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Odour Prevention at Biodiesel Fuel Producing Enterprises

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Gaseous, unpleasant, pungent and even harmful odour frequently leads to complaints and appeals to the authorities. For this reason an environmental review was carried out in a certain biodiesel fuel production enterprise, odour pollution sources were identified, their quantities estimated and their impact on the environment assessed. Following the initial environmental review, significant environmental aspects of biodiesel fuel production processes were evaluated. It was found that in technological processes of heating and pressing oil, triglycerides disintegrated in aromas causing discomfort. In order to reduce this impact, the appropriate economic management method and odour removal equipment are to be chosen. When solving this problem it is suggested to install biofilters - activated carbon adsorbers with a stationary adsorber layer and probiotics. In order to choose the adsorber, a calculation method of adsorber technical parameters has been developed in accordance with literature data. The proposed preventive odour reduction means and feasibility of their technical and economical application have been analysed.
Keywords: *biodiesel fuel, cleaner production, environmental indicator, odour, adsorber.*

1. Introduction

One of the most promising biofuel types is biodiesel fuel (further BD) which is produced of rapeseeds, sunflowers, soybean oil and animal fats. Developing BD production and its use, new jobs are offered in agriculture and processing industry. Aplication of BD assists in both reducing gas emissions and limiting direct dependence on fossil fuel.

In Lithuania development of BD, however, faces difficulties, because there is neither integral biofuel production and consumption experience, nor a steady biofuel market. Furthermore, a problem in BD production springs up, namely, odour formation during technological processes.

BD production enterprises are located rather close to villages and towns, therefore disagreeable strong odours are often the cause of people complaints and their appeals to the government authorities and the press.

Since January 2010 the Hygiene Standard 121 came into effect regulating odour observation and control in the residential and manufacturing environment.

With a view of well-balanced biofuel industry development and its conformity with stricter and stronger environment protection requirements, reduction and prevention of odour and pollutant emission to the air become especially relevant.

A problem of unpleasant odour is not easy to solve, its noxiousness and impact on health medically, environmentally and economically are difficult to evaluate (Rosenkranz, Cunningham 2003)

Odour emission is usually classified into undesirable and unpleasant to a degree when it begins affecting the environment negatively. Frequently odours are directly harmless to the health because people sense odours when their chemical substances concentration is negligibly low. Usually poisonous concentrations of chemical substances are significantly higher than sensitiveness to odours.

One of the means of reducing the risk to people and the environment is cleaner production (further CP) embracing the continual integrated environment protection strategy applied to processes, products and services. Implementation of CP is directed against formation of pollutants or, if they are already formed - towards their smallest amounts. The CP strategy plans the following preventive actions: 1) good housekeeping; 2) input substitution; 3) better processes control; 4) equipment modification; 5) technology change; 6) product modification; 7) effective energy consumption; 9) waste treatment or its reuse in the enterprise (Staniškis et al. 2002).

To avoid the negative odour impact on health and the environment the pollutants emission from enterprises is to be minimised to the lowest level achieved by reasonable efforts and they should not cause any undesirable effect.

There are two basic odour monitoring principles: (1) odour reduction in pollution sources and (2) removal of gaseous odour emissions before they reach the atmosphere. The odour control process begins from the source characterisation and involves: (1) identification of the sources emitting odorous compounds; (2) measurements of odour streams, evaluation of pollutants and their sources, planning the priorities of odour removal, (3) identification of the type of odorous compounds trying to select the suitable odour reduction technology (Shukla 1991).

A number of scientists (Rappert, Muller 2005; Mahin 2001; Dincer, Muezzinoglu 2006; Sironi S. et al. 2007; Bordado, Gomes 2003; Nabais 2006; Blanes-Vidal 2009; Zuokaitė, Zigmontienė 2003; Zigmontienė, Žarnauskas and others 2011) are deep into research on odour formation causes and the ways of their removal in oil refineries, food processing, paper, cardboard and rubber production, fertilisers, plastic production, washing and cleaning means, manure and sewage storages, dumps, sewage treatment and waste treatment enterprises

The BD production technology is globally modern, therefore there are insufficient studies how to remove the odour formed during the production process.

Reduction of the amount of odorous substances presents a task to search for measures of solving this problem.

The aim of this study is to estimate odour sources and to suggest odour reduction actions in association with an increase in environmental efficiency of the BD production.

2. Methods

Environmental effectiveness of the methods of odour sources identification and preventive odour reduction is evaluated by applying the technique of processes control of CP (Kliopova, Staniskis 2004). A relative environmental indicator of air emissions (rapidly degradable VOC or particulate matter) from a technological process is calculated in mass dimension g/t of produced production (PP) or raw material (RM).

The amount of odorous substances evaporating into the environment is calculated on the basis of the calculation methods of harmful substances emitting from the surfaces with a formed film (Тищенко 1991). Technical parameters (cross-sectional area of adsorbent layer, adsorbent diameter, height of adsorption layer, coefficient of adsorbed substance mass, equivalent diameter of adsorbent particles, yield, etc.) of an adsorber with a stationary adsorbent layer are calculated according to the calculations and formula presented in literature (Leskauskas et al. 2007; Balandis 2000; Балабеков 1991; Ветошкин 2006; Ветошкин 2004; Ветошкин 2003).

