Original Scientific paper
10.7251/AGRENG1801150P
UDC 504:628.4.042

DEFINING OPTIMAL LOCATIONS OF ESTABLISHMENTS AND TRANSPORTATION ROUTES FOR TREATMENT AND STORAGE OF ANIMAL WASTE

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ABSTRACT

In order to ensure a high level of public health and animal health protection in Bosnia and Herzegovina, it is necessary to improve the existing and/or provide quality management of animal by-products, i.e. to establish an infrastructure for quality and efficient treatment/disposal of animal by-products and waste of animal origin. This implies a wide range of activities in this field, such as measures to improve the legal and institutional framework, better data system management, establishment of by-product management model including transport solutions and technologies and provision of an adequate financial framework and sources of funding. At this point, the issue of management of animal by-products and animal waste in Bosnia and Herzegovina (BiH) has not been adequately addressed and poses a threat to both human and animal health. In this regard, establishment of a sustainable management system for animal by-products and animal waste is of utmost importance for further development of BiH agriculture. Inadequate management of animal by-products and animal waste poses a huge threat to the environment, endangering natural resources, watercourses, sources of drinking water, soil and atmosphere. This paper presents some of the activities related to establishment of this infrastructure, relating to the methodology of selection of locations for central plant and intermediate establishments for treatment and collection of animal waste and the definition of optimal transport routes and transport capacities.

Keywords: *animal by-products, animal waste, multi-criterial optimization, location analysis, categorization of animal waste.*

INTRODUCTION

One of the biggest challenges of the EU's standards adoption in the field of agriculture and the environment is to address the problem of harmless removal of

animal by-products and animal waste. Due to the increasing amounts and environmental impacts, waste, including animal by-products and animal waste (ABP / AW), is considered to be one of the most significant ecological problems of the contemporary world. Regulation EC 1069/2009 prescribes the health conditions that must be met when ABP / AW is manipulated on EU territory, or countries claiming to become EU members. It regulates the conditions under which the ABP / AW may be safely removed in order to exclude the risks to human and animal health, and prescribes the conditions under which ABP / AW may be used for animal nutrition, manufacture of cosmetic products, medical products or used for technical purposes. Also, Regulation 142/2011 regulates ways of implementing health conditions and determines the way of handling or managing ABP / AW.

According to the definition given in Regulation EC 1069/2009, animal by-products are parts of the animal body or whole carcasses of animals, products of animal origin, or other products derived from animals not intended for human consumption (Anonymous, 2009). These products defined in Regulation EC 1069/2009 include food waste obtained in the process of preparing food, used edible oil, foodstuff debris from restaurants and catering, animal waste produced from butchers and slaughterhouses, animal blood, feathers, wool, hooves, popcorn, skin, died of domestic animals, pets carcasses, bodies of dead animals originating from zoos and circuses, hunting trophies, manure, eggs, embryos and animal semen which are not intended for reproduction of animals. Anonymous, 2009).

Animal by-products and animal waste in BiH are mainly generated during slaughtering of animals for human consumption, during the production of products of animal origin in dairy factories, in animal husbandry during animal production e.g. technological mortality, manure and during the eradication of diseases as consequence of implementation of disease control measures. The main generators are farms, slaughterhouses or meat cuttings, processors and meat products producers, small scale farms, backyard farms and small rural holdings (Gagić, 2012). Regardless of their source and quantities, they pose a potential risk to public and animal health and threatens the environment, in particular with regard to transmissible spongiform encephalopathy (TSEs), pollution by dioxins and various exotic diseases (Gagić, 2012; Pearson and Dutson, 1992).

