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Odour emissions from the technological processes of coal extraction in Coal Mine Velenje

Emisije vonjav pri tehnoloških postopkih pridobivanja premoga v Premogovniku Velenje

Gregor Uranjek*, Simon Zavšek, Ivan Pohorec, Ludvik Golob
Velenje Coal Mine, Partizanska 78, 3320 Velenje, Slovenia
*Corresponding author. E-mail: gregor.uranjek@rlv.si

Abstract

Coal Mine Velenje with production of app 4 Mt of lignite per year is also emitting coal gases and various odours. Occasionally detected odours on the surface of the coal mine area and some of the nearby settlements may also result from the coal mine ventilation system and mined coal deposit on the surface.

In particular Ventilation station Pesje, which is located closer to Velenje, with its emissions represents an occasional locally recognized environmental problem.

On the one hand the legislation, which more and more sharpens and on the other hand the vision and corporate social responsibility dictates that the occurrence of odours Coal Mine Velenje undertakes thoroughly and fundamentally.

The objectives of this research are to develop and implement a robust odour emission monitoring system and collect the necessary data that are necessary to develop an understanding of formation and dispersion of odorous compounds at the process of underground coal excavation and surface coal deposition.

The research activities are divided in three main topics:

— Identification and evaluation of odour sources.
— Monitoring of odour emissions from sources on the surface (using chemical analysis and olfactomety).
— Design and implementation of odour dispersion model.

Key words: odours, coal mine, coal gases, odour dispersion modelling

Izvleček

Premogovnik Velenje s proizvodnjo pribl. 4 Mt lignita letno izpušča v ozračje premogovne pline in različne vonjave. Občasno zaznane neprijetne vonjave na površini pridobivalnega prostora in v nekaterih bližnjih naseljih so lahko tudi posledica prezračevanja podzemnih pridobivalnih prostorov premogovnika Velenje in deponiranja odkopanega premoga na površini. Predvsem ventilatorska postaja Pesje, ki se nahaja bližje Velenju, je s svojimi emisijami občasen lokalno prepoznaven okoljski problem. Po eni strani zakonodaja, ki se bolj in bolj zaostruje, po drugi pa vizija in družbena odgovornost podjetja zahtevajo, da se Premogovnik Velenje pojavljanja vonjav loti temeljito in temeljno.

Glavni cilji temeljnih raziskav področja emisij vonjav pri procesih pridobivanja in deponiranja premoga so pridobitev znanja in zajem podatkov, ki so potrebni za razumevanje pojavljanja vonjav v jami in na površini ter za razvoj in implementacijo merilnega nadzora vonjav za oceno vpliva na okolje.

Raziskave vonjav so razdeljena na tri glavna področja:

— Identifikacija in kvantifikacija virov vonjav (v jami in na površini),
— Merilni nadzor emisij vonjav na površini (z uporabo meritev, kemijske analize in olfaktometrije),
— Modeliranje disperzije vonjav za oceno okoljskega vpliva vonjav.

Kjučne besede: vonjave, premogovnik, premogovni plini, modeliranje disperzije vonjav

Introduction to the problem

The mixtures of gases, which are perceived as odours effect primarily on our olfactory and taste perception of the environment and in the case of unpleasant odours, have a disturbing effect. Despite the fact that odours are usually not toxic (individual toxic gases usually have much lower odour detection threshold (range 10^{-9}) than the mandatory limit values, can significantly affect on quality of life of the surrounding population.

Occasionally detected odours on the surface area of Coal Mine Velenje (CMV) impact and in the nearest settlements are primarily the result of mine ventilation (two surface ventilation stations Pesje and Šoštanj, with total continuous airflow between 21 000 m^3/min and 25 000 m^3/min) and of coal stockpile on the surface (capacity of stockpile is varies between 50 000 t and 800 000 t). Unpleasant odours are to present knowledge the result of detected presence of volatile sulphur compounds (VSC). Emitted VSC are formed and captured between the coal formation processes and are mainly released at the excavation process and other processes of coal crushing, transportation and deposing. VSC are also formed in the mine and the stockpile because of sulphur presence in the coal.

Presence of VSC is detected with gas concentration measurements with gas chromatography and electrochemical sensors from mine air and emission from stockpile samples. With mandatory monthly measurements are controlled known $(CH_3)_2S$ (DMS), H_2S and SO_2. With previous research measurements on the stockpile were also detected COS and CS_2.

Measurements of VSC are particularly exposing DMS concentrations which is countinouosly detected at concentration of more than 1×10^{-6} in air exiting roadways. The odour tresholds of detected VSC (mine and surface) are[1]: SO_2 0.87×10^{-6}; COS 0.055×10^{-6}, CS_2 0.21×10^{-6}; H_2S $0.000\,41 \times 10^{-6}$; DMS 0.003×10^{-6}.

