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Evaluation of Significant Environmental Aspects in Grain Processing

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The survey of the companies which belong to the Lithuanian Grain Processors' Association has been carried out for the analysis of the main environmental problems in grain processing. Significant environmental aspects are identified: inefficient heat and electricity consumption, biodegradable waste formation during grain processing and grain products production. Biodegradable waste is generated not only in technological processes, but in waste treatment too, for example, solid parts (C) collected in the air emissions treatment equipment, sludge in waste water tank, etc. Different volumes of biodegradable waste in this branch of industry are indicated in the literature on this subject. In Lithuania, biodegradable waste utilization problem exists since 2004 when this waste stopped being received in dumps. Their management makes some problems, inc. financial, therefore, the companies are interested in hiding the accurate waste volume. The majority of Lithuanian grain processing companies have their own composting sites for biodegradable (BD) waste collection, unfortunately, of limited capacity. To establish the quantitative parameters of grain processing processes, inc. relative environmental indicators, an experiment was performed in an ordinary grain processing company. The results and conclusions of this experiment are presented, a significant environmental control system is proposed.

Key words: *grain processing, environmental performance, environmental indicators, environmental management, Cleaner Production, biodegradable waste.*

1. Introduction

Agriculture is the main raw materials supplier for food industry. Lithuanian agrarian fund consists of 6 530 thousands ha, more than half of which is suitable for agriculture. The crop of grain corny plants makes 26%. Annual growth of grain harvest is clearly noticeable. In 2007, 3.07 M. t of grain was harvested in Lithuania, in 2008 – 3.49 M. t. In recent years, Lithuania has exported over 1 M. t of grain to the EU and other countries. Wheat comprises over 60% of this amount. Each year approx. 2 M. t of grain is left in the home market. Grains are processed in grain processing factories, stock-raising and poultry farms.

According to the data of the Department of Statistics of the Government of the Republic of Lithuania, 755.3 thousands t of flour, grains and mixed fodder were produced in Lithuania in 2007 (Index data base. The Department of Statistics of the Government of the Republic of Lithuania). The production size of grain processing products has the growing tendencies: from 2000 till 2007 the production of flour has increased by 23.13%, the production of mixed fodder has increased by 82.26% (see Table1).

Results of the research into the grain processing that was carried out in 2008 are presented in this paper. Estimation of significant environmental aspects of grain processing processes, their environmental impact and suggestions for optimization possibilities to reduce a negative environmental impact were the main targets of this research.

Companies that belong to the Lithuanian Grain Processors' Association and produce over 95% of producible fodder and over 97% of flour have been chosen as the objective of this research (in total - 32 companies). The experiment was carried out in the company which produces grains, flour, mixed fodder and has IPPC (Integrated Pollution Prevention and Control) permits.

To achieve the objective the following tasks have been taken:

1. To carry out the survey of the grain processing companies that belong to the Lithuanian Grain Processors' Association (2008);

2. To determine the main grain technological processing processes according to results of the survey, to evaluate the processes of input and output flows and to determine the limits of environmental indicators of grain processing (2008);
3. To evaluate improvement possibilities in the main environmental aspects of grain processing processes (2008);
4. To determine improvement in grain processing along with an increase in environmental efficiency (2009 – 2010).

Research methodology is presented in Fig. 1. The survey was carried out by means of a questionnaire method. Questionnaires were sent to all companies that belong to the Lithuanian Grain Processors' Association. Response was received from 75%. The filled out questionnaires were received from 24 companies: UAB "Agrochema", AB "Kauno grūdai ir partneriai", UAB "Malsena", UAB "Kratonas", AB "Kėdainių grūdai", AB "Jonavos grūdai", AB "Joniškio grūdai", AB "Marijampolės grūdai", AB "Vievio paukštynas", UAB "Biofabrikas", UAB "Linas Agro Grūdų c. Kūb", UAB "Bardra", UAB "Viking Malt", UAB "Maltosa", UAB "Uostukių Malūnas", AB "Rokiškio grūdai", AB "Šilutės girnos", AB "Tauragės grūdai", UAB "Robusta", UAB "Žemaitijos grūdai", UAB "Žvalguva", UAB "Eurokorma", UAB "Kemira GrowHow", UAB "Grūdų pirkliai".

Main environmental problems and solutions as well as significant environmental aspects were expected to be learnt from the survey respondents.

The environmental audit was carried out in the experimental company on purpose to determine main environmental aspects and their environmental impact. In the audit the IPPC proposal and permit were analyzed, input and output flows of the main technological processes were measured and evaluated together with company specialists, the material and energy balances were made. Environmental indicators were used to evaluate the company's environmental efficiency. Determining the objectives of processes optimization the basic principles of the Theory of Environment System were applied.

