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ASPECTS REGARDING FOREST POLLUTION WITH DUST PROVOKED BY TIMBER ROAD TRANSPORTATION

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Abstract: *Dust pollution resulted from road transport affects the forest vegetation; its noxious effects limiting problem is actual and opportune. In this paper, the filtering capacity of forest species for this type of emissions is emphasized, including the necessity to avoid their overloading. In the paper, quantitative aspects of dust pollution effect in case of timber road transportation are presented, by highlighting the dust quantity encountered on beech leafs after a certain transport duration, as well as its variation in accordance with the tree position (distance) from the road.*

Key words: *forest vegetation, dust, pollution, sedimentation.*

1. Introduction

Timber road transportation represents one of the base activities of forest economy, through which the woody material harvested from forests, according to management plans, is introduced in the economic circuit, in order to be utilized by its attributed destination (industrialization, constructions, fuel).

Timber transport is made by specialized forest vehicles, and it is developed, in a great proportion, on forest roads, deployed inside the forest as well as outside it - link roads to public network. Generally, forest roads are provided with gravel or gritted superstructure, which, in time, collects on its surface an important dust quantity, resulted from traffic and climatic activity. As a result, the roadway is physically degraded; its structural particles are fragmented in time, being smaller, leading to dust genesis. Wind, as well as traffic activity, disturb the dust particles from the roadway and facilitate their atmospheric propagation. The cyclic repetition of this process leads to roadway degradation as well as to environment pollution with dust, which affects both forest flora and fauna.

Forest constitutes an economic and spatial factor which obviously serves to the maintaining of an adequate social and natural environment, necessary for the creation of an optimum life space for mankind [1], [2], [5].

Dust is particularly dangerous for the human body, especially that with small dimensions of particles (<5 μm), because these can deeply enter pulmonary tubes, blocking carbon dioxide elimination and oxygen assimilation. More than that, dust could cause skin diseases (dermatitis, eczema), eye diseases, pharyngitis and bronchitis [7], [8].

Timber transport on roads with gravel or gritted structure generates an important

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dust quantity, which at the same time with vehicle traffic is raised in the atmosphere, spread and settled, at different distances, on tree leafs from proximity. Usually, the dust quantities periodically accumulated are washed by precipitations, and they do not gain damaging limits; but in dry periods there is the risk of some accumulations with negative effects on the vegetation conditions of the affected trees. It is obvious that, frequently, the dust contamination also contains chemical particles, generated by exhaust gases, this pollution intensity varying in accordance with the distance from the road edge. Also, the tree line constitutes a green shield for the trees inside the forest.

By considering certain research, forest vegetation retains important dust quantities, estimated to 580-600 kg/year/hectare, attaining 14-15 t/ha in a 25 years period. Also, it has been proved that the filtering effect of broadleaved species decreases in winter by 40%, and for the resinous species it remains constant. More than that, it was demonstrated that the renewing filtering capacity, by precipitation action and continuous leaf changing [3], with specification that the filtering effect of forest vegetation can be diminished or stopped due to high concentration of atmospheric dust, which settles on the leafs and affects the photosynthesis process.

The research showed that the species with pubescent leafs and evident nervures present, increased fixation capacity, underlining that from a quantitative point of view, dust presence is 50…60 times greater in cities in comparison with extended forest areas, these having a fixation capacity which is 3…6 times greater by comparison with inert areas [6].

By considering that timber transportation represents an obligatory condition for sustainable management, dust pollution due to road traffic phenomenon has to be accepted, but, at the same time, it arises the necessity for a careful study regarding its quantitative and qualitative aspects, in order to provide an evidence support regarding the damages which could appear in forest vegetation health state, as well as solutions for damaging effect limitation and diminishing.

Regarding the pollutant effect of dust deposits generated by road traffic, the research conducted in Israel [3], in order to obtain a clear image of leisure areas settled in the proximity of forest roads can be mentioned.

The investigations were realized by using high-accuracy instruments, respectively the STAPLEX device (American production), and they followed dust quantity determination (from atmosphere), in lateral zones situated in the proximity of forest roads, where the polluted atmosphere creates a real discomfort for tourists.

