STORAGE ALTERNATIVES AFFECT FUELWOOD PROPERTIES OF NORWAY SPRUCE LOGGING RESIDUES*

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ABSTRACT

The effect of harvesting logistics on the fuel characteristics of non-comminuted *Picea abies* (L.) Karsten (Norway spruce) logging residues from regeneration cuttings was studied in Southern Finland. Roundwood harvesting took place in the summer of 1999. Green residues were forwarded immediately to roadside storage areas for use during winter 1999–2000. Part of the material was left on the felling sites to dry for 4–8 weeks, after which the brown residues were also forwarded to the roadside for storage. Drying/ storage on the clearcut area continued into the fall. Altogether 12 roadside storage piles were made by mid-October 1999, half of them covered. Moisture, needles, and ash contents as well as element composition were analysed at the beginning and during the experiment.

Drying and storage conditions were exceptionally good during summer 1999. The cumulative evaporation of June through August was 150 mm, which was twice as high as the cumulative precipitation over the same period. As a result, the residues in roadside piles reached 22% moisture content in just 4 weeks. At the same time, the residues on the clearcut area in harvester-made heaps fell below the 20% mark, after which drying was much slower. With the approach of the fall and winter, the residue mass started to absorb moisture. As long as the weather was favourable, covering the piles did not seem to have much significance. However, with the increased precipitation, first rain and then snow, the uncovered roadside piles rewetted at a faster rate. This applied to both the green and the brown residues.

The fresh logging residues contained 19.1% needles. Seasoning the fuelstock lowered the percentage to 1.8% on the clearcut area and to 4.0% on the landing. This loss lowered the ash content from 2.1% to 1.5% during the first month of storage. The concentrations of nutrient elements were correlated with the ash content. Seasoning helped to lower the amount of chlorine from 200 mg/kg to 50 mg/kg.

Keywords: logging residues; seasoning; drying; storage; moisture; needles; nutrients; ash content.

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INTRODUCTION

It has been estimated that some 29 million m^3 of logging residues are left by logging operations in the forests in Finland annually. This is one of the largest under-utilised biomass reserves in our country. However, if this reserve is to be utilised the technical, economic, and environmental aspects must be taken into consideration. It has been estimated that soil fertility factors, bearing capacity, rockiness, and the small size of clearcut areas will limit the quantity of harvestable residues to some 8.6 million m^3, foliage included (Hakkila & Fredriksson 1996). Residue harvesting should be limited to final cuttings, as in thinning stands it is considered of vital importance to leave the needle mass in the stand to allow the nutrients to return to the cycle.

One of the more difficult tasks in biomass harvesting is managing the storage of the material. It is known from previous studies that long-term storage of comminuted biomass will give rise to significant losses in dry matter and net energy content, and even cause health risks among the users (Björklund 1982; Thörnqvist 1984; Kubler 1987; Jirjis & Theander 1990; Nurmi 1999). Still, it is necessary to use buffer storage at latitudes where conditions prevent contractors from supplying heating plants during the most severe winters. The most common storage sites for uncomminuted residue material are clearcut areas and roadside landings. In the near future some plants will store the material in bales at the utilisation site. Where the material is stored will be governed by roundwood harvesting logistics, equipment in use, the regeneration plan, and the nutrient status of the site.

When contemplating residue recovery in terms of fuel quality, one should not forget the needle mass in the fresh crown. Needles account for 25–35% of the dry weight of Norway spruce crown mass and 20–25% of *Pinus sylvestris* L. (Scots pine) crown mass, and where this mass ends up could make a big difference. The timing of recovery can have a significant effect on the yield per unit area. The needle mass is also important because it contains particularly high concentrations of some of the nutrients important for the tree growth, e.g., phosphorus, potassium, calcium, and magnesium.

The aim of this study was to measure how moisture content and needle amounts as well as the chemical composition of the ash of Norway spruce logging residues are affected by drying and by the type of storage site. A second aim was to determine the optimal drying times and best possible storage conditions for clearcuts and roadside landings in order to maintain the desired quality.

MATERIAL AND METHODS

The study material comprised three separate Norway spruce-dominated stands in Hartola, Southern Finland. The stands were owned by Stora Enso; they were located within 1 km of each other and hence were considered as one site with a total area of 10 ha. The roundwood harvest was carried out 24 May – 5 June 1999 by a contractor working with a single grip harvester and a forwarder.