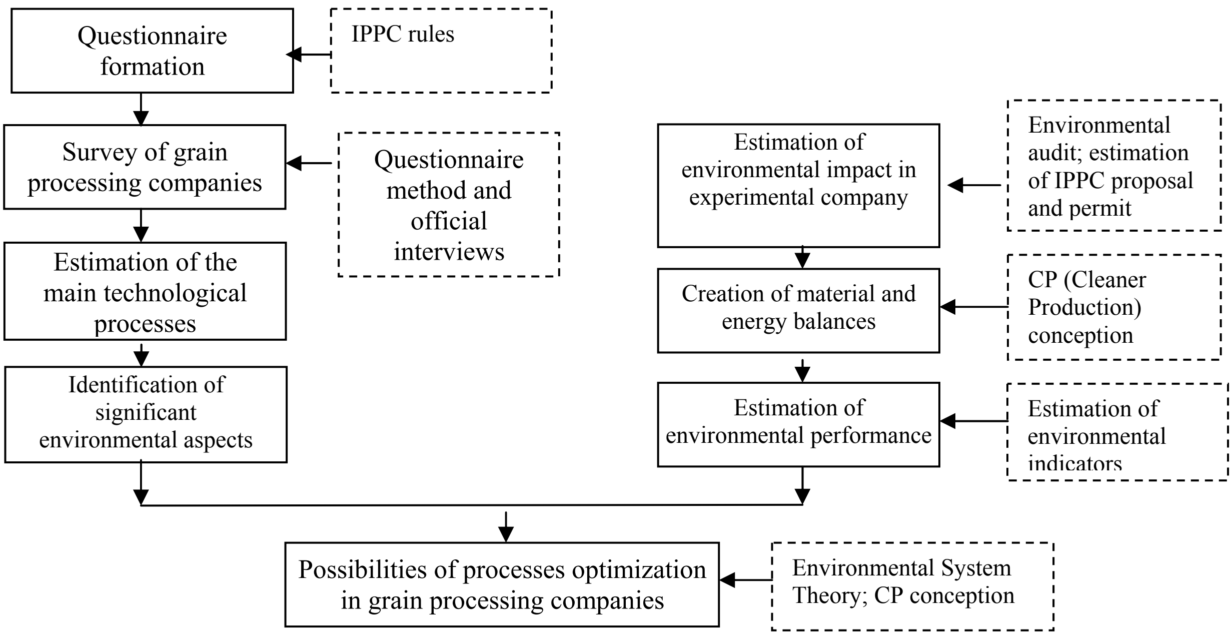

Fig. 1. *Methodology of estimation of environmental impact assessment (EIA) and of possibilities of increasing environmental efficiency in grain processing companies*

2. Main technological processes in grain processing

In grain processing companies grains are stored in an elevator department. In addition to the storage, in the elevator department grains are cleaned by applying various technologies. Cleaned grains are supplied to a grain processing department: for drying (if kept for a longer time), conditioning (or watering), and cooling - depending on the grain sort and further processing processes. Grains are dried in desiccators (hothouses) with gas-fired burners. Clean grains are delivered to desiccators and there they are dried to the base indices. Dried grains are kept in bins in granaries. Grains for milling are moistened up to 14% humidity. Qualitative grain products are produced in a milling department. Ready sieved flour is stored in bins of the mill from which flour is either loaded into flour-carriages for delivery or prepacked.

2.1. Flour production

Wheat and rye is raw material of flour.

The kinds of flour are:

- wheat flour: flour for baking (farina, top quality, first and second classes), flour for pasta (top quality, first class),
- rye: sieved and processed flour.

Basic methods of grain processing:

- Preparation of grain. Equipment whose operation is based on the difference of grain and main features of impurities is used to chaff grain impurities. It consists of technological refinement devices: aspirators, settlers, separators, spiral settlers, machines for stone separation, magnetic apparatuses.
- Grain conditioning - watering and storage at the fixed temperature (up to 5-6 hours). This process may be cold or hot.
- Grain milling. This process varies as onetime, repeated, simple (without bran chaff and vice versa), repeated specific (without producing grits, and vice versa, uniform, double and treble). The working principle of the milling equipment is based on pressing and shifting (rolls and millstones), striking (disk mills), striking and grinding (hammer mills) deformations. Rolls are used most frequently.
- Quality estimation. Production quality, flour bulk and humidity are controlled during the whole milling process. The control is performed in the mill laboratory, where the quality of flour is determined taking into account the flour bulk, humidity and the quantity of ashes.

2.2. Grits production

Raw materials: buckwheat, barley, wheat, oat, pulse grain.

Types of grits produced from

- buckwheat: kernels, splits
- barley: pearl-barley, splits
- wheat: farina, wheat cut grits;
- oats: steamed non-split grits, crushed oats;
- pulses: pod peas, beans and haricot beans are sold unprocessed, desiccated.

Basic grain processing methods:

- Grain preparation. Grains are refined and their impurities are removed. Then they are classified according to their bulk into fractions.
- Grain processing. Grains are husked, periseeds and partly seed-coats are removed.
- Cuisine preparation. Traditional grits are improved (starch is being pasted, proteins are denatured), later they are dried..

The grit husk is an ecological product that is formed after buckwheat grit shelling and used for cushions and mattresses sewing. Preparing grit husks for products, grits are additionally refined: grain remains are removed, impurities and seeds of other bio cultures are sieved, and dust is removed.

2.3. Mixed fodder production

Raw materials: various grains.

Production aim: fodder for cattle, poultry, birds, dogs, domestic fur animals.

Basic methods of grain processing:

- Grain preparation.
- Grain milling.
- Flour sieving. Flour from stone-ground stock is supplied above to sieving bins then flour flows to the sieving equipment and the process of sieving takes place.
- Batching. Grain flour that meets the requirements is batched to the prescribed mixture (fodder).
- Mixing. Batched mixtures go to mixed fodder.
- Formation (for example, granulation), packing and loading. Produced mixed fodder is supplied to the mixed fodder bins and then according to the purpose - to granulation, prepacking, extruding and loading.

Table 1. Volume of the main manufactured products in Lithuanian grain processing industry, thousands t/year, 2000 – 2007

Production, thousands t/year	2000	2001	2002	2003	2004	2005	2006	2007	Comparison of 2007 to 2000, %
Flour, inc.	**204.9**	**211.5**	**215.0**	**205.5**	**239.1**	**223.6**	**214.4**	**252.3**	**23.13**
wheat	149.4	158.0	164.5	158.6	189.8	177.8	174.0	229.5	53.61
rye	55.1	53.2	49.1	44.7	48.1	45.4	40.1	22.7	-58.80
Grain groats, inc.	**14.0**	**16.8**	**14.7**	**14.9**	**21.9**	**32.4**	**24.1**	**20.0**	**42.86**
farina	2.4	2.2	2.,0	1.9	2.4	2.0	1.4	1.3	-45.83
buckwheat	2.8	2.7	2.9	4.6	3.4	6.0	6.5	6.7	139.29
Mixed fodder	**265**	**254**	**277**	**282**	**360**	**394**	**454**	**483**	**82.26**

Information sources: Index data base // The main products production. The Department of Statistics of the Government of the Republic of Lithuania

3. Environmental impact of the grain processing processes

Input and output flows of typical grain processing equipment are presented in Fig. 2. Their quantity and toxicity depend on many factors such as manufactured products, technological processes, technical state of equipment, choice of process monitoring equipment or process control system, applied environmental decisions, personnel competence, and other related aspects.