The degradation of forest roads superstructure and dust pollution of adjacent areas can be researched by applying two research methods:

- laboratory research on physical and mechanical characteristics of the materials used in roadway construction, by using field samples which could be used in indirect determinations regarding degradation intensity;
- field research, which permits the direct determination of roadway behavior, which, if repeated in time, it would offer, in given conditions the necessary elements for a statistical analysis of degradation intensity [3].

In Figure 1, the way in which dust is produced and propagated by a forest vehicle is presented.

The dust quantity which could be raised from roadway surface depends on road structure, constructive characteristics of the road system, and vehicle speed.

Dust dispersed in the atmosphere is gradually settled, the bigger particles felling quicker, often even on roadways, whereas the smaller particles are transported by wind and settled at appreciable distances.

a)

b)

Fig. 1. *Arising and sedimentation of dust produced by a moving forest vehicle: a) production and rising of dust, followed by atmospheric pollution; b) atmospheric clearance after dust sedimentation*

The research of dust deposits' pollutant effect imposes knowledge of the phenomenon, including the dust quantities which can accumulate on tree leafs during a transportation period, as well as their quantitative extension. On the other hand, the evaluation of negative effects of these deposits, reflected by the general state of the affected trees, in comparison with those present inside the forest, respectively outside the polluted zone is imposed.

In the following paragraphs the aspects regarding the quantitative determinations of dust deposits on leafs and their spatial extension respectively their decreasing by distance from the road is presented. Aspects concerning the noxious effects of dust deposits on vegetation conditions and general state of studied species will be presented in another paper.

2. Research Location and Methodology

2.1. Research location

All the determinations were made on Valea Rea forest road from Management Unit I Jitia, Dumitreşti Forest District, Focşani Forest Administration [9].

Dumitreşti Forest District comprises forests from Râmnicu Sărat River basin, extending in the southern part of Vrancea County, as well as on a small part from Buzău County, managing in the year 2010 a total of 13,966.7 hectares (45% public owned forest and 55% private owned forest) [4]. National road Dumbrăveni-Dumitreşti-Jitia-Vintileasca, as well as forest roads network assures the accessibility of the forest fund in proportion of 91%.

The entire forest district area belongs to the first functional group, with soil protection functions [9], and the main characteristics of the studied zone are the following:

- average annual temperature: 6.8 °C;
- absolute maximum temperature: 38.8 °C;
- absolute minimum temperature: −32.5 °C;
- probable date for first frost: October 5th;
- probable date for last frost: April 15th;
- average annual precipitation quantity: 750 mm;
- annual aridity index: 48.2;
- predominant winds from north north-west direction, with an average annual velocity of 5.6…10.1 m/s;
- predominant species: beech [6].

The afferent stands are grouped into the following 3 altitudinal plant belts:

- FM2 - mountain mixed stands: 46%;
- FM1+FD4 - pre mountain beech stands: 39%;
- FD3 - hills with oak, beech and mixed stands of oak and beech: 15%.

From the above mentioned ideas, there can be deduced that the wood transport period usually presents a duration of 6 months, which can be fragmented by rains. Also, there can be considered that there are relatively extended dry periods which contribute to dust generation on roadway, and its spreading in the atmosphere provoked by vehicle circulation and wind. Altitudinal distribution of beech stands leads to altitudinal quantitative variations in dust suspended in atmosphere, including its accumulation on trees inside the forest.

2.2. Research methodology

The research methodology was complex and, according to the general research purpose, was individualized for quantitative evaluation of dust deposits, as well as for determining their noxious effects.

Gravimetric determinations were made by applying an unconventional original methodology, involving the study of the preponderant species from the area (beech leafs) - Figure 2.

Fig. 2. *Beech leaf with dust deposit*

For this purpose, the sample trees, both on tree line as well as inside the forest were selected. For a facile identification, each tree was marked by using a code.

By taking into consideration that the conducted research followed the investigation of leafs, at first they were marked with a colored strip, at the petiole level. Leafs located to the inferior part of the crown were preferred (for a better accessibility), generally on a height between 2…2.5 m above ground.