In analysed one year period from August 2010 to July 2011 the DMS in the air exiting ventilation shafts was detected always except in Pesje pit in August 2010 and in January 2011. The average DMS concentration in Pesje pit was 15.8×10^{-6} and in Preloge pit was 8.5×10^{-6}. Gases H_2S and SO_2 are not detected ($<1 \times 10^{-6}$) in period from August 2010 to July 2011 what is expected under normal operating conditions[2]. Coal stockpile measurements identified DMS, COS, CS_2. The estimated daily emissions of COS and CS_2 for the whole stockpile in the sampling period were 20 g CS_2 and 70 g COS (gas concentration was in range 10^{-9}). The DMS concentrations fell to less than 1×10^{-6} in a few days due to the releasing from freshly loaded coal[3].

The objectives of this research are to develop and implement a robust odour emission monitoring system and collect the necessary data and develop an understanding of formation, dispersion and environmental impact of odorous compounds in the process of underground coal excavation and surface coal deposition.

The research activities are divided in three main topics:

1. Identification and evaluation of odour sources.
2. Monitoring of odour emissions from sources on the surface (using chemical analysis and olfactomety).
3. Design and implementation of odour dispersion modelling to assess environmental impacts due to the emissions of underground coal excavation and surface coal deposition.

Odour perception and measurement

Odour perception

Olfaction, the sense of smell, is the most complex and unique in structure and organization and also the least understood of the five senses. While human olfaction supplies 80 % of flavour sensations during eating, the olfactory system plays a major role as a defense mechanism by creating a natural aversion response to malodours and irritants. Human olfaction is a protective sense, protecting from tainted food and matter, such as rotting vegetables, putrefying meat, and faecal matter. This is accomplished with two main nerves. The olfactory nerve (first cranial nerve) processes the perception of chemical odourants. The trigeminal nerve (fifth cranial nerve) processes the irritation or pungency of chemicals, which may or may not be odourants[4].

As perceived by humans, odours have five basic properties that can be quantified[4]: 1. intensity, 2. degree of offensiveness, 3. character, 4. frequency, and 5. duration. All of which contribute to the neighbour's attitude towards the odour as well as the business generating the odour.

Odour is measurable using scientific methods. Odour testing has evolved over time with changes in terminology, methods, and instrumentation. Odour terminology is linked to standard methods and the instrumentation used in these standard methods. A clear understanding of odour terminology is needed in order to discuss the uses of odour measurements[5].

The objective parameters of perceived odour are[5]:

- Odour Concentration – measured as dilution ratios and reported as detection threshold or recognition thresholds or as dilution-to-threshold (D/T) and sometimes assigned the pseudo-dimension of odour units per cubic meter.
- Odour Intensity – reported as equivalent butanol concentration in 10^{-6}, using a referencing scale of discrete butanol concentrations.
- Odour Persistence – reported as the dose-response function, a relationship of odour concentration and odour intensity.
- Odour Character Descriptors – what the odour smells like using categorical scales and real exemplars (e.g. fruity → citrus → lemon: from a real lemon).

These odour parameters are objective because they are measured using techniques or referencing scales dealing with facts without distortion by personal feelings or prejudices.

Additional measurable, but subjective, parameters of perceived odour are[5]:

- Hedonic Tone – pleasantness vs. unpleasantness.
- Annoyance – interference with comfortable enjoyment of life and property.
- Objectionable – causes a person to avoid or causes physiological effects.
- Strength – word scales like "faint to strong".

These odour parameters are subjective because individuals relying on their interpretation of word scales and relying on their personal feelings, beliefs, memories, experiences, and prejudices to report them[5].

The most common odour parameter determined by odour testing is odour concentration. The characteristic odour concentrations are called "odour tresholds". Odour tresholds are minimal detectable concentrations at specific odour characteristics (detection or recognition). They are usually reported as odour units (OU), defined as the volume of dilution (non-odorous) air divided by the volume of odorous sample air at either detection or recognition. Most often, odour threshold is used to mean detection threshold (DT), which identifies the concentration at which 50 % of a human panel can identify the presence of an odour or odourant without characterizing the stimulus. Detection threshold is the term most frequently used when discussing odour research. The recognition threshold (RT) is the concentration at which 50 % of the human panel can identify the odourant or odour, such as the smell of ammonia or peppermint[1].

Odour measurement methods

Odour is elicited by chemicals in a gas phase which are detected via olfaction producing recognizable smells (cinnamon, lemon) and/or chemesthesis which mediates pungent sensations (tingling, burning, etc) in response to substances such as ammonia[4].

There are a number of factors which affect odour including the volatile compounds themselves, the number of olfactory receptors available to bind them, the degree to which the compounds become solvated for receptor binding, temperature, humidity, and the matrix in which the odour-producing chemicals are embedded. In addition, individual chemicals may interact (chemically). Odours vary in threshold, intensity and hedonic tone[5].

Of particular importance has been the characterization and measurement of key potent odourants responsible for the unpleasant odour associated with specific process. Furthermore, each odourant has a unique odour and odour detection threshold which means that compounds, even if present at the same concentration, may have markedly different odour impacts[6].

Monitoring odours can be accomplished with analytical "chemical" techniques and sensory methods[6]:

Analytical techniques:

- *Chemical analysis* – indirect assessment involving the collection of a sample which, when analysed, will give the concentration of the various chemical species present. This includes wet chemistry, as well as sample collection followed by instrumental analysis by means such as gas chromatography (GC).
- Direct reading instrumental analysis – provides information on the concentration of specific chemical species or their concentrations relative to each other. This includes portable analysers (including portable GCs and GC-MS) and the "electronic nose", as well as colorimetric tubes.