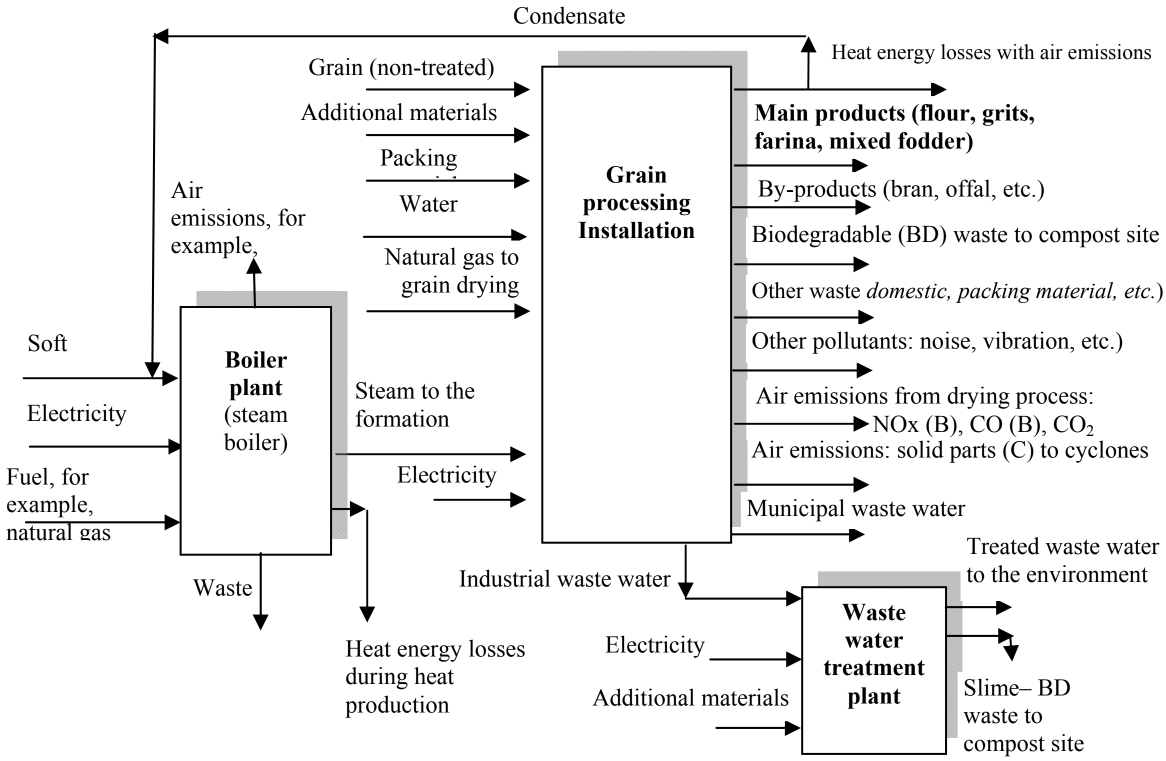

Fig. 2. Flowchart of a typical grain processing company
Comments: main flows are presented in this scheme without surface waste water, flows related to logistic department, and other possible additional processes

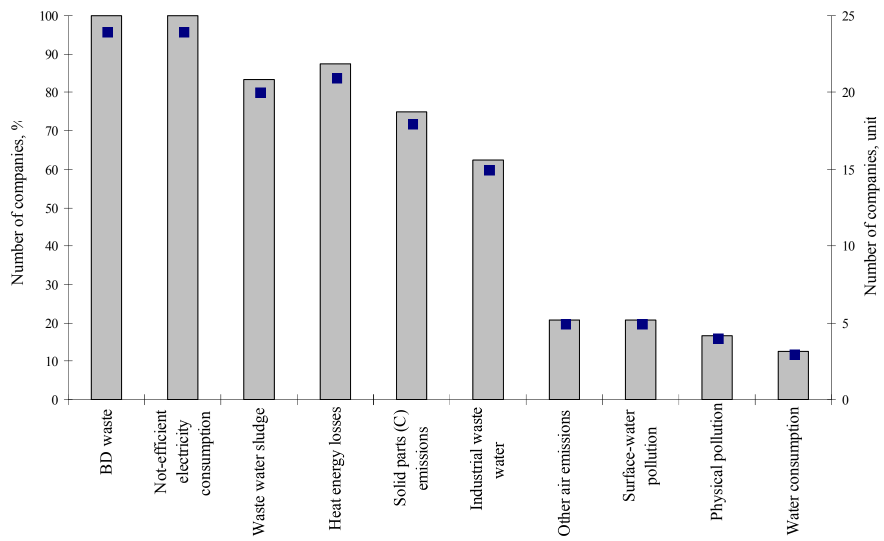

Fig. 3. Main environmental problems in grain processing companies (respondents' opinion)

During the official interviews, the respondents from 24 Lithuanian grain processing companies have had to indicate minimum five crucial environmental problems and to comment on the reasons of their origins and applied environmental solutions.

The respondents have indicated that the principal environmental problems in grain processing are related to the biodegradable (BD) waste formation and management inc. slime from industrial waste water treatment equipment or waste water tank, solid parts from cyclones during air emissions' treatment (see Fig. 3). Ineffective energy production and consumption are other relevant problems.

BD waste from grain processing is considered to be non hazardous waste as classified in category 02 03 of the European Waste Catalogue. This category integrates waste from fruit, vegetables, cereals (grain), edible oils, cocoa, coffee, tea and tobacco preparation and processing; canned food production; yeast and yeast extract production, molasses production and fermentation. Therefore, it is difficult to separate and estimate the exact amount of waste produced during grain processing processes using statistic data (Staniškis J.K., 2006; Juškaitė-Norbutienė R., Miliūtė J., Česnaitis R., 2007)

In accordance with the data of the Environmental Protection Agency (EPA), about 988.008 t of that waste were delivered to the waste management companies in 2007 (Waste collection and management, EPA, 2007). Over 95% of this waste belongs to food production and products' waste (statistic code: 0912). About 93% of this waste is dumped (waste management method D1), only 15.63 t of it were sent to compost sites (waste management method R3) (Waste collection and management, EPA, 2007).