3. Results and Discussion

3.1. Identification of odour sources in a certain BD enterprise

Identification of the odour emission sources is a first stage in the odour reduction process. To obtain a successful solution of this problem, the process evoking disagreeable odour is to be comprehensively understood and sufficient information on the sources of odour emissions and technological operations is to be gained. BD production consists of technological processes – rapeseed oil pressure and transesterification.

The rapeseed oil producing process is analogous to vegetable oil production. Rapeseeds are separated from large wet impurities by means of simple machines, air stream and sieves. Seeds to be pressed are initially dried up to 12% of moisture. To avoid seeds self-heating they are dried by active ventilation, and after this process the air heated to 1-5 °C is blown in. Dried seeds are usually cleaned and sorted from the rest of residual impurities by air streams, sieves and grain cleaners. During this process odourless solid particles get into the air.

Cleaned seeds are heated and moistened in a conditioner up to 110 ^{0} C. The heated mass is directed to the primary oil press which yields oil and oil cake. The pressed oil is filtered, while oil cake is heated in a conditioner. Heated rapeseeds oil cake is pressed by final presses. During the oil pressing no odours are formed, however, at the end of the shift when the presses are being cleaned odorous compounds pass into the air.

Pressed rapeseed oil is filtered and directed to refinement and transesterification. Successive technological processes take place in closed reactors under continuous conditions. From the storage raw oil is passed by a batching pump to refinement. In a heat exchanger it is heated by saturated steam (3 bars, 130 ^{0} C) up to the proper temperature. Further, it is passed to a blender, H_3PO_4 is poured in and oil is neutralised by the sodium alkaline solution NaOH. After blending it is passed to a separator where phospholipids are separated and then it is passed to a vacuum drier from which oil is transported to the oil storage.

From the storages rapeseed oil is passed by pumps to the blending tanks in which a certain amount of glycerine released from a first degree transesterification reactor is added. These substances are blended, and the blend is left to steady down. After 90 min two layers are formed: glycerine and ready rapeseed oil. Settled glycerin is flushed into the glycerine collection tank. Ready oil is transferred to the transesterification reactor together with catalyst KOH and methanol CH_3OH.

Transesterification proceeds in two stages. In the first the oil and the 1st catalyst dose are stirred in the first transesterification reactor, whereas glycerine sinks to the bottom and is pumped into the initial oil treatment reactor. Then the first degree rapeseed oil methyl esters (further ROME) and catalyst go to the second transesterification reactor where the second transesterification stage takes place. The under layer (glycerine) is poured into the glycerine tank, while ROME – to precipitation tanks.

There are three precipitation tanks: one is used for filling, the other for precipitating and the third for pumping out. ROME is pumped out from a certain precipitator height. The space under the ROME pump in the tank is reserved for glycerine precipitation separating it from methyl ester. The ROME goes to the long channel evaporator where CH_3OH is distilled in the vacuum. Formed methanol steam condenses in a refrigerator and flows into a vessel and is pumped to the CH_3OH storage tank. ROME without any methanol in it flows into the pumping vessel and goes into the reservoir cooled by water. Cooled ROME is directed to the separator for separating rough composite particles. Heavier fractions form glycerine phase and are collected into the pumping vessel and a glycerine tank. Refined ROME goes into the last precipitation tanks trying to deposit heavier fractions. Finally, ROME is pumped into its storage tank.

