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CHAPTER XIII

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THE QUALITY OF SOIL TARE FROM THE SUGAR PLANT WITH REGARD TO ITS UTILIZATION FOR SOIL FERTILIZATION

Introduction

One of the major waste from sugar industry is soil tare from the beet cleaning (soil tare) (MIZERSKA 2007). Soil tare is on the list of wastes, which the sugar plant can utilize 2006 (MINISTER OF ENVIRONMENT ORDER 2006). Soil tare has the highest share this group of waste. Under waste utilization regulation 27.04.2001 (LOW OF WASTE 2001) waste, the formation of which is impossible to prevent, and for which there exist technologically and economically feasible grounds to ensure proper recycling, under pertinent regulations of environmental protection, should be recycled in the first place.

Soil loss problem due to root crop harvesting is significant if we consider impoverishment in nutrients and organic matter. When harvesting root crops such as sugar beet, potato, carrot or leak, significant amount of soil retained by the root furrow is taken out from the field. Data from the intensive sugarbeet production show that the mass of wet soil sticking to the root (soil tare) may stand for up to 11% of the mass of the raw material that is delivered during the campaign (ORUC, GUNGOR 2008).

Soil material is retained on the storage roots and its amount is related to the shape of the root, the amount of lateral roots, depth of rooting, the composition of soil and the amount of water in it as well from the technique of harvesting. Soil mass taken out from the field depends also on the adhesive properties of soil and its water capacity, increasing with the increase of clay fraction and water contents in soil during the harvesting (LARYMERS, STRÄTZ 2003).

The amount of soil material brought with the beets to the sugar plant is related to morphology of root and its size. Large beet roots with a smaller or no furrow contain less soil. Moreover, the depth of rooting (fig. 1) that depends on the variety of beet and the technology of harvesting also influence the soil tare (VERMIEULEN, KOOLEN 2002).

Particularly large amounts of nutrients are taken out from soils rich in organic matter, with high water capacity. It was reported that a significant amount of nutrients is lost from soil; for example annual loss of phosphorus is up to 3.0 kg P ha^{-1} and nitrogen 30 kg N ha^{-1} during the sugarbeet production. Li and co-workers (LI et al. 2006) estimated that the largest losses of soil are reported during the potato and sugarbeet grow.

1 2 3 4 5 6 7

Fig. 1. Different depths of beet rooting: shallow (1-2) medium (3-5), deep (6-7).

RUYSSCHAERT et al. (2008) reported that soil losses during the root crop harvesting is comparable to soil degradation due to water or wind erosion. Soil losses at sugarbeet harvesting ranges between 1.2 to 1.9 t·ha^{-1} yr^{-1}, and 0.2 to 0.3 t·ha^{-1} yr^{-1}at potato harvesting. The process of soil losse due to sugarbeet production in Bavaria (Germany) ranges between 4.5 and 7 t·ha^{-1}·yr^{-1} (MAIER, SCHWERTMANN 1981).

Taking into account long term cultivation of root crops it is necessary to regard the decrease of soil profile depth as a result of soil adherence to the root surface.

A new parameter was used for characterization of soil erosion processes when harvesting such crops as sugarbeet (Beta vulgaris L.) SLCH (Soil Losses due to Crop Harvesting) (RUYSSCHAERT et al. 2007) or SLRH (Soil Loss due to Root crop Harvesting) (POESEN et al. 2001).

Long term study of SLCH for sugarbeet in Belgium showed that in the years 1968 – 1996 the annual values of this parameter equal 18.7 – 20.4 t·ha^{-1} in rainy years and 4.2 - 4.6 t·ha^{-1} in dry years.

Calculated annual mean value for SLCH was 5.0 t·ha $^{-1}$ (POESEN et al. 2001). The above data indicate that negative effects of the process is related to soil loss and its degradation and also to the increased costs of soil transport with the crop to the sugar plant.

Transportation of soil with the crop should be reduced as it causes environmental problems and the increase of costs of the final product (KOCH 1996).

In Poland the problem of soil tare utilization is not well recognized. It is not only of concern for working sugar factories but also those which are closed and have left waste and byproducts to be utilized. It is very important particularly in the light of environmental protection programs in regions and provinces where over 40 % of the total industrial waste come from sugar industry (MANAGEMENT OF WASTE DISPOSAL 2003).