In practice, the volume of this waste is bigger; because grain processing companies manage some part of BD waste with the municipal waste flow. Besides, majority of such companies digest or just collect BD waste in their own sites. Survey results show that more than 100 thousand t of BD waste were generated in the investigated grain processing companies during 2008.

Results of analysis of the grain and grain processing industries' production balances according to the statistic data from the Index database are presented in Table 2. In 2007, in Lithuania 2083.3 thousand t of grain were consumed, 216.5 thousand t of grain were reserved for seed, production losses amount to 60.7 thousand t, about 168.8 thousand t were supplied to beer and other alcohol production. Up to 1235.3 t of grain were supplied to mixed fodder production, 402 thousand t – to flour and groats production. Up to 65.594 thousand t/year of bran (remains of milling and other grain processing processes) formed. Thus, as a result, in 2007, about 64 thousand t of BD were generated only in flour and grits production.

The respondents have indicated that the greatest part of BD waste is generated in elevator departments during grain preparation and primary processing. The other part of BD waste goes with industrial waste water to waste water treatment plants (tanks) or slime reservoirs. The volume of BD waste having considerably decreased compared to 2000 year (see Table 2), BD waste management remains to be a great problem to grain processing companies.

Table 2. Evaluation of BD waste volume in Lithuanian grain processing companies

	[1]2000, thousand t/year	[1]2007, thousand t/year	Difference, %
Grain growing (production) volume	2 657.7	3 017	13.52
Grain export	137.1	903.5	559.01
Grain consumption in local market	2 358.8	2 083.3	-11.68
Grain reserve for seed	325.8	216.5	-33.55
Grain production losses	73.6	60.7	-17.53
Grain for bear production	56	105	87.50
Grain for other alcohol production	66.8	63.8	-4.49
Grain for mixed fodder production	1 374.0	1 235.3	-10.09
Mixed fodder production volume	265	483	82.26
Grain for flour and grits production	462.6	402	-13.10
Flour production volume	204.9	252.3	23.13
Grits production volume	14.0	20.0	42.86
Volume of bran	60.329	65.594	8.73
Evaluated volume of BD waste from flour, groats and bran production	183.371	64.106	-119.265

[1]Sources: Index data base // The Department of Statistics of the Government of the Republic of Lithuania
Comments: *this Table does not include the volume of grain import and store exchange.*

BD waste formation of such a big volume is a feature of this industry. It is very difficult to diminish the significance of this environmental aspect by optimizing the processes. BD waste dumping (waste management method D1) becomes a very costly process. One of the most popular ways of the u s e of this waste (R10) in Lithuania is composting it together with the other BD waste. Whereas, in many countries BD waste from grain processing industry is intensively used in alternative energy production.

In Lithuania, biogas production is the question of the day. Unfortunately, its decision faces many obstacles and no decision has been made as to which raw materials are to be used as alternative energy sources. Therefore, in a further work of our research in the field of optimization possibilities of grain processing processes the optimization of BD waste management by using one of the CP methods - the secondary waste usage in the company or in manufacture of other products will be given a fair attention.

In grain production companies heat energy is used for grain drying, mixed fodder formation (granular, extruded). In most companies heat energy is produced by burning natural gas. In this way these companies become the stationary sources of air emissions of NOx, CO, CO_2 (see Fig. 2).

Solid parts (C) get to the environment during all grain processing stages starting with grain entering the elevator to its milling processes. Besides, solid parts (C) are emitted into the air during pouring and packing processes. These air emissions from the organized sources (for example, air vents) are supplied to the solid parts treatment cyclones. Thus, about 90-98% of the solid parts (it depends on the treatment plant efficiency) become BD waste which goes to the company's compost site or to dumps together with the municipal waste flow.

Water in grain processing processes is used for watering (to reduce air emissions, to prevent fire), for wet shelling, for hot water and steam production. In some companies, waste water, first of all, is supplied to the local waste water treatment plants and only then to the environment. But, the majority of grain processing companies collect waste water into a special reservoir with solid parts' precipitator. Then, partly treated waste water is supplied to the town's waste water sewage system. Hereby, after waste water treatment slime becomes the other BD waste of grain processing companies.

4. Evaluation of environment indicators in grain processing installation selected for experiment

To evaluate the environmental performance and to estimate significant aspects of each grain processing processes and their mathematical values, the environmental audit was carried out in an ordinary grain processing company (further *experimental company*). The detailed information about each grain processing processes was collected for evaluation of processes' inputs and outputs flows and creation of the processes' material and energy balances.

Processes' input and output dates were estimated used the following possible environmental information sources: IPPC proposal, prepared by company's specialists, and IPPC permit, issued by the Regional Environmental Department; indication of measurement equipment; annual statistic reports; technological cards; personnel survey using theoretical EIA (Environmental Impact Assessment) calculating methods.

Table 3. Raw materials and waste flows in experimental company (primary evaluation)

Inputs and outputs materials of the grain processing processes	2008 (t/year)
Input materials	*109 770.09*
Grain consumption (before cleaning and primary processing)	62 000
Additional raw materials for mixed fodder production	45 769.89
Protein raw materials	2 000.2
Output materials	*108 575*
Manufactured products:	**107 796**
Mixed fodder	87 000
For cattle	51 000
For pigs	31 000
For poultry	2 000
For fish	3 000
Protein vitamins and supplements	2 000
Farina	2 500
Flour, highest quality	4 500
Flour, first quality	7 500
Bran (by-products with about 70% of nutrient)	4 256
Other products	40
Waste volume indicated in yearly statistic waste report for 2008	779
Difference between inputs and outputs:	*1 195.09*

[1]Sources: Account data of an experimental company

The company's account data and statistic waste report were analyzed and it was determined that in 2008 62 thousand t of grain and about 47.8 thousand t of other raw materials were processed and about 107.8 thousand t of various products were produced (see Table 3). According to the data of the primary waste report, 0.8 thousand t of BD waste were delivered to waste management companies (see Table 5). But the difference between raw materials' volume and the volume of manufactured products (inc. by-products) amounts to 1 195.09 t/year.

