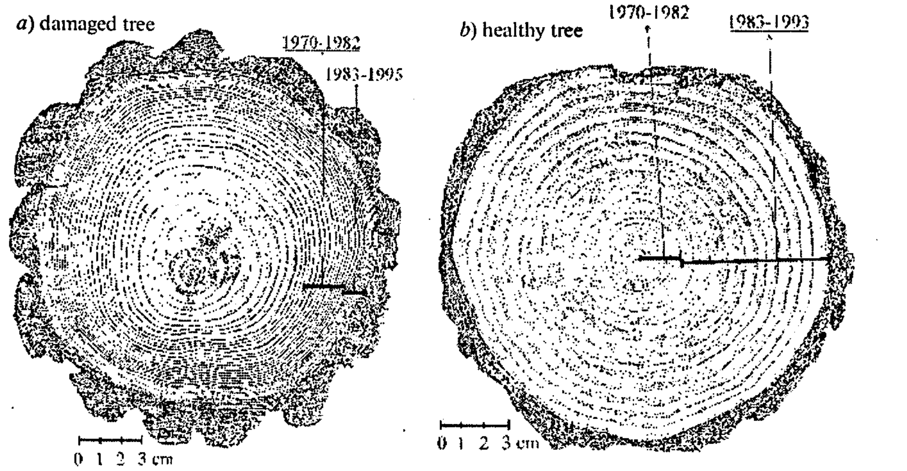
out air pollution. According to this equation, mean annual decreasing of tree ring widths after 1983 ranges from 0.721 to 2.759 mm (Table 1). Decreasing diameter increment amounts of trees in sample plots between 1983 and 1990 changed from 1.32 cm to 3.96 cm. Mean annual volume losses of individual tree are between 0.0019 and 0.0109 m^3 (Table 2). Until the year 1995, in which the ring samples were taken, the growing stock decreased between 10 and 84 m^3 (Ref. 12) (Table 3). It is determined that the better growth of the trees at sample plots numbered 1, 2 and 3, which contain high amount of sulphur in needles and which are affected by pollution was provided by the site conditions. Number of trees is few and soil depth is medium at the sample plot 1. At the sample plot 2, although the quantity of the trees is excessive, soil depth is medium and slope is 0 % (base land). At plot 3, the number of trees is few. All the data given above indicate that these sample plots have better site conditions than other sample plots under effect of air pollution and thus, more nutrient and minerals are taken from the soil[6].



Picture 1. Annual ring widths of damaged (*a*) and healthy trees (*b*) around Yatagan Thermal Power Plant in 1970-1982 (13 years before the power plant began to operate) and 1983-1995 (13 years after the power plant began to operate)

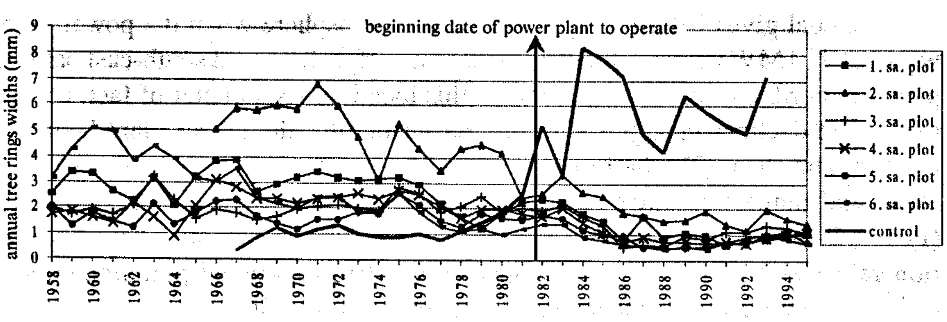


Fig. 1. Annual tree ring widths of calabrian pine trees around Yatagan Thermal Power Plant[6]

Table 1. Decrease of tree ring widths after the power plant began to operate[12]

Samp. plots	Sulphur in one year old needle (ppm)	Average annual tree ring width between 1983 and 1990 (mm)	Estimated annual ring widths by regression analysis between 1983 and 1990 (mm)	Difference (mm)	Losses (%)
1	6122	1.361	2.587	-1.226	47.4
2	7042	2.131	4.890	-2.759	56.4
3	6007	1.075	1.980	-0.905	45.7
4	3258	1.043	2.023	-0.980	48.4
5	4360	0.868	1.589	-0.721	45.4
6	5485	0.716	2.251	-1.535	68.2

Aliaga Refinery – Izmir. Aliaga refinery is located in Izmir city in the Western Turkey by Aegean sea. At the vicinity of Aliaga, there are many industrial establishments besides the refinery. The refinery was established in 1965, but began to operate at full capacity in 1974. The emission values measured in November 1989 show that SO_2 amounts range from 100 to 390 $\mu g/m^3$ and NO_x amounts between 50 and 90 $\mu g/m^3$ (Ref. 13). At the samples taken from calabrian pine and European black pine (*Pinus nigra* A r n o l d) trees, the rings started to narrow after 1975 and even further narrowed after 1983, and ring widths were under 1mm or less (Fig. 2)[14]. According to Aytug and Guven[4] after the refinery began to operate at full capacity, the annual rings of calabrian pine trees became narrower until 1991 (after 1986 and 1987, ring widths decreased to 0.2-0.1 mm). Although ring widths of the healthy trees were about 2.6-2.7 mm (Fig. 3), the individual trees affected from pollution died in 1990.