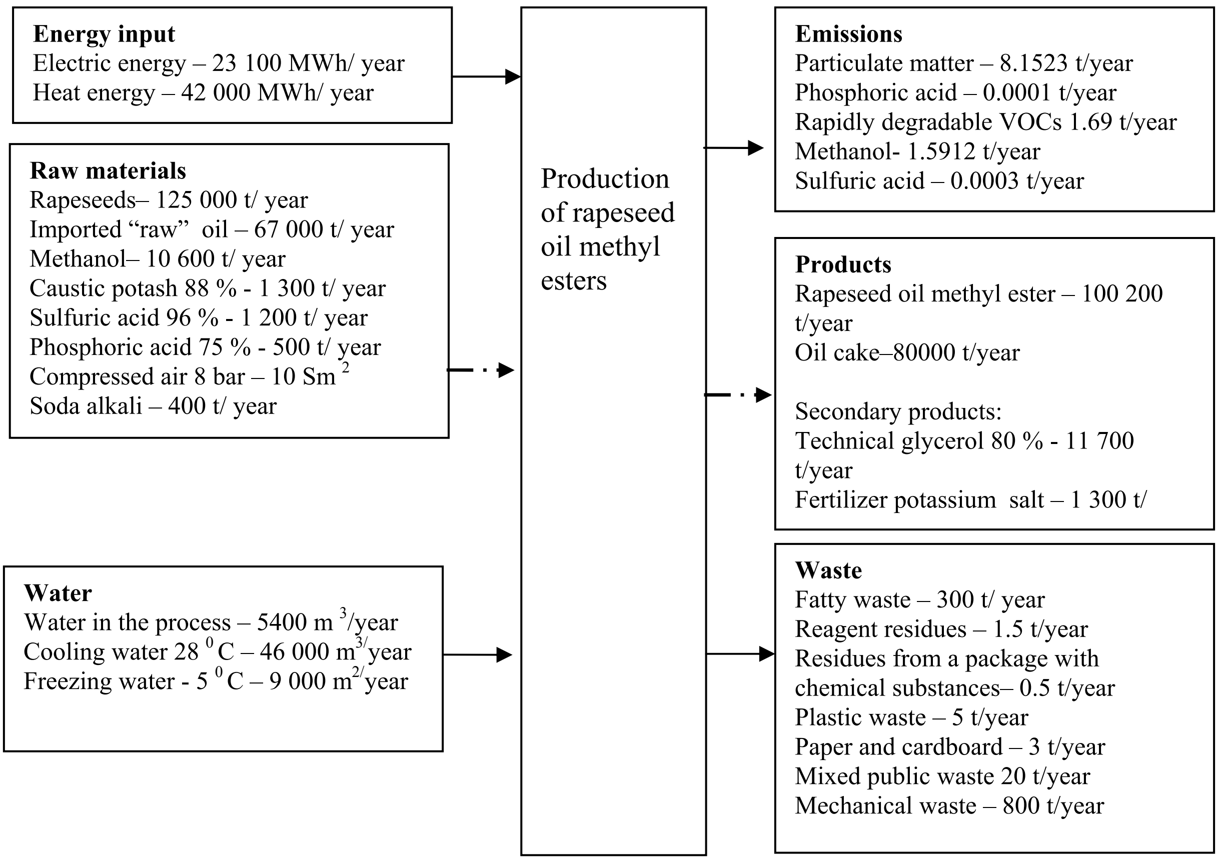

Fig.1. Energy and materials balance in BD production

Glycerine phase contains 61% of glycerine, 13-15% of methanol, fatty acids sodium salt and methyl esters. To increase the glycerine output its phase is pumped from the glycerine tank into the first glycerine processing reactor in which the phase is heated to the temperature of 60-65^{0}C. A certain amount of H_2SO_4 is added disintegrating alkali substances and soap. A glycerine layer is separated from a lighter layer of free fatty acids and esters by means of precipitation. Glycerine precipitates on the lower part of the first reactor and is pumped into the second glycerine reactor. Methanol contained in a glycerol layer is pumped out in the vacuum and when it condenses in a refrigerator and flows into the pumping tank, it is returned to the outdoor tank. The processed glycerine is pumped into its storage tank.

Newly formed lighter organic layer is also pumped into its storage tank.

Secondary products formed in BD production – rapeseed oil cake, glycerol, potassium sulphate fertilizers are sold as products.

In order to identify the odour sources, measurements of air pollution in rapeseed oil pressure and rapeseed cake storage departments were made. According to HN 121, the laboratory testing program of odour concentrations was concluded. Samples were taken and pollutant concentrations were tested. Measurement results are given in the IPPC permit.

In the BD production enterprise chosen for our experiments, CP has been initially analysed and the balance of energy and substances has been reached (Fig.1). Following the first analysis we could state that formation of odours in BD production was a significant environmental aspect in that branch of industry.

The data presented in Figure 1 indicate that in BD production various chemical compounds are emitted into the air. Its major part is particulate matter (PM) (8.1523 t/year), then are rapidly degradable volatile organic compounds (VOCs) (1.69 t/year). We have estimated that VOCs are the main provocative odour compounds.

Analysis of a technological process has shown that oil refining and transesterification processes take place when substances are transferred by pumps to the closed reactors, therefore in these processes no odour liberation sources are found. Then, the rape pressing department has been identified as a possible odour source. It is essential to study in detail the impact of oil production technological processes on the ambient air.

To optimise the processes with regard to the environment protection according to the results of air pollution measurements and applying the processes control method to CP (Kliopova, Staniškis 2004), in the enterprise chosen for experimentation each technological process of rapeseed oil production was attributed a relative environmental indicator (see Table 1). They make it possible to identify odour sources and to determine the cause of their origin.

Having analysed BD production technological processes it was found that the odour was emitted during oil pressing and rapeseed oil cake storing (see Table 1, Figure 2).

Table 1. Estimated environmental indicators (air pollution and odour formation) in a oil pressing department of the enterprise chosen for experimentation (research results)