Conditions of the study

One of the working sugar plants is Glinojeck S.A. located in the Ciechanów district, Mazowieckie province. Daily, the plant uses 12000 tons of beets. In the year 2007, 12 mln tons of sugarbeet were processed and corresponding amounts of soil tare plant was deposited in the vicinity of the plant.

The study of soil tare partly mixed with lime in the vicinity of the sugar plant in Glinojeck was undertaken. Soil tare was sampled from near the Glinojeck plant. Waste material has been collected for the last 20 years and consists of soil that was washed out from the beets and defecation lime (another by-product of sugar production).

Total area of the pile was 0.5 ha, with the irregular shape 132 x 81 m (Fig. 2). Prior to sampling, preliminary drilling was made and the studied area was divided into 14 plots. From each plot a collective sample consisting of 10 –15 sampling was taken. Material sampled from the depth 20 – 60 cm was analyzed.

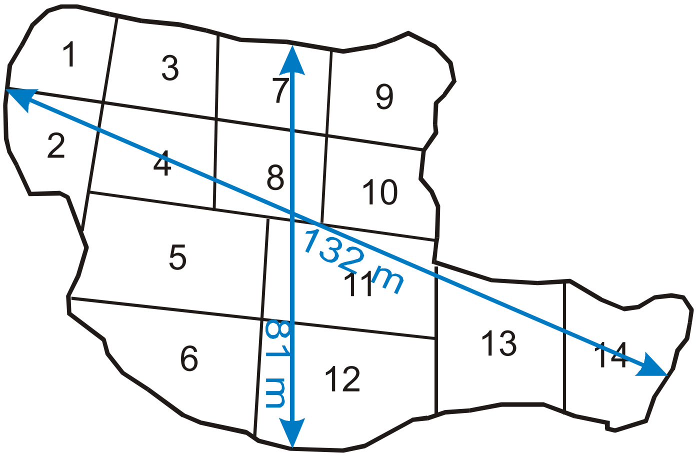

Fig. 2. Localization of samples taken for the analysis.

Soil material in the laboratory was dried in the room temperature; there was no plant residuum in it. There were no coarser fragments of stones except for several clums of lime stone.

Samples were sieved through a 1 mm sieve and the following analyses were performed:

1. pH in H_2O was determined potentiometrically on pH-meter Radiometer PHM.
2. Organic carbon was determined according to Tiurin`s (LITYNSKI 1976).
3. Content of $CaCO_3$ according to Scheibler (LITYNSKI 1976).

4. Texture was determined according to Boycouse – Cassegrande method in Prószyński modification.
5. Total phosphorus using molibdeniane method.
6. Total contents of macroelements (K, Mg, Na) and trace elements Zn, Cu, Ni, Pb, Cr and Cd) after mineralisation in concentrated acids (HF and $HClO_4$) (CROCK and SEVERSON 1980) was determined using AAS technique on Philips PU 9100X spectrometer.
7. Available forms of P and K according to Egner – Riehm method.
8. Available Mg according to Schatchabel`s.
9. Contents of S-SO_4 according to BARDSLAY – LANCASTER (1960).
10. Total content of Hg was determined using AMA 256 spectrometer.
11. Contents of available Zn, Cu, Ni, Pb and Cd according to LINDSAY and NORVELL (1978) after the DTPA extraction, on AAS spectrometer.

Soil tare composition

Analysis of soil tare samples (Table 1) showed that their pH was neutral or slightly alkaline with pH in H_2O in the range between 7.05 – 7.49 and the mean value at 7.26.

Table 1

Physico-chemical properties of the studied material

Soil No	pH in H_2O	C org.	$CaCO_3$	ø<0,002mm	Texture*
		[g kg^{-1}]	[%]		
1	7.05	5.9	17.77	1	LS
2	7.17	10.1	24.73	5	SL
3	7.13	9.6	21.12	2	SL
4	7.20	9.8	55.48	2	SL
5	7.25	8.3	21.23	10	SL
6	7.19	13.0	20.69	4	SL
7	7.39	10.9	24.88	4	SL
8	7.21	14.3	27.97	4	SL
9	7.28	10.9	22.56	4	SiL
10	7.31	9.2	17.43	2	SL
11	7.24	12.4	29.94	7	SL
12	7.49	12.7	24.13	5	SL
13	7.40	10.9	17.68	5	SL
14	7.37	9.7	29.23	5	SL
Mean	7.26	10.6	25.35	4	
Range	7.05-7.49	5.9-14.3	17.43-55.48	1-10	

* - LS - loamy sand, SL - sandy loam, SiL - silt loam (USDA)

Total organic carbon contents ranged from 5.9 to 14.3 g·kg^{-1} (with the mean value 10.6 g·kg^{-1}). Such amounts are characteristic for soils from sugarbeet fields usually rich in organic matter.

