Utilization of wastewater sludge as a fertilizer in short rotation forests on cut away peatlands

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The research has been conducted on fertilization of deciduous tree with wastewater sludge and optimization of doses for drained cut away oligitrophic peatland with left peat layer 1 m deep.

It was determinated, that after recultivation cut away peatland's with wastewater sludge (180-720 t/ha d.m.), the supply with nutritious substances improves peat soils fertility in 3-4 categories (from very poor N, P, until very rich), and acidity of peat in root zone is neutralized ($pH_{(KCl)}$ from 2.8, to 7.0). After fertilization with ecologically-economically acceptable doses (180-360 t/ha d.m.) the bests chemical parameters of soils are in the 1-st – 2-nd year, but in 3-rd – 4-th year in roots zone lack of nutritious substances is noticeable, which must be compensated with additional fertilization with mineral fertilizers or repeatedly with wastewater sludge.

On cut away upper type high-moor peatland local species - *Betula pendula* and *Betula pubescens*, less demanding for nutrients, grew better fertilized with minimal and moderate (180-360 t/ha d.m.) sludge application doses, and tree species, the needs of which in soil fertility are high - with moderate and maximal doses (360-720 t/ha d.m.). From the ecological point of view limited dose of fertilization up to 400 t/ha d.m. is sufficient and effective for growing short rotation forests on peat soils.

The increasing of current height of almost all tree in three-four years period shows that nutrients introduced with sludge have been enough for plants.

Key words: wastewater sludge, short rotation forests, deciduous tree, cut away peatlands

Introduction

Investigations on fertilization with wastewater sludge are carried out in many countries. Small doses (3-5 t/ha dry matter) are recommended to be used for fertilization of short rotation plantations on arable lands (Aronson, Perttu, 1994; Perttu, 1993; Perttu, Kowalik, 1995; Dickinson, Punschon, Hodkinson, Lepp, 1994; MAFF, 1993).

Short rotation forest in Lithuania on a large scale will be established in nearest years on sludge utilization areas of Kaunas wastewater plant on cut away peatlands. The building of representative in Lithuania wastewater plant of Kaunas, is foreseen to be finished in 1999. In contrast to foreign countries, the future wastewater sludge of Kaunas wastewater plant, is foreseen to utilize in a concentrated way on cut away peatlands, seeking not to pollute large areas. Sludge with application doses about 250 t/ha dry matter (d.m.) will be spread on about 10 ha of area annually. At maximum level of sludge producing about 50 ha of peatlands annually will be needed for sludge utilization. On these areas short rotation forests will be grown.

Maximal ecologically permissible doses of sludge (Diliūnas, Jagminas, 1998; Gradeckas, Diliūnas, Kubertavičienė, 1996; HN 48-1994; HN 60-1996 (Hygienic standards of Lithuania); LAND 10-96, LAND 20-96 (Standards of wastewater sludge utilization of Lithuania)) which have been determined in our research will be used. These doses depend on thickness of the remaining peat layer: when the layer is thicker than 0,3 m - up to 100 t/ha d.m., when is thicker than 0,5 -150-170 t/ha, when 1 m-350-400 t/ha d.m. The period for repeating fertilization also depends on thickness of peat layer: when the layer is thicker than 0,3 m -4-5 years, when is thicker than 0,5 m -7-8 years, when 1 m -9-12 years.

The remaining layer of peat on cut away peatlands possesses bigger absorbing properties of heavy metals, than mineral soils, stops them from migrating into deeper soil layers and ground water. The results of our complex studies obtained in laboratory and in field analysis of absorbing capacity of various rocks has shown, that peat has from some ten to several hundred times higher absorbing capacity of heavy metals, as compared with sand (Gradeckas, Diliūnas, Kubertavičienė, 1994). However, peat soils are very infertile, of very acid reaction, poor in nutritious substances. Under these conditions only some bushes and tree species naturally grow. Fertilization is necessary for improvement of peat soil. The cheapest fertilizer is wastewater sludge. The wastewater sludge is rich in humus and nutritious substances. It is

near to neutral reaction so is able to neutralize acidity of peaty soils and there is no need for liming. By using waste water sludge as a fertilizer the problem of wastewater sludge utilization, is solved.

