Czech University of Life Sciences in Prague

Faculty of Engineering

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The application of olfactometric method for the estimation of smell emissions in breweries

Diploma Thesis

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DIPLOMA THESIS ASSIGNMENT

Bortlová Klára

Thesis title
The application of olfactometric method for the estimation of odour concentrations in breweries

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Objectives of thesis
The goal of this thesis is the evaulation of the odour concentration during mashing in the selected breweries using olfactometric method.

Methodology
- The research of available literature
- The sampling of odour concentrations during different phases of mashing and hops boiling in selected breweries
- The evaluations of odour concentrations using an olfactometry
- The evaulation of results and discussion

Outline of the structure
- Introduction
- Literature research
- Sampling odours from different distances of brewhouse during wort production
- Evaluation of experimental data
- Results and discussion
- Conclusion

The proposed extent of the thesis
50

Keywords
brewery, wort, beer, production, odour emissions, olfactometry

Recommended information sources

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Declaration

I declare that I have worked on this diploma thesis independently and that I used only the sources listed in bibliography.

Prague, 9.4.2012: ....

Signature

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Summary: This study describes odour measurement in three selected breweries. The aim of this experiment was to determined odour concentration for brewery smell emissions. Lautering sweet wort and wort boiling with hops were selected for odour emissions sampling. Also there is comparison of different size of breweries and ratio of sweet wort and wort odour samples in each breweries. The conditions for odour sampling had to be changed according Czech Technical norm, which could not be conformed all the time. The results show as that the odour substances are not dependent on volume, but on another conditions. This study showed that the olfactometric method can be useful in different evaluations, not only for sewage treatments or agricultural buildings evaluations. The experimental obtained results had not confirmed the initial theory that the intensity of smell emissions depend on the size of the emissions source. Expected hypothesis were disproved.

Key words: Brewery, wort, beer production, odour emission, olfactometry

Aplikace olfaktometrické metody pro stanovení koncentrací pachových látek z pivovarů

Abstrakt: Tato práce popisuje měření pachových látek ve třech vybraných pivovarech. Cílem tohoto pokusu bylo učit koncentraci pachových látek v pivovarech. Pro odběr vzorků byla vybrána fáze scezování a chmelovaru. Tato práce také porovnává pachové látky z různě velkých pivovarů a poměr pachových látek sladiny a mladiny v těchto pivovarech. Odběrové podmínky podle normy ČSN EN 13 725 museli být pozměněny a tato norma nemohla být vždy dodržena. Výsledné hodnoty ukazují, že hodnota pachových látek nezávisí na objemu, ale i dalších podmínkách. Tato studie také ukazuje, že tato metoda nemusí být použitá jen u čističek odpadních vod nebo zemědělských budovách. Výsledky získané experimentálním měřením nepotvrzují původní teorii o růstu pachových látek v závislosti na velikosti zdroje. Očekávaná hypotéza tak byla vyvrácena.

Klíčová slova: Pivovar, mladina, produkce piva, pachové emise, olfaktometrie

CONTENT

1. INTRODUCTION

The goal of this thesis is the evaluation of the odour concentration during brewing in the selected breweries using olfactometric method. The selection of the theme sourced from environmental needs of modern brewery.

Nowadays the olfactometric method is used for determining odours from big sources, which smells unpleasant. The brewery odour smells pleasant, but pleasantness can be annoyed too. Using olfactometric method is possible to detect range of brewery odours. The brewery built in city centre can caused healthy problems of peoples living there, especially after mixing with others odours or air pollution.

The measurement for the thesis is classified as experimental. Three types of brewery are selected. Expected values should be increasing with higher brewery brew house volume and should be dependent on weather condition and brew house technology.

2. LITERATURE RESEARCH

2.1. ODOUR

According to the recent researches it was found that the intensity of odours and aromas affect the psychological state of man. There are any other sensory functions of humans, which is so strongly associated with information stored in the subconscious mind as the smell. In high concentrations may cause us health problems (Odour, 2010a).

The odour is the sensation came from stimulation of the olfactory organs. Whereas the odorant is a substance, that can cause olfactory response (Power, 2011).

2.1.1. Smell Olfaction anatomy

The smell is the oldest evolution sense presented in various forms by all animal groups. It obtains the chemical information from the environment and distinctive affect the emotions and behaviour (Odour, 2010a; Lawless and Hildegarde, 2010).

The olfactory system consists of 2 different organs in the nose. The first one is olfactory epithelium. It is yellow pigmented area located at the top of the nasal cavity (Assembly of Life Sciences, 1979; Pearce et. al., 2006). This area contains millions of bipolar receptor cells. The cells are connecting directly to the olfactory bulbs of the brain. The other organ of smell is the common chemical sense. It is the free-endings of the trigeminal nerve distributed throughout the nasal cavity. The trigeminal receptors are stimulated by odorants (Assembly of Life Sciences, 1979).

The smell detection begins with breath. The odour molecules are detected through a layer of mucus in the mucous membrane from which the sensory nerve fibres lead. There chemicals have to penetrate through the receptors membrane by means of protein transmitters. Each transmitter is able to bind only specialised molecules. The molecules in receptors cause a signal that is conducted by olfactory nerve to the olfactory centres of the brain. There is the sensation evaluated. The evaluation depends on previous experiences. The Last important phase is exhalation, which ensures receptors cleaning. (Odour, 2010a)

The people's sensitivity for odour intensity is dependent on used substance or substances. Nevertheless the human has ability to detect an imperceptible amount of fragrant (or stink) substances, which is not possible to recognize by the softest analysis. According Stuetz and Frechen (2001) the sensitivity of the physiological reception of an odour differs from person to person. The perceived intensity of an odour is not linearly related to its concentration. The absolute threshold can be lowest than 1 part of odorous substance on 50 billions parts of air (Odour, 2010b).

Although the people have not good developed olfactory system as animals, it plays an important role in their life. The untrained people are able to recognize up to 4 000 of odours (Odour, 2010a, Odour, 2010b), but the trained one up to 10 000 (Odour, 2010a, Odour, 2010b; Pearce et. al., 2006). By all accounts is the healthy human able to recognize up to 40 000 odours. The sensitivity of odour vary in men and women and among of individuals (Odour, 2010a, Odour, 2010b). The professionals which work in perfume testing and whiskey mixing have the ability to distinguish 100 000 various smells (Odour, 2010b). Odour sensitivity declines with age, a bad state of health (for example people who smoke) and can growth by training or by pregnant women (Stuetz and Frechen, 2001).

2.1.2. Basic definition

The population nuisance of an odour is the most usually complaint of population for environmental pollution for the whole world. The well known definition of health is: ,,The health is no only physically, but even as psychically well-being and spiritual health “ (Odour, 2010b).

Definition of smell is: ,,The smell is organoleptic (sensory) property that is perceived olfactory authority after a certain amount of inhaled substances.” An odour substance is a substance that stimulates the human olfactory systems so that it perceived an odour (Odour, 2010a). In contrast exists another possibly definition: „The properties of the taste substances breathed-in into the nasal or oral cavity of the expert causing him another kind of perception than tactual or visual perception of temperature.” from (Kraus, 2008).

According to penetration into nasal cavity and pleasantness can be divided sensation into two groups (Kraus, 2008):

1) **Pleasant smell** - If this sensation breathed-in into the nasal cavity, it is label as flavours or if it is coming from oral cavity it is aromas.
2) **Unpleasant smell**- also cold odour.

The term odour is under language barrier. In different country it has another meaning. For this diploma thesis is word ,,odour" used as neutral and means smell.

2.1.3. The emergence of odour

All of components have ability to release the single molecules or atoms, which characterise the chemical composition, in defined conditions. This free particles form the essence of various smell, which are in organic and inorganic nature Odour, 2010a).

The individual concentrations consist in measured gas not determine the type or intensity of odour. The substances and mixtures are interacted and combined and from that way they make a changeable character of odour for different concentration of substances in mixture and also for changeable composition of mixture due to wind. Furthermore there wasn't possible to create the database of individual odour mixtures and that's why is not possible to defined the odour threshold on the basis of concentration (Odour, 2010a).

A lot of people accept a strong odour for a short period of time justified that they don't smell it often. But each individual has a specific threshold for the frequency and duration of the odour, about which his tolerance is exceeded. From the human point of view, this exposure time can predict the negative effects of the health (Power, 2011).

Stuetz and Frechen (2001) write about two types of behaviour odour intensity:

- Odours where the perceived intensity increase rapidly for a relative small concentration change, but the dynamic range is small.
- Odours where the perceived intensity rise slowly with increasing concentration, but the dynamic range is large.

2.1.4. The source of odour

The agriculture companies, big industrial factories, sewage treatment, rendering plants, food industry are the primary source of pollutant odour. In this case it doesn't matter on the size of factory (Odour, 2010a).

2.2. THE DESCRIPTION OF BREWING BEER

2.2.1. Malting

The main raw material for brewing beer is barley. It has high starch content and good husk adhering. But for brewing beer the barley malt is used. The process which changes barley into barley malt is called malting and it is done in malt house (Brigs and Hough, 1981; Chládek, 2007).

Malting starts by sprouting and then is the barley spreads into big area, where the germination of grain starts. After germinating all grain has to be dried and then the sprouts are separated (Brigs and Hough, 1981).

2.2.2. Grinding

The malt is gridded before each brew. There are a lot of types of drilling machine, for example four or six roller mill. Grinding grain (grist) is able to absorb the water and release starch (Chládek, 2007; Kunze, 2010; Kosař and Procházka, 2002).

2.2.3. Mashing

The first step of mashing is grist mixing with the water in mash tun. This mixture starts heating –mashing in. there are two possibilities of mashing – decoction and infusion process. The starch grains swell up and at the temperature of 52˚C where is starch wax formed. At the temperature of 65˚C the starch wax is changed into fluid and at 72 - 75˚C change into sugar. Now the fluid is called the sweet wort (Brigs and Hough, 1981; Chládek, 2007; Kunze 2010).

2.2.4. Lautering

Lautering is separation of sweet wort from spent grain. It is done in lauter tank. The spent grain is sedimentated at the bottom of the lauter tank and form a lautering medium. Through this flows the sweet wort to the wort kettle. There is a lot of sugar still in the malt; from that reason malt is trickled by hot sparging water (Brigs and Hough, 1981; Chládek, 2007; Kunze 2010).

2.2.5. Hop boiling

The sweet wort in the wort kettle is brought to boil and after achieving boiling point the hops is added. The hops are added according to the brewing method. During brewing the vapour is evaporated with a lot of unwanted compounds (Brigs and Hough, 1981; Chládek, 2007; Kunze 2010).

2.2.6. Wort cooling and solid separation

The boiled wort has to be filtered and then cooled from 95˚C to 6˚C. The oxygen has to be added. The whirpool is used for separation of the rest of solid compounds (Chládek, 2007).

2.2.7. Fermentation

After oxygenation the yeasts have to be added. The yeasts are also aerated before. The main fermentation is in diversion of sugar into alcohol and carbon dioxide and has 4 stadiums. The wort at the end of fermentation is called the young beer (Chládek, 2007).

2.2.8. Lagering

After fermentation, the young beer is overdraft into lager tanks, where it rips by temperature of 0 - 3˚C (Chládek, 2007).

2.3. BREWERY SMELL EMISSIONS

In the vicinity of any brewhouse during brewing is often possible to detect smell. This can be indicated as odour pollution (Kunze, 2010). This odour is formed by the vapour generated by wort boiling of the wort. This vapour contains volatile compounds.

Brewery odours are the emissions that are leaking from brewery during brewing primary by chimney. The leakage of gaseous emission is direct dependent on current heating element and technology equipment of the Brewery (Basařová and Lejsek, 2010). But the wort boiling has the biggest evaporation into air. The other possibilities of detecting smells from brewery are following: wastewater treatment, storage and handling of co-by products, oil storage, ventilation and stack emission from the boiler (CBMC, 2002; Environmental Protection Agency, 2008).

