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Quantitative analyses of biogas plant accidents in Europe

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ABSTRACT

Rapid grow of biogas stations numbers across the Europe could be seen in recent past. This is also associated with an increase in the absolute number of operational accidents. In the opinion of experts who deal with safety engineering in the field of bioenergy installations, the number of accidents on biogas stations is growing faster than energy production from these stations. The aim of this paper is to open a discussion about interpretation and uncertainty of quantitative accidents assessment. For this purpose, 208 accidents of biogas stations were collected across Europe from 2006 to 2016. These data were statistically analysed.

An integral part of the work is also the calculation of event frequencies for selected scenarios, which in the future can facilitate the decision making of risk experts in similar installations. The work also addresses issues related to the reduction of the risk level in the biogas station operations.

1. Introduction

The share of renewable energy in EU has increased to 13% in 2012 as a proportion of final energy consumed and is expected to rise further to 21% in 2020 and 24% in 2030. Biogas productions is one of many sources of renewable energy. Biogas is produced in anaerobic biological process which can be used in many different fields. Most common is utilization of energy crops for biogas production [1]. Anaerobic biological process can be used for sewage sludge stabilization at waste water treatment plan. Production of biomethane from different biomass seems to be perspective [2]. The heat produced during biogas utilization is also task with growing importance. This heat can be used for central heating systems, cooling, drying, greenhouses heating etc. [3]. All these applications of biogas technology may pose a threat of accident. The increase in the number of accidents in the biogas stations operations started according to experts (especially German) at the turn of the 21st century. As a result, the German Commission for Facility Safety (KAS) decided to focus its controls on biogas stations. Over the years 2001–2006, the KAS carried out a total of 115 inspections [4]. Approximately from 2010, the number of scientific papers aimed to the biogas stations accidents topic, began to increase. The researchers started to deal with this issue more in detail. This topic is also steadily presented at conferences dealing with facility and operational safety. The work of British authors Jenkins et al. [5], summarize the dangers that threaten the operation of biogas stations and also give examples of accidents with fatal consequences, can be classified as professional literature. An interesting work in this area is also the work of Heezen et al. [6]. The authors deal with the classification of substances according to the relevant legal norms existing at the biogas station and also with the problems of large scale biogas stations covered by the SEVESO directive. In the field of scientific research concerning biogas stations and other biomass processing plants, a group of Italian authors is particularly active. For example, Moreno et al. deals with the identification of hazards in plants that produce energy from biomass [7,8]. Moreno et al. [10] notes the increasing number of accidents in this area compared to the increase in energy production. American author Seay et al. [9] notes in his work that in the US, unlike in Europe, the absolute number of accidents, which have occurred in the bioenergy sector, is decreasing. This fact is attributed to the data which confirms that, after the economic crisis, the US divert from renewable energy production and retreated towards the

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production of fossil fuel energy. The trend in Europe was exactly the opposite. However, trends are not quantitatively evaluated in the work.

Perhaps the most complex paper dealing with biogas stations accidents is currently the work of Moreno et al. [10]. The paper clearly shows a higher increase in accidents at biogas stations than the increase in energy production from biogas stations. Moreno et al. [10] also deal with the risk assessment of biogas stations and the protection of biogas station workers. The papers aimed to health and safety tools as well as direct worker protection was written by Pietrangeli et al. [11] and also by Saracino et al. [12]. Risk assessment of biogas stations is described in paper published by Scarponi et al. [13].

In the majority of papers dealing with biogas plants accidents, the growing trend in the number of accidents in this field is highlighted. However, data are often not statistically evaluated. The objective of this work is to carry out quantitative analysis of data related to biogas plants accidents and to compare results with other authors. The aim this work is to finding the answer to question "What is the trend of biogas plant accident?" with utilization of statistical tools. The next aim of this paper is to stimulate a discussion on the safety of biogas stations.

2. Material and methods

Data collection was conducted for the period from 2006 to 2016. In total, 208 accidents from different European countries were included in the database. Following countries were involved: Germany, Czech Republic, Austria, Lithuania, Switzerland, Great Britain, France, Italy and Luxembourg. Method for gathering data was similar to work Moreno et al. [10]. Data collection was supplied from several sources. These were primarily scientific papers, expert articles, articles from scientific conferences, and databases such as ARIA [14], eMARS [15], ZEMA [16]. In addition, information from newspaper articles were used. The internet search engines have been given text strings of the type "biogas" and logical operator AND related to the type of accident such as "explosion", "fire", "leakage to the environment", etc. The input text strings have been translated into several languages, such as English, Italian, French and German. The database was divided into several columns indicating: Order, year of crash, month, day, time, state, locality, number of fatal, heavy and light injuries, property damage, event type and cause of the event.

