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A review of potential critical factors in horse keeping for anaerobic digestion of horse manure

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ABSTRACT

Keeping horses causes environmental impacts through the whole chain from feed production to manure. According to national statistics, the number of horses in Sweden is currently 360,000 and is continuing to increase. This result in increasing amounts of horse manure that has to be managed and treated, which is currently done using practices that cause local, regional, and global environmental impacts. However, horse manure and its content of nutrients and organic material could be a useful fertiliser for arable land and a substrate for renewable energy production as biogas. The aim of the paper is to identify and describe potentially critical factors in horse keeping determining the amount (total mass) and characteristics (nutrient content and biodegradability) of horse manure, and thus the potential for anaerobic digestion. A systematic combining approach is used as a structural framework for reviewed relevant literature. All factors identified are expressed as discrete choices available to the horse keeper. In all, 12 different factors were identified: type and amount of feed, type and amount of bedding, mucking out regime, residence time outdoors, storage type and residence time of manure in storage, spreading and soil conditions, and transport distance and type of vehicle fuel used. Managing horses in terms of these factors is of vital importance in reducing the direct environmental impacts from horse keeping and in making horse manure attractive as a substrate for anaerobic digestion. The results are also relevant to environmental systems analysis, where numerical calculations are employed and different biogas system set-ups are compared to current and other treatments. In such assessments, the relevance and importance of the critical factors identified here and corresponding conditions can be examined and the most promising system set-up can be devised.

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1. Introduction

Horses used for training, leisure and competition make a substantial contribution to social, economic, and environmental values in Western society. For example, people rehabilitate and develop useful skills with the help of horses and grazing horses help to maintain biodiversity [1–3]. Moreover, horse keeping and the equine sector contribute to GDP in many European Union countries [4,5].

Horse keeping has various environmental impacts through e.g. use of resources and emissions to air, soil, and water from different activities such as feeding, transport, housing, grazing, and outdoor paddocks. Negative environmental impacts associated with horse manure management include nutrient enrichment in soil and nutrient leaching from paddocks and stored horse manure [6]. Other environmental aspects include emissions to air from horse manure and bedding material [7].

Statistics on the number of horses in Sweden in 2010, based on predictions from a survey, show a total of 360,000, which represented a 10–20% increase on the number in 2004 [8]. Approximately 75% of Swedish horses are kept in close proximity to urban areas and about 17% of riding schools and trail-riding enterprises in Sweden report a lack of services for horse manure management [9].

Low rates of recovery and utilisation of nitrogen (N), phosphorus (P) and potassium (K) from livestock are a global problem [10]. Organic matter and recycled nutrients in manure are important for the structure and nutrient content of agricultural soil [11]. Horse manure has a natural content of nitrogen and phosphorus and if it is not used as fertiliser on farmland, natural cycles of nutrients are broken, increasing potential nutrient leaching and eutrophication and creating a need for chemical fertiliser [12,13]. Production of nitrogen fertiliser involves significant use of natural gas and generates emissions, which contributes to global warming [14]. Moreover, the current use of limited phosphate resources for phosphorus fertiliser is reported to be unsustainable [15]. Thus, by reducing consumption of chemical fertiliser through re-using manure, several problems could be mitigated.

Previous Swedish and international studies have examined environmental aspects of horse manure management, horse manure in horse paddocks, and management of spent bedding material [16–20]. Economic and practical problems and aesthetic concerns associated with horse manure management are mentioned by several authors [17,19,21]. At the same time, there is increasing interest in utilising renewable energy from different types of organic waste to solve waste management problems and decrease use of fossil energy [18,22]. As part of these efforts, the biogas potential of horse manure and spent bedding material, which are regarded as waste problems for the horse industry, has been studied [18,19]. Biogas systems often lead to improvements in resource efficiency, energy recovery, and environmental impacts compared with existing waste handling and agricultural practices [23,24].

Previous research on horse manure and environmental impact is focused on different parts of horse keeping, but so far studies applying a systems perspective on horse manure management incorporating, comparing, and discussing the importance of different aspects is lacking. This study was aimed to shed some light on the first part, the manure production. Challenges in the following manure treatment including biogas systems, composting, incineration, etc. and environmental comparisons of these will be covered in sequential papers. Thus this paper will contribute to the bigger picture and thus to conceptualisation of the problem.

The objectives of the present study was to (1) review predominantly scientific literature on horse keeping and manure management, (2) structure the findings in a framework, and (3) identify and describe potentially critical factors affecting the amount (total weight) and characteristics (nutrient content and biodegradability) of horse manure. The factors covered involved horse management practices and their environmental impact. Doing this will increase the understanding of the underlying conditions in manure generation in using horse manure as a feedstock for combined energy recovery and nutrient recycling in anaerobic digestion.

2. Method

The research approach was mainly based on a literature review for retrieving information and a systems perspective for structuring this information. Field observations were used to confirm findings in the literature and their influence on system design. The method can be described as a 'systematic combining' approach (Fig. 1), where multiple sources of data are used and theory and reality are matched during the research process as passive data are scrutinised and active data are discovered [25].

Literature on horse keeping, horse manure management, manure nutrient content, biogas potential, biodegradability, and environmental impact from horse manure was reviewed using these phrases as search criteria. Priority was given to relevant peer-reviewed scientific papers found in databases, e.g. ScienceDirect and Google Scholar, but also grey sources such as reports, official statistics, information issued by authorities and relevant authority websites were used.

The framework for combining different types of information was guided by a systems perspective. This meant that horse keeping was viewed as a set of activities affecting horse manure and horse manure management. The system studied comprised all activities within horse keeping affecting horse manure, from feeding of horses to soil fertilisation, and relevant factors were identified using a life cycle approach in combination with the retrieved information. The identification process was performed by the authors by combining the framework from a specific paper and adding on knowledge about material and energy flows caused by the activities identified in literature. Judgements on the specific relevance of each issue were made by the authors supported by the literature information. The identified factors influence the amount and characteristics of horse manure relevant for anaerobic digestion and environmental impact. This means that other environmental impacts from equestrian sports or horse keeping in

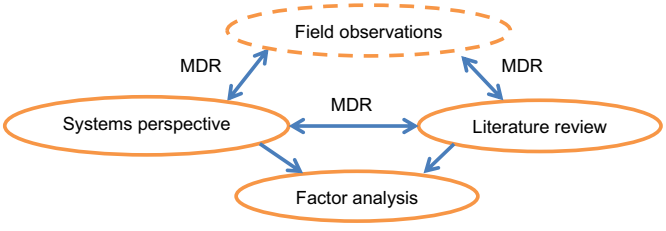

Fig. 1. The modified systematic combining approach used in this project (from [25]). Arrows represent matching, direction, and redirection (MDR).