	PROCESS	SIGNIFICANT ENVIRONMENTAL ASPECT- FORMATION OF ODOURS AND AIR POLLUTION	ENVIRONMENTAL INDICATOR	EXISTING APPLIED ENVIRONMENTAL METHOD
1	Rapeseed oil production (admission and storage of rapeseeds): Rapeseeds input (RM) - 127500 t/year.; cleaned and dried seeds (PP) – 125 000 t/year.			
	Rapeseeds cleaning	Particulate matter	2.2 g/t RM; 2.24 g/t PP	Cyclone, cleaning effectiveness 91.7 %
2	Rapeseed oil production (oil pressing, pressed oil refinement): Rapeseeds input (RM) – 125 000 t/year.; refined oil (PP) – 50 000 t/year			
	Rapeseeds conditioning and pressing	Particulate matter	34.56 g/t RM; 86.40 g/t PP	Cyclone, cleaning effectiveness 88 %
		Rapidly degradable VOCs	3.36 g/t RM; 8.4 g/t PP	General department ventilation
3	Rapeseed cake storing and loading Rapeseed cake input (RM) – 80 000 t/year; oil cake (PP) – 79 500 t/year			
	Oil cake cooling, storing, loading onto transport means	Particulate matter	6.75 g/t RM; 6.79 g/t PP	Pocket bag type filter
		Rapid degradable VOCs	2.55 g/t RM; 3.68 g/t PP	General department ventilation

Comment: RM- raw material of the technological process; PP – products produced in the analysed technological process

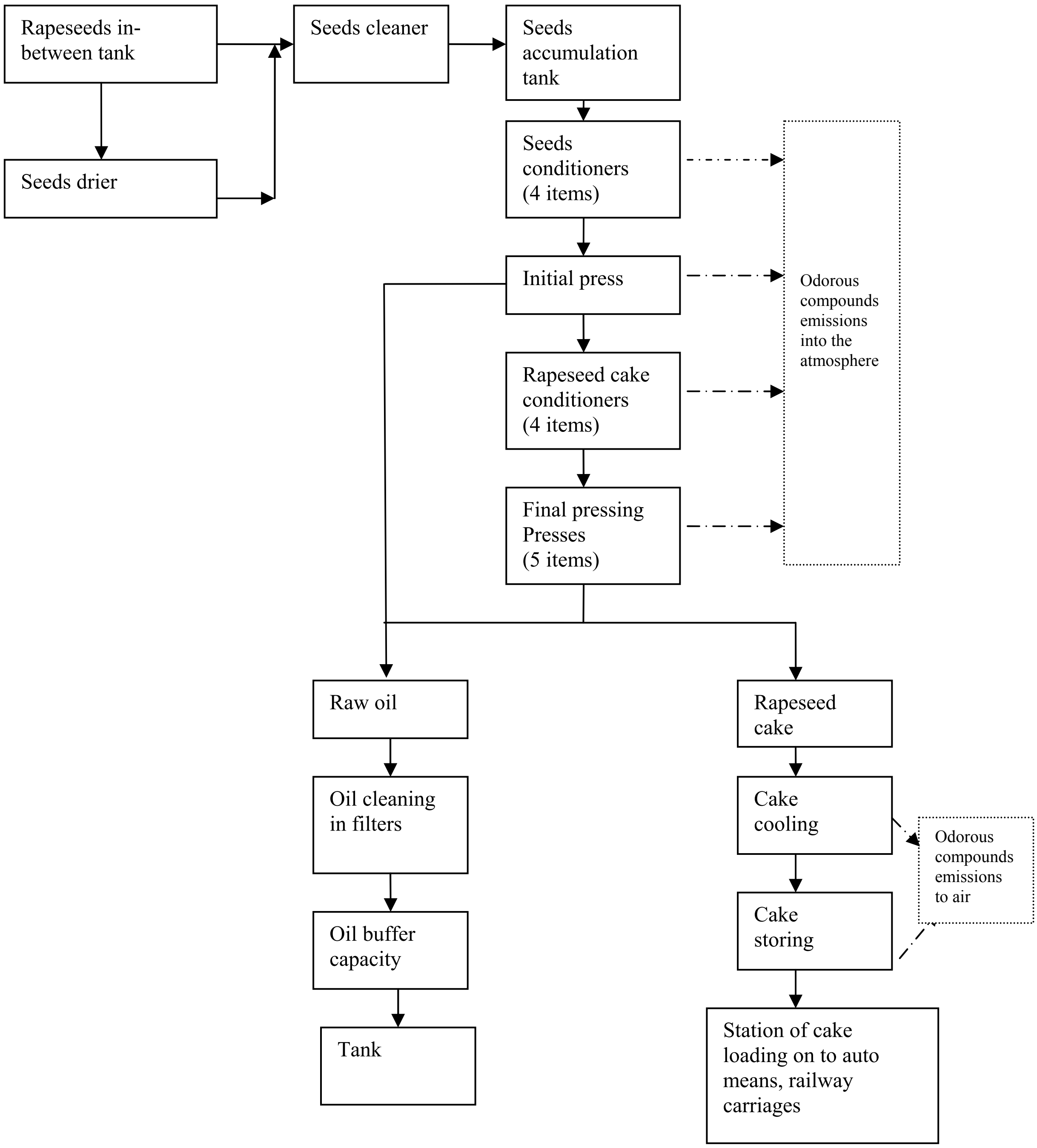

Fig. 2. Odorous substance sources in BD production

Calculations given in Table 1 have indicated that when conditioning and pressing rapeseeds, a relative environmental indicator of rapidly degradable VOCs reaches 3.36 g/t of raw materials, while during oil cake storing and loading – 2.25 g/t. Rapidly degradable VOC quantities are not large, nevertheless they cause unpleasant odour.