Animal by-products are an organic matter that, in the external environment, under the influence of atmospheric factors, is degraded by the formation of gases of unpleasant odors and other decomposition products (Feiner, 2006). These ABP / AW degradation products directly or indirectly pollute the environment. Such places become the habitats of stray dogs, rodents, scavengers, birds and insects, which in search for food become vectors of transmitting infectious diseases. At the same time, these substances penetrate the soil and become the risk of long-term pollution of the ecosystem. Inadequate handling of manure and other animal waste in rural areas, in addition to the risk of the occurrence of destructive epidemics of contagious animal diseases, can also lead to the pollution of rural wells, drinking water sources or contamination of agricultural crops in the fields, fruits and

vegetables with the agents of infectious animal diseases from which people can get sick (Sannik et al., 2015).

Animal waste according to EC Regulation 1069/2009 is classified into one of three categories (according to the level of risk), where its treatment and use is regulated for each of the categories (Anonymous, 2009). Technologies of ABP/AW safe destruction, disposal and processing can be based on incineration, rendering, production of motor fuel, production of biogas, composting, alkaline hydrolysis and other approaches (Sannik et al., 2015; Oreopoulou and Russ, 2007). Categorization of animal waste should be carried out at the place of its generation, using appropriate clearly marked containers, in the manner regulated by applicable regulations (Sannik et al., 2015). Animal waste producer (generator) should be responsible for its separation and categorization in the manner stipulated by regulations. In general, category 1 consists of brains of ruminants, parts their intestine (ileum), spinal cord and similar tissue of ruminants. The dead animals are classified in category 2a and may be Category 1 if it is found that they have died from the disease such as Bovine Spongiform Encephalopathy (BSE), TSE in sheep, or from diseases that can cause people to become ill (zoonosis). The content of the digestive tract and manure fall into category 2, while category 3 consists of low-risk materials and can be treated in a rendering machine, composted, and used for the production of biogas, pet food production and in another acceptable way.

The infrastructure for management of animal waste in the narrow sense consists of all facilities, equipment and means for its collection, transport, storage, disposal, destruction or processing, whether it is a space or collection containers, intermediate facility for temporary collection or other means of care.

Central treatment facilities are spaces and facilities for the final treatment of animal waste and disposal in such a way that it becomes harmless to health and the environment. Intermediate facilities are places and temporary storage areas, from which regular discharge should be provided to the central treatment facility, or to the place of final disposal.

Identification and selection of locations for animal waste management infrastructure facilities means conducting detailed geospatial (location) analysis. The result of this analysis is the optimal solution for the central treatment facility and intermediate establishments for the collection of animal waste. Based on these, it further defines and analyses the transport routes, identify transport solutions and calculates the investment and operational costs of the animal waste management infrastructure. Location optimization is carried out in two phases: the first one is definition solutions at the level of smaller administrative spatial units (local administration), and in the second one is selection of micro-locations of objects according to defined criteria (Huisman, 2009). When developing an analytical model, particular attention should be paid to sources and data sets to be used for computing and presentation of the quantity of generated animal waste, which are further used, along with the criteria, to select sites for animal waste management facilities (Ponjavic, 2011). The next paper section describes the methodology and criteria for selecting the location of such objects.

MATERIAL AND METHODS

The analytical process of selecting optimal solutions can be implemented through five steps: problem definition, analysis planning, data collection, location analysis, and conclusion (de Smith, 2015). Data collection is the most sensitive step in this process and has a direct impact on all the steps in the analytical process. Location analysis includes application of appropriate analytical methods, tools and models. At the end of the process, the results are analyzed and conclusions are made. Based on the solutions offered, the final decision on location selection is made by the representatives of the competent institutions.

The location analysis is based on data on calculated amounts of generated animal waste at the level of local governments with projections for the year in which the animal waste management infrastructure would be started in full capacity. For the purpose of designing these capacities in Bosnia and Herzegovina it is necessary to use all available official data relating to: animal import and export, generator register per municipality (slaughterhouses and farms register), number of animals and slaughtered animals by municipalities, number of registered companies for meat production and other records.