Sensory methods (relating to human response):

- *Olfactometry – a sensory assessment* – which gives an assessment of the physiological response to a particular mixture – strength, quality, characteristics – which provides information on the likely population response. This is obtained by exposing trained individuals to samples of the odorous air, either in the laboratory or in the field.

These are many division of categories for odour measurements techniques and some techniques could fall into more than one. There are a number of different methodologies in use for odour analysis. Selection of a particular method will depend upon: the purpose of the measurement; the frequency of monitoring (once-off, periodic, continous); the location at which the odour is sampled; whether a point source or area (surface) source; the nature and complexity of the emission - a single compound or a complex mixture[6].

Olfactometry measurements (dynamic olfactometry)

Olfactometry uses trained individuals and standardized procedures to measure odour levels. The main advantage of olfactometry is the direct correlation with odour and its use of the human sensitive sense of smell. Olfactometry also has the advantage that it analyses the complete gas mixture so the contribution of each compound is included[7].

Odours are a combination of gases—some in nearly undetectable concentrations. The human nose can sense these gases and gas combinations at extremely low levels. No instrument can match the sensitivity of the human nose. Several techniques have been employed to assist the human nose in determining detection threshold and intensity. The most popular method of odour measurement uses an instrument called the dynamic olfactometer and an odour panel[7].

Olfactometer (dynamic olfactometry) presents three air streams to the trained panellists (standards). One air stream is a mixture of non-odourous air and an extremely small amount of odourous air from a sample. The other two air streams have only non-odourous air. Panelists sniff each air stream and are asked to identify which air stream is different than the other two non-odourous air streams. Initially panelists must guess which air stream is different, because the amount of odourous air added is below the detection threshold[7].

In steps, the amount of odourous air added to one of the air streams is doubled until the panelist correctly detects which air stream is different. The air stream with the odour is randomly changed each time. Figure 1 illustrates the olfactometry measurement process.

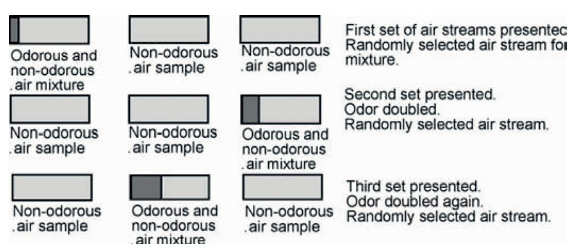

Figure 1: *Olfactometer dilution sequence of sample*[7].

The detection threshold is the non-odorous airflow rate divided by the odorous airflow rate when the panelist correctly recognizes which air stream is different. A panel of eight trained people is significant enough to analyze each odor sample. The panel's average concentration is reported and used for analysis[7]. This statistical approach is called triangular forced-choice method (also EN 13725:2003: Air Quality – Determination of Odour Concentration by Dynamic Olfactometry).

Olfactometers (Figure 2) are not portable and an operator closely controls sample delivery. The dilutionto-threshold ranges are available to be presented at 14 dilutions that represent a range in dilution-to-threshold of 8 to 66.667 (AC'SCENT olfactometer). These units are often used in a laboratory setting by 7 to 10 panelists.

Figure 2: *The AC'SCENT ® International Olfactometer was designed specifically to meet all requirements of the CEN odor testing standard, EN 13725:2003 and ASTM International E679-04.*

Odorous emissions from the processes of underground coal excavation and surface coal deposition

The objectives of this research are to develop and implement a robust odour emission monitoring system and collect the necessary data and develop an understanding of formation, dispersion and environmental impact of odorous compounds in the process of underground coal excavation and surface coal deposition.

Identification and quantification of odour sources

With processes of underground coal excavation the coal gases from coal seam are released on the working sites and instantly diluted with airflow formed by mine ventilation system (two ventilation stations). With mine ventilation system the diluted coal gases are emitted to the surface. In addition from excavation working sites (longwall and roadbuilding) the coal gases are also released (releasing characteristics are different for single gas species) from the coal transportation system (conveyer system is transporting coal on the surface).

Gases are also released from crushed coal on the stockpile (capacity 50 000–800 000 t). On the stockpile excavated coal is daily loaded/unloaded regarding coal production of CMV (10 000–25 000 t/d) and coal consumption of Power plant Šoštanj (up to 15 000 t/d). The stockpile is not covered and is fully exposed to the weather conditions.

The major potential odorous sources detected by humans in the mine and on the surface are to the present knowledge volatile sulphur compounds (VSC) which were detected in the mine and on the surface.

The origin of VSC is coal seam (formated and caught between coal formation) and possible formation of new VSC and transformation of VSC from coal seam, respectively. The released VSC from the coal seam and coal with 1.7 % of sulphur on average[8] are immediately after excavation exposed to the mine air and later atmospheric condition on the coal stockpile. Due to the reactivity and solubility of VSC formation and transformation is possible.