The quantity of odorous substances suddenly increases when several times a month the production is stopped, presses are opened, oil cakes are removed from press plates. During cleaning of the presses PM and rapidly degradable VOCs pollutants were measured.

Analysis of the applied environmental methods of solving the odour reduction problem at the enterprise (see Table 1) indicates that particulate matter (PM) emitted from the technological process is cleaned in cyclones and bag-type filters. Rapidly degradable VOCs are removed by ventilators. Thus, odorous substances enter the atmosphere and their irritating odour causes people complaints.

Having identified the odour sources we have determined that odour formation should be related to the chemical changes of oil present in its cake which are stipulated by high temperature and air oxygen.

3.2. Qualitative and quantitative evaluation of odorous substances

Physical and chemical properties of odorous substances are mostly affected by the type of odour source which depends on a raw material type and production process (Philips 1996).

Basic components of rapeseeds, BD raw material, are fat (37-43%), protein (18-26%) and cellular substance (7-16%). Rapeseed oil is ester of glycerol and unsaturated oleic (62%) linolenic (32%) fatty acids and a small amount of saturated palmitic (4%) and stearic (2%) acids.

Pressing and heating of oily rapeseeds unsaturated fatty acids form a radical usually deployed close to the double bond and initiate the oxidation of unsaturated fatty acids which compose oil (Franke 1980). This radical easily reacts to the air oxygen forming peroxide. According to the principle of a chain reaction mechanism peroxide immediately creates a new radical out of fat acid which in turn combines with the air oxygen and releases the new peroxide radical. Then takes place a destructive auto-oxidation cycle consisting of three stages: chain initiation, propagation and termination.

Chain initiation:

$$RH \rightarrow R\bullet \text{ (free radical)} + H\bullet \quad (1)$$

$$RH + O_2 \rightarrow R\bullet \text{ (free radical)} + HO_2\bullet \quad (2)$$

Chain propagation:

$$R\bullet + O_2 \rightarrow RO_2\text{. (peroxide radical)} \quad (3)$$

$$RO_2 + RH \rightarrow ROOH \text{ (hydroperoxide)} + R\bullet \text{ (free radical)} \quad (4)$$

Chain termination:

$$R\bullet + R\bullet \rightarrow RR \quad (5)$$

$$R\bullet + ROO\bullet \rightarrow ROOR \quad (6)$$

$$ROO\bullet + ROO\bullet \rightarrow ROOR + O_2 \quad (7)$$

During this process, 100 radicalas are created from the initial one. Under favourable conditions, following this chain mechanism, an exponentially accelerating fats oxidation may quite promptly occur. Therefore, the oxidation is usually related to the changes accompanied by disagreable odour.

Fat oxidation reactions also occur during its storage, e.g. odours escape from oil cake containing 6 – 8% oil. During the storage of fat its oxidation takes place according to the same common schemes as heat oxidations do..But, temperature conditions of these two reaction mechanisms affect the formation of different VOCs. For example, hydroperoxide concentration in the heat produced oxidation remains very low because hydroperoxides are highly thermally nonresistant, whereas at low temperatures they are more stable, their significant quantities may be formed before they decompose into volatile compounds. For this reason the differences among relative volatile products and other compounds are observed during the fat oxidation due to the temperature and oxidation occurring during its storage.

Since the oil pressing process is the same as that of vegetable oil, the odours forming in these processes are identical to those formed in the oil industry. We have found out that in our investigated enterprise the odour is the mixture of low concentrations of various organic and inorganic compounds. Typical odorous compounds formed in the rape processing period are: aldehydes, ketones, lactones, alcohols, acids, esters, ammonias, amines, pyrazines, sulfides, hydrogen sulfide and mercaptans. These compounds are not poisonous, they are easily split by microorganisms.

Other scientific researchers (Battistoni, Fava 1983; Rappert, Muller 2005; Васильева 2000) have estimated that the emissions from medium sized oil production enterprises are conditioned by volatile fatty acids of low molecular mass and aldehydes evoking the odour. During the oxidation of fatty acids in oil, volatile fatty acids of C_4-C_8 carbon atoms and aldehydes are formed possessing special odour.

After our calculations we have determined that from the conditioning and pressing system of rapeseeds and the oil cake storage there come 0.67 t/m of rapidly degradable VOCs into the atmosphere which when passing to the residential areas cause the sense of discomfort. Then an imperative rises to search for the ways of odour reduction

3.3. Application of CP preventive methods reducing odour emissions from the oil pressing technological process

Having identified the sources of odour, we have determined that its main source is raw material. Oil in rapeseeds subjected to the air oxygen and the temperature oxidises and during oxidation odorous rapidly degradable VOCs are formed. According to the CP strategy disagreeable odours may be avoided by changing raw materials. In this case it is unreasonable to do so, because rape is renewable raw material. When BD produced of rape is used in diesel engines, a closed CO_2 cycle is formed which is significant in the environment protection (Montrimaitė et al. 2010).