The aim of research was to investigate the influence of wastewater sludge on cultivation of fast growing tree species on cut away peatlands and determine optimal, ecologically safe doses of fertilization for short rotation forests.

Methods

The research has been cunducted on fertilization of deciduous tree with wastewater sludge and doses have been optimized for drained cut away oligitrophic peatland with left peat layer 1 m deep, which had been fertilized using various doses. Ground water level is about 1 m deep. The wastewater sludge has been spread entirely on the surface with three layers of different thickness - 6, 12 and 24 cm. Thus, there were four variants of the experiment: minimal dose - 180 t/ha, average - 360 t/ha, maximal - 720 t/ha of dry matter and not fertilized variant. Half plots have been ploughed and wastewater sludge has been ploughed up to peat. Since in not fertilized plots all test plants have grown especially poorly so a minimal dose (180 t/ha d.m.) has been chosen for control variant. This dose has been compared with a bigger dose, in order to determine optimal dose of wastewater sludge for growing various tree species.

Experiments of optimizing of sludge application doses on cut away peatland have been established in 1993 and fifteen species of trees and their hybrids tested. Variants were established with three replicates by 30 tree, planted in rows (1x3 m), planting density is 3.3 $x10^3$/ha, the height of seedlings was 0.5- 1.0 m. Tested plants aged five years.

Chemical analysis of applied sludge and soil of experimental plot was conducted - $pH_{(KCl)}$ determined with potentiometer, hydrolyzable nitrogen by the method of Kornfild, available phosphorus by the method of Kirsanov, available potassium with flame photometer.

Wastewater sludge with moisture content 55%, applied to experimental plantations, according to granulometric content represents consolidated sand with great amount (16.4-30.2%) of organic matter. It is close to neutral reaction ($pH_{(KCl)}$ - 6.6), contains great amount of humus (12.6-17.5%), substantial quantities of hydrolyzable nitrogen (533-792 mg/kg) and available phosphorus (1470-1930 mg/kg) and a small amount of available potassium (153-298 mg/kg).

At the end of every vegetation period tested tree have been recorded continuously. The stem height, current height increment and diameter at 1,3 m above ground have been measured. The data of measuring have been processed by mathematical statistic's methods. The significance of variants differences has been evaluated by Student's criteria (t).

Results

On cut away upper type peatland, fertilized with sludge, the concentration of the main nutrients (N, P, K) and soil's reaction in tree roots zone directly depended on the quantity of sludge dose (180-720 t/ha d.m.) and technology of sludge spreading (Table 1). Only the layer of wastewater sludge or layer of sludge mixed with peat corresponds to the highest category by provision plants with available nitrogen and phosphorus. The highest concentration of nutrients at the beginning of fertilization has been up to 10-20 cm in depth and after 3-4 years nutrients have been found more only up to 10 cm in depth. The part of nutrients are migrating to deeper 40-70 cm horizons. This process goes on quicker when wastewater sludge is ploughed up to peat. Lack of nutrients must be compensated with additional fertilization with mineral fertilizers - N -120-150 kg/ha/yr, P -20-50 kg/ha/yr, K - 80-100 kg/ha/yr (Ledin, Perttu, 1989), or repeatedly with wastewater sludge 100-250 t/ha d.m. with period of refertilization 4-9 years respectively. Lack of potassium amount in the sludge may be compensated with additional application of potassium fertilizers.

In the fifth year of tree growth (Table 2), better tendency is noticeable in variants with sludge ploughed up to peat, because tree have deep root system. Growth of the most perspective tree species (Fig.1.) - birch and aspen in not fertilized variant shows, that mostly adapted to the upper type peatland conditions is *Betula pubescens*. Birches are less demanding for nutrients species of tree, so in this trial overdosing effect very typical of them has been obtained: *Betula pubescens* grew better fertilized with minimal (180 t/ha d.m.) sludge dose and *Betula pendula* - with moderate dose (360 t/ha d.m.). Worst growth of birches was on the area with maximal sludge application dose (720 t/ha d.m.) - *Betula pendula* did not survive. Tree species, the needs of which in soil fertility are high - *Populus tremula, P. tremula* hybrid x *P. tremula*, *P. tremuloides* x *populus tremula* hybrid, *P. berolinensis* and *Acer negundo* (Table 2), better grew fertilized with moderate and maximal sludge doses (720-360 t/ha d.m.). Faster growing *Populus tremuloides* x

