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DETERMINATION OF NEW BIOSECURITY INDICATORS ON CATTLE AND PIG FARMS BASED ON DIFFERENT PUBLICATIONS

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Abstract: In recent years, numerous plans and programs, instructions, recommendations, scientific opinions, analysis, reports, best practices, regulations and other type of publications have been published in publications, other than in journals and symposiums proceedings that consider indicators of biosecurity on cattle and pig farms in order to improve their health and productivity. These indicators were created mainly as results of research in numerous national and international projects, which consider key indicators and prescribe on-farm assessments of biosecurity on cattle and pig farms. In the assessments of the biosecurity level in different systems of rearing and accommodation on cattle and pig farms, the need to determine indicators was observed. The publication about plans and programs, instructions, recommendations, scientific opinions, analysis, reports, best practices and regulations, related to biosecurity level contain numerous indicators. The analysis of these publications aims to determine the main characteristics of the existing and to generate ideas to define new biosecurity indicators of the animals on cattle and pig farms.

Key words: cattle, pig, biosecurity indicators, publications

Introduction

When considering farm level biosecurity, it is useful to think simultaneously about three related concepts: biosecurity planning, Hazard Analysis at Critical Control Points (HACCP), and risk management. Biosecurity plans are used to prevention certain negative events (*Uhlenhoop, 2007*), and undertaken biosecurity measures were presented by *Hristov et al. (2007)*, as well as the most significant failures in biosecurity by *Stanković and Hristov (2009*).

According to *Dickerson (2019)*, who was measuring success in biosafety and biosecurity activities in laboratories, there is a lack reliable data on the scope of community (number and types of laboratories, number of personnel "at risk", activities conducted in labs, etc.), the effect of contemporary laboratory manipulations and technological innovations on biorisks, enable measurement of the effectiveness of control measures, on incidents and near-misses, understanding of the absolute and relative impacts of various engineering, administrative, and operational interventions on biosafety and biosecurity, and lack of standardized performance indicators and metrics, reliance on counting number of incidents to gauge "success". Finally, there are no data on the impact of human behaviours on the effectiveness of any biorisk management systems, including livestock farms. This is not only applicable to the laboratories, but in any of production plants, including livestock farms.

Definition of term indicator and its desirable traits

Generally, an indicator is a specific, observable and measurable characteristic that can be used to show changes or progress a programme is making toward achieving a specific outcome. There should be at least one indicator for each outcome. The indicator should be focused, clear and specific *(ANON, 2010)*. An indicator should be defined in precise, clear-cut terms that describe clearly and exactly what is being measured. The indicator should describe the data required and the population among whom the indicator is measured, but they do not specify a particular level of achievement – terms "improved", "increased", or "decreased" do not belong in an indicator. Indicators provide both qualitative and quantitative data which offers a simple and consistent approach to monitor, measure and determine performance and achieve accountability *(Kusek and Rist, 2004; Tengan et al., 2021)*. *Gudda (2011)* also outlines the CREAM criteria: all indicators should be Clear, Relevant, Economic, Adequate and Monitorable. Good indicators have to be *valid* (accurate measure of a behaviour, practice, task that is the expected after the intervention), *reliable* (consistently measurable over time, but not subjective), *precise* (defined in clear terms), *measurable* (quantifiable by available tools and methods), *timely* (provides a measurement at time intervals relevant), *programmatically important* (achieving the programme objective), according to *Gage and Dunn, (2009)*. In addition, indicators should be SMART, which means Specific, Measurable, Achievable, Relevant, and Time-bound. They should be clearly defined, measurable, and achievable within a reasonable timeframe, relevant to the goals and objectives of the program or project, and have a set timeframe for measurement *(ANON, 2023)*.

Therefore, survey of biosecurity indicators has to be performed no less than periodically, in order to obtain more adequate, more reliable and more precise ones.

The types of indicators

Basically, there two types of indicator that may be applied in biosecurity level or biorisck level assessment *(ANON, 2010; ANON, 2023a)*. *Quantitative indicators* tell if the activities are taking place as it was planned, but do not provide any information on their effect or impact. *Qualitative indicators*, on the other hand, are usually concerned with outcome, providing information on changes caused by the undertaken activities. Unlike quantitative indicators which are in numeric forms, qualitative indicators are non-numeric and help determine the level of progress towards the achievement of objectives. It is, therefore, necessary to monitor both process and impact of undertaken activities.