The main flows of BD waste in grain processing companies are as follows:

- Grain infusions: granulated, minor, sprouted dark grain, or grain touched by vermin, or grain touched during drying processes;
- Rubbish additives: outside seeds, defective grain, mineral and organic additives, spur, smully grain, dead insects;
- Grain peels;
- Solid parts from air emissions treatment plants;
- Sludge from industrial waste water reservoirs or treatment plants.

The results of evaluation of material and energy balances of each grain processing processes (primary processing in elevator, drying, milling, mixed fodder production, steam production) are presented in Table 4. Absolute and relative environmental indicators were calculated for each environmental aspect. Relative environmental indicators will come to assistance in evaluating the process optimization possibilities and in estimating alteration results in environmental performance after the implementation of CP innovations (Kliopova I., PhD thesis, 2002).

Table 4. Determination of significant environmental aspects in experimental grain processing company

	Department / Processes	Significant environmental aspect	Environmental indicator, 2008		Existing applied environmental method
			Absolute value, units/year	Relative value	
1	**Elevator** (primary treatment (*grain separation from waste, grain shelling and primary processing*)) grain consumption (G) – 62 000 t/year; grain after primary processing (MP) - 60 917.211 t/year				
1.1	Grain receiving and primary processing	Air emissions from 11 stationary sources:solid parts (C)	5.828 t/year	≤0.5 mg/m^3; 0.094 kg/t of G; 0.096 kg/t of MP	Solid parts treatment plans (cyclones LIC of treatment efficiency – up to 96.7%)
		Solid parts, accumulated in cyclones (BD waste)	170.778 t/year	2.754 kg/t of G; 2.803 kg/t of MP	This waste is stocked for a time in special tanks in company's territory
		BD waste	906.183 t/year	14.616 kg/t of G; 14.876 kg/t of MP	This waste is carried to company's BD waste composting site
		Electricity consumption	775.650 MWh/year	12.51 kWh/t of G; 12.733 kWh/t of MP	
1.2	Grain drying (in desiccators)	Natural gas consumption	289 517 n m^3/year	4.67 nm^3/t of G; 4.753 nm^3/t of PP	Heat energy is produced in stove with natural gas burning burners. It reduces energy losses and air emissions
		Air emissions from 4 stationary energy sources: CO (B) NOx (B) Total:	1.312 t/year 0.489 t/year 1.801 t/year	≤5 mg/m^3 ≤0.085 mg/m^3 0.029 kg/t of G; 0.030 kg/t of MP	
2	**Milling department** grain consumption (G) – 19 488 t/year; MP (flour highest quality, flour 1st quality, farina, bran, the other) – 18 800 t/year				
2.1	Grain watering and wet shelling	Water consumption	2 920 m^3/year	0.15 m^3 /t of G; 0.155 m^3 /t of MP	Waste water is supplied to the waste water reservoir, from it - to town sewage system
		Waste water	2 920 m^3/year		
		Sludge in waste water reservoir (BD waste)	40 t/year	2.053 kg/t of G; 2.128 kg/t of MP	Sludge is delivered to the waste management company
2.2	Grain milling	Air emissions from 7 stationary sources of milling department: solid parts (C)	4.383 t/year	0.225 kg/t of G; 0.233 kg/t of MP	Grain watering, solid parts treatment plants
		Solid parts accumulated in cyclones (BD waste)	128.44 t/year	6.591 kg/t of G; 6.832 kg/t of MP	This waste is utilized with municipal waste flow or in the company's BD waste composting site
		BD waste	515.182 t/year	26.436 kg/t of G; 27.403 kg/t of MP	This waste is utilized in company's BD waste composting site
		Electricity consumption	1 653.862 MWh/year	84.866 kWh/t of G; 87.971 kWh/t of MP	

	Department Processes	Significant environmental aspect	Environmental indicator, 2008		Existing applied environmental method
			Absolute value, units/year	Relative value	
		Heat energy consumption	266.33 GCal/year or 309.74 MWh/year	15.894 kWh/t of G; 16.476 kWh/t of MP	Heat energy is produced in boilers burning natural gas
3	**Mixed fodder department** Grain consumption (G) – 41 429.211 t/year; consumption of other additional materials – 47 770.089 t/year; total consumption of raw materials (RM) – 89 199.300 t/year; manufactured production MP: mixed fodder – 87 000 t/year; protein vitamins and supplements – 2 000 t/year; total volume of MP – 89 000 t/year.				
3.1 – 3.4	Component dosage; Component mixing; Grain crushing; Granulation	Air emissions from 7 stationary sources: solid parts (C)	6.32 t/year	0.071 kg/t of RM; 0.071 kg/t of MP	Solid parts treatment plants
		Solid parts, accumulated in cyclones (BD waste)	185.20 t/year	2.076 kg/t of RM; 2.081 kg/t of MP	This waste is utilized in company's BD waste composting site
		BD waste	7.78 t/year	0.087 kg/t of RM; 0.087 kg/t o MP	This waste is utilized in company's BD waste composting site or recycled to the technological processes
		Heat energy (steam) consumption in granulator	178.063 GCal/year or 207.09 MWh/year	2.322 kWh/t of RM; 2.326 kWh /t of PP	Steam is produced in the company boiler house burning natural gas
		Electricity consumption	1940.015 MWh/year	21.749 kWh/t of RM; 21.8 kWh/t of MP	
4.	**Boiler house** produced heat energy is supplied to all company's production departments, volume of company's manufactured production – 107 796 t/year				
4.1	Heat energy production (steam or hot water): 3922,979 GCal/year or 46430,425 MWh/year	Natural gas consumption	530 387 nm^3/year	4.920 nm^3/t MP	
		Air emissions from stationary source : CO(A) NOx (A) Total emissions:	 1.8517 t/year 5.141 t/year 6.9927 t/year	0.065 kg/t of MP	
		Electricity consumption	48.529 MWh/year	0.450 kWh/t of MP or 1.045 kWh/MWh of heat energy	

Comment: MP – manufactured production in the analyzed department; G – grain; RM – raw material

5. Significant environment aspects control system proposed to grain processing companies

The suggested Significant Environment Aspects Control system (see Fig. 4) for grain processing processes was developed according to the Environment System Theory (Staniškis J., Stasiškienė Ž., Kliopova I., Monograph, 2002) and by applying the methods of Process Control in Cleaner Production (Kliopova I., PhD thesis, 2002; Kliopova I., Staniškis J.K., 2004).