On the CMW (mine atmosphere) gas concentrations are monitored continuously (CH_4, CO_2, CO) with network of gas sensors or periodically (CH_4, CO_2, $(CH_3)_2S$ (DMS), H_2S, O_2, CO, H_2, NO, NO_2, SO_2) with analytical tests by gas chromatography (FID and FPD) and electrochemical sensors in the laboratories.

Measurements of VSC are particularly exposing DMS concentrations. The analysis of gas concentrations of one year periode from August 2010 to July 2011[2] has highlighted DMS concentrations. In air exiting ventilation shafts the DMS was detected always except in Pesje pit in August 2010 and in January 2011. The average DMS concentration in Pesje pit was 15.8×10^{-6} and in Preloge pit was 8.5×10^{-6}. The DMS concentrations up to 10×10^{-6} were periodically detected in air exiting roadway from the main transporation system. Gases H_2S and SO_2 are not detected ($<1 \times 10^{-6}$) in period from August 2010 to July 2011 what is expected under normal operating conditions.

Coal stockpile concentration measurements in 2003 identified DMS, COS and CS_2. The estimated daily emissions of COS and CS_2 for the whole stockpile in the sampling period were 20 g of CS_2 and 70 g of COS (gas concentration was in range 10^{-9}). The DMS concentrations fell to less than 1×10^{-6} in a few days due to the releasing from freshly loaded coal[3].

According to above listed, two ventilation stations (exiting mine air) are presenting point odour sources and coal stockpile is presenting area odour source on the surface of CMV excavation area (Figure 3).

The presented odour sources potentionaly effect few tens of kilometers of underground roadways and on the surface more than 10 km^2 of CMW area and some of nearby settlements. That means very large and diverse environment that's needs understanding regarding potential odorous environmental effect.

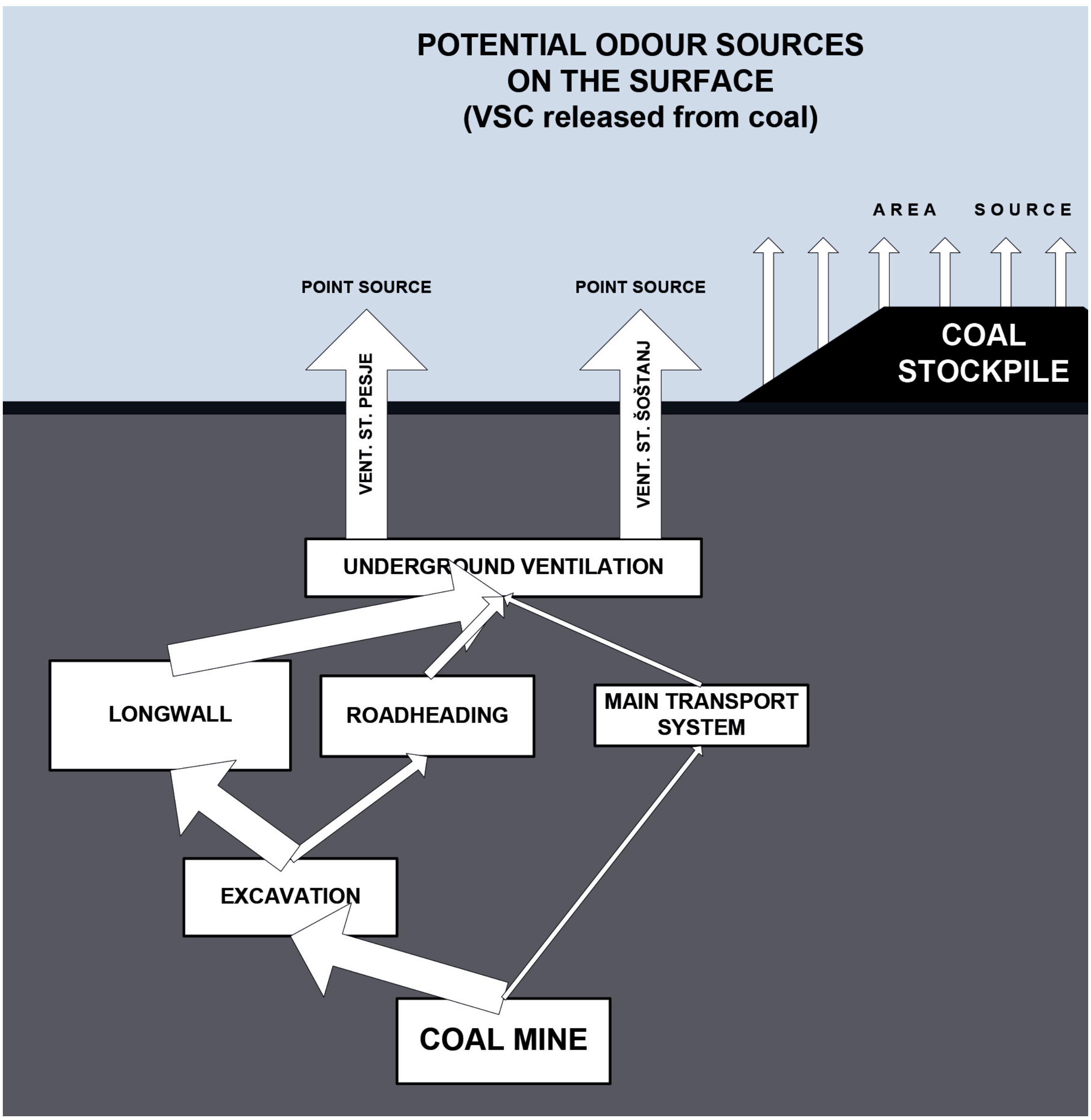

Figure 3: *Schematic presentation of odour sources in CMV.*

The main objectives of identification and quantification of odour sources are (Figure 4):

- Identification of odorous compound in the mine air and on the surface.
- Developing the understandment of main influences on the odour intensity and the correlations between the specific influences in the mine and on the surface.
- Evaluation of odour sources.