In addition, according their traits, the indicators may be described as *(ANON, 2023b)*: *input indicators* (measuring the resources used, such as the amount of funding, staff time, or materials), *output indicators* (measuring the direct results or products of a program or project or set of measures undertaken), *outcome indicators* (measuring the changes or impacts that result from a activity, such as improvements in health or income), *process indicators* (measuring how well a set of measures is being implemented, such as the quality of services provided, the timeliness of delivery, or the level of stakeholder engagement), *impact indicators* (long-term, enduring effects of a programme or project on a population or environment can be measured, as specific sort of performance indicator), *efficiency indicators* (measuring the cost-effectiveness of a program or project, such as the ratio of resources invested to results achieved), *effectiveness indicators* (measuring the extent to which the set of measures is achieving its objectives), *quality indicators* (measuring the quality of program or project delivery, such as the satisfaction levels of beneficiaries), and *sustainability indicators* (measuring the potential for undertaken measures, program or project to continue after external support has ended).

Previously stated facts indicate what a good indicator of the level of biosecurity or biorisk on a livestock farm should be like. In summary, when measuring or assessing achieved biosecurity level in certain moment of time on certain farm, there should be at least one indicator for one trait or outcome or result, which has to be focused, clear and specific, and precisely and unambiguously defined.

Achievements in farm biosecurity assessment

When analyzing biosecurity plans and programs, instructions, recommendations, scientific opinions, analysis, reports, best practices, regulations and other type of publications, it is clear that farm biosecurity level assessment is based on certain components of biosecurity, such as isolation, traffic control and sanitation *(Buchman et al., 2007)*, or pillars of biosecurity, that is physical security, personnel management, material control and accountability, transport security and information security *(ANON, 2012)*, more or less defined in detail.

The inability to measure accurately and reproducibly the biosecurity and hygiene status of farms has long been one of the main obstacles in the pursuit of improvements in both. If farm managers need to be motivated to enhance the biosecurity or hygiene status of their farm, it is essential to provide them with quantitative goals and benchmarks, which can be used to position the farm with respect to its biosecurity and hygiene status, so that the measures required for improvements can be identified and their impact subsequently measured, if possible quantitatively *(Dewulf and Van Immerseel, 2018)*.

The systems that have been designed for making inventories of biosecurity measures taken in animal production are mostly developed as checklists or as manuals either by independent advisory organisations, or as support material for vaccines, such as COMBAT system (Boehringer Ingelheim) that helps to identify biosecurity hazards in relation to the PRRS infections in pig production, and many of these systems were developed with a view to controlling a specific disease, Wageningen University checklist developed for the risks factors and introduction and spread of *Streptococcus suis* in herds *(Wageningen University, 2008)* and PADRAP system designed by the *American Association of Swine Veterinarians (2007)* and Iowa State University (*Holtkamp et al., 2010*), that evaluates the biosecurity protocols for breeding or growing pig herds and identifying possible risk factors for PRRSV infection.

EFSA created specific documents for specific transmissible diseases, such as classical swine fever (*2009*) and avian influenza (*2016*). Experts identified and ranked a set of biosecurity measures against avian influenza that can be implemented in different areas of a farm that are classified as high or low risk – such as, respectively, a poultry house or places where feed is stored. These measures include preventing contact between wild birds and poultry, indoor housing of birds, and keeping geese and ducks separate from other poultry. EFSA recommends the development of biosecurity guidance tailored to the needs of individual farms, preferably before an outbreak. EFSA also scrutinized issues related to classical swine fever in wild boars, regarding detection, prevention, control and eradication, which can help to define certain usable indicators in establishing required biosecurity level on farms or hunting grounds. Taking into account nature of mentioned diseases, active surveillance and early detection is considered to be crucial in their successful control.

Terrestrial Animal Health Code (2022) created by OIE, may be useful in designing new biosecurity indicators; for instance, chapter 1.4. points out importance of wildlife as reservoir and indicator of risk for human population and domestic animals, and chapter 2.1. provides recommendations and principles for conducting transparent, objective and defensible risk analyses for international trade. The components of risk analysis are 1. hazard identification, 2. risk assessment, 3. risk management, and 4. risk communication, all using biosecurity indicators to recognize, evaluate and manage risks (Figure 1.).