Gaseous emissions of a brewery can be divided into two groups:

- **Toxic emissions** - include Sulphur Oxides, Carbon monoxide and hydrocarbons. Higher productions of these gases have breweries that use solid fuel (Basařová and Lejsek, 2010). Finally the toxic emissions can be called as combustion emissions (Keilbach, 2009).
- **Non-toxic emissions** - between these types belong vapour, fermented carbon dioxide, aromatic substances (Basařová and Lejsek, 2010) and also minor source of volatile organic components (El-Rayes, 1997). Although these substances are non-toxic get it on greenhouse effect. Therefore, their number have to be limited (Basařová and Lejsek, 2010). These emissions are specific for brewing and have an origin in fermentation and self brewing. The condensate (or vapour before) of evaporation of hops boiling consist about 99% of water. The rest of percentage contains organic substances from hops and malt and about 161 constituents which belong to the classes of alcohols, aldehydes, alkanes, esters, furanes, ketones and terpenes. The concentration of these substances is about 5 - 338µg/l (Keilbach, 2009).

2.3.1. Possibilities of reducing smell emissions

Emissions from combustion of fossil fuels are regulated by the national and international law and rules as Kyoto protocol and others, but for smell emissions are not any limitations there. Reports from the odour experts about odour emission of a brewery can reduce the risk of problems (Krottenthaler et al., 2009). The techniques for odour emission increasing are specified in Best Available Techniques (BAT), which are written in Reference document on Best Available Techniques (BREF). The directive applies to breweries above 1 million hectolitres of beer production per year and takes into consideration the location of the breweries, available technology and socioeconomic effect. It looks for the way between environment and people's needs (CBMB, 2007).

Because this thesis is focus on odours emission, it will be mention only reducing non-toxic emissions.

In addition the condensed vapour contains high amount of energy, which leaks into the air. When 1 kg of steam condensed into 1 kg water (both at temperature 100˚C) it releases 2260 KJ. This energy can be definitely lost or saved (Kunze, 2010; Nollet and

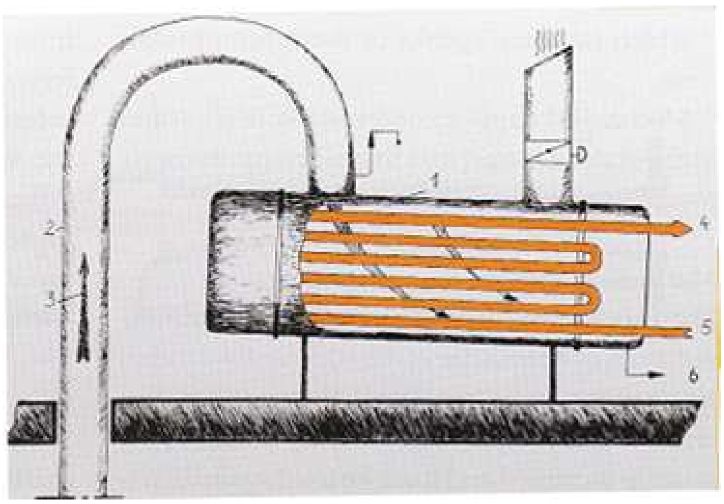
Sinha, 2007). During atmospheric boiling wort with a hop is evaporated around 8-12% of the water (Nollet and Sinha, 2007).

For reduction of smell emissions from brewing can be used the kettle vapour condenser or the vapour compression, which consist of the mechanical vapour compression and the thermal compression (Krottenthaler et al., 2009; Kunze, 2010; Basařová, 2010; Chládek, 2007; Nollet and Sinha, 2007). The main idea of using these equipments is to save energy. The other quite important thing is to eliminate odour emission into the air.

•The kettle vapour condenser

The vapour during hops boiling escapes out by chimney. By installation the kettle vapour condenser (picture 1) into chimney is possible to achieve condensation of this vapour. The vapour goes through the condenser (100°C), where the cold water (30°C) is pumped and by heat exchanger is heated to about 80°C and by this the vapour condensates. It is possible to use one or two phase cooling system, but nowadays is used only the first (Kunze, 2010). The energy from the condenser can be store in the energy saver (Kunze, 2010; Nollet and Sinha, 2007).

Picture 1 - The Kettle vapour condenser



Source: Kunze, 2010

1 hl of evaporated water increases the temperature of 0,8 hl from 30°C to 80°C (Kunze, 2010). Using the condenser for wort preheating could be saved about 20-30% energy. For wort boiling with hops the condenser installation reaches the saving of the thermal energy 55 – 60% (Basařová, 2010).

During wort production is evaporated 6% of the steam. This released steam is condensed in the vacuum condenser. Heat released by condensation is used for heating water for next brewing or it is used for direct heating of the pan (Basařová, 2010).

•Vapour compression of vapour

Because the vapour from hops boiling has temperature of 100°C, it is not possible to use it for direct heating, but after compression rises the temperature of the vapour to 102-108°C and pressure 0,05 MPa. At this vapour is then used for heating the wort kettle. The Necessary condition is boiling without air (Kunze, 2010).

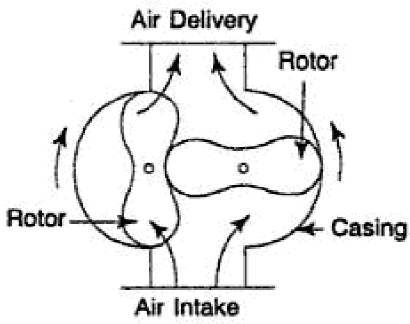
- ***Mechanical compression of vapour***

The compression of vapour from hops boiling is done by a turbo, a screw or Roots blower, which is able to compress the vapour onto demanded pressure (Kunze, 2010; Chládek, 2007). The result of this compression is the vapour prepared for heating purposes (especially for direct heating of the same wort kettle from which is the vapour origin) (Kunze, 2010). Nevertheless, the heating up of the wort begins with the fresh steam into the wort kettle, where the wort circulates by the pump through the external boiler to heats up and then goes back into the wort kettle (Kunze, 2010; Nollet and Sinha, 2007). The compressor is switched on, when the temperature reach 102-106°C at the outlet. The producing vapour is compressed to 0, 009 – 0,04 MPa of overpressure (Kunze, 2010; Basařová, 2010; Chládek, 2007; Nollet and Sinha, 2007).

The Roots blower is the most used, which works in similar way as a gear oil pump. There are two or three lobed rotors which rotate in air tight container. Each rotor has two lobes. The two lobed roots blower compressor (picture 2) While that the rotors rotate in casing (Rajadurai, 2003).

The picture of brew house with mechanical vapour compression is in appendix 1.

Picture 2 - The Roots blower compressor



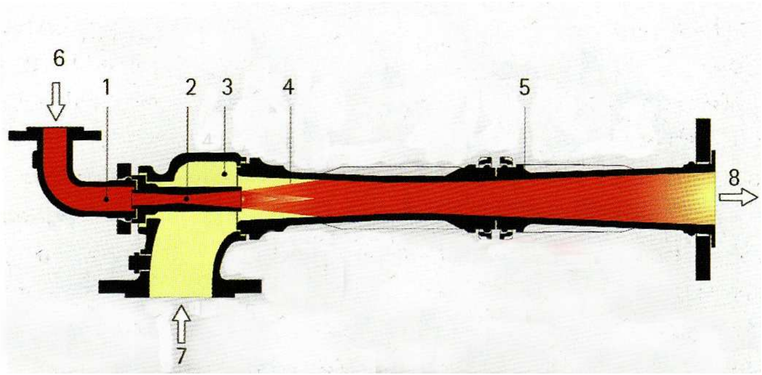
Source: Rajadurai, 2003

For this kind of compression it is not necessary to install the vapour condenser and the sweet wort should not be preheated. The disadvantages are in the complicated plant engineering, high noise level, and high maintenance price and peak electricity demands (Kunze, 2010; Nollet and Sinha, 2007). This kind of compression makes sense only if the brewery makes at least 5 brews daily (Kunze, 2010).

- ***Thermal compression***

This principle is based on the same principle as mechanical compression, but instead the Roots blower is there used the steam jet compressor (Kunze, 2010; Chládek, 2007) (picture 3) and its using in brewhouse is possible to see in appendix 2.

Picture 3 - The Steam Jet Compressor



Source: Kunze, 2010

As in the previous case, the wort is heated at first by the life steam from boiler. The wort is drawn by circulating pump through the external boiler, where is heated up and returned back into the wort kettle. The steam jet pump is started at 106°C of the wort temperature. The vapour is sucked in by the steam jet pump and compressed to overpressure 0,8-1,8 MPa and highest temperature. The compressed vapour is then lead to the external boiler, where heats up the circulating wort. The vapour condensates (106°C and overpressure 0,01- 0,04 MPa) again in the external boiler from which is picked up in the condensate vessel (Kunze, 2010; Nollet and Sinha, 2007). From this vessel is the vapour leads by a condensate pump back into steam jet pump (Kunze, 2010) or the rest of this vapour (30- 38 %) condensates in the condensate cooler and produces hot water (Kunze, 2010; Nollet and Sinha, 2007).

The advantages of thermocompression are following (Kunze, 2010; Nollet and Sinha, 2007):

- trouble free operation with low maintenance cost
- no peaks in the consumption of electric energy
- low noise and vibration-free
- The disadvantages are in:
- high area of surface for temperature changes,
- high production of hot water
- necessary high pressure (up to 1,8 MPa).

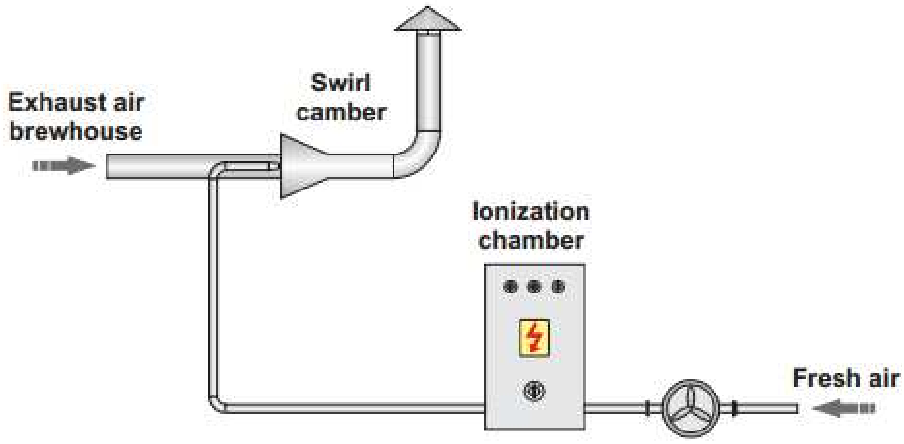
The thermal compression is cheapest than the mechanical compression for both small and big brewery on condition that the hot water can be used for some purposes as washing (Kunze, 2010) or preheating the sweet wort (Nollet and Sinha, 2007).

The other ideas were invented, for example own brewery sewage. In 2004, the zero emission process was realised. The vapours and exhausted air were led into a common vapour pipe. Through this collecting pipe, the vapours together with combustion air flow to a small vessel that is fired by methane from the brewery's own sewage plant. In case of oxygen-rich combustion, the aroma components are completely oxidized to CO and water and thus made odourless. However, this system is expensive. But the new one was invented four years later; it is called the cold combustion (Huppmann, 2008).

• Cold combustion

Cold combustion (picture 4) works similar as nature during thunderstorm, where the fresh air is perceived. The vapour which leaks to the atmosphere from brewhouse is ionized in a swirl chamber before the end of the chimney. To the ionisation chamber the fresh air is supplied and then it goes to the swirl camber, where is mixed with brewery vapour. The mixed gas goes out through a vapour stack. This system reduces 70 % of original intensity (Huppmann, 2008).