After the roundwood harvest, two-thirds of the fresh green residues were forwarded to the roadside for storage. This was done during the first week of June 1999. The material was held in eight residue piles, each approximately 25 m and 3.5 m high. To facilitate the best possible drying conditions the piles were positioned so that they were surrounded by clearcut areas in all directions. Four of the piles were then covered with a fibreglass and bitumen-reinforced 230 g/m^3 paper. This cover material is produced by Walki Wisa, a UPM Kymmene subsidiary in Pietarsaari, Finland.

The remaining residues were left on the clear-cut areas to dry, after which the now brown residues were forwarded to the roadside landing into four new piles. Two of these were also covered with the reinforced paper for protection from rain and snow. Altogether 12 experimental piles were made.

The roadside piles and the residues left on the clearcut were sampled approximately once a month, as follows. The piles were divided into sections in a lengthwise direction so that the same section would not be sampled twice. Samples were taken from five cross-sectional layers — the top, centre, bottom, and two intermediate layers. Extracting was done with a grapple loader, mounted on a forwarder or a truck. After extraction the sample was placed on a tarpaulin and from there hand-fed into a small chipper. Chips of 10 mm nominal size were blended and a 1-litre-sized sample was separated and placed in a plastic bag for moisture, ash, and elemental analysis. A separate 0.1-litre sample was collected for the determination of needle contents. Simultaneously, the brown residues in harvester-made heaps on the clearcut area were also sampled. The material required for sampling was forwarded from the clearcut to the roadside and then chipped and sampled in the same manner as the samples from the roadside piles.

Moisture contents were determined by drying the samples at 102°C to a constant weight. The ash content was determined by raising the temperature to 550°C over 8 hours, followed by another 8 hours at 550°C. The elemental analysis was done by first digesting the sample material in nitric acid (HNO_3) + hydrogen peroxide (H_2O_2) solution then putting it in a CEM MDS-2000 microwave digestor followed by ICP analysis. Chlorine was analysed as chloride (Cl^-) by extracting it from the sample in sulphuric acid (H_2SO_4) solution and then titrating the extract in silver nitrate ($AgNO_3$).

The percentage of the needles was determined from the small 0.1-litre samples. The sample was first dried to 102°C, stored in an exsiccator, and then separated into needles and a fraction comprising all other parts of the residue. After separation the fractions were weighed.

A portable solar-operated weather station was kept at the study site. The main interests were evaporation rate and precipitation.

RESULTS AND DISCUSSION

Moisture Content

The moisture content (m.c.) of fresh logging residues varied from 50% to 55% on a green weight basis. In early June 1999, when the roundwood harvesting operation was taking place and the residues were waiting to be collected, the moisture content dropped below 40%. The moisture content of the eight green piles varied from 31.2% to 38.6%. Once in the piles the material unexpectedly continued to dry at almost the same rate as on the clearcut area. By the time the dry brown material was forwarded to the roadside landing in August it had already absorbed some moisture. At that point those residues that had been forwarded to the roadside landing in the green state had continued to dry and were at 20% m.c.

When the evaporation started to even out in August (becoming nil in October), those residues which were not covered started to regain moisture and so to lose quality as a fuelwood at a fast rate. This rate was fastest on the clearcut area where the material was spread out and had more exposed surface area than in the roadside piles. Both uncovered "green" and "brown" residue piles regained moisture at a relatively rapid rate, reaching 35–40% m.c. in mid winter. However, inspite of the rewetting this material was still very usable as fuel. Covered residues, both green and brown, maintained their quality quite well, and were a full 15% m.c. lower than the non-covered ones (Fig. 1).

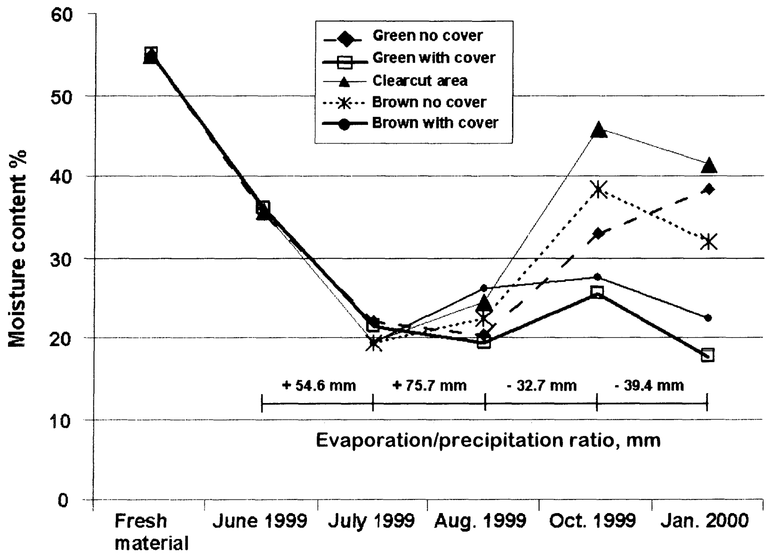

FIG. 1–Moisture content (green weight basis) of Norway spruce logging residues as a function of time.