Table 1. Changes in the main nutrients (N, P, K) concentration and soils reaction in four years period on cut away upper type high-moor peatland applying different sludge doses

Dose of sludge t/ha d.m. and spreading way	Thickness of layer, cm	$pH_{(KCL)}$		Hidrolizable N, mg/kg		Available P_2O_5, mg/kg		Available K_2O mg/kg	
		1993	1996	1993	1996	1993	1996	1993	1996
720 t spread on the surface	0 - 24	7,3	6,8	360	200	980	100***	89**	84**
	T 0 - 10	5,9	3·7	450**	380**	2120	290***	140*	85*
—"— ploughed up	0 - 24	6.4	5,6	380	160	870	210	114***	53**
	T 0 - 10	4,1	3,5	230*	110*	550	140**	86*	75*
360 t spread on the surface	0 - 12	6,8	6,2	340	140	560	150***	50*	37*
	T 0 - 10	4,7	3,0	400**	350**	430***	60**	110*	45*
—"— ploughed up	0 - 12	6,6	5,0	260	200	570	240	85**	83**
	T 0 - 10	4,0	3,0	370**	310**	990	50*	60*	32*
180 t spread on the surface	0 - 6	6,7	4,6	620	270	3190	350	85**	50**
	T 0 - 10	3,8	2,8	780***	590***	220***	120**	80*	65*
—"— ploughed up	0 - 6	6,4	4,2	450	240	920	350	107***	46*
	T 0 - 10	3,7	2,8	600***	560***	220***	60**	90*	73*
0 (not fertilized)	T 0 - 10	3,4	3,2	350**	270**	140**	70**	115*	105*

Fertility categories (Šleinys, 1986; Vaičys, Raguotis, Šleinys, 1979):
* -very infertile
** - infertile
*** - moderately fertile
**** - fertile
not marked -very fertile

populus tremula hybrid is most promising in all sludge application doses (Fig. 1.). From the ecological point of view limited sludge application dose up to 400 t/ha d.m. is sufficient and effective for trees.

The current height increment (Fig. 2.) of almost all tree species fertilized with 360 t/ha d.m. dose of sludge in three-four years period have been increasing, however in the fifth year it started decreasing. Only *Populus tremuloides* x *populus tremula* hybrid grew faster in the fifth year. The growth intensity of some tested tree species was lower in 1994, when there was drought over vegetation period. The increasing of the current height increment over a period of three-four years shows that nutrients introduced with sludge have been enough for plants. However, from the ecological point of view repeating fertilization in four years period may be carried out only with small doses of sludge (up to 100 t/ha d.m.). It is more desirable operationally to make a single large application of sludge (350-400 t/ha d.m.) in a period of nine years to keep transport and spreading costs to a minimum, than apply small units of sludge in short periods.

The influence of fertilization for short rotation forests most of all is indicated by the biomass increment (Table 3). Best growing *Populus tremuloides* x *populus tremula* hybrid with maximal sludge application dose (720 t/ha d.m.) during five years have accumulated volume 61.5 m^3/ha of wood which corresponds to 26.7 t/ha, of dry biomass. The current biomass increment in fifth growth year amounted to 12.9 t/ha d.m. and it's no less, than necessary biomass increment of willow energetic plantations. The obtained results have indicated that along with willows utilizing waste water sludge on cut away peatlands for short rotation forests fast growing deciduous tree and their hybrids are very perspective.

Conclusions

1. After recultivation cut away upper type peatland's with wastewater sludge (180-720 t/ha d.m.), infertile with very acid re action soils are being enriched with nutrients and also there is no need for liming. The supply with nutrients improves peat soil fertility in 3-4 categories (from very poor N, P, until very rich), and acidity of peat in root zone is neutralized (pH from 2.8, until 7.0). Reaction of peat soil and the quantity of the main nutrients depend on the dose of used wastewater sludge, the way of sludge spreading and period of time after fertilization.