Content of calcium carbonate differentiated from 17.43 to 55.48 % with the mean value 25.35 %. High amounts of $CaCO_3$ in the analyzed soil material came from another byproduct (defecation lime) in sugar technology; at present changed technology allows to separate lime from the soil material.

Texture of the studied material is mainly loamy, with the clay fraction (ø < 0.002 mm) content in the range 1 – 10 % (Table 1). Fine size clay particles dominate in tare soil from the sugar plant (MIZERSKA 2007). This fraction presents highest sorption capacity for nutrients.

Adhering soils removed from the surface layer of beet fields contain appreciable amounts of essential plant nutrients such as total phosphorus (except samples 1 and 10) and potassium, calcium and magnesium: 0.73 $g{\cdot}kg^{-1}$, P; 2.4 $g{\cdot}kg^{-1}$, 80.67 $g{\cdot}kg^{-1}$ Ca and 2.3 $g{\cdot}kg^{-1}$ Mg (Table 2).

The content of available forms of potassium was high and very high (PN-R-04022 1996) and ranged between 158.0 and 282.0 mg kg^{-1} of soil. Phosphorous and magnesium contents were high (PN-R-04023 1996; PN-R-04020 1994) and were in the range from 153.0 to 192.0 $mg{\cdot}kg^{-1}$ and 215.0 – 515.0 $mg{\cdot}kg^{-1}$ respectively. High contents of macroelements in soil tare can be a source of essential plant nutrients. Moreover, the addition of lime is a source of calcium in soil tare and such enrichment improves physical properties of soil and soil pH (MIZERSKA 2007).

Table 2

Total contents of macroelements

Soil No	P	K	Mg	Ca	Na
	($g{\cdot}kg^{-1}$)				
1	0.07	5.4	1.7	53.7	0.3
2	0.75	2.6	2.1	83.2	0.3
3	0.85	2.6	2.0	86.7	0.3
4	0.72	2.7	3.9	90.4	0.3
5	0.36	1.7	1.9	82.6	0.4
6	0.75	2.3	2.7	84.7	0.3
7	0.75	2.0	2.1	91.6	0.3
8	0.88	1.9	2.5	85.7	0.3
9	0.65	2.2	2.1	87.9	0.3
10	0.20	1.6	1.9	73.2	0.2
11	1.60	1.7	2.2	59.4	0.4
12	1.11	2.7	2.6	89.2	0.4
13	0.75	2.2	2.1	79.2	0.4
14	0.75	2.0	2.4	81.9	0.4
Mean	0.73	2.4	2.3	80.67	0.3
Range	0.07-1.60	1.6-2.7	1.7-3.9	53.7-91.6	0.2-0.4

The content of $S\text{-}SO_4$ ranged from 76.6 to 157.0 $mg{\cdot}kg^{-1}$ (mean 117.0 $mg{\cdot}kg^{-1}$) which is characteristic of the top soil material rich in clay fraction. The observed sulphur contents in $S\text{-}SO_4$ form are high but typical for the natural level of this element (Table 3) – TERELAK et al 1998.

Table 3

Content of available forms of selected macroelements

Soil No	P	K	Mg	$S-SO_4$
	(mg·kg^{-1})			
1	192.0	158.0	215.0	157.0
2	188.0	203.0	385.0	108.5
3	175.0	141.0	315.0	127.6
4	175.0	166.0	275.0	110.6
5	153.0	170.0	305.0	76.6
6	179.0	224.0	335.0	157.2
7	183.0	208.0	260.0	106.8
8	181.0	212.0	515.0	138.0
9	177.0	282.0	315.0	98.2
10	175.0	212.0	295.0	113.6
11	183.0	212.0	340.0	102.1
12	172.0	282.0	315.0	124.6
13	175.0	299.0	305.0	110.6
14	172.0	232.0	320.0	106.7
Mean	177.0	214.0	321.0	117.0
Range	153.0-192.0	158.0-282.0	215.0-515.0	76.6-157.0