Technological grain processing processes (see Table 4) are the object of the control system.

$\mathbf{X_{out'}(t)}$ are indicators of significant environmental aspects – state variables of that system, for example:

- $X_{out1'}(t)$ – volume of BD waste, expressed by t/year or t/t of manufactured product (MP) or t/t of processed grain;
- $X_{out2'}(t)$ – heat energy consumption, MWh/year or kWh/t of MP;
- $X_{out3'}(t)$ – electricity consumption, MWh/year or kWh/t of MP;
- $X_{out4'}(t)$ – volume of air emissions - solid parts (C), t/year or t/t of MP;
- $X_{out5'}(t)$ – volume of sludge from waste water reservoir or treatment plant, m^3/year or l/t MP;
- $X_{out\,n'}(t)$ - other possible state variables;

$\mathbf{X_{out}(t)}$ – direct or indirect measured (*evaluated, determined*) process output variables - environmental indicators of the controlled grain processing processes.

All state variables $\mathbf{X_{out}(t)}$ of the processes have the variation limits or limitations, for example, environmental limits, requests for product quality, technological requirements for raw materials, energy consumption, water, for processes, product, waste, etc. (Kliopova I., PhD thesis, 2002; Kliopova I., Staniškis J.K., 2004): $X_{out4}(t)_{min.} \leq X_{out4}(t) \leq X_{out4}(t)_{max}$.

These limitations in CP in Process Control are evaluated as eligible values or control targets $\mathbf{X_{in}(t)}$.

For example, the limitations for absolute indicator $X_{out4'}(t)$ (*volume of air emissions - solid parts (C), generated in the analyzed company*) are as follows:

$$0 \text{ t/year} \leq X_{out4}(t) \leq 19.314 \text{ t/year},$$

where

19.314 t/year – maximum volume of solid parts (C), evaluated during the inventory of air emissions and fixed in IPPC permit.

The limitations of relative environmental indicator $X_{out4'}(t)$ have to be indicated either in concentration dimension (mg/m^3) or in mass dimension – t/t of manufactured production (MP):

$$X_{out4'}(t) = 19.314 / 139\,800 = 0.138 \text{ kg/t},$$

where

139 800 t/year – maximum volume of manufactured production (MP) in accordance with a technical project fixed in IPPC permit.

Then, the targets for this indicator $X_{out4'}(t)$ are as follows:

$Xin_4(t) \leq 0.5$ mg/m^3 (*maximum concentration of solid parts (C), fixed in IPPC permit*);

$Xin_4(t) \leq 0.138$ kg/t of MP.

or

$0 \text{ mg/m}^3 \leq X_{iš4}(t) \leq 0.5 \text{ mg/m}^3$,
$0 \text{ kg/t} \leq X_{iš4}(t) \leq 0.138 \text{ kg/t}$.

Results of the analyses of environmental indicators in the experimental company in 2008 show that 16.531 t/year of solid parts (C) were emitted to the air during all grain processing processes (see Table 4). Hereby, a relative value for this state variable $X_{out4'}(t)$ is equal to 0.153 kg/t of MP and exceeds the limitation $X_{in4'}(t)$ by 10%.

In case of grain processing technology improvement, the volume of BD waste has to be increased. Therefore, target $X_{in1}(t) = 0$ for indicator $X_{iš1'}(t)$ (*volume of BD waste in grain processing company*) is inexpedient. Consequently, new environmental indicators in the waste management environmental area could be evaluated in such companies by new state variables, for example,

$X_{out6'}(t)$ – volume of managed BD waste in accordance with the Rules of Waste Management, t/year *or*

$X_{out7'}(t)$ – volume of BD waste utilized in dumping sites, t/year.

System target for such state variables will be:

$Xin_6(t) \rightarrow X_{out1'}(t)$;
$Xin_7(t) \rightarrow 0$.

In case of our experimental company, $Xin_6(t) < X_{out1'}(t)$ (see Table 5).

D(t) are disturbances affecting the object or environment impact on production processes. Input state variables $\mathbf{X_{out'}(t)}$ deviations $\Delta\mathbf{X}(t)$ from definite targets $\mathbf{X_{in}(t)}$ arise exactly due to these input sequences. Some of disturbances are uncontrolled system's inputs to grain processing companies. For example, the quality of grain supplied by an agricultural company to grain elevator depends on the quality and peculiarities of grain growth and collection processes, on climatic conditions during grain growth. Grain quality affects the volume of BD waste after primary grain processing. Due to this fact, till now in Lithuanian grain processing companies, disturbance compensation or feed-forward control system has not been applied. In the method of Cleaner Production through Process Control such feed-forward control system is used for the prevention environmental activity (Kliopova I., PhD thesis, 2002; Staniškis J., Stasiškienė Ž., Kliopova I., Monograph, 2002).

Table 5. BD waste formation in the experimental grain processing company, t/year, 2008

Analyzed department	BD waste volume from company's report	Evaluated waste volume (after development of material balances)
Mixed fodder production	6.32	192.98
Milling	4.383	683.622
Elevator	768.297	1 076.961
Total BD waste volume:	779 t/year	1 953.563 t/year

The feedback control system is applied to environmental activity of grain processing companies. This system is considered to be the deviation compensation system and is used in CP for reduction or minimization of a negative environmental impact and risk of the production process due to pollution and losses. Implementation of the air emissions treatment plants, waste water treatment plants or sedimentation reservoir, composting sites for BD waste is a result of this reactive environmental control system.