Picture 4 - Schematic of an air ionisation system



Source: Huppmann, 2008

Other emission that results from beer production is carbon dioxide.

• Collection of carbon dioxide

During fermentation is produces carbon dioxide as waste gas (Basařová and Basař, 2010). Beer Fermentation in closed fermentation tanks allows the uptake of carbon dioxide. The purified and liquefied carbon dioxide can be used for further use in the brewery (Basařová and Basař, 2010; Chládek, 2007):

- Air expulsion from the lager - and bright beer tanks.
- Kegs and bottles filling.
- The driving gas fro beer drafting.
- Artificial carbonization of beer HGB system.

- Degassing of water in the production of non-alcoholic beer.
- Inert atmosphere generation in tanks.
- Sales for soft drinks production.

Thus obtained CO_2 is highly environmentally friendly. From 1 hl of wort during fermentation can be obtained after reducing losses 2-3 kg of CO_2 (Basařova and Basař, 2010).

By the registration and following up on odour complaints, by assessment of activities that might cause odours and by regular inspection and maintenance of containment measures in area that can cause odours can be achieved the minimisation of environmental impact of odours (CBMC, 2002). Environmental Protection Agency (2008) recommended reusing the gaseous substance and odours as much as possible and also for removing of the odour is advice using biofiltres, bioscrubbers, dynamic filter, electrostatic separators. Also can be used dispersion of odours through capture of air and exhausting through an appropriately designed stack, or absorption and adsorption (carbon filter) system and also used thermal, boiler or catalytic treatment to control emissions from exhaust air.

2.4. ODOUR MEASUREMENT

In assessing of odour measurement it is significant to distinguish odorants and odours. Odorants are the compounds which are responsible for odour origin, while an odour is the effect of the odorants that is detected by the olfactory system (Gostelow, 2003).

The determining intensity problem of the analytical method is the variable character of odours in the mixture. Representation of all chemical substances contained in the sample has a significant odour impact on the quality and intensity of odour. The substance can interact with others in the mixture. Some substances have ability to increase or decrease the intensity of the odour (Odour, 2010b).

Nowadays, the olfactory nuisance is at the top of the list of air pollution complaints. Mainly, the air pollution has the source in anthropogenic pursuit (Brattoli et.al., 2011).

Currently, there are several methods of the emission and the odours measuring:

a) First method is defined by **ČSN 83 5030** (1998) **– Effects and assessment of odours - Determination of annoyance by questioning- repeated brief questioning of neighbour panellists**. This standard describes the method for odour annoying population research. It can be short-term (2-3 months) or long-term (12-14 months) and it's possible to choose from 3 main methods. In the article of Odour (2010a) is written, that this method has origin in Germany, where a lot of people from affected areas complained on the basis of subjective feeling. It isn't for identification the source of odour in the locality.

b) The second method, **defined by ČSN 83 5031** (1998) **– Determination of odorants in ambient air by field inspections**. This standard specifies conditions and methods of determining an incidence of odours in the ambient air. This method is convenient for evaluating immediate condition. The assessor goes in defined area and does and the evaluation of air quality by inhalation in specific time and in specific intervals (ČSN 83 5031, 1988; Odour, 2010a).

c) The last method, which is accredited by Czech law as the only one method for exact measurement is defined by **ČSN EN 13 725** (1998) **is called Air quality- Determination of odour concentration by dynamic olfactometry**. This method is described below in special capture.

2.4.1. History of odour measurement

The smell impact of population is known for long time and is the most common complaint for environmental pollution in Czech republic and of course the majority of the developed countries (Van Harreveld, 2011). The agriculture area was not the only one problem – from the beginning of industrialisation in the big cities (London, Paris), the air pollution include smell was started.

The specific odour measurement doesn't have long history. The first knowledge of odour measurement comes from rural areas and areas with a large sewage treatment plants. From the measuring and monitoring comes theory of affecting health. Intensive and long-term annoying odour can affect mood, emotions, choice of partner, and an immune and endocrine system (Odour, 2010b).

2.4.2. Analytical measurements

Analytical methods are used for qualitative and quantitative evaluation of chemistry sample composition. According to Prichard and Green (2001) is analytical measurement defined as: ,, A generic application of a scientific principle that can provide information about a samplé,,. Analytical measurement contains analysis- measurement of substance in the sample.

In analytical measurements are used these techniques:

- **Electrochemistry**- measure pH by pH diode (Prichard and Green, 2001).
- **Gas chromatography- mass spectrometry** (GC/MS) **–** it is for analysis of air quality. It produce a list of substances which are there involved and their concentration (Brattoli et.al., 2011). The sample is adsorbed into sorbent material, which concentrates compounds of interest and then evaluating (Prichard and Green 2001). The disadvantage is inability to detect lower concentration, because the device has limit for detection. Another disadvantage is high cost and inability to compare intensity with human perception (Brattoli et.al., 2011).
- **Gas chromatography- Olfactometry** (GC-O) - is the most widely using method since 1952 (Prichard and Green 2001), frequently for the evaluation of food aromas (Brattoli et.al., 2011). Gas chromatography coupled traditional gas chromatography with sensory detection (Brattoli et.al., 2011) - it separates the individual components of a mixture, which are then presented with a sniffing port (Assembly of Life Science, 1979), where trained person or panel could detect the active odour species (Brattoli et.al., 2011). The advantage of this technique is in identification of odour-active compounds.
- **Electronic nose –** this device is developed on anatomy of human nose in United States. It is used in the food, beverage and perfume industries for quality control and development of the products (Odour, 2010a; Power, 2011). It is sensor- based device that is capable of discrimination between a variety of simple and complex odours (Brattoli et.al., 2011).The sensor array detects the odours as chemical components and records the numerical results. The electronic nose can have 32, 64 or 128 sensors and every sensor recognize its own individual character (Odour, 2010a; Power, 2011).

Analytical measurement is often used for air-pollution measurement and has a social and economic impact (Assembly of Life Science, 1979). On the other hand the measurement of odour by analytic methods is not soluble in present. The reason for it is in substances, which the people feeling as odour (smell), that are in too much low concentration, often under the border of analytical device detection. The analytical methods are available to specify only restricted spectrum of substances in odour gas (Odour, 2010b).

2.4.3. Sensory measurements

Sensory measurement is based on employ the human nose as the odour detector (Gostelow, 2003; Xavier, 2006). In this sense, everything depends on experienced human, where is measured only a total effect of the odour. Anyway there are a lot of factors which can influence the perception of the odour. For example there are properties of gas, variability in sense between different observers, etc. (Gostelow, 2003; Xavier, 2006). This is usually minimised mitigate by using a panel of observers. Results of measurement are then averaged. Other factors which can affect observers are the presentation of samples, the environment in room and the flow rate (Gostelow, 2003).

•Measured parameters

In environmental odours are possible to detect four sensory parameters:

1) **Threshold concentration –** There are two types of odour threshold; detection and recognition (Gostelow, 2003; Assembly of Life Science, 1979; Nicolai et.al., 1997). Detection threshold is defined as the lowest concentration of an odorant in clean air, where is detected some odour. Recognition threshold is defined as the lowest concentration of an odorant in clean air, where is recognized the specific odour (Nicolai et.al., 1997). Recognition threshold is mostly higher than detection threshold by a factor of 1.5 to 10 (Gostelow, 2003, Assembly of Life Science, 1979). According to (DEP, 2002) is the detection threshold normally 50%. This concentration is defined as 1 odour unit.
2) **Intensity –**is the perceived strength of an odour above its threshold (Gostelow, 2003, Assembly of Life Science, 1979; DEP, 2002). It is determined by an odour panel and is described in categories which progress from “not perceptible”, then “very weak”, through to “extremely strong” present (DEP, 2002).

3) **Character** - is basically how the odour smells like (Gostelow, 2003, Assembly of Life Science, 1979; DEP, 2002). The odour character allows distinguishing different odours. The character of an odour may change with a dilution (DEP, 2002). It can be characterized by terms (table 1), which are written in description vocabulary (Brattoli et.al., 2011).

Table 1- Category scale

0	No odour
1	Very faint odour
2	Faint odour
3	Easily noticeable odour
4	Strong odour
5	Very strong odour

Source: Assembly of Life Science, 1979

4) **Hedonic tone –** is the degree of pleasantness or unpleasantness (Gostelow, 2003; DEP, 2002), often closely linked to its character (Assembly of Life Science, 1979). For this evaluation is used the numeric scale, where the most pleasantness is at one end (positive value) and the most unpleasant at the other (negative value) (Gostelow, 2003). On the other hand the perceptions differ from person to person, and are strongly influenced by previous experience and emotions (DEP, 2002).

Also for odour can be some other data, which influence the perception (DEP, 2002):

- Frequency of the odour occurrence.
- Intensity of the odour.
- Duration of the exposure to the odour,
- Offensiveness of the odour
- Location of the odour.

- **Subjective method**

In this method is used only human nose without any other equipment (Gostelow, 2003). The advantages of subjective method are in need no special equipment and can be obtained quickly in a cheapest way. This method is used for preliminary assessments. Evaluation of results is harder due to natural changes in sensitivity of odour even for training persons (Xavier, 2006). It includes these parameters of measurement: odour character, hedonic tone and intensity (Gostelow, 2003; Xavier, 2006). For odour character and hedonic tone parameters there is no available objective technique (Xavier, 2006).

The oldest technique for measuring sensory stimuli is direct scaling technique. In this case the observer matches up the number with the intensity of odour or compares with referent gas (n-butanol). This form do not express unpleasant odour (Xavier, 2006).

- **Objective method**

In this method is used the human nose in conjunction with some form of dilution apparatus (the olfactory mask) (Gostelow, 2003; Xavier, 2006). According the ČSN EN 13 725 (1988) is objective methods whatever in which reduced influence of personal opinion are. For this evaluating can be used olfactometer device. This device dilutes the sample with odour-free air. By olfactometry method exist two categories of dilution (Gostelow, 2003; Xavier, 2006):

- Static - the mixing of given volumes of odours and odour-free air.
- Dynamic - the mixing of flows of known compositions. Dynamic dilution is better than static one. The advantages are in possibilities to constant sample delivery to olfactory mask.

Similar measurement techniques relating to remove or reduce subjectivity by an olfactometer (Gostelow, 2003; Xavier, 2006):

- Threshold olfactometry - the sample is diluting with odour-free air until the threshold concentration is detected. Concentration is then set as number of dilution needs to achieve the threshold concentration.
- Supratreshold olfactometry – comparison of an odour with referent gas until it reach the same intensity and the result is expressed as equivalent concentration of referent gas.

For indicating an odour there are used two forms (Gostelow, 2003; Xavier, 2006; DEP, 2002):

- YES/NO method – diluted sample or clean swilling air are emitted only from one port. Panellist is asked if he feels the smell or not. If yes he has to push the YES button.
- Forced-choice method – two or more ports from that are emitted an odour sample or odour-free air. Panellist has to choose which port contains an odour using keyboards. It is possible to use the special buttons for inkling.

2.4.4. Sampling methods

Sampling of the odour can affect other measurement procedure. The aim of sampling is to avoid sample losses due to sorption of surfaces through the air is sampling, protect sampled air to escape or before changes in character or in time. In that case the material of sampling lines and storage has to be odourless with low permeability in order to minimise losses and the physical and chemical reactions with the air sample have to be at minimum level. The odour is often collected in containers or canisters, polymer bags or on adsorbent materials (Brattoli et.al., 2011). The appropriate materials for sampling, storage and evaluating are written in next capture.

The storage bags (and containers) can be filled using direct or indirect technique (also called active and passive) (Stuetz and Frechen, 2001; Brattoli et.al., 2011):

- **Direct sampling** - filling under pressure by pumping the sampling air into the bag. This principle of sampling has high risk of contamination, because of large surface in it.
- **Indirect sampling –** using by the sampler for dynamic olfactometry. The bag is placed inside hollow tube. This tube is connected to the suction of an air pump. Sampling air is sucked into the bag by reducing the pressure inside the tube. The tube should be transparent for controlling of filling the bag.