Better understanding of VSC presence in mine air is fundamental. The study and analysis of factors that are responsible for the presence (mine and surface) and amount of released individual VSC and correlations between factors are necessary (Figure 4).

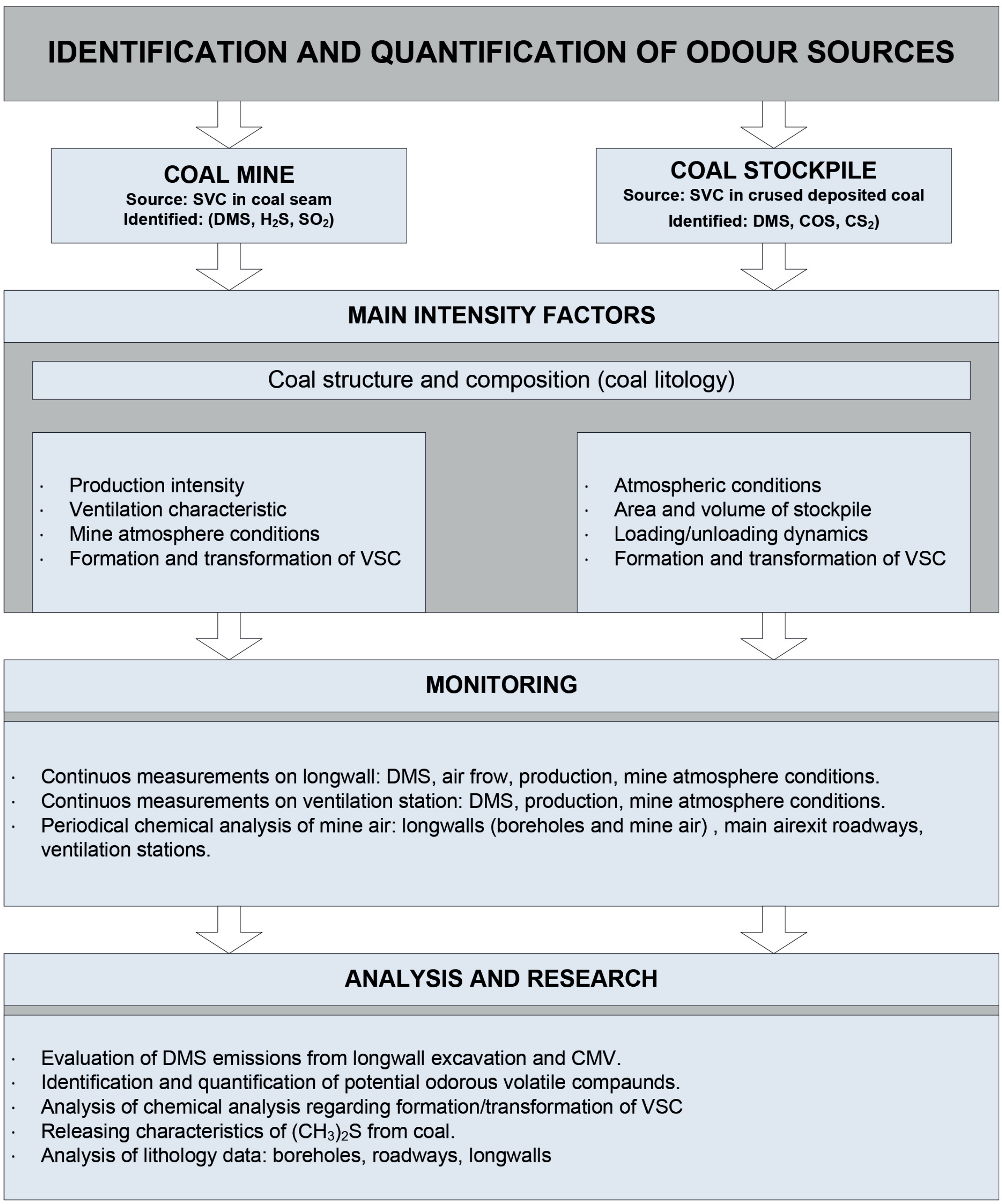

Figure 4: *Main activities of identification and quantification of odour sources.*

From the time of excavation and during transport coal is in contact with mine air. Also coal seam in excavation (longwall or roadbuilding sites) is in constant contact with mine air. Due to the known reactivity of fresh coal and reactivity and solubility of sulphur compounds atmospheric condition the formation and transformation of VSC are possible, respectively[9].