Needle Content

As seen above, leaf seasoning applied on logging residues is a very effective means of lowering moisture content. However, when there is no more free water available in the branch wood, needles start to die and fall out. At the beginning of the experiment needles accounted for 19.1% (s = 6.7) of the dry mass of the fresh logging residues. A month later there were only 1.8% (s = 0.5) left on the clearcut area and 4.0% (s = 4.2) on the roadside landing. Almost all the needles were lost during the first month (Fig. 2). The slight increase in needle content towards the end of the year was caused by freezing as needles, loose or intact, when frozen on to the branch material do not shed during handling as easily as when unfrozen.

The small amount of needles in the residue material which had dried on the clearcut area was of no surprise, but the result on the landing was not expected. It had been assumed that although the needles came loose they would still be retained within the grapple-held bunch and would end up in the sample. For some reason this did not happen. The sampling technique, including the difficulty of separating the cut needles from the chipped sample, is responsible for only some of the bias. Unfortunately, the overall low quantity of needles remains a matter for speculation.

The reduction in needle content reduced the ash content of the residue material from 2.1% to 1.5% during the first month of storage (Fig. 2). This could be expected, as the ash content of the needle fraction is higher than that of wood and bark. However, a slight increase towards the end of the drying season was observed. The cause could have been the digestion of cellulose sugars by microbes and soil contamination during handling. This activity would release carbon dioxide and water, simultaneously increasing the concentration of mineral element, i.e., ash.

FIG. 2–Percentage of needles and wood ash in residue material in different treatments.

Nutrient Concentrations

The major nutrients determined from the logging residues correlated with the ash percentage (Fig. 3). With the exception of aluminum and iron, however, the heavy metals did not show any correlation. The concentrations were very small or undetectable and were not affected by the amount of ash present.

Needles are known to be particularly rich in phosphorus, potassium, calcium, and magnesium (Mälkönen 1974; Finér 1989). Because of this it was anticipated that the shedding of needles would bring about a reduction of element concentrations in the remaining residues. However, the data did not support this prediction very strongly (Fig. 3). This is because boron, calcium, and magnesium are found in equally high or higher concentrations in branch bark. As a result the drop in needle percentage did not affect the average concentration of these elements in the fuelstock. The results were different with potassium and phosphorus, which are found in high amounts in needles and in much lower amounts in branch wood and bark. As a result the amount of potassium and phosphorus in the fuelstock was lowered by needle shedding.

There are two other nutrients that are considered important as corrosive agents from the combustion point of view. These are chlorine (Cl) and sodium (Na). Since chlorine is found mainly in the needles it is of no surprise to find that concentrations correlated well with needle