Also the source of odour which should be measured is divided into active and passive sources, but in different meaning:

- **Active –** this source is characterised by a measurable outward airflow (chimney or another outlet). Between active sources belong also small areas (for example biofilter) which can be covered. For this sampling the static hood can be used for covering the source to protect him of ambient air during sampling (Frechen, 2010; Brattoli et.al., 2011).

• **Passive –** to this source belong landfills, manure, etc. which don't have a measurable airflow. For this type of measurement was invented a wind tunnel (Brattoli et.al., 2011), because is not possible to cover all surface. The wind tunnel is placed over the emitting surface. The base have to be tightly sealed and the shape can be choose according the state rules (Frechen, 2010; Brattoli et.al., 2011), but according the Czech ministry of environment, the volume of the tunnel have to be 200 litres at minimum. The tunnel has two hole- outlet and inlet. The inlet is fed by clean air in calculating speed, to achieve 0,05 m3/s on outlet. This should stimulate the real condition. Further information about collecting with a wind tunnel is defined in (Kužel, 2008).

During each measurement should be known the meteorological data. For conventional model is needed to know at least 2year´s data of the area. For simple situation is possible to know only hourly average. The collecting data are (DEP, 2002):

- wind speed
- wind direction
- air temperature
- air humidity

The weather affects the volatility of compounds, preventing or enhancing movement into the gaseous phase where and odour can be dispersed downwind (Power, 2011).

2.5. DYNAMIC OLFACTOMETRY

Olfactometry is an objective method that is based on subjective observation, but eliminates most external effects through complex statistical calculations based on the logarithmic perception of odour intensity and strict restrictions on the measurement (Odour, 2010c). The method of dynamic olfactometry is defined by European standard EN 13725 Air quality-determination of the concentration of odorous substances dynamic olfactometry (ČSN EN 13 725).

Principe of olfactometry lies in dilution of odour samples with clean air to find the smallest odour concentration by assessors. This concentration is called odour threshold and it is equalled one odour unit. Concentration of odour units means how many times is necessary to dilute the sample with clean air to reach odour threshold (Odour, 2010c).

Possible division of olfactometry was written up.

2.5.1. History

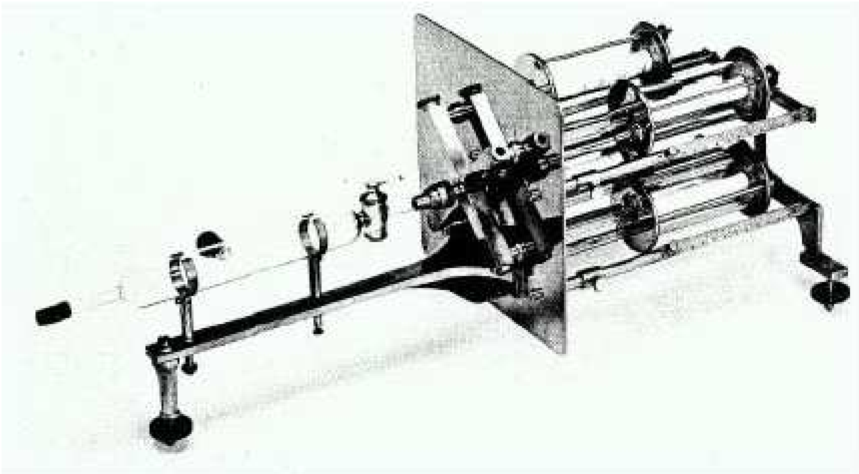
In the United States and throughout Europe in the 1970's and 1980's there was a significant increase in public concern for odours from industrial, agricultural, and waste water treatment facilities. During this time, governments in many of these European countries implemented standards and regulations for odours. Many of the regulations required the measurement of odours through olfactometry, either to prove compliance or to measure and monitor odours. Olfactometry has been used throughout the 20 th century in the medical research community. However, there has existed variability of results due to differences in olfactometer design and operating performance as well as the lack of consistency in odours testing methods used. (Mc Gingley and Mc Gingley, 2001)

In the 1980's countries in Europe began developing standards of olfactometry. Some of these standards developed and published include:

In 1971 was set practical guideline on new and existing livestock operations in Netherlands. Thanks to this, a quantitative air duality guideline for odours from industrial sources was introduced in 1984. As Van Harreveld, (2011) write, the guideline was based on measurement of odour emissions using olfactometry. After a few years of the researches later, the Dutch NVN2820:1990 standard was done. Many years later The European Union countries have been introduced in April 2003 the EN 13725:2003 standard.

But solitary olfactometry has been practised in 19th century. The first thresholds were announced in 1848 with studies appeared in 1890´s (Van Harreveld, 2011). In 1888 accurately, the Dutch physiologist, Hendrick Zwaardemaker invented a Zwaardemaker olfactometer (Picture 5). It was a tube, which could regulate the amount of a gaseous odorant before introducing into the nose. The length of the tube calibrated the amount of odour (Psychology Wiki, 2012).

Picture 5 - Zwaardemaker olfactometer



(Van Harreveld, 2011)

The device consists of a short pipe, made of odourless kaolin, which can be placed in the nose. The odorants were held inside a metal cylinder to prevent outside smell (Van Harreveld, 2011).

Nowadays device has the roots since 1960´s. During this very short period was step by step invented 3 generation of the olfactometer:

- **1960 – 1979 Static dilution method** – manual method which used the syringes for odourless air. It was incompliant and unsteady thanks to inaccurate measurement. Material of the syringe absorbed the odour (Dynascent, 2011).
- **1980 – 1989 Olfactometer with rotameter** – airflow of the odourless air was measured with a rotameter to determine the dilution ratio. Everything was still based on manual operation. The sniffing ports were under a backward pressure, which could change the dilution ratio. The material was still inadequate and the area inside the olfactometer was so big, that allowed absorbing an odour (Dynascent, 2011). During the 1990s was the olfactometry method refined in significant way (DEP, 2002).
- **1990 – 1999 Olfactometer with mass flowmeter** – for dilution of the sample was used mass flowmeter. For the first time was possible to use 2 dilution steps or one phase with more flowmeters. The olfactometer worked automatically, but the sniffing ports had still a backward pressure. The device didn’t allow a user calibration (Dynascent, 2011).

- **2000 – The present – Digital olfactometer –** the computer control everything fully automatically (cleaning, diluting, evaluating etc.). The valve are calibrated by mass airflow and are used the Venturi's nozzle which are independent on decreasing pressure. By one phase is fully parallel dilution. This generation permits accurate dilution ratios from 2 to 128 000 in 17 dilution steps. The odour contamination is minimized by using low contact area. Cleaning of the olfactometer is very quick and the air during cleaning reaches 180 km/h (Dynascent, 2011).

The first related device was introduced in 1958. It was the field olfactometer (called scentometer). It was hand-held device which allows evaluating the odours on site. It created a series dilution by mixing odorous ambient air with odour-free air, which was cleaned by carbon filter. This method is to nowadays economically attractive, because the result is immediately known. Very big disadvantage is in ambient environment, which is also odorous and the observer can be confused. In 2002 was introduced new device called the Nasal Ranger™ , which extend consistent and accurate measuring results (Bratolli et.al., 2011.

2.5.2. Sampling equipment

Nowadays there are too much rules for everything. In this method is defined few basic rules according to Czech technical standard ČSN EN 13725 which include specifics materials and rules.

• Materials

Materials which come into contact with sampling gases have to be from special materials according the Czech technical standard ČSN EN 13725 (1998). These impervious materials not be allowed to release any odour into sample and can't react with a gas (Kraus et. al., 2008; ČSN EN 13725, 1998; Brattoli et. al., 2011). It has to have a low diffusion permeability and smooth surface (ČSN EN 13725, 1998). There requirements comply especially (Kraus et. al., 2008; ČSN EN 13725, 1998; Brattoli et. al., 2011):

- Stainless steel
- Glass
- Polytetrafluoroethylene (PTFE) also called Teflon®

- Fluorinated ethylene propylene (FEP)
- Polyethylene terephthalate (PET, Nalophan TM)
- Polyvinyl fluoride (PVF, Tedlar TM)

Other materials for example brass, natural rubber or silicone rubber are not suitable for its reaction with gases or they can product their own odour (ČSN EN 13725, 1998; Stuetz and Frechen, 2001).

• Sampler

The sampler is hollow plastic tube equipped by a vacuum pump on one end. Inside sampler is an empty sampling bag (Kraus et. al., 2008). This tube is made of polytetrafluoroethylene, fluorinated ethylene propylene, polyethylene terephthalate and Stainless steel (ČSN EN 13725, 1998).

• Sampling bags

Qualities of sampling bags are very important. In the production of the new batch is everything strictly under control. Before using the bags are tested for tightness. Each bag is evacuated by a pump. At the correct tightness of the pump flow rate drops to zero. After it is bag closed by cork and all bags are storied in transport container (TSO Praha, 2008). The sample bags have to keep following criteria (Kraus et. al., 2008; ČSN EN 13725, 1998; Stuetz and Frechen, 2001):

- Be odour free and proof
- Do not absorb odours
- Do not react with the odours samples
- Vacuum and overpressure resistant
- Required barrier properties
- Perpetuate the same odour quality and have to prevent any significantly loss for at least 30 hours by temperature of 20°C
- Sufficient volumetric capacity (at least 10 l)

Losses from bags may be from adsorption on the bag wall, permeation through the plastic wall, condensation or photo-catalysed reactions (Stuetz and Frechen, 2001).

Stuetz and Frechen 2001 (Stuetz and Frechen, 2001) in their research show effect of bag material on ethyl benzene recovery. The best material for bags is Tedlar^{TM} which have excellent performance. For this case is this material recommended for air toxic sampling. Cheapest material is Nalophan, which is doesn't have so quality (appendix 3).

For bags the polytetrafluoroethylene, polyvinyl fluoride and polyethylene terephthalate are used (ČSN EN 13725, 1998).

It is possible to reuse bags (ČSN EN 13725, 1998), but there is problem with cleaning. Process of cleaning is expensive, to long and have following hard control (Kraus et. al., 2008). Detergents have to be without pungent odour, have to be clean consequently with odour-free air and perfectly dried (ČSN EN 13725, 1998). This process is not always successful, but is possible to reuse it up to 10 times at best according to (Stuetz and Frechen, 2001). One cleaning process is about 20% of the cost of a new bag.

• Olfactometer device

This device helps to evaluate odours (Kraus et. al., 2008). It dilutes gas examples with neutral gas in defined ratio and submits it to assessors for the assessment (ČSN EN 13725, 1998). Most frequently it can be designed up to 8 stations around the round table. Every panel (section) is separated from each other by partition walls (appendix 4) (Kraus et. al., 2008). In each section which can be called a "sniffing place", are the sniffing port with the glass olfactometry mask (one for yes/no method and second for forced-choice method), diodes and buttons for answers (Frechen, 2010).

Setting standard ČSN EN 13 725 (2008) indicates construction criteria. The length, inside diameter of pipeline and the dwell time in it should be minimal for prevention contamination of odours. For materials stand the same rules as for the other sampling devices (cannot affect odours attributes) (Kraus et. al., 2008). Construction of device has to be constructed to prevent any noise or sensory suggestion about expected sample (ČSN EN 13725, 1998). The olfactometer must be constructed of components made of glass, stainless steel, or polytetrafluoroethylene (ČSN EN 13725, 1998; McGingey, 2001).

The temperature of reference gas and odours sample which emanate from device must not be varied in 3°C of temperature in laboratories (ČSN EN 13725, 1998).