Total contents of microelements in the soil material were typical for soils having loamy and silty texture. Samples contained relatively high amounts of phytoavailable zinc and copper (Table 4). The contents of nickel, lead, cadmium and mercury were on the levels of natural and fulfilled all the requirements needed for its agricultural application (KABATA-PENDIAS, PIOTROWSKA 1987). Similarly, the properties of phytoavailable forms of these metals in analyzed soil tare were low (Table 4).

The contents of analyzed metals were in the acceptable range, and stemmed from the variability of composition of soil brought from the beet fields, and the amounts of lime added during the process of sugar production.

Table 4

Total contents and available forms of selected microelements

No	Zn*	Zn**	Cu*	Cu**	Ni*	Ni**	Pb*	Pb**	Cd*	Cd**	Cr*	Hg*
	$[mg \cdot kg^{-1}]$											
1	22.7	1.02	3.3	0.4	9.62	0.73	18.66	1.96	0.12	0.04	8.45	0.012
2	22.22	1.19	4.01	0.42	9.86	0.81	10.17	0.3	0.15	0.06	10.24	0.012
3	28.62	1.26	3.51	0.46	9.37	0.74	12.71	0.54	0.25	0.08	11.36	0.019
4	19.22	1.37	2.96	0.44	9.3	0.8	10.75	0.45	0.26	<0.02	11.01	0.015
5	24.6	1.23	3.47	0.53	9.42	0.53	10.3	0.26	0.44	0.04	10.42	0.012
6	27.7	1.59	3.17	0.55	9.46	0.62	15.45	0.9	0.69	0.08	10.95	0.02
7	31.87	1.47	2.9	0.71	9.19	0.75	12.46	0.7	0.55	0.05	11.27	0.015
8	23.27	1.37	3.06	0.73	9.0	0.7	7.95	0.27	0.67	0.12	10.92	0.02
9	22.65	1.63	3.02	0.58	9.1	0.65	11.32	0.4	0.72	0.12	10.64	0.015
10	28.02	1.72	2.69	0.47	9.2	0.73	13.02	0.6	<0.02	<0.02	12.15	0.013
11	41.02	1.74	3.29	0.78	8.94	0.7	19.1	0.5	<0.02	<0.02	13.72	0.016
12	65.77	1.52	3.15	0.74	9.04	0.74	10.56	0.46	0.17	0.07	14.55	0.016
13	64.85	2.26	2.65	0.64	9.05	0.8	13.29	0.77	0.09	0.07	14.66	0.016
14	58.85	2.24	2.85	0.43	8.71	0.82	11.25	0.28	0.15	0.11	13.85	0.015
Mean	34.38	1.54	3.15	0.56	9.23	0.72	12.64	0.6	0.31	0.07	11.73	0.015
Range	19.22-65.77	1.02-2.24	2.69-4.01	0.4-0.78	8.71-9.86	0.53-0.82	7.95-19.1	0.26-1.96	<0.02-0.69	<0.02-0.12	8.45-14.66	0.012-0.02

* - total content, ** - content of DTPA extractable forms

Summary

The results of the chemical and physico-chemical analysis indicate that the waste from sugar plant (soil tare) is a valuable material for the fertilisation of sandy soils, with acid pH values, and poor in nutrients for plant.

Agricultural application of the soil tare is not hazardous for the environment as regards the contents of heavy metals such as Pb, Hg, and Cd.

Thus, soil tare, - the waste which comes from cleaning and washing of sugar beets is proper for the enrichment of fields in nutrients, also as the additive of other waste such as composted sewage sludge.

Having taken into consideration the fact that bulb and root plants (beet) left relatively low amounts of plant residue in the soil, and even then the residue undergoes swift mineralisation, it would be beneficial to apply soil tare on the beet fields, from which the most valuable components were removed together with the crop. Such a supplementation would decrease the value of the SLCH indicator, and the losses linked with it, and comporable to the losses during erosion process.

Soil tare is also recommended for landscaping during such investments as construction of highways, sodding of artificial embankments, slopes or pits.

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