Taking the course of odours prevention it would be most acceptable to apply a proper good housekeeping. To prevent air pollution with odorous compounds, the following managing and organizational actions are suggested:

- To develop and implement strict employee responsibilities and their distribution in the environment management system;
- To air the premises of the oil pressing department none the less than 3 times an hour;

- To clean the presses at fixed periods;
- To load oil cakes onto auto transport or railway carloads in the closed manner;
- To study the emissions according to the consorted control schedule of stationary environmental air pollution sources and to analyse the obtained results;
- To carry out laboratory odour analyses and odour dispersion modelling;
- To implement the preventive odour reduction actions on the basis of both the odour survey and its dispersion modelling results.

Even negligible concentrations of rapidly degradable VOCs are found to cause odour, therefore the enterprise must introduce odour removal facilities. Undesirable odour poses a difficult problem and only coordination of various odour removal actions may help solving it.

3.4. Choice of odour removal equipment

There are many technologies which enable specialists to reduce odours emitted from industrial enterprises. Odour removal technologies apply various principles, such as physical, chemical and/or biological (Schlegelmilch et al. 2005; Baltrėnas et al. 2008; Denafas 2000; Air Quality Services 2011; Dragt ir Van Ham 1991; Philips 1996).

To remove odorous compounds from the emitted air stream most of odour removal technologies include filtration, absorption (by scrubber), adsorption, thermal oxidation/combustion, chemical oxidation and biological oxidation (biofiltration, bioscrubbing). Some of the mentioned technologies may be used in a single odour removal system. With a view to reach the ultimate odour removal effect, we have selected the technology under the following criteria: (1) volume of accumulated gas (or vapour) and its stream speed, (2) origin of odorous compounds to be removed and composition of their mixture, (3) level of the odour control to be achieved, (4) investment and operation price and (5) safety restrictions.

To be competitive in biofuel industry these technologies have to possess specific properties: (1) stable and secure operation in removing odorous compounds from the polluted air stream, (2) easy adjustment to the changes of high speed air stream and .odour intensity, (3) no generation or generation only of a small amount of environmentally harmful chemical by-products, (4) formation of only a small amount of solid and/or liquid waste during operation and (5) low cost of equipment, operation and maintenance.

Following the above given criteria the comparative analysis of the air purifying technologies (see Table 2) show that effective, inexpensive and technologically reliable equipment for absorbing odours are adsorbers and biofilters.

Table 2. Comparison of odour control methods

	OPERATING COST	MATERIAL COST	MAINTENANCE COST	POLLUTION RISK	REMOVES ALL ODOURS	REMOVAL EFFICIENCY
Water Stripping	High	Low	Low	Yes	No	Low
Incineration	High	High	High	Yes	Yes	High
Carbon Sorption	Low	High	High	No	Yes	High
Chemical Scrubbing	Low	High	High	Yes	Yes	High
Biofilters	Low	Low	Low	No	Yes	High

To remove odour we have chosen a biofilter/ adsorber with probiotics. The operation of this device is based on adsorptive and biological cleaning principles. The air comes into a biofilter/adsorber through the air supply pipe in its central part. The air is supplied from the bottom up through the layer of the active carbon adsorbent and biomedium. The biofilter contains air heaters with a temperature regulator maintaining a constant temperature in biomedium. This device removes particulate matter and rapidly degradable VOCs.

Odour and dust are removed when polluted air is in contact with the adsorbent and prabiotics on the filters. Purified air may be sent back to the department premises.

In order to achieve odour removal effectiveness main technical parameters of the biofilter/adsorber are to be calculated.

Having studied the technological process and defined the odour formed in this process, we have calculated the amount of evaporating odorous substances in the rapeseed heating and pressing process. Knowing the oil press efficiency and its data we have defined both the quantities of rapidly degradable VOCs evaporating from the press area and the odour concentrations formed in the premises air.

The investigated enterprise produces 50 000 t of rapeseed oil a year. Oil is pressed by six presses: one is used for initial pressing the other five – for final.

After calculation of the quantities and concentrations of rapidly degradable VOCs in the premises we can choose technological equipment for removing odours. The quantity of volatile fatty acids and aldehides depend on the area of the press plates. According to our calculations the concentration of rapidly degradable VOCs formed in the premises per hour when the presses are being cleaned reaches 0.038 kg/h.

In order to choose a biofilter/adsorber and an absorbent of a proper model, it is necessary to know the gas output of the mixture of purified rapidly degradable VOCs with the air, biofilter/adsorber diameter, cross-sectional area, adsorption layer height and adsorption period of time.

Parameters of the odour purifying equipment are calculated referring to the BD production size and the data given below:

- Gas mixture yield G_m=3780 kg/h; V_m=3150m^3/h;
- Rapidly degradable VOCs yield V_m=39.7 kg/h
- Temperature of vapour mixture: T=60^0 C;
- Pressure of gas mixture p=0.8 bar;
- Density of gas mixture ρ_m=1.2 kg/m^3;
- Dynamic viscosity of gas mixture: μ_m=1.95·10^{-5} kg/(m·s);
- Density of adsorbent (active carbon) ρ_a=500kg/m^3;
- Diameter of adsorbent granules: 2-3 mm;
- Initial adsorbent mass X_{pr}=0 kg/m^3;
- Final adsorbable mass: Y_g=0.0001 kg/m^3;
- Gas rate in adsorber: ω=0,25 m/s;
- Pressure of saturated vapour of comparable compound bensenium at 20^{0}C: P_{pr1}=9998 Pa;
- Pressure of saturated vapour of rapidly degradable fat acids at 20^{0}C: P_{pr2}=2160 Pa;
- Coefficient of adsorption attraction β =2.53;
- Diffusion coefficient of adsorbed substance: D_y=2.83·10^{-5} m^2/s.