Yenikoy Thermal Power Plant – Mugla. Yenikoy Thermal Power plant is also situated within the borders of Mugla city like Yatagan Thermal Power plant. The potential power of the plant is 2×210 MW and was founded in 1988. The flammable sulphur rate is 2.61% in the lignite coal used at plant. When the plant works at the power 210 MW, the SO_2 emission is 5824 $mg/m^3/h$[11]. It is determined that the tree rings become narrower at the vicinity of the power plant but not as certain as the case of Yatagan Power Plant and these decreases of the ring widths became after 1990[3,15] (Fig. 4).

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Table 2. Comparison of diameter and volume values of sample trees in 1982 and 1990 to those estimated by regression analysis[12]

Sam. plots	1982 diam. ($Ø_{1.3}$) without bark (cm)	1982 volume without bark (m³)	1990 diameter ($Ø_{1.3}$) without bark (cm) real	estim.	differ.	1990 breast volume without bark (m³) real	estim.	differ.	Averages between 1983 and 1990 diameter ($Ø_{1.3}$) without bark (cm) real	estim.	differ.	Averages between 1983 and 1990 breast volume without bark (m³) real	estim.	differ.
1	18.93	0.1778	21.11	23.28	-2.17	0.2675	0.3254	-0.0579	0.27	0.54	-0.27	0.0112	0.0185	-0.0072
2	16.31	0.1106	19.72	23.68	-3.96	0.1969	0.2839	-0.0870	0.43	0.92	-0.50	0.0108	0.0217	-0.0109
3	11.89	0.0410	13.61	15.16	-1.55	0.0621	0.0771	-0.0150	0.22	0.41	-0.19	0.0026	0.0045	-0.0019
4	14.42	0.0852	16.09	17.81	-1.72	0.1227	0.1503	-0.0276	0.21	0.42	-0.22	0.0047	0.0081	-0.0035
5	13.49	0.0579	14.88	16.20	-1.32	0.0854	0.1012	-0.0158	0.17	0.34	-0.17	0.0034	0.0054	-0.0020
6	13.96	0.0757	15.11	17.77	-2.66	0.0974	0.1348	-0.0374	0.14	0.48	-0.33	0.0027	0.0074	-0.0047

Table 3. Growing stock losses on 1 ha area in 1995[11]

Sample plot	Tree number (ha)	Mean stand height in 1995 (m)	Mean stand diameter without bark in 1995 (cm)	Mean decreasing of ring width 1983-1990 (mm)	Estimated mean stand diameter ($Ø_{1.3}$) without bark in 1995* (cm)	Real stand volume in 1995 (m³)	Estimated stand volume in 1995 (m³)	DIfference (m³)	Losses (%)
1	250	16.7	30.2	1.226	33.4	134.51	164.40	29.89	18.2
2	1175	7.5	7.4	2.759	14.6	17.05	66.12	49.07	74.2
3	525	11.7	21.3	0.905	23.7	98.44	121.39	22.95	18.9
4	800	9.9	16.3	0.98	18.8	74.33	99.39	25.06	25.2
5	975	7.2	9.9	0.721	11.8	24.30	34.38	10.08	29.3
6	1125	13.5	17.7	1.535	21.7	168.08	252.42	84.34	33.4

*Mean stand diameter should be in 1995 was estimated by regression analysis by using decreasing values of annual ring widths.

