Radiological impact of using forest biomass for energy and recycling the ash

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INTRODUCTION

Today the development and research of bioenergy production is extensive due to the increasing cost of energy and the common goal to reduce atmospheric emissions of greenhouse gases from combustion of fossil fuels. Natural and artificial radionuclides found in forest biomass harvested for energy need consideration when the concepts for bioenergy are optimised. Also, the ash of biofuel is decisive to the radiation exposure of both workers handling the ash and the public using forests fertilised with the ash.

Currently, harvest residues received from thinning or final cutting of stands, and stump harvesting, are of prime importance to the delivery of biofuel from forests (Kuusinen and Ilvesniemi, 2008). The nutrient removal from forest with collected harvest residues and stumps, and the need to compensate such losses are of interest from the radioecological point of view.

Our study aims to clarify the effect of the use of forest biomass for energy on human exposure to radiation. Short and long-term consequences of the recurrent cycle of biofuel harvesting and ash fertilisation to radioactive contamination of forests were examined and are discussed. We also focus on the effect of biomass harvesting and recycling of ash on radionuclide budget and distribution in forests.

We review the chain of bioenergy production regarding radiation exposure to the public using forests and to workers involved in handling of ash. A case study demonstrates the changes in ^{137}Cs activity of a spruce stand on mineral soil during rotation, with and without recycling of ash.

MATERIALS AND METHODS

The experimental studies, made in collaboration with energy industry and STUK, have resulted in data for activity concentrations of radiocaesium in forest biomass used as fuel in the form of woodchips, and ash (Vetikko *et al.*). In ash of wood by-products of forest industry, the artificial ^{90}Sr and ^{137}Cs and the natural radionuclides ^{40}K, ^{210}Pb, ^{226}Ra, ^{232}Th and ^{235}U and also the solubility of most of these radionuclides have been determined (Rantavaara and Moring, 2001). The field experiments, in collaboration of STUK and METLA, have provided data on the effect of ash and mineral fertilisation on ^{137}Cs contamination of stemwood and other fractions of trees (Aro and Rantavaara, 2002; 2004; Aro *et al.,* 2002; Kaunisto *et al.,* 2002; Rantavaara and Aro, 2003; Rantavaara *et al.,* 2002; Rantavaara and Raitio, 2002). Ash fertilisation has a clear mitigating effect on the transfer of ^{137}Cs from soil to trees and other vegetation (Rantavaara and Aro, 2003). This is because potassium in ash reduces the uptake of ^{137}Cs, regardless of its origin. Therefore the reduction is significant for the ^{137}Cs accumulated earlier in soil and the ^{137}Cs of ash. The results obtained in these field studies are used here for calculation of radionuclide contamination in harvest residue, radiation exposure in forests, and changes in radioactive caesium budget of the stand.

Effect of ash returning to forest on human exposure from the Chernobyl-derived ^{137}Cs was derived for a spruce stand with contamination level of about 40 kBq m^{-2}. Human radiation exposure in forests, considering the recycling of biofuel ash is compared with the dose criteria for the public and for workers in the bioenergy production. The intervention level for radionuclide contamination of forest floor corresponding to acceptable exposure of workers and the public to external radiation can be derived for the suggested dose criteria.

RESULTS AND CONCLUSIONS

In undisturbed boreal forests radionuclide contamination of trees, particularly of stemwood and understorey vegetation, will decline after treatment of forest floor with potassium containing ash of tree biomass or mineral fertiliser. The effect appears slowly and lasts long. Reduction in solubility of most radionuclides during combustion of biofuel also has a mitigating effect on contamination of vegetation from radionuclides in ash and soil. Therefore, returning an acceptable amount of ash to forest will reduce the activity concentrations of biofuels from forests in the long term. The dosage should be related to the nutrient status of the forest.

Compared to not returning of nutrients to forests in the long term, the ash of forest biomass distributed to forest floor reduces contamination of trees and other vegetation as regards to most radionuclides. This fact suggests reducing doses to end users of wood, and also from ingestion of wild food received from forests (Levula et al., 2000).

Evaluation of other environmental consequences of harvesting forest biomass for energy, such as breaking the surface of forest floor (Kuusisto and Ilvesniemi, 2008), will reveal additional, but not necessarily significant, effects on the radionuclide dynamics in forests. To be acceptable, bioenergy is expected to be produced in a sustainable way (Stupak *et al.,* 2007). Implementation of bioenergy concepts reviewed for sustainability may not reveal significant changes in our conclusions about radiation impact of bioenergy. Changes in human exposure will depend on the site conditions and silvicultural methods applied. Either decrease – with recycling of ash, or increase of radiation exposure – if nutrient losses due to biomass harvesting are not compensated, seems possible.

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