Following the calculations the operating adsorption layer height is 0.12 m. According to the requisite adsorption conditions the layer height is too small to reach a 99.9% air purification degree. For this reason, it should be increased to 1 m increasing the adsorption span correspondingly.

Active carbon composed of 2-3 mm particles is characterized for high adsorption rate, distinctive surface, selectivity and long life. When gas emission leftovers are cleaned, carbon soon becomes wet and must be dried. Dried carbon is to be either recuperated to the initial adsorption process or burnt as fossil fuel.

Following the forming 3150 m^3/h gas mixture yield, technical parameters of a biofilter/adsorber are defined as: operating pressure – 10 bars; yield– 3606 m^3/h; height– 2.8 m, width– 1.2 m, depth – 1.1 m.

To achieve a continuous adsorption process we recommend the parallel installation of connected biofilters/adsorbers. Then the first biofilter/adsorber adsorbs the odour, in the others - pollutants are separated and regeneration of an adsorbent takes place. If a desorption process is longer than adsorption pressing, it is advantageous to install a bigger biofilter/adsorbent system .

3.5. Environment protection and economy evaluation of suggested odour reduction actions

To evaluate effectiveness of the odour reduction methods the odour is to be measured and the dispersion modelled.

When in the accredited laboratory the odour concentration is measured and the qualitative character of disturbances caused by odour is determined using Standard EN 13725:2003 and the dynamic olfactometry method, the hedonic tone characterizing relative odour pleasure or unpleasantness is evaluated. In the oil pressing department after installation of the biofilter/adsorber the odour is evaluated by 7700 hedonic tones, in the oil cake storage – by 4600 hedonic tones.

By applying the methods of processes control in CP (Kliopova, Staniškis 2004), the environmental indicators are shown in Table 3 before and after installation of the biofilte/adsorber and introduction of management and organizational actions.

Table 3. Evaluation of environmental benefit of odour reduction actions

POLLUTANT	**ENVIRONMENTAL INDICATOR PRIOR INNOVATION**		**ENVIRONMENTAL INDICATOR AFTER INTRODUCTION OF INNOVATION**		**DECREASE IN AMOUNT OF POLLUTANTS**	
	Absolute value, t/year	**Relative value g/t**	**Absolute value, t/year**	**Relative value, g/t**	**Absolute value, t/year**	**Relative value, g/t**
Particulate matter	4.32	34.56 RM; 86.40 PP	1,9505	15,6 RM; 39,01 PP	2,3703	18,96 RM 47,39 PP
Rapidly degradable VOC	0.42	3.36 RM; 8.4 PP	0,1058	0,85 RM; 2,12 PP	0,3187	2,51 RM 6,28 PP

Comment: RM- raw material of the analysed technological process; PP – produced product in the analysed technological process

Calculation results (see Table 3) indicate that after application of odour reduction preventive actions the emissions of PM and rapidly degradable VOCs decrease. The relative environmental indicator of the latter decreases four times, that of solid particles – twice. Table 3 shows decrease in rapidly degradable VOCs for a unit of raw material and production, but it does not reflect the odorous compounds variations in residential areas. The dispersion of odours is evaluated by a modelling method.

Following results of the odour studies the modelling calculations of odour concentration dispersion by the ADMS 4.2 program have been performed within the 2 km range around the object of economic activity (see Table 3).