Dilution range has to be from 2^7 to 2^{14} with measurement range bordered with maximum and minimum of dilution range 2^{13} (ČSN EN 13725, 1998; McGingey, 2001). The basic schema of dilution principle is shown on picture 6.

Picture 6 – Flow scheme of dynamic olfactometer

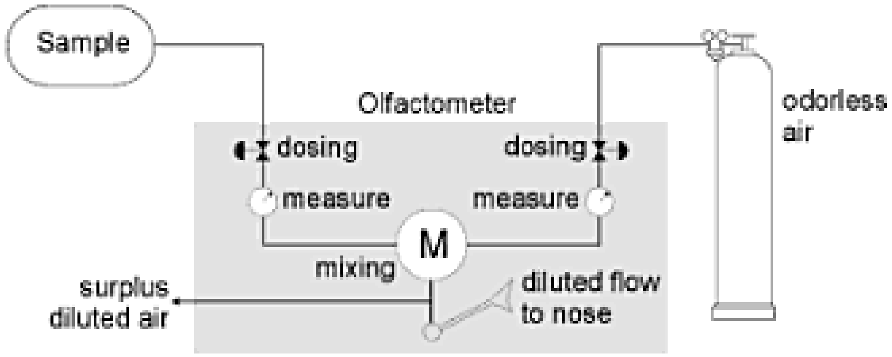


Figure 2.1. Flow scheme of dynamic olfactometer (after Frechen, 1994).

Source: Gostelow, 2003

2.5.3. Gases

- **Neutral gas**

Czech technical Standard (ČSN EN 13725, 1998) defined this gas as breathable. All members and operator must consider it as odourless gas. It is tested every time before each measurement. If someone assesses this gas as odour, it has to find and eliminate the source of odour.

- **N-butanol**

N-Butanol is used as a calibrating gas after every session for each assessor (Nicolai et.al., 1997). N-butanol gas is primary alcohol with a 4-carbon structure. It belongs to the group of fusel alcohols, which have more than two atoms and have significant solubility in water. N-butanol is a minor product of the fermentation of sugars and other carbohydrates and it is presenting many foods and beverages. The largest use is in an industrial intermediate (30).

2.5.4. Laboratory

Laboratory for olfactometry testing have to satisfy specific criteria. There is not permitted any smell or odour released from any material in the room (floor, walls, furniture). There is prohibited to open window. In that case is the room ventilated through a carbon filter (ČSN EN 13725, 1998), which removes background odours before entering the room to hold the air clear (28). Quantity of CO_2 in the room shall be less than 0, 15% (ČSN EN 13725, 1998).

The ČSN EN 13725 (1998) standard requires that the olfactometer have to be calibrated at each dilution level with a suitable gas (Mc Gingey, 2001).

2.5.5. Odour panel

ČSN EN 13 725 defined odour panel as: “A group of assessors used to analyze an odorous sample by olfactometry”. Each member of commission has to keep the code of conduct. Member of the commission (assessor) can be a person more than 16-years old. Every assessor is obligate to be motivated for conscientious executing of the task and have to take part in the whole measurement. During the measurement and 30 minutes before the beginning, is prohibited to eat (neither chewing gum nor sweet) and smoke. For drinking is allowed only fresh water. Very important is personal hygiene of the assessors. Using deodorants and perfumes can disturb the concentration (ČSN EN 13725, 1998).

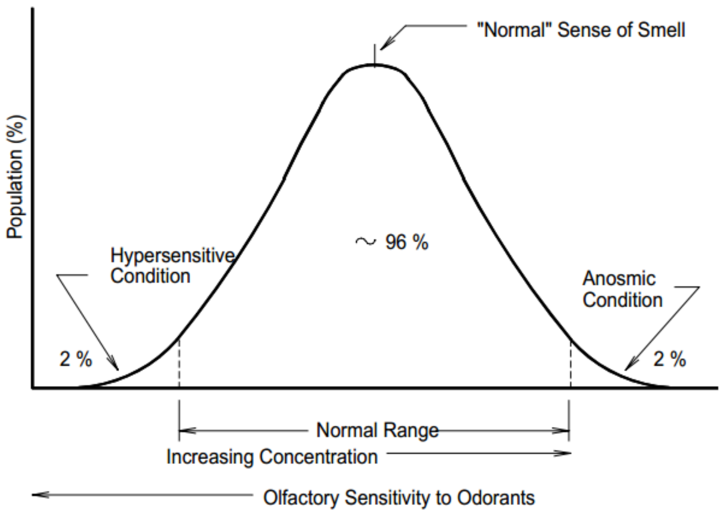
The assessor can be expelled due to injury, which limits the perception (ČSN EN 13725, 1998) and automatically are excluded smokers, drug dependency, pregnancy and serious allergies (Nicolai et.al., 1997). Whole group of assessors are under the expecting to adapt in laboratory 15 minutes before the beginning of the measurement. During the measurement is not allowed to discuss the results (ČSN EN 13725, 1998).

People’s sensitivity to odours varies widely. The general population’s olfactory sensitivity follows a typical bell curve (Picture 7). The panel should be from the general population and at the same time (Nicolai et.al., 1997).

The size of assessors is given by the number of section at the table. The lowest number is 4 assessors according to (ČSN EN 13725, 1998). Because of the evaluation method the chances are that some assessors may be out of that specific measurement day, therefore it might be convenient to operate with 5 assessors to obtain passable results (Frechen, 2010).

Every assessor has to pass the exams from N-butanol measurement and every year has to be certificated again. Proper training of the assessors can improve the reproducibility of the results (Nicolai et.al., 1997). Only assessors who have balanced performance, repeatability and accuracy are allowed to continue as assessors (Mc Gingey, 2001).

Picture 7 – Olfactory sensitivity to odorants



(Nicolai et.al., 1997)

2.5.6. European odour unit

The European odour unit (ou_E) is defined according to (ČSN EN 13725, 1998) as:

“That amount of odorant(s) that, when evaporated into one cubic metre of neutral gas at standard conditions, elicits a physiological response from a panel (detection threshold) equivalent to that elicited by one European Reference Odour Mass (EROM), evaporated in one cubic meter of neutral gas at standard conditions”.

The European Reference Odour Mass (EROM) (ČSN EN 13725, 1998):

“The accepted reference value for the European odour unit, equal to a defined mass of a certified reference material. One EROM is equivalent to 123mg n-butanol (CAS 71-36-3) evaporated in one cubic meter of neutral gas. This produces a concentration of 0.040mmol/mol”.

2.5.7. Sampling

Before every measuring every observer has to know, what will be measured and from which source. It can be differentiate between active and passive sources. The active source is measurable with an outward airflow (for example chimney) and the passive source has no measurable outward airflow, only emitting odours (Frechen, 2010).

The samples should be immediately analysed how it is possible, but maximum time for prolongation is 30 hours. The bag with the sample is kept below 25˚C and not be supposed to expose the direct sunlight or the intensive daylight (ČSN EN 13725, 1998).

During sampling have to be note the meteorological data, which were describe earlier.

2.5.8. Measurement

The measurement in olfactometry is defined as the peak of dilutive series necessary to obtain sufficient data to calculate the concentration of odorous substances in a sample panel of all members (ČSN EN 13725, 1998).

There are two possible methods, which were mentioned upwards – forced choice method and yes/no method (ČSN EN 13725, 1998; Brattoli et.al., 2011).

Each assessor before measurement obtains its own breathing mask, which should be put into port. After running the olfactometer, places its nose about one inch from the mask. The air from the device is directed to the nose and allows normal breathing (Nicolai et.al., 1997).

Each sample is measured in 3 sequent with minimum of 10 concentrations and only then is the sample evaluated with 95% possibility. Dilution of the sample is done by computer for several dilutions, while there is alternatively brought the diluted sample and clean air in intervals of 2,2s. For the clean air sample must the assessor answered negatively. In the case of positive answer more then once, is he exclude from the measurement (Odour, 2010c).

The olfactometer software presented the samples to the panel on its own, but its preferred ascending order presentation, because after strong odour (lower dilution) is heavy to detect weak odour (higher dilution) (Brattoli et.al., 2011). Therefore the first dilution is with very large volume of air to be undetectable for human nose. After that the volume of air is decreasing until each panellist detect positively and odour in the dilution. At this stage each panellist gets at detection threshold, which is calculated as geometric mean between the dilution of the last negative answer between odour intensity and concentration (Brattoli et.al., 2011).

The results can be right, only with more then 50% positive answers. Also answers with large deviation are excluded and the measurement is repeated. Eventual value can be evaluated from minimum 4 assessors. The final result is calculated as a geometric mean of the all approves measurement. The geometric average is chosen, thanks to exponential perceptions of odour. The result is expressed as odour units per cubic meter (ou/m^3) (Odour, 2010c; Brattoli et.al., 2011).

The measurement can be do directly at place chosen for sampling odour, but the disadvantage are in necessary isolated place from odour environment, because panellists can be adapted for it and the measurement will not be good (Brattoli et.al., 2011).

3. OBJECTIVES OF THESIS

The goal of this thesis is the evaluation of the odour concentration during brewing in the selected breweries using olfactometric method.

This measurement was realized only as experimental. In the Czech Republic and in the world at the time of writing was not found to much scientific article focusing on this topic. The first one was introduce in 2008 (Kraus, 2008), but the data from it cannot be used, because there is different phases of brewing measured. And the second one compares the ground level odour from brewery with odour from stabilised wastewater bio solids (Needham and Freeman, 2010). But any found works did not write about direct measuring in brewhouse or at chimney. Therefore this work is one of the first works with these aims and could be used for other experiments in this field of science. The aim of this measurement was to determine the odour concentration from breweries and comparison with different size of breweries.

4. MATERIAL AND METHODS

The Dynamic Olfactometry method was used for this diploma thesis. It is set by norm ČSN EN 13 725 and as a solitary method is appreciated for odour intensity measurement in Czech Republic.

The olfactometry analysis has been conducted in the corporate laboratory of Dynamic olfactometry of Czech University of Life Sciences in Prague and Research Institut of Agricultural Engineering in Prague, p.r.i. (picture 8). The odour substances sampling has been realised by measuring group RIAE, p.r.i. Prague.

Picture 8 - Olfactometry laboratory

Source: Klára Bortlová

4.1. USED EQUIPMENT

4.1.1. Vacuum Sampling device, ECOMA EP. 162

The unit consists of a partially evacuated plastic container (picture 9). There is a battery-powered blower at the bottom of the container, which had ability to evacuate to maximal value 2000 Pa below ambient pressure. The container is constructed of transparent plastic in order to allow observing the expansion of the sample bag. The filling time depends on current pressure situation (10 – 20 seconds) (Ecoma, 2012).

There is a press- button on the top of the handlebar for the operation of the sampling device. Due to the lower availability of some locations and distances there is a shoulder belt on the device. The equipment has a relatively low weight of 4 kg (Ecoma, 2012).

Picture 9 – Vacuum sapling device

Source: Klára Bortlová

For odour sampling a 10 litre Nalophan NA© sampling bags were used (picture 10). The sampling tube is made from PTFE. After sampling each sample should be immediately locked by the cork. The cork should have the following dimensions (Ecoma, 2012):

- The lower ending diameter should be 4 mm.
- The upper ending should be 7 mm.
- The length of cork should be around 16 mm.

Picture 10 – Sampling bag

Source: Klára Bortlová

4.1.2. Olfactometer ECOMA T08, EO. 8806

The olfactometer T08-8 offers the evaluation of odour concentrations, the evaluation of the odour intensity and the hedonic tone. This device also offers the possibility of measurement directly at the locale and directly after the sampling. It is equipped with a fully automatic dilution system, which has a dilution range from 2^3 to 2^{17}. The volumetric flow is constant for all dilution intervals. The structural parts getting contact with the sample air and the neutral air are made of glass, PTFE and refined steel without any exception. The dilution system can be heated. The eight panellists can measure simultaneously. The panel places are designed ergonomically. The olfactometer system also works silently (ECOMA, 2010). The technical data are specified in the table 2 (Ecoma, 2012).