Severe injury was defined as an injury requiring long-term hospitalisation. Light injury was defined as an injury only requiring home care or short-term hospitalisation (for example for observation, examination for exclusion of severe internal injury etc.).

Statistical analysis was performed using software tools Statistica 12 (StatSoft, USA) and software R (Open Source, v. 3.3.2). All hypotheses were tested at a significance level $\alpha = 0.05$. Confidence interval of relative frequencies for various type of accidents was calculated by binomial test with utilization of software R. Exploratory data analysis, correlation analysis, power test analysis were carried out with the help of software Statistica 12.

3. Results and discussion

The figure below shows the percentages of accidents number in individual countries within Europe. The category "Others" represents following countries: Great Britain (3 accidents, 1.4% share), Italy (3 accidents, 1.4% share), Latvia (1 accident, 0.5% share), Luxembourg (1 accident, 0.5% share). As can be seen from Fig. 1, Germany ranks first in the number of incidents (76% of the monitored accidents in total amount). This situation is due to the fact that more than half of biogas stations in Europe are currently located in Germany. Moreno et al. [10] stated, that Germany also occupies the first place with the same share, i.e. 76%. This share was calculated from the number of 169 accidents at biogas stations, which occurred around the whole world. In category "Others" were mostly calculated accidents which occurred outside Europe in work by Moreno et al. [10]. When this category is removed, the proportion of accidents in Germany would increase in this work up to 80%. For comparison, the value of 80% presented in the paper by Moreno et al. [10] is lies within a confidence interval (72%–82%) calculated for the rated data. Both comparisons are therefore consistent at the significance level $\alpha = 0.05$. Data consistency was also recorded for France (p-value = 0.319) and Great Britain (p-value = 0.8). Inconsistent results were shown in case of Italy (p-value = 0.003). The reason is the low number of records in the case of the submitted paper (3 records in total), than in the case of work by Moreno et al. [10] (11 records in total). The difference between these numbers can be caused by several reasons: higher number of accidents in the past (unlikely, the number of biogas stations grow steeply in the last ten years), or the fact that Italy is the home of authors, it follows a higher data collection success rate in their native environment. The advantage of the home environment in finding accident records and the unavailability of accidents information in some countries with low numbers of biogas stations can distort the probability distribution of accident occurrences in individual countries. For this reason it is not possible to compare the number of accidents to the number of biogas stations in a given country and

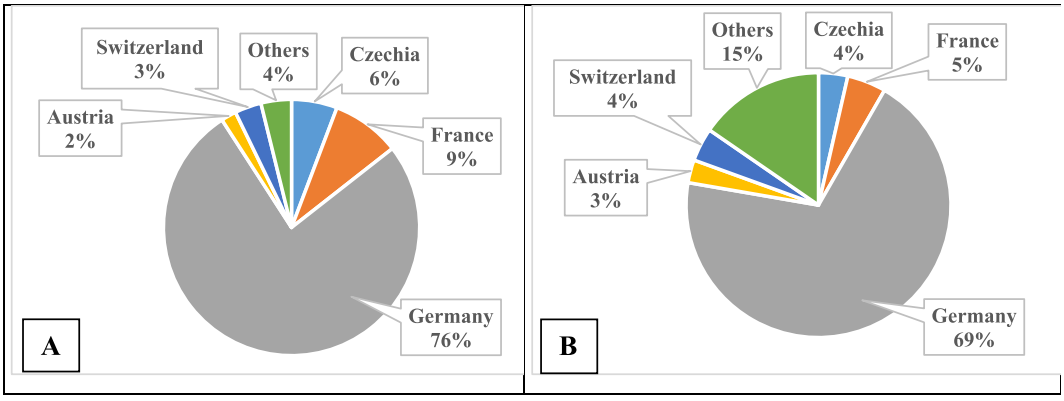

Fig. 1. Percentage share of accidents in individual countries, 208 events (A), the share of individual countries in the total number of biogas stations in 2015 (B).