Many studies of Velenje lignite (geo-mechanical, structural geology, coal petrology, isotopic geochemistry, etc) revealed that knowledge about petrographic heterogeneity of lignite is crucial to understand complexity of gas properties and gas behaviour in the course of the mining within the lignite seam of CMV. For example, amounts of from-lignite-released gases depend on petro-chemical characteristics of coal and of technology of advancement and of lignite excavation[8].

Monitoring of odour emissions

On the large CMV area are recognized three main potentional odour sources of two different source types: 2 point sources (ventilation stations) and area source (coal stockpile).

The two types of sources have very different emitting characteristics. The ventilation stations are emitting mine air with known quite constant airflow quantity and gas composition that varies because the "underground influences". However, with the continuous monitoring of airflow and gas composition the averaged emission rates (gas emissions [g/h], odour emissions [OU/h]) can be quite easily estimated. On the other hand, the estimation of emission rates of the emitted odorous volatile compounds by diffusion is very complex due to the constant varying of great number of influences, mainly of releasing characteristics of captured in the coal or later formed volatile compounds, area/volume of stockpile, loading/unloading dynamics and coal manipulation on stockpile, cracks on the stockpile surface, atmospheric conditions, etc... Different emission types demand different sampling technics.

In addition, the large monitoring area demands the optimization of sampling locations that will realistically present odorous emission and odour imissions is very complex.

For odour field monitoring is often used standardized "grid method" according to VDI 3940: Measurement of odour impact by field inspection[10, 11]. Downside of this minimum six months lasting method is that a lot of man and equipment resources is needed for systematically inspection of area devided of squares (ussualy 250 m × 250 m[11]). In case impact evaluation of an anaerobic digestion plant[10] for inspection of approximate area 2 km × 1 km 16 a group panellist was recruted (selected according to EN 13725) and trained to recognise the typical plant emission odours.

The realistic presentation odorous emission and odour imission is also possible with specific characteristic sampling locations when you have good understandment of local weather.

Prior to odour and gas concerations monitoring the analysis of meteorologic data is necessary for detailed understendment of atmospheric characteristic of VCM wider area in all seasons of the year. The analysis and the specifics regarding odour dispersion will help to optimize the sampling location and number of samples.

Dispersion of odours is mainly impacted by topography around the odour source and atmospheric condition.

Differences between traditional dispersion modelling and odour modelling appear in at least three areas: at the source, at the receptor (the nose) and en-route from the source of the odours to the receptor. When conducting odour dispersion modelling, some features that odour sources are different from sources of industrial pollutants have to be taken into account. According to previous researchers, these features may include[12]:

- The odour source is at or near ground level.
- There is insignificant plume rise due to the vertical momentum or lower density of a mass flow of warm gas.
- The source may be of relatively large areal extent.
- The important receptor zone may be relatively close to the source of emissions.
- The difficulty in measuring the odour emission rate.
- The spatial and temporal variability in emission rates.
- The relatively low intensity of emissions.

Usually the at odour monitoring in addition of atmospheric condition the odour concentration and odour intensity are measured for later impact assessment with odour modelling.
In the case of CMW for monitoring of odourous emissions and odour imissions the simultaneous gas concetrations and odour measurement are necessary. With simultaneous measurements the odour compounds/odour data with same base and conditions are acquired which are essential for correlations research between VSC concentrations and odour concentration of ambient air.

From the results of the measured gas concentration data (DMS is only VSC continuously detected at concentrations more than 1×10^{-6}) and from expirence can be assumed that in most situations the individual VSC is only or major infuence odorous compound of detected odour.
The odour matrix of odorous emissions and odour imission from CMV is expected to be far less complexed than at livestock operation regarding of number of odouros compounds. At manure decomposition is produced between