The olfactometer works on principle of a dilution system, where a sample of odorous air is diluted with neutral air. Two gas jet pumps are connected in a row and operate with neutral air. The first dilution step sucks the air out of the sample bag. The diluted air flows through the second dilution step and further via the rotary slide valve to a panellist port. The odorous air will be mixed intensively with odourless air in the gas jet pumps. The mixture flows via the rotary slide valve to the sniffing ports. While one panel member is provided with mixed air, the opposite panels members receive neutral air, the panel members who are in the expiration are provided with a minimal flow neutral air (Ecoma, 2012).

Table 2 - Technical data of Olfactometer TO8-8

Dimension, L x W x H, a) assembled b) transport size	a) 900 x 900 x 470 mm b) 650 x 650 x 270 mm
Weight	22 kg
Dilution principle	Gas jet pumps anc dallibrated precision orifices for sample dosage
Control mechanism of volumetric flow	Calibrated measuring orifice disk
Surplus outlet for sample air	Outlet air via active coal filter
Number of outlet for odour samples	8
Number of panellists simultaneously on device	8
Desing of oflactometric exit	Non-sealing glas masks
Volumetric flow of odour sample	Min. 1,2 m^3/h each place (inhaling place)
Greatest set dilution	2^{17}
Smallest set dilution	2 3
Interval stepps	Factor 2
Standards deviation of setting of dilution stages	< 10%
Response time	< 1 sec
Setting time	< 1 sec
Maintenance interval	12 months

Source: Ecoma, 2012

The concentration of the sample starts below the threshold and increases. With the first odour impression the YES button has to be pushed. The result for minimal 4 panel members who proved the odour impression in 3 rounds the odorant concentration is giving as a multiple of the threshold of the odorant concentration in odour units per m^3 (OU/m^3) (Ecoma, 2012).

The breathing frequency is given by optical signals. The procedures are run simultaneously for the four panellists. The total measurement program is computer controlled by *Olfactometer software* and runs automatically. The olfactometer panel is show in picture 11 (Ecoma, 2012).

Picture 11 – Panel of olfactometer

Source: Klára Bortlová

The *filter system* (picture 12) consists of a pipe, a floor plate and a sealing cover of perspex. This unit is bolt to a base plate of stainless steel. The sealing between pipe and floor plate is a permanent kind, between pipe and cover it is realised by a special joint ring. The cover is interlocked with the unit floor plate- pipe by means of six screw connections of stainless steel. Air inlet and outlet are quick lock connectors for pressurised air (Ecoma, 2012).

Picture 12 – The filter system

Source: Klára Bortlová

The empty system is checked to a pressure of 0,1 MPa. Due to the safety no higher pressure than 0,4 MPa should be connected to the system. To ensure this a pressure relief valve is situated at the inlet. The filter system is filled with silicagel to separate humidity, with activated carbon to precipitate organic compounds (as for example odours), with cotton wool and micro filter as dust precipitator (Ecoma, 2012).

The air to be filtered is conducted by a tube from compressor or from gas cylinder to the filter system. The corresponding end of the tube is pushed into the quick lock connector on top of the filter system (inlet side with silicagel) - provided that the cut edge is proper and straight. It is pushed to the limit stop and then drawn back slightly to ensure a safe seat (Ecoma, 2012).

The outlet of the filter system is below the floor plate and the tube to the olfactometer which is connected in the same way as described above should be installed directly, as short as possible. It is ingenious to install a tee piece quick lock connector before the olfactometer to connect a pump piston for example for the pre dilution of sample in the bag. To release the tubes from the quick lock connectors at first the pressure is bled from the system. Then the tube can be drawn out by pushing down the black part of the quick release connector at the same time (Ecoma, 2012).

4.1.3. Thermo-hygro-barometer COMMETER D4141

Digital recording thermo-hygro-barometer is designed to measure and record the air temperature and relative humidity by the external probe, the air temperature around the device, pressure and pressure tendency over the past 3 hours with the possibility of direct full-time display of dew point temperature recalculated values of atmospheric pressure on the sea level (Regmet, 2012).

Measured values are shown on the LCD display and a selected time interval can be saved to internal memory and retrieved from memory at any time. The device communicates with the PC via RS-232 serial port. The Thermo-gyro-barometer is shown on picture 13. The selected measurement parameters are in table 2 (Regmet, 2012).

Picture 13 – Thermo-hygro-barometer

Source: Klára Bortlová

Table 3 - Selected measurement parameters of Thermo-hygro-barometer

Atmospheric pressure:	
Range of measurement	800 - 1100 hPa
Resolution	0,1 hPa
Accuracy	± 2 hPa at ambient temperature at 23 °C
Temperature:	
Range of measurement	internal -10 až +60 °C, external -30 až +105 °C
Resolution	0,1 °C
Accuracy	± 0,4 °C
Relative humidity	
Range of measurement	0 - 100 % RV
Resolution	0,1 % RVV
Accuracy	± 2,5 % RVV in range 5 - 95 % RV at 23 °C

4.1.4. Vane Anemometer TESTO 445

The Vane Anemometer instrument measures temperature, relative humidity, dew point, absolute humidity, degree of humidity, enthalpy, all types of air velocity, volume flow, pressure and indoor air quality. Data can be saved according to location and then analysed on PC or printed. Selected measurement parameters are in table 3. The Vane Anemometer is shown on picture 14 (Testo, 2012).

Table 4 - Selected measurement parameters of Vane Anemometer

Operating range (25 mm probe)	0,4 - 40 m/s
Resolution	0,01 m/s
Accuracy	±0.2 m/s ±1%
Operating range (3 mm probe)	0 to +10 m/s, -20 to +70 °C
Resolution	0.01 m/s (0 to +10 m/s), 0.1 m/s (+10.1 to +20 m/s)
Accuracy	±(0.03 m/s ±5%, 0 to +10 m/s

Picture 14 – Vane anemometer

Source: Klára Bortlová

4.2. USED METHODS

4.2.1. Selected breweries for odour sampling

For odour measurement were chosen these breweries:

- **Brewery A**

Brewery A is representative of the microbreweries, because produced beer is intended for research purposes only. The brew house consists of two vessels; volume of each is approximately 10 hl, the diameter is 1m. The chimney leading from wort kettle has diameter 18cm. Traditionally this brew house produces light beer with 12% fermentable extract, once a year this brewery brews the dark lager also. The beer is being brewed usually twice per month. Brewery is located on the suburbs of the town. The generated steam from brew house escapes directly into atmosphere.

- **Brewery B**

To select another brewery was taken into account the size and location. The emission can persecute people in residential areas. For this reason the brewery near the centre of the town was chosen. Brewery B has a long tradition of brewing in our country and brews 13% fermentable extract dark lager, which is from brewed from four kinds of malt. Its brew house has two vessels of volume 64 hl. Despite its size this brewery is still one of the breweries of restaurant type. The brew is done one times weekly, the brewery does not have any equipment to condense odours, that why generated steam escapes directly into atmosphere

- **Brewery C**

The last brewery represents big group of breweries – it is one of the biggest breweries in Czech Republic. The brewery is equipped with 6 vessels brew house. The volume of wort kettle is 880 hl with 8 brews daily. The wort kettle has diameter of 9,5 m and chimney leading from it has 21 cm. The lauter tun has got diameter of 11m and its chimney has 60 cm. The selection of brewery C sprang from the need more advanced technology to prevent leakage of air emission (odorous substances). Strictly speaking, the brew house is equipped with a mechanical compressor-the Roots blower (blower type SH-4, size 41-73). Without this facility the neighbourhoods of the brewery would be polluted 5 days a week of constant odour. The position of this the brewery is near the city centre too. The brewery produces 10 kinds of beer.

4.3. THE SAMPLE SELECTION

The selection of the technology phase of beer production for the collection of odorous substances was not easy. Sampling time had to be adapted to the time possibilities of metering group and permits of individual breweries. Therefore, in the final stage of preparation for the evaluation of odorous substances was tried to select the following phase of brewing:

- Lautering (sweet wort).
- Boiling with hops (wort).

4.4. SAMPLING

Sampling and measurements were classified as non-certified and experimental in compliance with Standard EN 13 725. The Samples of odorous gas were collected into sampling bags with sampling equipment by measuring group RIAE, p.r.i.

Sampling conditions were not same for all breweries, but it had to adapt to the current capabilities of individual breweries and operating conditions. From each selected technological phase of measurements were collected 2 bags. During the sampling time the meteorological conditions were recorded (appendix 5). Samples were repeated to confirm the measured concentrations of odorous substances.

The sampling from brew house looked that: The valve of chimney was closed and the samples could be collected. The vapour could evaporate through the open vessels door. This method of sampling should simulate the same condition at chimney.

The sample time has been always over five minutes. The brewing beer technology phases do not permit standard procedure according the ČSN EN 13 735. During each measurement the relative humidity, air temperature and atmosphere pressure was recorded.

Although the sweet wort is choose in the phases of lautering, the samples are collected from wort kettle (not lauter tun) in brewery A and B because of two vessel brewing and because the chimney.

The sample from each measurement were hidden in paper box (picture 15), where were protected before outside influence as sunlight or rain.

Picture 15- Paper box

Photo by Klára Bortlová

4.4.1. Brewery A

There was the first experimental measurement in brewery A and the first range value was determined. The sweet wort and wort odour sample were sampled from brew house (wort kettle) due to unsuitable weather.

In the second measurement the wort kettle sampling was repeated thanks to invalid results. Unfortunately, there were mistake by sampling and the chimney was opened. Determined values could not be used.

The third sampling was focused on chimney wort odour and also the wort odour from wort kettle. The aim of sampling from chimney and from the wort kettle was comparison between it.

During the last measurement, two samples of sweet wort from the wort kettle, two samples from chimney, and three samples of wort from chimney and also from wort kettle were sampled. Only in that case the three samples were sampled.

4.4.2. Brewery B

There were only two sampling days in brewery B. Both days, two bags of each kind were sampled only from the wort kettle. There was not allowed to take samples from chimney.

4.4.3. Brewery C

The sampling were also realised in two days. The samples from brewery C were collected only from chimney. For efficiency assessing of mechanical compressor were the wort odour sample collected from compressor chimney. Collecting from main chimney of wort kettle looks dangerous and it works only at the beginning of hops boiling. This value should show the efficiency of it. Each pan or tank has own outlet in this brewery.

4.5. MEASUREMENT

The olfactometry measurement of samples was conducted in corporate laboratory of Dynamic olfactometry of Czech University of Life Sciences in Prague (CULS Prague) and Research Institute of Agricultural Engineering in Prague, p.r.i. (RIAE, p.r.i. Prague). The samples were analysed by Olfactometer TO8-8, which woks on YES/NO principle. The panel of assessors consisted from a member of measuring group of RIAE, p.r.i. Prague and volunteers. The picture from olfactometer measurement is in appendix 6.

5. RESULTS AND DISCUSION

The resulting values were calculated by olfactometry software that is a part of the olfactometer equipment and the measuring group from RIAE, p.r.i. Prague, which worked out these results into so- called notation of measurement. The original list from olfactometer software is in appendix 8.

The values in this work are first processed for each phase and brewery technology separately. To assess the differences of odorous substances are then compared with each breweries according to the method of collection and size of the brewhouse. Each value are in odour unit (OU_E/m^3) or odour flow rate (OU_E/h^{-1}).

With respect to statistical treatment of results would be necessary to collect more samples, which in this case would be expensive[1] and time impossible. This measurement could be realized only through cooperation CULS Prague and RIAE, p.r.i. Prague. Another limiting factor is the willingness of breweries. Coordination measurements of this thesis depended on at several people. Representative values would have to be long-term, which can not be with regard to the diploma thesis performed.