2. By influence of wastewater sludge chemical qualities of the soils are improved and also the growth of tree and bushes is accelerated. After fertilization with ecologically-economically acceptable doses (180-360 t/ha d.m.) the bests parameters of soils are in the 1-st – 2-nd year, but in the 3-rd – 4-th year in root zone lack of

Table 2. The influence of fertilization with wastewater sludge for deciduous tree growth in the fifth year on cut away upper type peatland

Tree species	Doses of sludge t/ha d.m.	Stem height M±m, m	t	%	Stem diameter at 1.3 m above ground M±m, cm	t	%
Sludge spread on the surface of peat							
Betula pendula	180	4.9±0.2	-	100	3.1±.0.4		100
	360	5.8±0.1	4	117	4.8±0.3	3.1	152
	not fertilized	1.5±0.1	17.4	29			
B. pubescens	180	6.0±0.1	-	100	4.1±0.2	-	100
	360	6.4±0.1	3	107	5.0±0.2	3.4	122
	720	4.9±0.3	3.5	83	3.1±0.3	2.5	77
	not fertilized	2.7±0.2	13.9	46	1.5±0.1	13.5	37
Populus tremula	180	4.4±0.1	-	100	3.0±0.1	-	100
	360	6.4±0.1	13.8	145	4.3±0.4	3.4	144
	not fertilized	0.7±0.1	41.6	17			
P. tremuloides x *P. tremula* hybrid	180	5.6±0.3	-	100	4.5±0.3	-	100
	720	8.2±0.3	6	146	7.2±0.4	5.7	159
P. tremula hybrid x *P. tremula*	180	5.7±0.4	-	100	4.1±0.5		100
	360	5.4±0.2	0.8	94	3.6±0.2	0.8	89
	720	7.0±0.2	2.7	122	4.9±0.6	1	120
P. berolinensis	180	5.9±0.2	-	100	4.8±0.3		100
	360	5.8±0.1	0.6	98	4.7±0.3	0.1	99
	720	6.0±0.3	0.3	102	6.0±0.4	2.7	126
Acer negundo	180	5.7±0.3	-	100	4.8±0.3	-	100
	360	5.3±0.3	1	93	4.5±0.3	0.8	92
	720	6.1±0.2	1.3	108	6.4±0.6	2.4	133
Sludge ploughed up to peat							
Betula pendula	180	5.5±0.1	-	100	3.7±0.2	-	100
	360	6.1±0.2	2	110	4.2±0.3	1.5	114
	not fertilized	1.8±0.1	22	32	0.6±0.1	16.2	15
B. pubescens	180	6.0±0.1	-	100	3.9±0.2	-	100
	360	5.8±0.1	0.9	97	4.6±0.2	2.5	116
	720	5.1±0.1	5.9	86	2.1±0.2	6.7	53
	not fertilized	2.7±0.2	13.7	45	1.2±0.2	11.6	31
Populus tremula	180	4.0±0.3	-	100	2.4±0.3	-	100
	360	4.5±0.1	1.4	112	2.6±0.1	0.8	110
	720	4.7±0.2	1.8	117	2.2±0.5	0.4	91
	not fertilized	1.1±0.1	8.6	27			
P. tremuloides x *P. tremula* hybrid	180	7.7±0.2	-	100	6.2±0.5	-	100
	360	8.5±0.1	4	111	7.2±0.5	1.5	116
	720	8.4±0.2	2.4	109	7.6±0.5	2.1	123
	not fertilized	2.3±0.2	21	30	1.3±0.3	8.6	21
P. tremula hybrid x *P. tremula*	180	5.9±0.3	-	100	3.4±0.2	-	100
	360	6.8±0.1	3	116	5.0±0.4	3.7	145
Acer negundo	180	3.9±0.2	-	100	2.1±0.2	-	100
	360	4.3±0.2	1.5	109	3.0±0.3	2.9	144
	720	4.9±0.3	3.3	126	2.5±0.2	2	122

Table 3. The influence of fertilization with wastewater sludge for *P.tremuloides* x *P.tremula* hybrid growth, volume and biomass accumulation in the fifth year on cut away upper type peatland

Dose of sludge, t/ha d.m.	Density plants, 10^3/ha	Stem height, m	Stem diameter, cm	Volume m^3/ha 4 years old	Volume m^3/ha 5 years old	Current increment, m^3/ha	Biomass, d.m., t/ha 5 years old	Current increment, m^3/ha	%
180	3.33	7.7	6.2	23.3	40.3	17.0	17.5	7.4	100
360	--"--	8.5	7.2	31.7	57.6	25.9	25.0	11.2	151
720	--"--	8.4	7.6	31.7	61.5	29.8	26.7	12.9	174