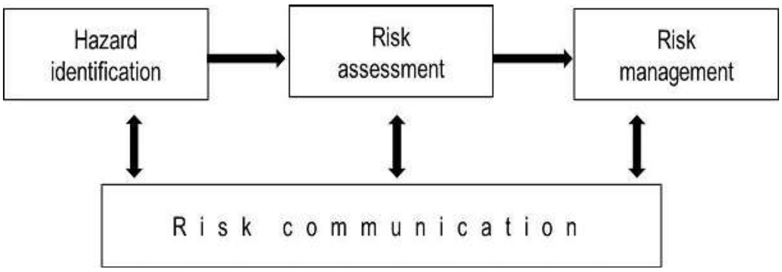

Figure 1. The four components of risk analysis

National veterinary authorities generally published fact sheets on the principles of biosecurity, in order to reduce the risk of introduction and spread of classical swine fever for instance *(DEFRA, 2007)*; in Australia, information on biosecurity is available for stakeholders *via* the *Australian Pork Industry (2003)*, and pig producers manuals for that include an internal audit system called APIQ√® which stands for Australian Pork Industry Quality Assurance Programme (www.apiq.com.au), for producers to adopt and apply good farming management, animal welfare, food safety, biosecurity and traceability practices.

The Biocheck.UGent™ biosecurity risk-based scoring system for quantification on-farm biosecurity was developed at Ghent University, available for use in pig, poultry, beef and veal farms *(Ghent University, 2015)*. It has general approach to biosecurity, focusing on paths of transmission of many types of transmissible diseases. Questionnaires for pig production include 109 (pig) mainly di- or trichotomous questions in several subcategories (2 to 19 questions each) for internal and external biosecurity, and weight factor for each subcategory and question *(Laanen et al., 2013)*. The final score for both internal and external biosecurity range from 0 to 100 points. Finally, the results are presented in a report and spider diagram, allowing evaluation of the strong and weak points of the biosecurity on a particular farm, providing guidelines for improvements.

Similar to mentioned Biocheck.UGent™, in 2011, the Ministry of Agriculture, Water Management and the Forestry of the Republic of Serbia financed the development of Guidances of Biosecurity Standards on cattle, pig and poultry farms (2011), and the Questionary for farm biosecurity assessment within, related to numerous indicators, which was developed in TR project 20110 "Welfare and Biosecurity Standards Development and Implementation in Improvement of Dairy and Pork Production" (2008-2011), and financed by Ministry of Science and Technology Development of Republic of Serbia *(Hristov and Stanković, 2009)*. Each indicator with different numbers of parameters within, is rated from grade 0 to 5: *Insufficient, without the potential to improve the biosecurity in the foreseeable future* – 0; *Insufficient, with the potential to improve the biosecurity in the foreseeable future* – 1; *Sufficient* – 2; *Good* – 3; *Very good* – 4 and *Excellent* – 5, and summarized. In addition, a SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) is applied for a more detailed overview of the possibilities for reducing the negative and improving the positive aspects of biosecurity on farms and completing the final audit. All of the 15 indicators have to be analyzed in order to find the biggest threat to biosecurity on the farm to overcome the disadvantages, risks that may hinder or prevent the overcoming disadvantages. The farm is then graded according to a rating scale: Group V 0-1.99 insufficient, Group IV 2.00-2.49 sufficient, Group III 2.5-3.49 good, Group II 3.5 - 4.49 very good and group 4.5 - 5.00 excellent. The indicators which are used are: 1. planning and monitoring the implementation of biosecurity measures, 2. farm isolation, 3. quarantine, 4. health status of the farm population, 5. movement and traffic control, 6. attitude towards visitors, 7. nutrition and water supply control, 8. manure management, 9. removal of dead animals, 10. presence of other species of animals on the farm, 11. rodent population control, 12. insect population control, 13. bird control, 14. sanitation, and 15. farm's attitude towards the environment.

Comparing to Biocheck Pigs questionnaire, part A. farm characteristics, in *Hristov and Stanković* questionnaire (*2009*), the size of the farm and categories of pigs are taken into account through different indicators, but the stuff size, their experience in keeping pigs, and the age of the facilities were not taken into account. In *Hristov and Stanković* questionnaire (*2009*) "stand down" period was investigated, comparing to "pig-free period (longer than 12 hours)" in Biocheck Pigs; part E. vermin and bird control are similar to indicators 11. Rodents control, 12. insects control and 13. birds control; indicator 2. farm isolation of presented questionnaire is similar to the part F. location of the farm of the Biocheck Pigs; differences are related to the wild boars presence; The indicator 4. heard health status of the farm population is similar to the part G. disease management of Biocheck Pigs. On the other hand, Biocheck Pigs parts H. farrowing and suckling period and I. nursery unit and J. finishing unit give more detail information regarding to this issue than in the presented questionnaire, which is covered by mentioned indicator; part K. measures between compartments, working lines and use of equipment of Biocheck Pigs is covered by different indicators of presented questionnaire (*Hristov et al., 2023*).