All results are presented into graph in appendix 9

[1] The price for one average measurement is 10 000 CZE, according to Kollarczyková (2008) the price for bigger sewage treatment is up to 30 000 CZE.

5.1. RESULTING VALUES FROM BREWERY A

During olfactometric measurement the time was noted (table 5). The results of sampled sweet wort are shown in table 6.

Table 5 – The time range of olfactometric measurement, brewery A

1.day	16:00 - 17:00
2.day	17:05 - 17:45
3.day	16:20 - 17:20
4.day	13:30 - 14:15 15:05 - 15:25 16:15 - 17:10

Table 6– Overview of reached results from brewery A, sweet wort odour samples

A - Sweet wort				
Sample	**Odour unit OU_E/m^3 per bag**	**Odour unit OU_E/m^3 per measurement**	**Odour flowrate (OU_E/h^{-1})**	**Place of measurement**
ASL1/1	44	64	-	lauter tank
ASL1/2	94			
ASL2/1	50	60	-	
ASL2/2	73			
ASL3/1	62	55	-	
ASL3/2	49			
ASCH4/1	302	199	2016	chimney
ASCH4/2	132			

The individual values of sweet wort sampled from wort kettle looks approximate. The difference is only in each bag measurement that is common. But there is high difference between sample number ASCH4/1 and ASCH4/2, where the first bag measured values is more than twice higher. The average (final) values of sweet wort odour sampled from wort kettle and chimney are in table 7.

Table 7 – The average values of sweet wort odour from wort kettle and chimney

A - Sweet wort - Wort kettle			
Measurement	Odour unit OU_E/m^3 per measurement	Odour unit OU_E/m^3 final result	Odour flowrate (OU_E/h^{-1}) final result
1	64	60	-
2	60		
3	55		
A - Sweet wort - Chimney			
4	199	199	2016

In comparison of sweet wort odour collected in wort kettle and chimney, the sweet wort odour from chimney is 3,3 times higher than from wort kettle.

The wort odour measured values are in table 8.

Table 8- Overview of reached results from brewery A, wort odour samples

A - Wort				
Sample	Odour unit OU_E/m^3 per bag	Odour unit OU_E/m^3 per measurement	Odour flowrate (OU_E/h^{-1})	Place of measurement
AWW1/1	invalid sample	-	-	wort kettle
AWW1/2	invalid sample			
AWW2/1	wrong measurement[2]	-	-	
AWW2/2	wrong measurement[3]			
AWCH3/1	invalid sample	163	27360	chimney
AWCH3/2	163			
AWCH4/1	391	405	82440	
AWCH4/2	420			
AWW5/1	invalid sample	-	-	wort kettle
AWW5/2	invalid sample			
AWCH6/1	419	419	85320	chimney

Both bags from the first measurement in brewery A were evaluated as invalid sample. The other two bags from second measurement were wrong measured and the last round had also invalid sample. Therefore there is any useful wort odour result from wort kettle. During olfactometric measurement of wort sampled at chimney were observed these pieces of knowledge:

- Low diluted sample contain a lot of aromatic substances

- After obtaining low diluted sample any observer was not able to recognise high diluted sample and it caused poor results
- The wort odour had changeable character

Wrong measurement was caused by opened chimney. The values from this measurement were 80 and 56 OU_E/m^3 (and 89 OU_E/m^3) and it means average of 75 OU_E/m^3.

The average value of wort odour collected from chimney is in table 9. The results differ from bags again. Both value from the first valid measurement are two times lower than from second and third valid samples. Because the first value is almost 2 time lower and others results are similar, there had to be wrong measurement conditions.

There is not possible to compare chimney wort odour with wort kettle odour, because no valid number from wort kettle odour.

Table 9 - The average values of wort odour from chimney, brewery A

A - Wort - Chimney				
Measurement	**Odour unit OU_E/m^3 per measurement**	**Odour unit OU_E/m^3 final result**	**Odour flowrate (OU_E/h^{-1}) per measurement**	**Odour flowrate (OU_E/h^{-1}) final result**
3	163	329	27360	65040
4	405		82440	
6	419		85320	

In comparison of sweet wort odour from chimney with wort odour from chimney (table 10) there is ratio 1:1,7. It can be considered as the wort from chimney is twice higher than sweet wort from chimney.

Table 10 - Comparison of sweet wort and wort odour from chimney and flow rate, brewery A

Chimney					
Sweet wort	**:**	**wort**	**sweet wort**		**wort**
199	:	329	2016	:	65040
1	:	1,7	1	:	32,3

5.2. RESULTING VALUES FROM BREWERY B

The brewhouse was not good ventilated and from that way there would be accumulation of odour substances. It can affect results of course. The time range of olfactometric measurement is in table 11.

Table 11 - The time range of olfactometric measurement, brewery B

1.day	14:23 - 15:00
2.day	13:33 - 14:15

Olfactometric analysed results are in table 12.

Table 12 Overview of reached results from brewery B, sweet wort odour samples

B - Sweet wort				
Sample	**Odour unit OU_E/m^3 per bag**	**Odour unit OU_E/m^3 per measurement**	**Odour flowrate (OU_E/h^{-1})**	**Place of measurement**
BSL1/1	158	152	-	wort kettle
BSL1/2	146			
BSL2/1	invalid sample	98	-	
BSL2/2	98			

From the table is possible to see that the values from first day measurement are about one half higher than from the second day. It should by cause among other things than only time, but naturally the earlier time means different phases of brewing- mashing.

The final results for sweet wort are shown in table 13. The final result looks tolerable and expresses the average of evaluated data. The sampling and evaluating of odour can be easily affected as has been mentioned.

Table 13 – The average values of sweet wort odour from wort kettle

B - Sweet wort - Wort kettle			
Measurement	**Odour unit OU_E/m^3 per measurement**	**Odour unit OU_E/m^3 final result**	**Odour flowrate (OU_E/h^{-1}) final result**
1	152	125	-
2	98		

The smell of sweet wort was not seemed favourable during the sampling time inside the brewhouse. In contrast, this smell was the most pleasantness during olfactometer dilution.

The sampling during hops boiling after adding hops was done immediately in both days. Despite this accuracy the results are not similar. There could be other factors, for example exhaustion or adaptation on smell during olfactometric measurement.

The wort samples from brewery B are shown in table 14 and its average are written in table 15. There is possible to see, that the evaluating data rise with bag. From the first day of measurement it can be caused by perception of odour panel.

Table 14 - Overview of reached results from brewery B, wort samples

B - Wort				
Sample	**Odour unit OU_E/m^3 per bag**	**Odour unit OU_E/m^3 per measurement**	**Odour flowrate (OU_E/h^{-1})**	**Place of measurement**
BWW1/1	193	214	-	wort kettle
BWW1/2	238			
BWW2/1	327	327	-	
BWW2/2	invalid sample			

Table 15 - The average values of sweet wort odour from wort kettle

B - Wort - Wort kettle			
Measurement	**Odour unit OU_E/m^3 per measurement**	**Odour unit OU_E/m^3 final result**	**Odour flowrate (OU_E/h^{-1}) final result**
1	214	271	-
2	327		

In comparison of sweet wort and wort odour samples, the wort has two times higher odour intensity (table 16). This could confirm that the wort odour has two times intensively smell that the sweet wort odour.

Table 16 – Comparison of sweet wort odour with wort odour from wort kettle

Wort kettle		
Sweet wort	**:**	**wort**
125	:	271
1	:	2,1

5.3. RESULTING VALUES FROM BREWERY C

The samples from brewery C were collected only from chimney. For efficiency assessing of mechanical compressor were the wort odour sample collected from compressor chimney. Collecting from main chimney of wort kettle looks dangerous and it works only at the beginning of hops boiling. The time range of olfactometric measurement is in table 17.

Table 17 – The time range of olfactometric measurement, brewery C

1.day	13:20 - 14:20
2.day	12:25 - 13:30

There is a significant difference between first and second days (as the brewery B); results are in table 18. Due to measured flow rate is possible to see how the intensity of odour increasing with the velocity. Difference in values only confirmed as significant difference can be between two same measurements. The weakness of this sampling would be inaccuracy in sampling time (the sweet wort lautering run quite long time and the second day bags had been sampled at the end of lautering process).

Table 18 - Overview of reached results from brewery C, sweet wort odour samples

C - Sweet wort				
Sample	**Odour unit OU_E/m^3 per bag**	**Odour unit OU_E/m^3 per measurement**	**Odour flowrate (OU_E/h^{-1})**	**Place of measurement**
CSCH1/1	170	167	68040	chimney
CSCH1/2	163			
CSCH2/1	56	78	5400	
CSCH2/2	108			

The average values of sweet wort are in table 19.

Table 19 - The average values of sweet wort odour from lauter tun chimney, brewery C

C - Sweet wort - Chimney				
Measurement	Odour unit OU_E/m^3 per measurement	Odour unit OU_E/m^3 final result	Odour flowrate (OU_E/h^{-1})	Odour flowrate (OU_E/h^{-1}) final result
1	167	123	68040	36720
2	78		5400	

Although the ratio between odour intensity (OUE/m3) of the first and second measurement is approximately 2:1, the ratio of odour flow rate is approximately 13: 1. From this data is possible to do conclusion, that the odour intensity increasing with odour flow rate, but not proportional. The results of wort odour are in table 20.

Table 20 - Overview of reached results from brewery C, wort odour samples

C - Wort				
Sample	Odour unit OU_E/m^3 per bag	Odour unit OU_E/m^3 per measurement	Odour flowrate (OU_E/h^{-1})	Place of measurement
CWCH1/1	invalid sample	-	-	chimney
CWCH1/2	invalid sample			
BWCH2/1	157	157	10800,0	
BWCH2/2	invalid sample			

Results of the first measurement were under threshold of each assessor and there is only one value from the second day results (table 21).

The comparison between sweet wort and wort shows wort´s value 1,3 times higher. The odour flow rate is 3 times higher for sweet wort.

Table 21 - Comparison of sweet wort odour with wort odour from chimney

Chimney					
Sweet wort	:	wort	Sweet wort	:	wort
123	:	157	36720	:	10800
1	:	1,3	3,4	:	1

An important benefit of this measurement can be contrasted flow of odorous substances and sweet wort - wort, when the output from a mechanical compressor is greater than 2x wort fragrance. (For this reason, any technology aimed at reducing emissions of odorous substances during this phase).

5.4. COMPARISON OF BREWERIES

From outgoing results were found that the wort has two times intensive smell (odour) than the sweet wort. Surprisingly the smallest brewery (10hl) had higher value at chimney than 880hl brewery. It can show that the vapour compression works good. The comparison is in table 23.

Table 22 – Comparison between brewery A and B, sweet wort odour from wort kettle

Sweet wort - Brew house		
A	**:**	**B**
60	:	125
1	:	2

Difference between breweries is not much high as was expected.

The table 23 shows sweet wort odours ratios sampled from chimney in brewery A and C. The brewery A has 1,6 times higher result than brewery B.

Table 23 – Comparison between brewery A and C, sweet wort odour from chimney

Sweet wort - Chimney		
A	**:**	**C**
199	:	123
1,6	:	1

As it possible to see in table 24, the wort odour from chimney in comparison between brewery A and C is brewery A odour 1, 8 times higher than brewery C odour.