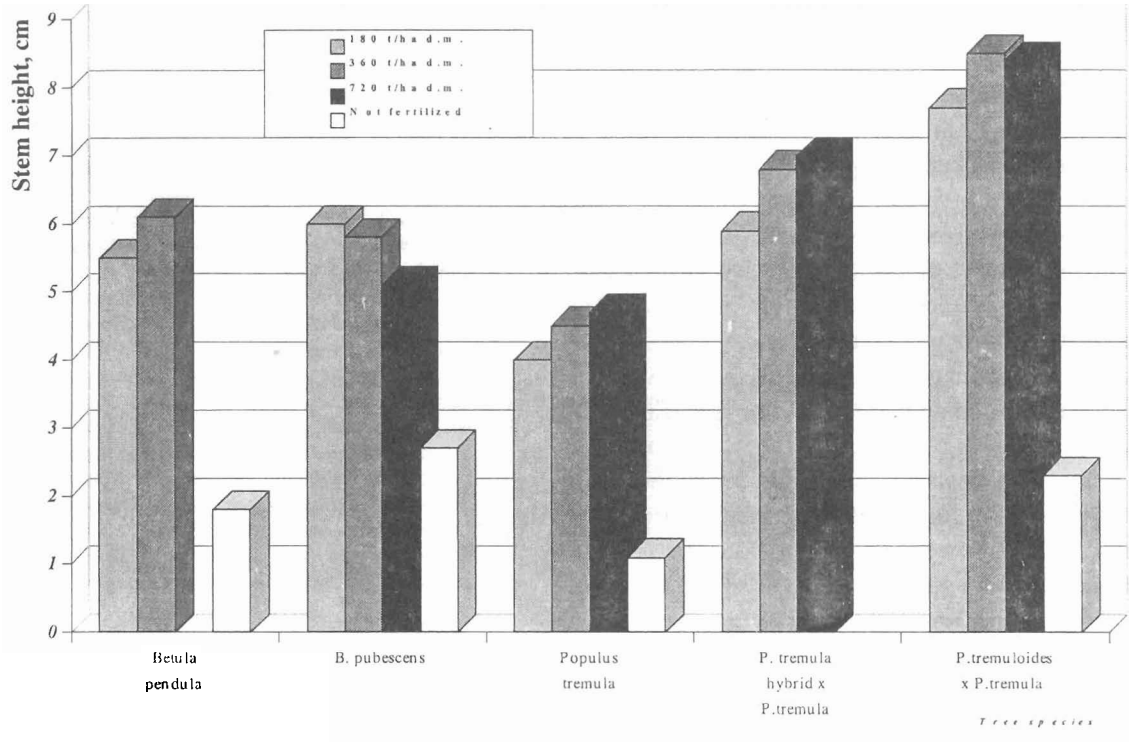

Figure 1. The influence of fertilization with sludge for birch and aspen growth in the fifth year on cut away upper type peatland