After forest vehicles passing and a minimum period after that (without rain) the marked leafs were prevailed and analyzed by determining their weight in two successive determinations realized with an analytical balance. The first determination was made on leafs polluted by dust deposits (A), and the second one on leafs cleared form dust by using a brush and a wet sponge followed by mechanical drying (B).

Two determination samples containing 25 leafs each, harvested from 2, respectively 4 m distance from the road edge were utilized. These determinations were made during the vegetation period - August-September 2011.

3. Results and Discussions

The results for the gravimetric determinations of both samples are presented in Tables 1 and 2. In these tables, the last column contains the weight of dust deposits for each sample, calculated according to the difference from the two weight determinations, according to relation (1):

$$\Delta = A - B. \quad (1)$$

As can be observed in Table 1, the average dust deposit in the case of sample 1 was of 0.4091 dg. In the case of sample no 2, the average value of dust deposits was of 0.1899 dg (Table 2).

Table 1

Gravimetric determinations - sample 1: 2 meters from road edge

Nr. crt.	Leaf mass before clearing *A*	Leaf mass after clearing *B*	Dust sediment mass $\Delta = A - B$
	[dg]	[dg]	[dg]
1	9.396	9.005	0.391
2	9.804	9.412	0.392
3	8.931	8.456	0.475
4	8.768	8.391	0.377
5	8.025	7.602	0.423
6	9.412	9.101	0.311
7	8.589	8.117	0.742
8	8.853	8.412	0.441
9	8.887	8.421	0.466
10	9.512	9.178	0.334
11	10.252	9.808	0.444
12	9.654	9.212	0.442
13	7.985	7.525	0.460
14	8.254	7.852	0.402
15	11.250	10.789	0.461
16	11.871	11.512	0.359
17	12.212	11.812	0.400
18	8.965	8.521	0.444
19	9.875	9.425	0.450
20	11.454	11.108	0.346
21	10.014	9.679	0.335
22	9.632	9.252	0.380
23	8.562	8.192	0.370
24	9.732	9.340	0.392
25	11.589	11.129	0.460
Total dust deposits quantity			**10.227**
Average dust deposits quantity			**0.4091**

Table 2

Gravimetric determinations - sample 2: 4 meters from road edge

Nr. crt.	Leaf mass before clearing *A*	Leaf mass after clearing *B*	Dust sediment mass $\Delta = A - B$
	[dg]	[dg]	[dg]
1	9.396	9.005	0.391
2	9.804	9.412	0.392
3	8.931	8.456	0.475
4	8.768	8.391	0.377
5	8.025	7.602	0.423
6	9.412	9.101	0.311
7	8.589	8.117	0.742
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23	8.562	8.192	0.370
24	9.732	9.340	0.392
25	11.589	11.129	0.460
Total dust deposits quantity			**10.227**
Average dust deposits quantity			**0.4091**

This fact is to a great extent correlated with the harvested leafs shape and area; they had approximately the same size and area, and they have been chosen in order to provide a larger area for dust deposits, thus assuring quantifiable deposits.

The graphical representation of the two mass determinations in case of sample no. 1 (Figure 3) and those of sample no. 2 (Figure 4) highlights that the differences of dust deposits from the studied samples were insignificant (they could be appreciated as uniform).

For a more rigorous interpretation, determinations regarding the dust quantity on leaf area unit were realized in order to provide a more illustrative indicator, named specific accumulation index. The specific accumulation index is expressed in decigrams/cm^2.