Table 24 – Comparison between brewery A and C, wort from chimney

Wort - Chimney		
A	**:**	**C**
284	:	157
1,8	:	1

Brewery odours are surprisingly different than was expected. Recalculation on odour unit per hectolitre does not have sense for the wort kettle size and its evaporating area. There have to be find relationship between evaporated area, diameter of chimney, maybe the length of chimney's tube and also brewery equipment. The next influences of evaporating could be the properties of the beer, which are defined in Hlaváč (2007) and the chemical properties specific for individual beer brand. This characteristic has origin in raw materials (malt, hops). Even Vera et. al. (2011) writes that the beer odour evaluation is very complicated, because the results depend on several volatile chemical compounds that belong to very heterogeneous groups as for example alcohols, esters, sulfur compounds, ketones, aldehydes, which present at very different concentrations. The results of Vera et. al. (2011) work show that the beer compounds differ from brands. For evaluating the volatile chemical compound the electronic nose based on coupling of headspace with a mass spectrometer were used. In case of this thesis, these observations of samples from different breweries have variable character and intensity from each other. For example brewery B brews the dark lager from 4 kinds of malt (in difference stage of drying and roasting) and 2 kinds of hops. It is very probable that this is the reason for high number of odour intensity. Other works focused on beer flavours measuring were used electronic nose (Pearce, 1993) and gas chromatography (Wang, 2006) for evaluation. Another comparison was not possible despite unavailable sources.

6. CONCLUSION

The results of this study allowed a comparison of the odour values sampling during various stages of brewing in various breweries of different sizes. The comparison has been done between samples gained from the breweries and compared in following ways: A – B and A - C. In comparison with brewery A, the values of odour emissions from the brewery B were significantly higher. The samples obtained from chimneys of the breweries A and C showed higher values, obtained from much smaller brewery A. The original hypothesis of increasing odour values of odour with expanding volume of brewhouse was surprisingly not to the correct one.

This theory and results introduced in the diploma thesis show that olfactometric method for the estimation of odour concentration in breweries shows another technique of sampling and evaluating than the standard ČSN EN 13 725. The sampling time of individual samples had to be adapted for the length of individual technological phases of brewing. Problematic part of the collection may be unavailability of odour samplings from the brewery chimney, especially because in the old breweries located in buildings of the centre of the historic town. Equally, it is not possible to sampling from nowadays brew house that operate on the principle in absence of atmospheric air.

Individual evaluation used an olfactometer measuring can be easily influenced by many factors. The evaluation also shows some problems that can only be eliminated by experienced and professional members. The perception of a sample can influence the length of individual breaths of each commission member (each human varies in different numbers of breaths per minute) and the predetermined length of the presentation of the sample and rinsing may not suit everyone. It is also very important to keep distance from the olfactometric mask and find suitable angle of the nose. Another factor affecting the functionality of olfactory cells can be the temperature of the sample, decisiveness and quick response of each respondent (sometimes it can take long time before the respondent realised that they actually feel the smell and it is late to press the YES button; or under influence of strong odour the odourless sample is pressed).

If is the odour measured is a good question to think about which method should bee chosen, because there are lots of methods of odour measuring. It is already known that the systematic annoying of smell may harm health. Good question for the future could be as smell affects plant and animal production (if poorly ventilated buildings affect the quality of milk and other products or by how many plant products from relatively clean areas have a better quality than industrial areas).

I classify myself as a longer lasting smell very unpleasant affair. I was born in a small town, where the dog foods are being produced; unfortunately the intensity of the odour is not too high and regular. I can not imagine that I must breathe this smell every day. The kind of the odour may also play an important role, but in this case the intensity and duration are important. Even the best flavour for a long time will begin to be annoying.

I find out the smell of brewing beer to be very pleasant. But there are also people who do not like beer, so it smells to them unpleasant. I studied in the city where the beer had been brewed every day within two years and at the end of the last year the smell from the brewery was very annoying for me.

With regard to the own opinion on olfactometer evaluation I have few reservations about it. I think the air velocity in the olfactory mask is quite high, and paralyzes the olfactory cells. Also break between steps (odourless sample) could be slightly longer in order to nose regenerate more. Each member of the group should have to press the yes button in the case if they feel a certain smell only, but from my own experience it happened to me that I did not push the button, because I realized too late, that actually I feel the odour. The method should be improved later.

For possible future measuring I would recommend to realise the sampling in two similar breweries and compare both plants together. And maybe then, compare those plants with another type of the same size of brewery and brew house equipment.

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8. LIST OF PICTURES

9. LIST OF TABLES

10. LIST OF APPENDICES

Appendix 1 – Vapour compression

Appendix 2 – Thermal compression

Appendix 3 - Sampling bags

Appendix 4 –Olfactometer T08

Appendix 5 – Sampling data

Appendix 6 – Olfactometric measurement

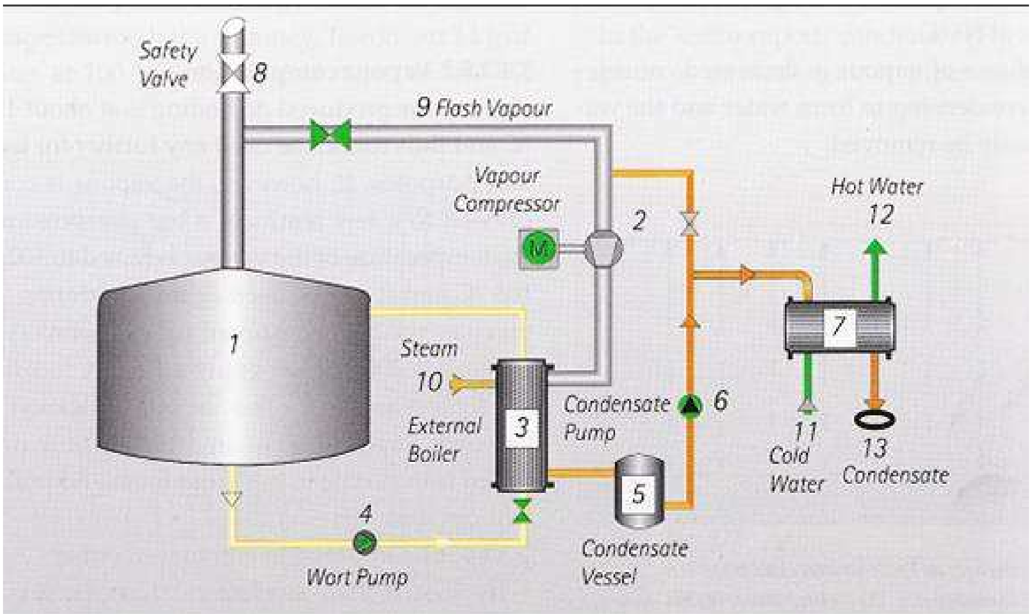
Appendix 7 – Sampling meteorological data during measuring

Appendix 8– Olfactometer data

Appendix 9 – All evaluated data

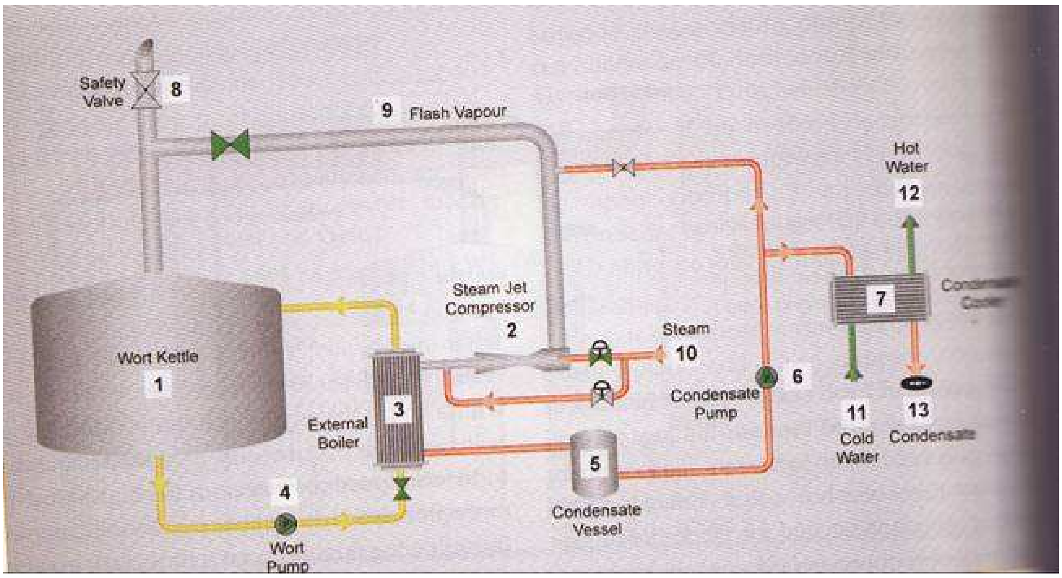
11. APPENDICES

Appendix 1 – Vapour compression



Source: Kunze, 2010

Appendix 2 – Thermal compression



Source: Kunze, 2010

Appendix 3 - Sampling bags

Source: http://www.odournet.com/instruments/sampling/sample-bags/

Appendix 4 –Olfactometer T08

Source: http://www.odournet.com/instruments/olfactometer/odournet-to-series/

Appendix 5 – Sampling data

Brewery A						
	1. day		2.day		3.day	
	the sweet wort	hops boiling	the sweet wort	hops boiling	the sweet wort	hops boiling
Time	*14:00 - 14:21*	*16:00 -16:26*	-	*15:32 - 15:54*	*14:22 - 14:55*	*15:32 - 16:12*
Pressure (hPa)	979,9 - 980,4		-	994,1 - 994,4	996,8 - 997,5	
Temperature (^oC)	21 - 22,3		-	9,0 - 9,5	14,2 - 15,4	
Relative humidity (%)	73,4 - 82,3		-	41,6 - 45,9	50,3 - 57,1	
air velocity (m/s)						

Brewery A						
	4.day					
	the sweet wort wort kettle	the sweet wort chimney	wort in wort kettle	wort in chimney	wort in chimney	-
Time	*12:40 - 12:55*	*13:04 - 13:20*	*14:38 - 14:55*	*15:37 - 15:59*	*16:03 - 16:10*	
Pressure (hPa)	981,7 - 981,8	981,4 - 981,7	980,8 - 981,3	980,2 - 980,6	980,2	
Temperature (^oC)	12,8 - 13,1	14,8 - 17,9	12,1 - 12,3	16,8 - 17,9	10,9 - 11,1	
Relative humidity (%)	98,9 - 100	72,7 - 89,3	97,7 - 98,2	81,5 - 89,3	98,5 - 99,0	

Brewery C					
	1. day		2.day		-
	the sweet wort	hops boiling	the sweet wort	hops boiling	
Time	*09:26 - 09:42*	*09:50 - 10:08*	*09:15 - 09:37*	*09:49 - 10:05*	
Pressure (hPa)	102,0 - 102,1		100,9 - 101,0		
Temperature (^oC)	7,2 - 9,4		6,8 - 11,6		
Relative humidity (%)	93,7 - 94,6		41,8 - 57,7		

Appendix 6 – Olfactometric measurement

Source : Klára Bortlová

Appendix 7 – Sampling meteorological data during measuring

Source : Klára Bortlová

Appendix 8– Olfactometer data

T08 by ECOMA GmbH — Measurement of odour threshold - yes/no — Software by SPS Productions
Version: 1.3.2.0

Measurement: 120320 Brewery B
Date: 20.3.2012 12:40:49
Sample: 120320 s11
Operator: Operator 1

$\overline{Z}_{ITE}$ = 208 OU/m3 (23,2 dB)

Panel members	Round 1	ΔZ	Round 2	ΔZ	Round 3	ΔZ
panel member 1	724	3,5	724	3,5	45	-4,6
panel member 4	724	3,5	362	1,7	724	3,5
panel member 1	362	1,7	181	-1,1	45	-4,6
panel member 2	362	1,7	45	-4,6	91	-2,3
panel member 3	5793	28,0	362	1,7	91	-2,3
panel member 4	181	-1,1	181	-1,1	91	-2,3

Panel members	Err. rel. air	Err. blanks
panel member 1	0	0
panel member 4	0	0
panel member 1	0	1
panel member 2	1	0
panel member 3	0	2
panel member 4	0	0

Generated comments:
panel member panel member 3 not calculated in measurement result (-5<z<5)

Appendix 9 – All evaluated data