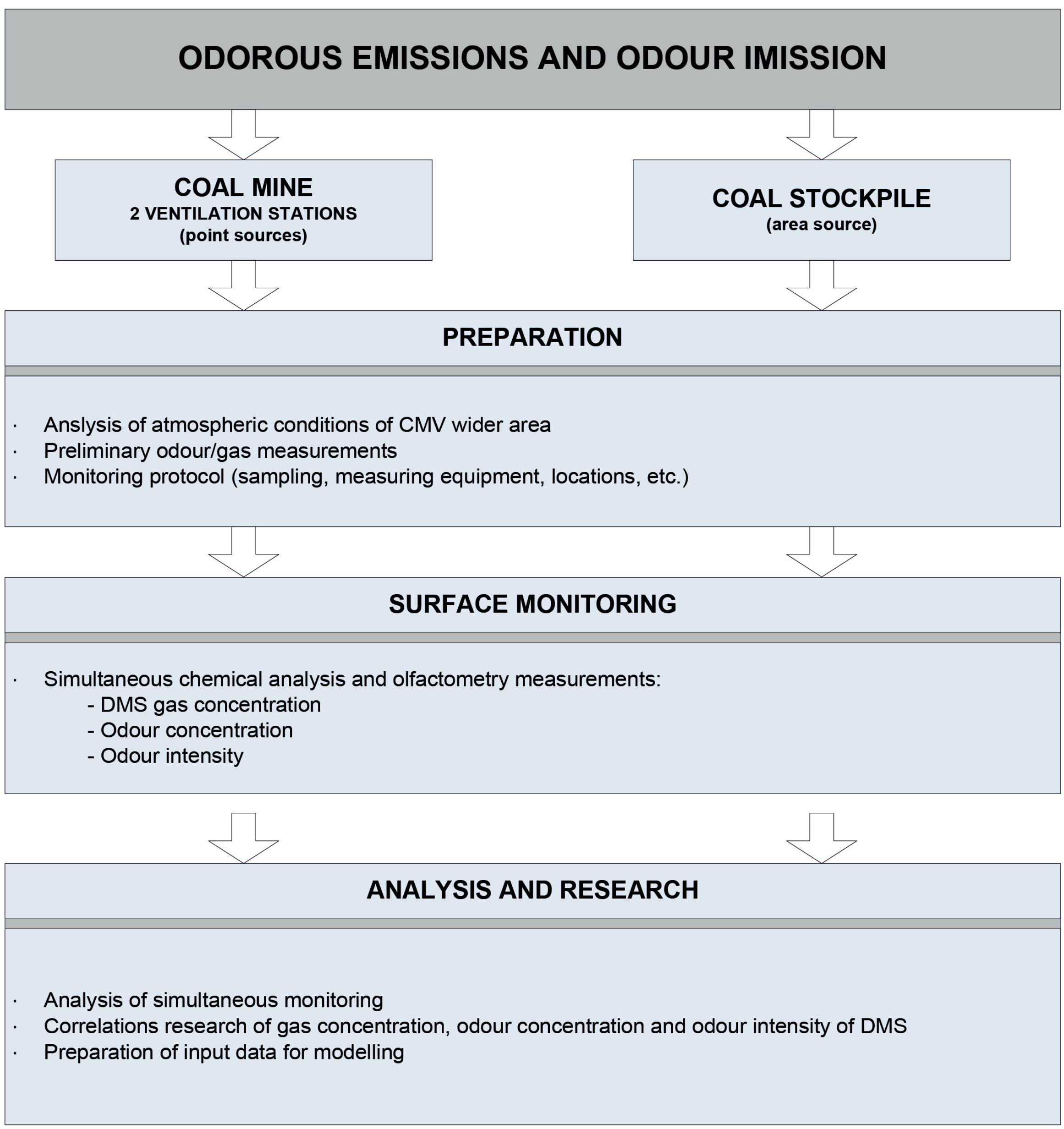

Figure 5: *Main activities of monitoring of odour emissions.*

80 and 200 odouros compounds; 168 have been identified in swine manure[7].

In case of CMV is assumed that major odorous compound is DMS. Therefore the DMS gas/odour interdependence can be potentionally essential base for odour modelling regarding control and validation with DMS dispersion modelling (traditional dispersion modelling) and for odour/DMS monitoring network design based on DMS sensor and enoses, respectively.

The monitoring of odorous emissions part will be focused on (Figure 5):

— Analysis of atmospheric conditions VCM wider area.
— Simultaneous measurements of gas concentration, odour concentration and odour intensity.
— Analysis of simultaneous monitoring.
— Correlations research of gas concentration, odour concentration and odour intensity of DMS.

Design and implementation of odour dispersion model

Dispersion modelling offers means to assess the way in which specific sources influenced by environment are having impact on the same environment.

After odours sources are identified and quantified and impacts of significant influencing factors on the releasing and formation of odorous compounds are known the revealed data are base for odour modelling.

For the assessment of odour impact also the gas concentrations modelling can be aplied, especially if odorous compounds are indentified and quantified. If the correlations between odour concentration and gas concentration of specific species (for example DMS) is known the gas modelling is equivalent and can used for control and validation, respectively.

The modelling of odour emissions and their dispersions will be divided in to two areas: mine and surface.

For the study of influences on mine odour sources the mine ventilation design software will be applied. The test model will be designed in Ventsim Visual. Ventsim Visual is mine ventilation design software with main feature as 3D graphic, simulate paths and concentrations of smoke, dust, or gas for planning or emergency situations, short term and long term planning of ventilation, simulation of gas and aerosol, etc[13]. For this study will be designed simplified test model (regarding to CMV roadway system) to evaluate sources from the longwall working sites and dispersions with airflow in the airexiting roadways and further dispersions all the way to the surface. The simplified model is more appropriate regarding specific correlations study. With the Ventsim Visual the main focus will be dispersion study of gas concentrations