Suggested potential farm biosecurity level indicators and their traits

Analyzing available biosecurity plans and programs, instructions, recommendations, scientific opinions, analysis, reports, best practices, regulations and other type of publications, it may be noticed an almost identical or very similar point of view of the problem and therefore similar path of measuring or assessment of biological risk or biosecurity level on livestock farms. In addition, it has to be taken into account complexity of potential indicator. Some of them are easy to answer with yes or no or more or less; other consist of several parameters, each describing certain part of the issue.

For instance, it is common and correct to assess health status of the animals on the farm using veterinary data on clinical examinations and undertaken therapy, but, since the farm biosecurity level is being assessed in one particular moment in time, it would be correct (and definitely more simple) to include certain objective and easy to see clinical signs and their prevalence in different categories of animals on particular farm. In Canadian Dairy Farm Biosecurity General Risk Assessment Questionnaire (*ANON, 2018*) are suggested abortion, lameness, mastitis, diarrhoea, pneumonia, death and culling for milking cows, and diarrhoea, pneumonia and death for calves. For same species and other ones, it would be useful to include impaired breathing, coughing, constipation, persistent vomiting, skin rash, bruising or bleeding without previous injury, and nose, eye or genitalia discharge too. All of these clinical signs should be defined and explained in order to establish thresholds and minimize subjective differences between observers. Talking about mastitis, somatic cell count limit is defined as 500,000 cells/ml of milk; nevertheless, other signs have to be included, such as changes in milk, quarters and systemic signs.

Indicator of possibility to isolate farm or production unit and prevent physical breakthrough of vectors is often limited on perimeter and gate under control and should be supplemented with additional parameters. *Hristov and Stanković (2009)* suggest that location of the premise in respect to and required distance from risk sources is necessary, as well as separation of clean and dirty routes for movement and supply on the farm, knowledge of dominant winds directions, and protective belt of trees and shrubs which surrounds the premises. Explaining term ‘bioexclusion’, *Torremorell (2021)* in Merck Veterinary Manual point out that a systematic approach is required to prevent pathogen movement across protection zones, which are physical or imaginary barriers between farm sections, so as to eliminate or decrease the number of disease-causing organisms within the animal's environment. Sound epidemiologic principles should be used to establish zone boundaries while making use of existing physical/geographic barriers.

In Article 2.1.4. Risk assessment steps in Chapter 2.1. Import risk analysis of *Terrestrial Animal Health Code (OIE, 2022)* are presented all required steps of risk assessment regarding introducing new animals in the country, which can also be applied to the introduction of animals into an area, farm or pasture. These steps are 1. entry assessment, 2. exposure assessment, 3. consequence assessment, and 4. risk estimation, and any of these steps could be and are used separately for several other biosecurity issues, such as visitors policy or other animals on the premise, *e.g.* Nevertheless, risk of introducing newly acquired animals, even with any type of quarantine measures is serious risk which have to be estimated and taken into account.

Entry assessment consists of describing the biological pathways necessary for an importation activity to introduce pathogenic agents into a particular environment, and estimating the probability of that complete process occurring, either qualitatively as description or quantitatively as a numerical values It describes the probability of the “entry” of each of the hazards (the pathogenic agents) under each specified set of conditions with respect to amounts and timing, and how these might change as a result of various actions, events or measures. Examples of the kind of inputs that may be required in the entry assessment are: *biological factors* (species, age and breed of animals, agent predilection sites and vaccination, testing, treatment and quarantine), *country factors* (incidence or prevalence, evaluation of Veterinary Services, surveillance and control programmes and zoning and compartmentalisation systems of the exporting country), and *commodity factors* (quantity of commodity to be imported, ease of contamination, effect of processing and effect of storage and transport). If the entry assessment demonstrates no significant risk, the *risk* assessment does not need to continue.

Exposure assessment consists of describing the biological pathways necessary for exposure of animals and humans in the importing country to the hazards (in this case the pathogenic agents) from a given risk source, and estimating the probability of the exposures occurring, either qualitatively (in words) or quantitatively (as a numerical estimate). The probability of exposure to the identified hazards is estimated for specified exposure conditions with respect to amounts, timing, frequency, duration of exposure, routes of exposure, such as ingestion, inhalation or insect bite, and the number, species and other characteristics of the animal and human populations exposed. Some of inputs that may be required in the exposure assessment are: *biological factors* (properties of the agent), *country factors* (presence of potential vectors, human and animal demographics and spatial distribution, customs and cultural practices, and geographical and environmental characteristics), and *commodity factors* (quantity of commodity to be imported, intended use of the imported *animals* or products and disposal practices). If the exposure assessment demonstrates no significant risk, the risk assessment may conclude at this step.