Quantities of certain categories of animal waste are calculated on the basis of statistics on livestock, livestock balance and number of slaughtered animals obtained from competent institutions for statistics (Sannik et al., 2015; Sannik et al., 2016). In order to properly assess the needs and projected capacities of storage facilities and treatment / disposal of animal by-products and their location, it is necessary to undertake a study to estimate the expected quantities of animal waste and by-products of animal origin arising in all stages of primary agricultural production of domestic animals (Anonymous, 2009). This study must include an estimate of the expected quantities generated by all generators of the animal by-products, regardless of their capacity, precisely because the livestock production in BiH is fragmented and is mainly based on a significant number of small rural farms, which, in mass, give significant quantities of animal by-products or waste. It is also necessary to estimate the quantities that occur in all plants for the production of food of animal origin. It is necessary to determine the value of all categories of by-products, precisely because of the fact that for each category special infrastructure is provided: separation and categorization in special collection courts, separate transport of different categories of waste, special processing plants, etc. The analysis should be based on precise data on the number of cattle, structured at the level of animal species and animal categories and distributed to the level of the municipality. Data on the number of slaughtered cattle must also be available, or data on the quantities generated by slaughterhouses and processing plants for meat, dairies, etc. The above information must be kept continuously for several years (min. 3 years) in order to correctly determine the trends and to perform forecast of future quantities of ABP/AW based on trends from the past. However, these data are often unavailable or data that can be obtained carries a certain degree of error, so it is necessary to check them well before making final conclusions and also adjust them if they are not correct with theoretical data such

as expected number of offspring per cow, piglets per sow, etc. (Kučević, 2015; Gutić sa saradnicima., 2016). This adjustment is also useful whenever central database on animal registration and identification is not present or operational, system of public statistics is not optimal, etc., as is the case in BiH. The total quantities of different categories of animal by-products are assessed by calculating the conditional heads, LSU (livestock units), using the standard methodology and multiplying the obtained values with the literature data on the expected technological mortality of animals during primary production (Uremović, 2004; Gagić, 2012), (Eurostat Statistics Explained, Glossary: Livestock unite (LSU), 2013);.

Data on the theoretical values of waste resulting from the slaughter of different animal species and categories have been taken from the literature and used to calculate the expected amount of waste that occurs when slaughtering different animal species and categories of livestock (Rede and Petrović, 1997; Vuković, 1998).

The criteria used for site selection for treatment and collection of ABP / AW are:

- road distance from the site to generated quantities aggregated at the level of municipality
- quantities of ABP/AW for treatment (collection) generated during slaughter of livestock in households (for private purposes)
- quantities of ABP/AW generated during slaughter of livestock in slaughterhouses
- quantities of ABP/AW generated by animal deaths

The aim of optimization is minimization of the transport costs ie equal accessibility of the site to all generators. Transport costs are minimal when the total length of all routes, pondered with generated quantities of ABP/AW, to the central location is minimal. This may be expressed by the formula:

$$\text{SUM } d_i(q_{HHi}+q_{SHi}+q_{Ci}+q_{IMEi}) = \text{min. } (i=1\ldots n)$$

where:

- n – total number of municipalities
- d_i – length (duration) of transport from central location to *i* municipality
- q_{HHi} – quantity of ABP/AW generated by slaughter of livestock at households in *i* municipality (HH – *household*)
- q_{SHi} – quantity of ABP/AW generated by slaughter of livestock in slaughterhouses in *i* municipality (SH – *slaughterhouse*)
- q_{IMEi} – quantity of ABP/AW collected at location of intermediate establishment (IME - *intermediate establishment*)
- q_{Ci} – quantity of ABP/AW generated by animal deaths in *i* municipality (C – *cracass*)

RESULTS AND DISCUSSION

The following table summarizes the aggregate quantities of animal by-products / animal waste (ABP / AW) for Bosnia and Herzegovina calculated on the basis of available statistical data with a prediction in 2020:

Table 1. Amounts of ABP / AW for BiH

Enitity/district/state Category of ABP/AW	Federation of BiH (t/year)	Republika Srpska (t/year)	Brcko District (t/year)	BiH (t/year)
ABP/AW category 1	2,864	3,743	45	6,652
ABP/AW category 2a	11,022	10,381	361	21,764
ABP/AW category 3	37,159	34,238	200	71,597
Total 1 + 2a + 3	51,045	48,362	606	100,014

Figure 1 (left) shows a thematic map of ABP / AW calculated per category for all municipalities. In order to determine the location of intermediate establishments, it is necessary to define service areas in BiH, which will be serviced by individual facilities. These areas can be formed by grouping adjacent municipalities, depending on the criteria set, i.e. the higher administrative and economic-functional organizations (eg. cantons or regions). Intermediate locations are defined for these areas according to formula (1), and then the location of the central treatment facility for the 1st, 2nd and 3rd ABP / AW treatment (Figure 1, right) is also determined.

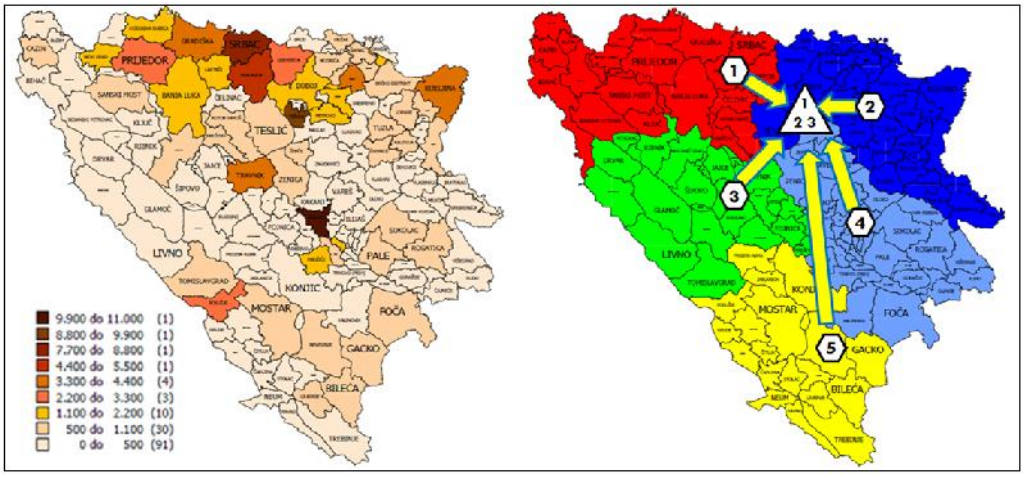

Figure 1. Total quantity of ABP/AW 1st, 2nd and 3rd category prediction in tones for 2020 (left), and service areas with locations of intermediate establishments and central plant (right).

Based on route network analysis within individual service areas, it is possible to identify routes for transporting animal waste to intermediates and central facilities, and using other statistical data (length of road, animal waste quantity, etc.) to

define transport solutions and calculate investments and operational transport costs of animal waste management.

CONCLUSIONS

Quality control of by-products and waste of animal origin implies a wide range of activities such as the assessment and implementation of measures to improve the legal and institutional framework, better database management, the establishment of an appropriate management model including transport solutions and technologies, and the provision of an adequate financial framework and sources of funding. One of the most important tasks within the framework of the construction and development of animal waste management infrastructure is the selection of optimal locations for the facilities. This task is carried out by applying the appropriate spatial and non-spatial criteria. The most important criteria are the road distance and the amount of generated waste for the transport between generators, intermediate establishments and central plant. When optimal locations are found, transport routes and capacities can be analysed, and investment and operating costs calculated. After determining the location in the wider area follows the selection of micro location for objects by the techniques of multi-criteria analysis and cooperation with the local administration to carry out public debate and make the final decision.

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