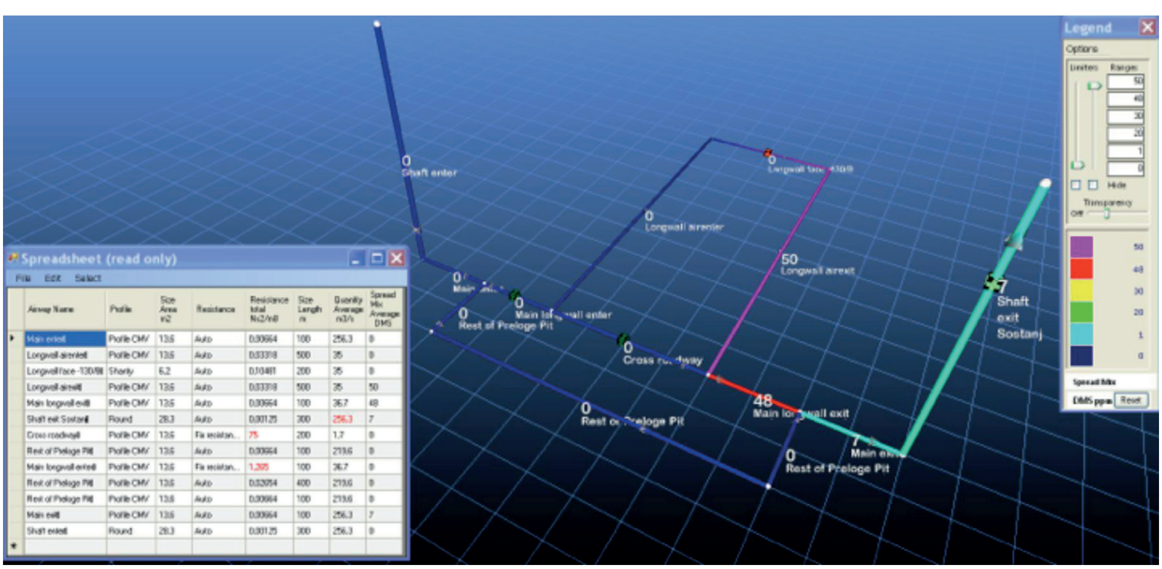

Figure 6: *Example of DMS dispersion modelling for longwall face.*

(no odour option in the software) of specific gas species under the influences of ventilation design and ventilation parameters. Because the dispersion of specific gas compound and odour (odour units – OU/m^3 are actually number of dilutions) in the same environment is similar the dilutions specific gas compound and dilutions of odours are comparable.

The modelling of odour impact on the surface is much more complex process mainly because of the modelling of atmospheric conditions of the wider researched area and because of the challenging quantification of odour sources (especially emission rate of area source – coal stockpile). Accuracy of odour impact assessment is mostly dependent of precision of atmospheric model and precision of odorous sources quantification.

The focus will be on design and implementation of odour dispersion model to assess surface environmental impact due to the emissions of process of underground coal excavation and surface coal deposition. The odour dispersion model will be then tool for study for specific influence factors of atmospheric conditions on the emission rate of odour sources and emission rate of specific odorous compounds.

For the design of odour dispersion model it will be necessary to use the software that is capable of mathematical simulation of atmospheric dispersion and air pollutant dispersion. The CALPUFF modelling system is also used for environmental impact assessment of SO_2, NO_2 and PM_{10} from emission of Thermal Power Plant Šoštanj (www.okolje.info).

CALPUFF has been accepted by the U. S. EPA as a preferred model for regulatory applications from 2003. It consists of three main components: CALMET, CALPUFF and CALPOST. CALMET is a meteorological processor that develops hourly wind and temperature fields in the three-dimensional gridded modelling domain; CALPUFF is a transport and dispersion processor that simulates dispersion and transformation processes of pollutant(s) along the dispersion way; CALPOST is a postprocessor used to process the files from CALPUFF to produce a summary of the simulation results[14].

CALPUFF is a Lagrangian puff dispersion model that is able to simulate the effects of complex meteorological condition in the process of pollutant transport. This model can handle emissions from any types of sources including point, line, area, and volume sources. It could be driven by either complicated three-dimensional meteorological data provided by CALMET for a full run or simple meteorological data from a single weather station.

Conclusions

The presented research plan addresses the problem of occasionally odour pollution of CMV underground coal excavation impact wider area. As the main surface odour sources are recognized: ventilator stations Pesje and Šoštanj and coal stockpile.

The ventilation stations (two point odour sources) are emitting between 21 000 m^3/min and 25 000 m^3/min of mine air. The concentrations of mine gases are time varying (in case of odours, concentrations of VSC) and are mainly dependent of coal seam composition and of technological, vetilation and mine atmosphere parameters.

The coal stockpile is an area odour source with varying in size (area and volume) and varying composition and releasing characteristics of deposited coal.

Gas concentrations measurements in the mine are particularly exposing DMS concetrations that are continuously detected at odour supratreshold concentrations in airexiting underground roadways. The DMS odour detection treshold is 0.003×10^{-6} and the monitored DMS concentrations are $>1 \times 10^{-6}$.

The emitting point and area odour sources are dispersed according to the atmospheric conditions (also diffusion in calm conditions).

Due to the size and versatility of impact area, the range of influences, varying conditions and the odour science the research plan is divided in three main topics:

1. Identification and evaluation of odour sources;
2. Monitoring of odour emissions from sources on the surface (using simultaneous chemical analysis and olfactomety);
3. Design and implementation of odour dispersion modelling to assess environmental im-

pacts due to the emissions of underground coal excavation and surface coal deposition.

The topics follow the logical sequence of odorous compounds identification, quantifications of odour sources emission rates and development of odour dispersion models for development of an understanding of formation, dispersion and environmental impact of odorous compounds for implementation of technical measures to reduce odour impact and odour monitoring system.

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