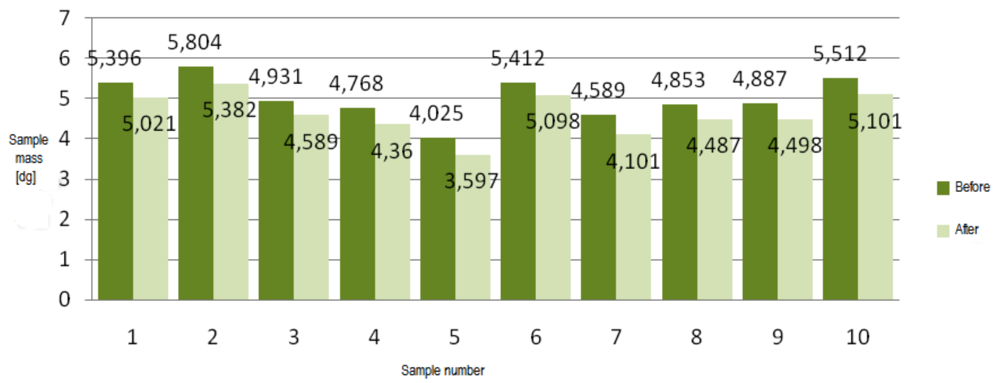

Fig. 3. *Masses for harvested leafs, sample 1, before and after determinations*

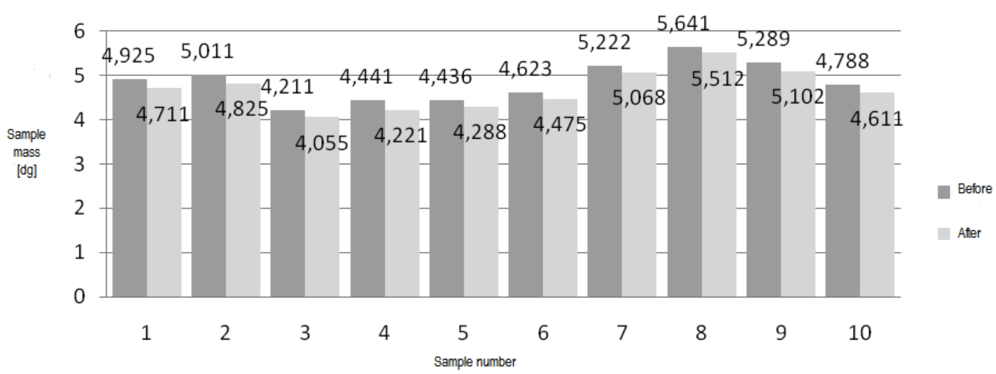

Fig. 4. *Masses for harvested leafs, sample 2, before and after determinations*

For this index determination, from each sample 10 leafs were extracted, whose surfaces were determined by generating their contour on paper and considering the afferent dust deposits. Two micro samples were obtained this way, and their total area was of 153 cm^2 (for sample 1), respectively 150.5 cm^2 (for sample 2).

By dividing the total dust accumulations corresponding to each micro sample (2.0454 dg, respectively 0.9494 dg) to the mentioned areas, there resulted the specific accumulation indexes (*DS*) for the two analyzed situations: on a 2 meter distance from the road edge:

$DS_1 = 2.0454/153 = 0.013$ dg/cm^2,

respectively,

$DS_2 = 0.9494/\ 150.5 = 0.006$ dg/cm^2,

for 4 meter distance from the road edge.

The two indexes' analysis underlines the fact that the dust deposits accumulation decreases directly with the distance from the road edge. At the distance of 4 meters, the dust quantity represents almost half by comparison with the distance of 2 meters (46%).

Graphical representation of dust deposits, expressed in dg, for each investigated sample (Figures 3 and 4), suggests that the mass of dust deposits decreases proportionally with the distance from the road, the rapport of average dust deposits (*DM*) being of 0.46 and sustaining the conclusion generated by specific deposits' analysis.

4. Conclusions

From the conducted research, the following conclusions can be extracted:

- Forest pollution with dust provoked by road timber transportation represents a complex problem being influenced by numerous factors (roadway quality, vehicle characteristics, weather, forest species, and trees location in relation to the road);
- The research treated, for the time being, only quantitative aspects which will be followed by qualitative research;
- From the quantitative assessment resulted the following average indicators (relative to the distance from road):

- Average dust accumulation

$DM_{2m} = 0.4091$ dg;

- Average dust accumulation

$DM_{4m} = 0.1899$ dg;

- Specific dust accumulation

$DS_{2m} = 0.006$ dg/cm^2;

- Specific dust accumulation

$DS_{4m} = 0.013$ dg/cm^2.

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