Since some disturbances could be controlled, a feedback-feed-forward control system is suggested for significant aspects control in grain processing (see Fig. 4) (Staniškis J., Stasiškienė Ž., Kliopova I., Monograph, 2002).

For example, application of waste energy in the mixed fodder production department will allow not only minimize consumption of heat energy (reactive activity), but also air emissions (CO(A), NOx(A), CO_2) during heat energy production.

The main objective of this control system in environmental activities is to form such possible strategic actions **U (t)** for grain processing processes, which could ensure the fulfillment of the system targets $\mathbf{X_{in}(t)}$.

Undoubtedly, each suggested method for minimizing the environmental impact of significant environmental aspect (-s) is to be evaluated using feasibility analysis and CP methodology (Staniškis J., Stasiškienė Ž., Kliopova I., Monograph, 2002).

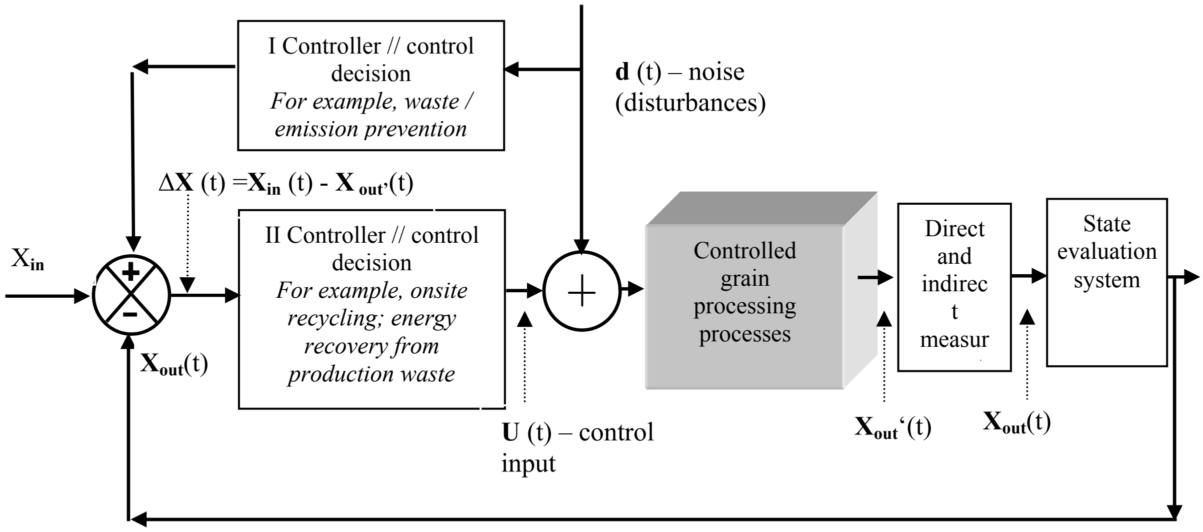

Fig. 4. Significant environmental aspects control system in grain processing

6. Conclusions

To identify the reasons of environmental problems in any company, it is necessary to estimate environmental indicators of all company equipment and each process individually. In this case, the method of materials and energy balances is applied. Thus, the relative values of each environmental indicator are estimated for all grain processing processes in an experimental company. It enables those who are concerned to identify the significant environmental aspects (results presented in Table 4) and the reasons of their origin.

Significant Environmental Aspects Control System is proposed to grain processing companies and it can come to assistance in estimating the environmental efficiency of planned and implemented environment innovations. In this stage, proper estimation of the limitations of each indicator of each controlled aspect (control targets) and proper evaluation of possible disturbances is of great importance. Limitations of the process state variables of grain processing companies are indicated in IPPC permits (*the largest permit concentration of some air pollutant (mg/Nm^3), volume of this pollutant per year (t/year)*) and are based on the environmental or health safety requirements presented in the instructions, etc. Some emissions' limit values for installations listed in Annex 1 of IPPC rules (*AB "Kretingos grūdai"; AB "Malsena"; UAB "Kauno grūdai ir partneriai"*) are defined in the BAT (The Best Available Techniques) reference documents (*BAT for Food, Drink and Milk industries; BAT for Energy Efficiency*).

We suggest to apply the relative indicators, such as the volume of raw materials consumption, energy, generated waste, waste water, pollutants resulting from production of 1 t of manufactured products (in each technological state) or from processing of 1 t of grain.

The result of experiment shows that real volume of BD waste, generated in Lithuanian grain processing processes, exceeds that which is officially declared in the annual statistic waste report. For example, in 2008 in the experimental company the difference in volume makes 2.5 times (see Table 5). Thus, in this company, 18.12 kg of BD waste were generated during production of 1 t of products or 17.8 kg - during processing of 1 t of raw materials.

If the whole grain processing company is considered as an installation, the greater part of BD waste (more than 55%) is generated in the elevator department. But, having determined the relative indicators for BD waste area for each grain processing process, it was defined that its significant volume was generated in the milling department: up to 35 kg/t of grain (G) and 36.36 kg/t of manufactured production (MP).

In addition, due to the developed material and energy balances for separate processes, we can evaluate the volume of BD waste for separate products. Hereby, it was evaluated that in 2008 in the experimental company about 10 kg of BD waste were generated for the production of 1 t of mixed fodder and up to 55 kg - for the production of 1 t of farina, flour and by-product (bran). If we consider bran as BD waste too, this indicator will increase to 365 kg/t or up to 27% of used grain in this product production.

The air emissions as solid parts (C) from all technological units are the other significant environmental aspect in grain processing. For example, up to 0.153 kg of these air emissions for the produce of 1 t of products are emitted from 25 sources of air emissions in the experimental company. Solid parts (C) which are collected in cyclones increase the volume of BD waste.

Furthermore, results of the analysis have revealed the other very important environmental and economic problem in grain processing – a large volume of energy consumption. For example, more than 10 thousand MWh of energy was consumed in the analyzed company in 2008. Its makes about 0.09 MWh/t of MP. Heat energy losses are obtained during heat energy production (about 10%), burning natural gas, in technological processes (steam losses in the mixed fodder production department).