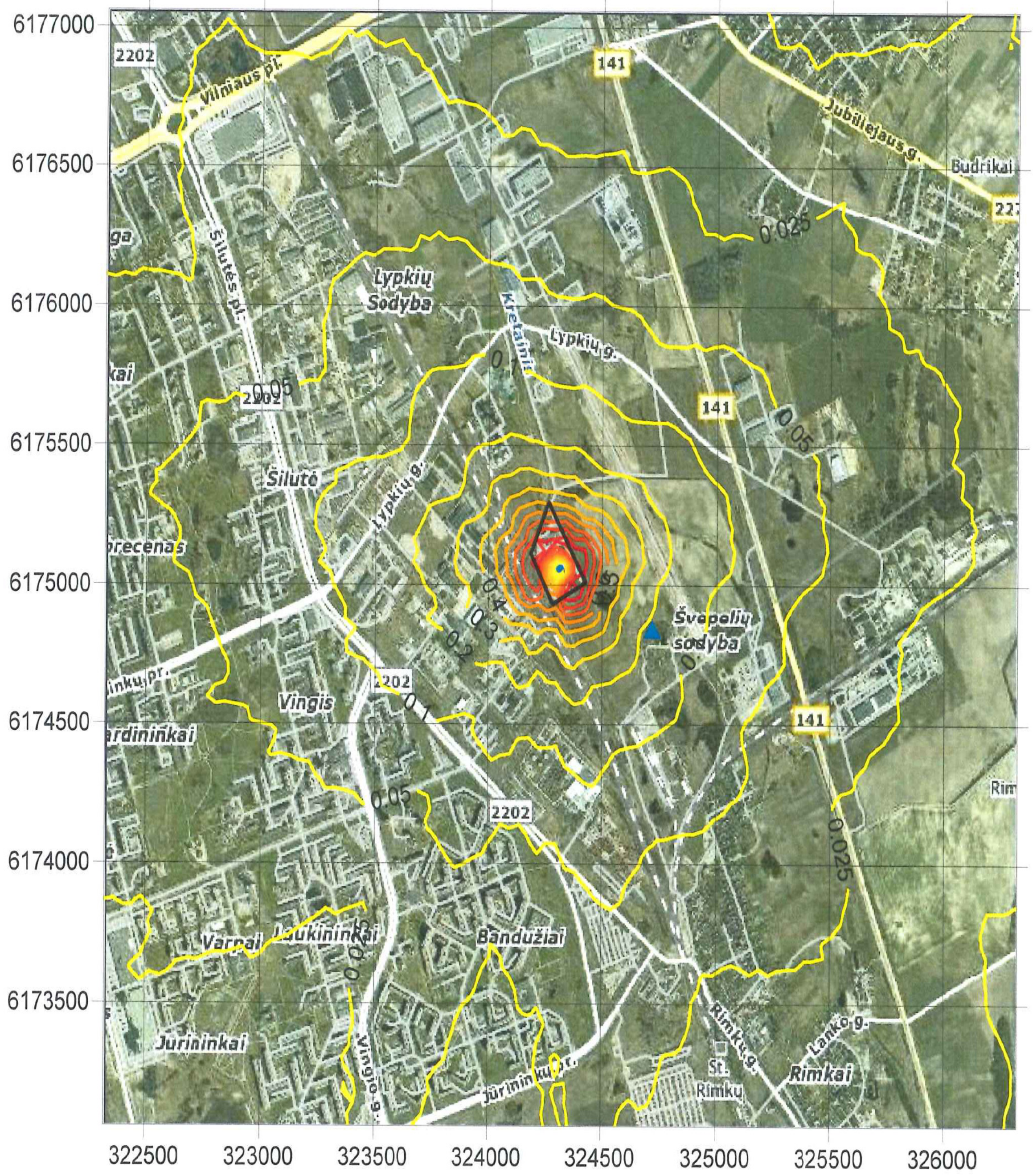

Fig. 3 Predicted of long term ground level odour concentration (OU $_E$/m^3 hourly averages)

Modelling the results presented in Fig. 3 show that an hourly average of maximum long term ground level odour concentration in the territory is 0.97 OU/m^3 (0.120 limiting value). This concentration is reached at about 100 m distance in south/eastern direction from the air pollution source of the enterprise. It is the highest concentration which is formed due to unfavourable meteorological conditions. In the nearest residential homestead (Svepeliai) hourly averages of the maximum long term ground level odour concentration of 0.21 OU $_E$ /m^3 (0.026 limiting value) do not exceed the planned odour concentration limiting value (8 OU $_E$ /m^3).

Results of odour dispersion modelling show the environmental efficiency of taken preventive odour reduction actions.

Investment for introduction of the odour control system will reach 300 thousand Lt and will repay in 2.5 years.

4. Conclusions

1. Formation of odour in the oil pressing technological process in production of biodiesel fuel is determined to be a significant environmental aspect in this branch of industry. When conditioning and pressing rapeseeds, a relative environmental indicator of rapidly degradable VOCs reaches 3.36 g/t of raw material, and 2.55 g/t during storing and loading of oil cake. Formation of odour is related to the chemical changes of the oil contained in rapeseeds and the oil cake conditioned by high temperatures and air oxygen.
2. To reduce the odour it is suggested to employ preventive proper good housekeeping, to introduce managerial and organizational actions and odour removal equipment. Following the comparative analysis of air-cleaning technologies, technical parameters of an odour removal biofilter/ adsorber are calculated. Its height is to reach 2.8 m, width – 1.2 m, depth – 1.1 m, height of an operating adsorption layer – 0.12 m.
3. Combining various odour removal methods after installation of a biofilter/adsorber in the oil pressing department the odour has decreased by 7700 hedonic tones, in the oil cake storage – by 4600 hedonic tones. With the introduction of the biofilter/ adsorber the particulate matter and rapidly degradable VOCs emissions have also decreased four times and twice, respectively.
4. Results of odour dispersion modelling indicate the environment protection efficiency of odour reduction actions. In the environmental territory the predicted long term ground level odour concentration (OU_E/m^3 hourly averages) is 0.120 of the limiting value and it is reached at a distance of about 100 m from the pollution source in the enterprise. Introduction of preventive actions of odour reduction in BD production technological process opens the door to the further development of biofuel industry.

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