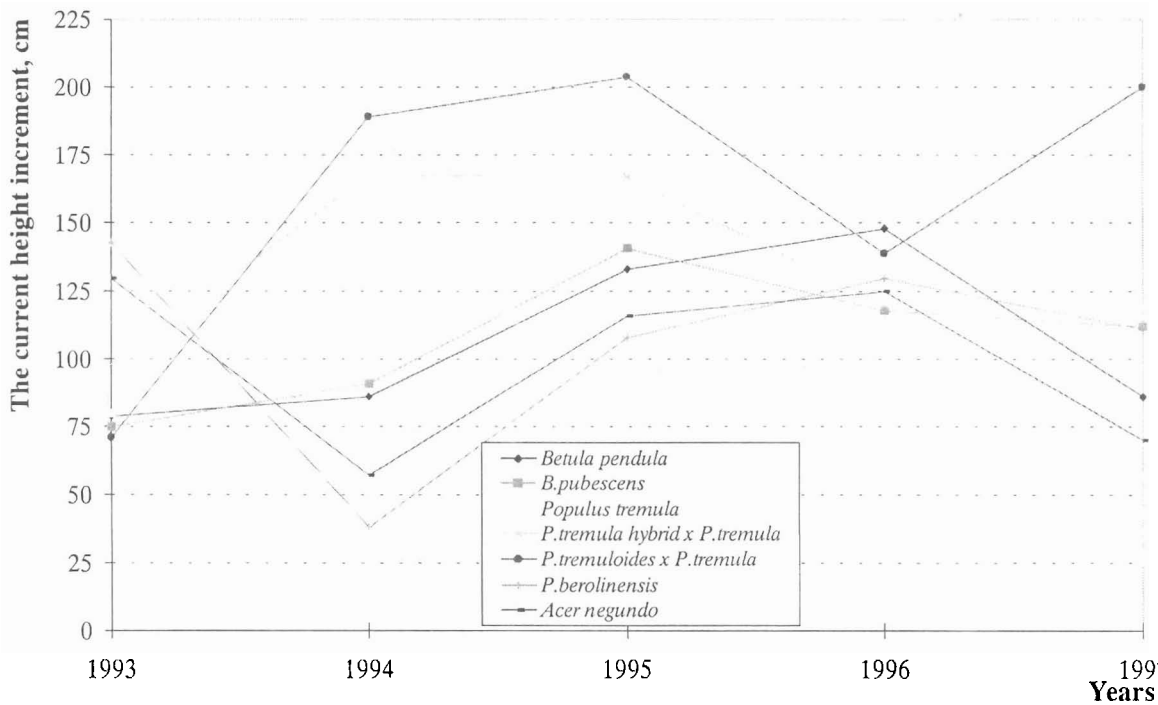

Figure 2. The current height increment of tree species fertilized with sludge (360 t/ha d.m.) on cut away upper type peatland

nutrients is noticeable, which must be compensated with additional fertilization with mineral fertilizers or repeatedly with wastewater sludge. Because of chemical substances migration to deeper horizons, plouging up of wastewater sludge to peat is not desirable.

3. On cut away upper type high-moor peatland local species - *Betula pendula* and *Betula pubescens*, less demanding for nutrients, grew better fertilized with minimal and moderate (180-360 t/ha d.m.) sludge application doses, and tree species, the needs of which in soil fertility are high - with moderate and maximal doses (360-720 t/ha d.m.). From the ecological point of view limited dose of fertilization up to 400 t/ha d.m. is sufficient and effective for growing short rotation forests on peat soils.

4. By utilizing wastewater sludge on cut away peatlands for growing forests of short rotation along with willows deciduous tree and their hybrids are very perspective. The biomass productivity of the most perspective tree species in the fifth year of the growth reached 12.9 t/ha d.m. and is not less than necessary biomass increment for willow energetic plantations.

References:

Aronsson P. , Perttu K. L. 1994. Wiliow vegetation filters for municipal wasterwaters and sludges. A biological purification system. Proceedings of a study tour, conference and workshop in Sweden, 5-10 June 1994. Swedish University of Agricultural Sciences. - Uppsala,-230 p.

Diliūnas J., Jagminas E., Kaminskas M., Čiužius G., Bajorinas V. 1998. Hidrogeologiniai nuotekų dumblo panaudojimo išeksploatuotų durpynų rekultivavimui aspektai. - Vilnius, "Geologija", T. XXIII, p. 148-157.

Dickinson N. M., Punschon T., Hodkinson R. B., Lepp N. W. 1994. Metal tolerance and acumulation in willows. In: Aronsson P. and Perttu K.L. 1994. Willow vegetation filters for municipal wasterwaters and sludges. A. biological purification system. Proceedings of a study tour, conference and workshop in Sweden, 5-10 June 1994.-Uppsala, p. 121-127.

Gradeckas A., Diliūnas J., Kubertavičienė L. ir kt. 1994. Kauno vandenvalos įmonės dumblo panaudojimo miškų ūkyje galimybių tyrimas. Ataskaita už 1994 [Investigations of possibilities of utilization wastewater sludge of Kaunas wastewater plant for short rotation forestry]. Girionys, Reports of 1994 year. - 168 p.

Gradeckas A., Diliūnas J., Kubertavičienė L. ir kt. 1996. Kauno vandenvalos įmonės dumblo panaudojimo miškų ūkyje galimybių tyrimas. Ataskaita už 1996 [Investigations of possibilities of utilization wastewater sludge of Kaunas wastewater plant for short rotation forestry]. Girionys, Reports of 1996 year. - 196 p.