Since 2008, the Institute of Environmental Engineering (KTU APINI) participates in international FP7 programs' project "Polygeneration of energy, fuels and fertilizers from biomass residues and sewage sludge" (ENERCOM). The main aim of this project is to develop innovative high efficient technology for polygeneration of electricity and heat energy, solid fuels and high quality compost/ fertilisers from different BD waste (sewage sludge and greenery waste mixed to biomass residues). KTU APINI – one of eight projects' partners. The main role of APINI in this project is to evaluate the possibilities to produce fuels - briquettes and/or pellets from different compositions of compost, sawdust, peat, and to carry out the EIA (Environmental Impact Assessment) of this fuel production and usage.

After implementation of this project, physical and chemical characteristics of grain processing BD waste will be analyzed The results of this analysis will allow finding and choosing the optimization possibilities of BD waste management in grain processing companies: either its granulation and direct usage as a fuel or energy production (for example, in the same grain processing companies), or mixing BD waste with the other one (for example, obtained in food industries in stockbreeding farms') for methane gas production or its usage as a high quality fertilizer, etc. Such BD waste reusing for energy or other products production purposes (*Waste-to-Energy and Onsite recycling prevention methods in Cleaner Production*) will enable our country to decrease the energy consumption from non- renewable energy sources.

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Reikšmingų aplinkos apsaugos aspektų vertinimas grūdų perdirbimo procesuose

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(gauta 2009 m. rugsėjo mėn.; atiduota spaudai 2009 m. rugsėjo mėn.)

Šiame straipsnyje pateikiami atlikto tyrimo grūdų perdirbimo pramonėje 2008 metų dalies rezultatai. Pagrindinis tyrimo tikslas – nustatyti grūdų perdirbimo procesų reikšmingus aplinkos apsaugos aspektus ir numatyti procesų optimizavimo galimybes, kaip sumažinti grūdų perdirbimo procesų neigiamą poveikį aplinkai. Tikslui pasiekti buvo nustatyti tokie uždaviniai:

– atlikti grūdų perdirbėjų asociacijai priklausančių grūdų perdirbimo įmonių apklausą (2008 m.);
– remiantis apklausos rezultatais nustatyti, pagrindinius technologinius grūdų perdirbimo procesus, įvertinti procesų įėjimo ir išėjimo srautus ir nustatyti grūdų perdirbimo procesų aplinkos apsaugos indikatorių ribas (2008 m.);
– atliekant eksperimentą nustatyti reikšmingus grūdų perdirbimo procesų aplinkos apsaugos aspektus (2008–2009 m.);
– numatyti grudų perdirbimo procesų optimizavimo galimybes, kaip padidinti aplinkosauginį veiksmingumą (2009–2010 m.).

Atliekant apklausą, buvo tikimasi sužinoti grūdų perdirbimo įmonių pagrindines aplinkos apsaugos problemas bei jų sprendimo būdus ir nustatyti reikšmingus aplinkos apsaugos aspektus respondentų atžvilgiu. Respondentai nurodė, kad pagrindinės perdirbimo procesų aplinkos apsaugos problemos susietos su biologiškai skaidžių (BS) atliekų tvarkymu, įskaitant grūdų perdirbimo atliekas, nuotekų valymo įrenginių arba nuotekų surinkimo rezervuarų dumblą ir t.t. Respondentai taip pat nurodė kietųjų dalelių (C) išmetimus į aplinkos orą visuose grūdų perdirbimo etapuose ir dideles energijos sąnaudas.

Nustatant pagrindinius aplinkos apsaugos aspektus iri jų poveikį aplinkai eksperimentui parinktoje įmonėje, buvo atliktas aplinkos apsaugos auditas, kurio metu sudaryti viso įrenginio bei atskirų procesų medžiagų ir energijos balansai, nustatyti visų technologių procesų įėjimo ir išėjimo srautai, įvertinti procesų santykiniai aplinkos apsaugos indikatoriai ir taip nustatyti reikšmingi aplinkos apsaugos aspektai. Visi duomenys susisteminti į specialiai šiam tikslui Excel programoje sudarytą duomenų bazę.

Tyrimo metu nustatyta, kad grūdų perdirbimo procesuose susidarė gerokai daugiau BS atliekų negu oficialiai pateikiama metinėse atliekų ataskaitose. Kiekybiškai daugiausia atliekų susidarė elevatoriaus ceche – per 55 proc., kur atliekamas grūdų valymas ir pirminis apdorojimas. Perdirbamos ir ceche pagamintos produkcijos atžvilgiu reikšmingas kiekis BS atliekų susidarė malimo ceche, pvz., eksperimentui parinktoje įmonėje – iki 35 kg vienai tonai perdirbamų grudų arba iki 36,36 kg vienai tonai ceche pagamintos produkcijos, vertinant, kad grūdų sėlenos – tai ne atlieka, bet subproduktas, nes įmonė už jo pardavimus gauna pajamas. Taip pat, naudojant sudarytos duomenų bazės duomenis, buvo įvertinta, kiek BS atliekų susidaro atskirų produktų gamybos metu.

Taip pat analizės rezultatai parodė kitą labai svarbią grūdų perdirbimo įmonių problemą – elektros ir šilumos energijos sąnaudas: analizuojamame objekte sunaudojama iki 0,09 MWh vienai tonai produkcijos pagaminti. Nemažai šilumos nuostolių susidaro šilumos energijos gamybos metu (iki 10 proc.), deginant gamtines dujas, taip pat ir technologiniuose procesuose, pvz., garai į aplinką kombinuotų pašarų ceche, šilumos nuostoliai džiovykloje.

Nustatant procesų optimizavimo tikslus, taikant pagrindinius Aplinkos sistemos teorijos principus, grūdų perdirbimo įmonėms pasiūlyta reikšmingų aplinkos apsaugos aspektų valdymo sistema, kuri galės padėti vertinti planuojamų ir įdiegtų aplinkosaugos projektų efektyvumą. Šiame etape labai svarbu tinkamai nustatyti kiekvieno valdomo aspekto indikatoriaus kitimo ribas – valdymo tikslus ir tinkamai įvertinti galimus trikdžius.