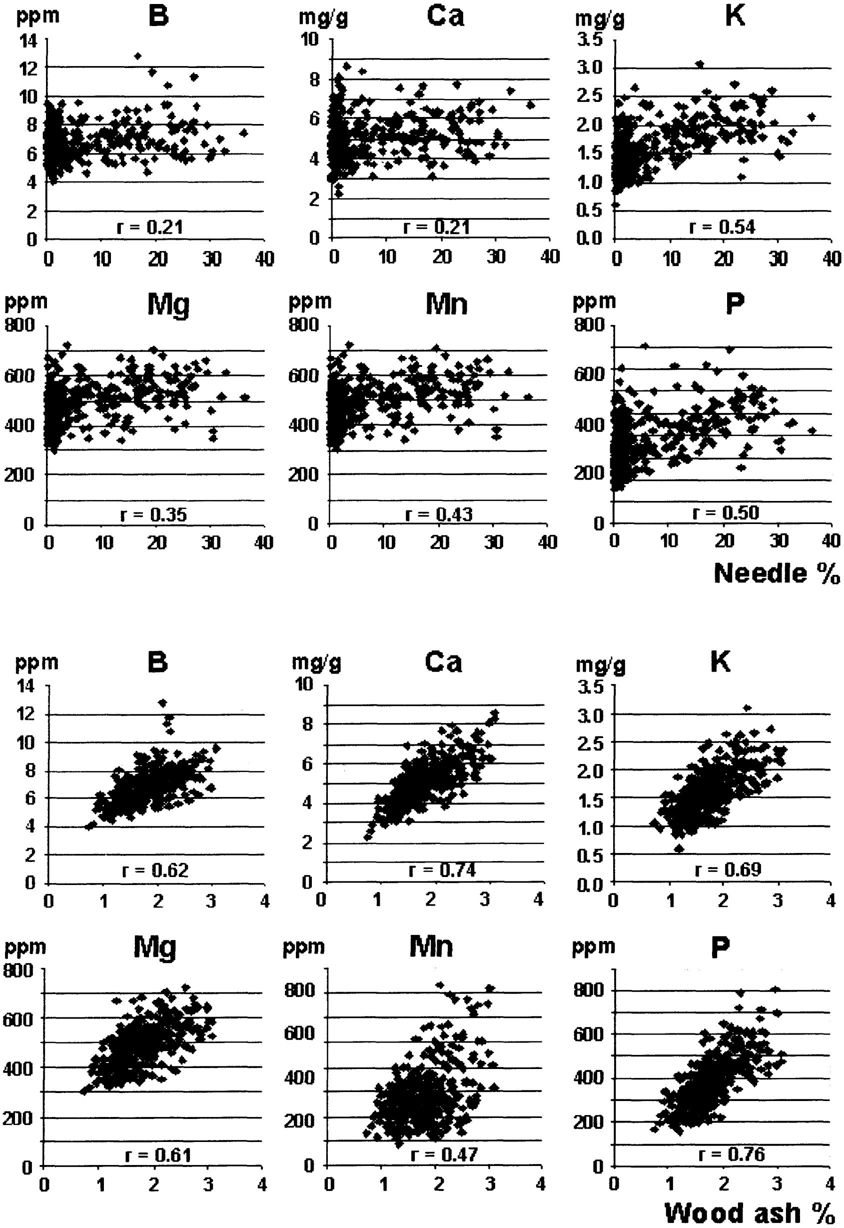

FIG. 3–The concentration of various elements in residue material as a function of needle and wood ash percentage.

content (Fig. 4). Since the concentrations of chlorine are as high as 200 mg/kg in fresh logging residues and 400 mg/kg in the needle component, one can expect seasoning to lower chlorine concentrations considerably. This can be seen in Fig. 5 where chlorine levels closely follow the amount of needles. It can be concluded that if chlorine is a critical factor in the maintenance of combustion systems, seasoning the material can considerably lower the amount of clorine in the fuel.

Sodium on the other hand was not affected by defoliation, but the concentrations are so low to begin with (5–40 ppm) that the use of residue material, whether green or brown, is not likely to cause a problem in combustion.