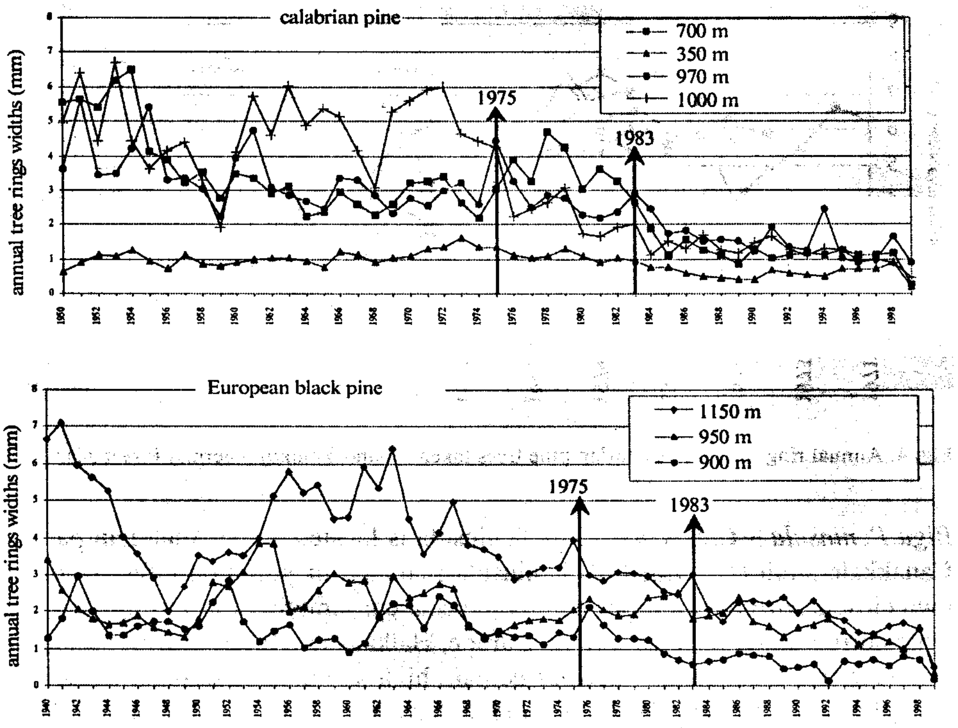

Fig. 2. Annual tree ring widths of calabrian pine and European black pine tree samples taken from Izmir vicinity[14]

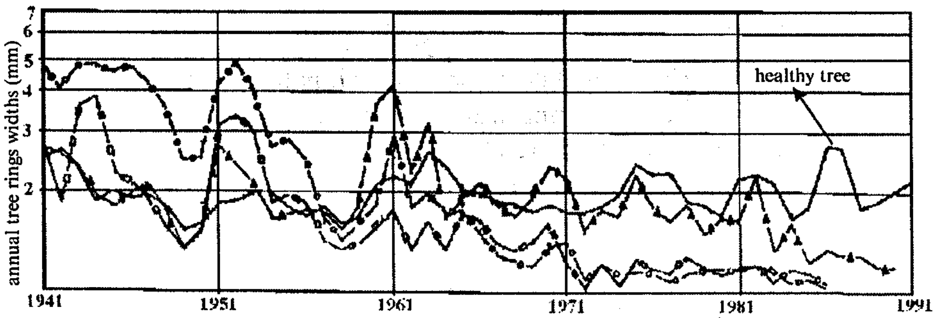

Fig. 3. Time-course of annual ring width of calabrian pine collected from both Aliaga and Izmir regions. Each value is the mean of 9 samples[4]

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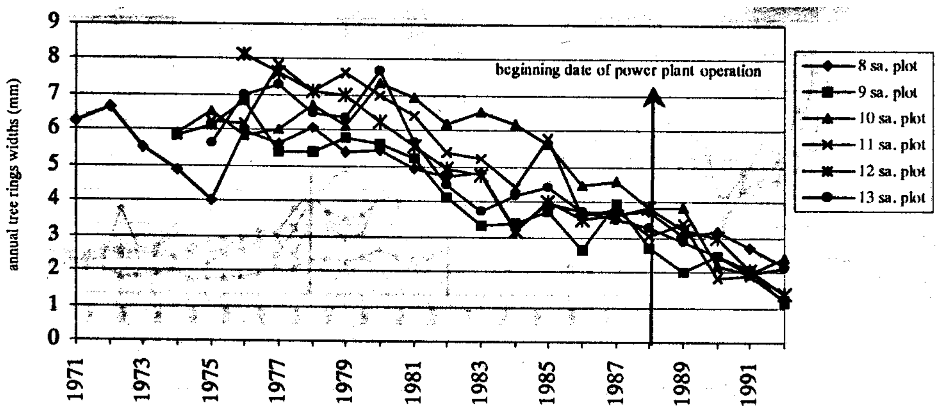

Fig. 4. Annual ring widths of calabrian pine trees taken around Yenikoy Thermal Power plant[3]

Biga Peninsula – Canakkale. Biga Peninsula is located at the Anatolian part of Canakkale strait (Dardanelles). Peninsula is under air pollution effect from its own close environment (especially by the coal consumption for heating), and far from surroundings such as Middle Europe, Balkans and the Marmara region. It was recorded that the pine needles contain high amounts of sulphur, and especially ida mountain fir (*Abies equi-trojani* A s c h e r s. et S i n t.) died or partly died, year rings became quite narrow at the individuals similar to European black pine and fir trees at mountainous lands[7].

CONCLUSIONS

Widths of annual tree rings might decrease due to air pollution effect. Initial reason for decrease of annual tree ring widths as well as of diameter and volume values is damage on leaves that are photosynthesis organs of trees. If the site characteristics are not better (dry climate, shallow soil, high tree density, high concentrations of harmful gases, etc.), damage degree increases. Thus, even though trees under intensive air pollution effect can still live, material losses emerge at large scales. These material losses emerge as both tree volume losses and wood losses that may change physical and mechanical properties of wood (resistance, density, etc.), depending on contraction of annual tree rings[8].

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