HN 48-1994. Lietuvos higienos norma. Kenksmingos medžiagos. Didžiausia leidžiama ir laikinai leidžiama koncentracija dirvožemyje. [Hygienic standards of Lithuania. Harmful substances. Maximal ecologically permissible and provisional concentration in soil]. - 25 p.

HN 60-1996. Lietuvos higienos norma. Kenksmingos medžiagos. Didžiausia leidžiama ir laikinai leidžiama koncentracija dirvožemyje. [Hygienic standards of Lithuania. Harmful substances. Maximal ecologically permissible and provisional concentration in soil]. - 25 p.

MAFF (Ministry of Agriculture Food and Fisheries), 1993. Review of the rules for sewage sludge application to agricultural land: soil fertility aspects of potentialy toxic elements. London, MAFF Publications, 91 p.

LAND 10-96. 1996. Nuotekų dumblo naudojimo normos [Standards of wastewater sludge utilization]. - 20 p.

LAND 20-96. 1996. Nuotekų dumblo naudojimo normos [Standards of wastewater sludge utilization]. - 20 p.

Ledin S., Perttu K. L. 1989. Climatic, edaphic and management requirements for energy forestry. In: Modelling of Energy Forest: Growth. Water Relations and Economics. Eds. Perttu K. L. and Kowalik P. J. - Simulation Manographs 30. Pudoc, Wegeningen, 198 p.

Perttu K. L. 1993. Biomass production and nutrient removal from municipal wastes using willow vegetation filters. Journal of Sustainable Forestry, Vol. 1(3), p. 57-70.

Perttu K. L., Kowalik P. J. 1995. Salix vegetation filters for purification of waters and soils in Northern and Eastern Europe.- Presented at the IUFRO Congress in Tampere, Finland, 5-10 August 1995. - 13 p.

Šleinys R. 1986. Miško trešimo žinynas. [Forest fertilization reference book]. - V.: Mokslas, 1986. - 156 p.

Vaičys M., Raguotis A., Šleinys R. 1979. Miško dirvožemių žinynas. [Forest fertilization reference book]. - V.: Mokslas, - 149 p.

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УДОБРЕНИЕ ОСАДКАМИ СТОЧНЫХ ВОД ЛЕСОНАСАЖДЕНИЙ КОРОТКОГО ОБОРОТА НА ВЫРАБОТАННЫХ ТОРФЯНИКАХ

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Резюме

Изучено влияние различных доз (180, 360, 720 т/га с.в.) осадков сточных вод на рост 15 древесных пород и их гибридов на выработанных торфяниках верхового типа.

Установлено, что при удобрении осадками сточных вод (180-720 т/га с.в.) обеспеченность питательными веществами на торфяной верхового типа почве увеличивается на 3-4 категории (от очень бедных (NP) до очень богатях), а кислотность торфа в ризосфере неитрализируется (от $pH_{(KCl)}$ 2,8 до 7,0), поэтому существенно увеличивается продуктивность насаждений. Через 3-4 года после удобрения, из-за использования растениями и выщелачивания с осадками, содержание питательных веществ в ризосфере значительно снижается. Недостаток питательных веществ устраняется подкормкой минеральными удобрениями или повторным внесением осадков сточных вод.

На рекультивированных торфяннках верхового типа местные малотребовательные древесные породы (береза бородавчатая и пушистая) показали лучший рост при удобрении средними (360 т/га с.в.), а быстрорастущие древесные породы (осина, тополь, клен) - максимальными (720 т/га с.в.) дозами. В экологическом отношении ограниченные дозы осадков сточных вод до 400 т/га с.в. являются достаточными для выращивания плантаций древесных пород на торфяных почвах. После внесения удобрений даже на 3-4-ом году жизни, при достаточном наличии питательных веществ, текущий прирост древесных пород увеличивается.

Для разведения насаждений короткого оборота кроме ив весьма перспективными являются быстрорастущие лиственные древесные породы и их гибриды. Продуктивность биомассы гибрида канадской осины х осиой обыкновенной на пятом году жизни достиг 12.9 т/га с.в. и не уступил продуктивности ив, предназначенных для выращивания биомассы.

Ключевые слова: осадки сточных вод, торфяные почвы, насаждения короткого оборота, древесные породы.