Consequence assessment consists of describing the relationship between specified exposures to a biological agent and the consequences of those exposures. A causal process should exist by which exposures produce adverse health or environmental consequences, which may in turn lead to socio-economic consequences. The consequence assessment describes the potential consequences of a given exposure and estimates the probability of them occurring. This estimate may be either qualitative (in words) or quantitative (a numerical estimate). Examples of consequences include: a. direct consequences (animal infection, disease and production losses and public health consequences), and b. Indirect consequences (surveillance and control costs, compensation costs, potential trade losses, and adverse consequences to the environment).

Risk estimation is integrating the results from the entry assessment, exposure assessment, and consequence assessment to produce overall measures of risks associated with the hazards identified at the outset, taking into account the whole of the risk pathway from hazard identified to unwanted outcome. For a quantitative assessment, the final outputs may include: estimated numbers of herds, flocks, animals or people likely to experience health impacts of various degrees of severity over time, probability distributions, confidence intervals, and other means for expressing the uncertainties in these estimates, portrayal of the variance of all model inputs, a sensitivity analysis to rank the inputs as to their contribution to the variance of the risk estimation output, and analysis of the dependence and correlation between model inputs.

When using pasture and/or hay as forage, potential weeds and pasture pests have to be identified and prevented, by checking with regional council and the advisory service for information and advice, also whether feed sourced from off-farm doesn't contain seeds of weeds new to farm (*Dairy NZ, 2023*). Presence of toxic plants, weeds and pasture pests should be included as part of indicator nutrition or separate indicator.

The sanitation and hygiene measures and on-farm biosecurity interventions in order to prevent and control infection to address antimicrobial resistance are primarily focused on human population protection, but they are also important to public health, as they can reduce the emergence and spread of resistant bacteria to consumers, farm workers, and the surrounding farm environment. Last but not least, biosecurity interventions (*OIE,* 2019) mainly focus on farmed animals, but their effect on protecting farm workers from animal infections (other than the known zoonoses) is not always measured or it is neglected. Recognising antimicrobial resistance as a development problem, the World Bank proposed the term antimicrobial resistance-sensitive to classify interventions that indirectly impact antimicrobial resistance by reducing multiple infections concurrently and the term antimicrobial resistance-specific for interventions aiming to curb antimicrobial resistance and antimicrobial use directly (*World Bank, 2019*). In this context, both hygiene and biosecurity procedures can be antimicrobial resistance-sensitive, *e.g*., improving access to clean water and sanitation facilities or supporting farmers to implement biosecurity measures. Both intervention types can be implemented at a system level through standard operative procedures (SOP), from which point they could influence risk factors embedded in social structures and address socioeconomic vulnerabilities. Presence of increased therapy use of antibiotics, antimicrobial resistance, the correctness, timeliness and increased use of sanitation preparations, and presence of persistent infections in farm populations might be used as quality indicator for successful sanitation procedures, especially if related SOP are not clear or followed.

When Dr Jeroen Dewulf was asked, in personal communication, for his opinion: what is the most important in establishing required biosecurity level on farm, he said that the most important thing is a good biosecurity plan, and that is truth. Similarly, in assessing farm biosecurity, besides well chosen and designed indicators, one of the most important things is systematically created questionnaire. The questions can and should lean on each other and, if necessary, partially intersect, which gives a clear and detailed picture of the situation on the farm. It is very demanding to create modular and systematic questionnaire which would give precise description of biosecurity level of particular farm, but when achieved, mentioned traits enables adjustment and increased usability of such questionnaire.

Conclusion

Presented data of available biosecurity plans and programs, instructions, recommendations, scientific opinions, analysis, reports, best practices, regulations and other type of publications indicate what a good indicator of the level of biosecurity or biorisk on a livestock farm should be like.

It may be noticed complexity of potential indicators and high similarities point of view of the problem and therefore similar path of measuring or assessment of biological risk or biosecurity level on livestock farms.

Some of them are easy to answer with yes or no or more or less; other consist of several parameters, each describing certain part of the issue.

In summary, when measuring or assessing achieved biosecurity level in certain moment of time on certain farm, there should be at least one indicator for one trait or outcome or result, which has to be focused, clear and specific, and precisely and unambiguously defined.

Survey of biosecurity indicators is complex and has to be performed no less than periodically, in order to obtain more adequate, more reliable and more precise ones.

When assessing farm biosecurity, besides well chosen and designed indicators, systematically created questionnaire is of great importance. The questions can and should lean on each other and, if necessary, partially intersect, in order to give a clear and detailed picture of the situation on the farm. Modular and systematic questionnaire enables adjustment and increased usability of such questionnaire.

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