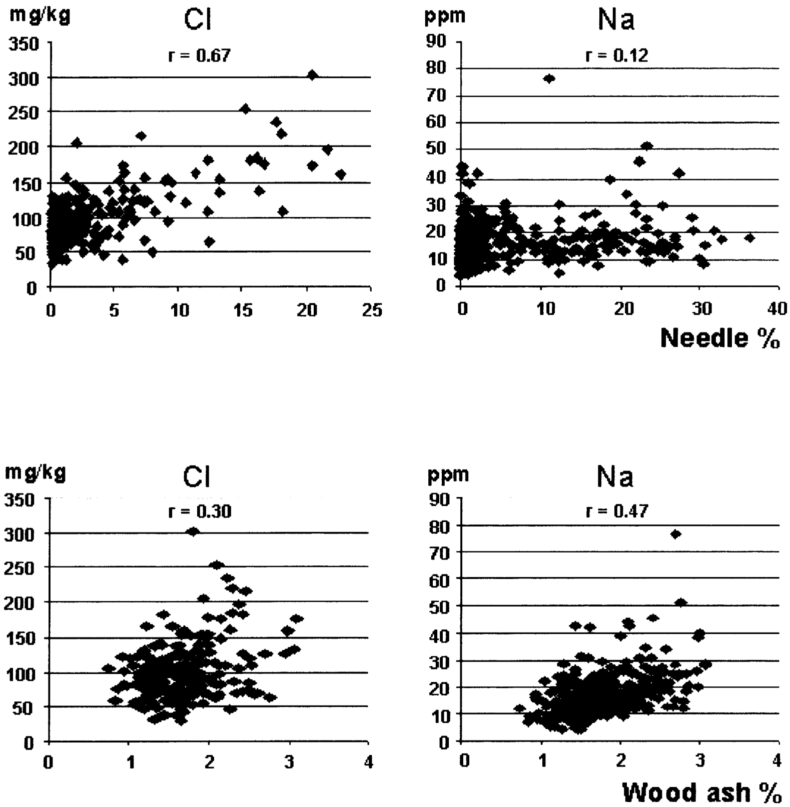

FIG. 4–Chloride (Cl^-) and sodium (Na) concentrations in residue material as a function of needle and wood ash percentage.

CONCLUSIONS

Fresh logging residues loose moisture very fast during early summer when evaporation is particularly high. A storage/drying time of only 2 to 3 weeks on the site may lower the moisture content to 30%. This is low enough for almost any type of combustion facility. Extending drying time to a month will further lower the moisture content but may not be necessary. Hence it can be recommended that if drying on the clearcut area is favoured the recovery of the brown residue material should indeed take place earlier than was done in the

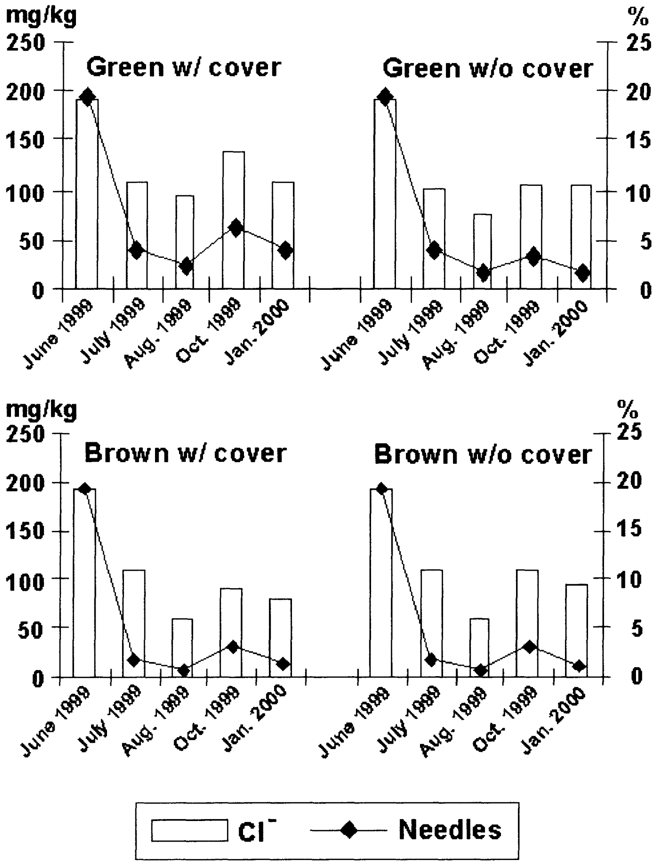

FIG. 5–Needle percentage and chloride (Cl^-) concentration as a function of time.

experiment (2 months). One should further recognise the fact that it is often the regeneration work and machine availability that will determine the suitable recovery time once the preliminary drying has taken place.

In good weather, material can dry well in piles on the landing. The initial loss of moisture is slightly lower than on the clearcut area. However, if the planned time of use is far off in the future this should not be a problem. Covering was found to protect the piles during the fall and early winter. Moisture content was much higher in the uncovered piles of both green or brown residues. The unfortunate aspect of this "green" alternative is high initial moisture content. Hauling fuel with 50% water may increase hauling costs.

When the residue material dries, needles will die and eventually fall off. It is the choice of the procurement organisation that will determine where this nutrient-rich component will end up. If the nutrients contained are an important issue for site fertility, then one might consider seasoning on the clearcut area followed by a timely collection and storage in piles. In this case one has to accept dry matter losses of 20–30% but higher heating value caused by the lower moisture content will compensate for most of the losses. If, however, nutrients are of no concern but the yield is, then the residues can be recovered green.

The quantity of needle mass did not affect the ash content or elemental composition to a great degree. However, it did affect the concentration of certain nutrients. It can be concluded that chlorine is governable by allowing logging residues to dry on the site and be collected as brown. Soil improvement did not seem to suffer from the loss of needles.

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