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A visualisation tool to understand disease prevention and control practices of stakeholders working along the poultry supply chain in southern India

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In this paper, we show how we developed a visualisation tool to challenge perceived notions about biosecurity on poultry farms. Veterinarians and veterinary public health professionals tend to present biosecurity measures as a universal and cost-effective solution for preventing and controlling diseases on farms. However, we illustrate how biosecurity is an ill-defined term, making it difficult to talk about or apply in practice. As a result, we demonstrate how we moved away from using the term biosecurity in our research by designing a visualisation tool. The tool was to allow us to open up dialogue around disease prevention and control, and make tangible the tacit situated practices of stakeholders working along the poultry supply chain. Our findings show that for those working along the poultry supply chain, the term biosecurity was either consistently open to interpretation, or too rigid to reflect or allow for local variations. We conclude by highlighting how our visualisation tool offers insights into why researchers must move beyond using biosecurity as a term, and instead envisage, design, and develop local solutions to prevent and control diseases on poultry farms.

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Introduction

The prevention and control of diseases in livestock is a major concern for the health of humans and animals around the world (Thumbi et al., 2015). One of the preferred veterinary solutions for controlling diseases in livestock is the implementation of biosecurity measures (Robertson, 2020).

The word biosecurity has increasingly been used since the 2000s, as an all-encompassing term to describe the various global responses to emerging biological threats (Koblentz, 2010). Despite being adopted by global institutions, governments, and individuals, literature on biosecurity shows that the term is difficult for both scholars and practitioners to describe and interpret (Waage and Mumford, 2008). As a result, the term is commonly described through examples of the various practices, measures, and techniques used to secure life from diseases and other biological threats (Dobson et al., 2013).

The widespread acceptance of biosecurity as a globally optimum solution for disease prevention and control raises a number of questions for design researchers and social scientists. The most pertinent for this paper is; how is biosecurity understood and interpreted by both researchers and stakeholders, when there is no consistent definition of the term either in literature or in practice. In an attempt to answer this question, we adopted a design-led approach to explore how the term biosecurity was interpreted and applied by stakeholders working along the poultry supply chain in southern India.

This paper starts by exploring the ways in which biosecurity has been described by different academic disciplines, and the inconsistencies that have subsequently emerged. We then show how we developed a visualisation tool in an attempt to break down the term biosecurity into the discrete, individual practices and measures often described under its rubric. In the second half of this paper, we present the findings from our research in southern India, where we used the visualisation tool with different stakeholders working along the poultry supply chain. Our findings suggest that there is no clear reason for researchers and practitioners to continue using the term 'biosecurity', particularly on farms or with farmers, as there is no consistency over its definition or practical application. We conclude that there is a collective need to move away from using biosecurity as a term, and instead develop disease control solutions that are context specific, and co-produced with stakeholders in local contexts.

Integrated farming and poultry diseases

India is the fourth largest producer of broiler meat in the world (Sasidhar and Suvedi, 2015). In this paper, we focus on contracted broiler farms, managed by poultry integrators—some of which were linked to multinational corporations in the US and Europe. On contract farms, farmers are responsible for rearing birds and the integrator provides farmers with chicks, feed, vaccines, disinfectants, veterinary services and medicines. At the end of the production cycle, the birds are bought back by the integrator and the farmer receives rearing charges. In this process, integrators control the movement of feed and flocks.

Although studies have shown that contract farming provides employment for more than four million people in India (ibid: 2015), intensive rearing practices also pose an increased health risk to both animals and humans. In accordance, there are a large number of common viral, bacterial, and parasitic diseases recorded on Indian poultry farms (Prasad and Singh, 2008). This is coupled with mounting reports of antimicrobial use (AMU) and antimicrobial resistance (AMR) (GARP, 2011). Veterinary practitioners and veterinary public health professionals argue that the implementation of biosecurity measures will reduce the risk of the introduction of disease and the consequent morbidity and mortality rates (Stokstad et al., 2020). Veterinary studies have further linked the adoption of biosecurity measures to a decrease in AMU and the subsequent health risk of AMR (Laanen et al., 2013).

In order to prevent and control diseases in the poultry sector, in 2015, the Indian Government released general guidelines advising state and private poultry farmers to adopt biosecurity measures (DADF, 2015). These guidelines, which are published in English, include a lengthy checklist for effective biosecurity, with a focus on; farm location and design, restricting access to birds, cleaning and sanitation, downtime between crop cycles, and the hygienic disposal of poultry manure and of dead birds. Despite these guidelines, veterinary studies suggest there remains a lack of biosecurity knowledge among Indian farmers, particularly in small-scale and backyard poultry production systems (Samanta et al., 2018). The fact that studies on disease control often focus on farmers inability to correctly adopt biosecurity measures, indicates why it is so important to develop tools that allow researchers to understand what biosecurity actually means, not just for farmers, but also veterinarians and public health practitioners who commonly advocate for biosecurity measures in practice.

Biosecurity: a universal term with multiple meanings

In the opening line of an FAO report on biosecurity, the authors begin by stating, 'this study begins with a consideration of definitions and principles because of the great variability in meaning when the word biosecurity is chosen' (2016). The observation that there are a varied number of ways in which biosecurity can be interpreted, has also been noted in many academic papers and books, with authors often beginning their work with their own definition of the term (Waage and Mumford, 2008; Dobson et al., 2013).

The inconsistencies over how biosecurity is interpreted and defined, further extends to its application on farms. When discussed in terms of specific measures, the FAO defines farm biosecurity in relation to three technical components: 'segregation, cleaning and disinfection' (FAO, 2008: p. 12). The adoption of these components have, in turn, been linked by the FAO to an increase in productivity and profitability, thereby incentivising farmers to adopt biosecurity measures on their farms (ibid). Yet, while biosecurity is described by the FAO and researchers, as the optimum way to prevent diseases on farms, studies continue to show that biosecurity measures are either not consistently adopted, or continuously fail in practice (Shortall et al., 2018; Thompson, 2021) This suggest why, as Bruce Braun notes, 'it would be a mistake to imagine that all forms of managing biological risks are the same, either historically or geographically, or even that in any given place biosecurity names a single or fixed set of practices' (2013: p. 45). Thus, despite the fact that researchers, the FAO, and animal health practitioners have all highlighted that biosecurity can be interpreted, defined and applied in multiple different ways, veterinary studies continue to advocate for and promote biosecurity as 'best practice' on farms (Aleri and Laurence, 2020). As a result, farmers are also condemned by veterinarians and public health practitioners when they fail to follow biosecurity protocols.

Despite the noted ambiguities around biosecurity, the term has still become a dominant way of talking about disease risk, prevention, and control. In accordance, social scientists have critically explored the assumptions that underpin biosecurity as well as the consequences of biosecurity in practice. This literature shows, for instance, how biosecurity is premised on an idea that it is possible to close down spaces in order to prevent and control diseases, a spatial assumption that pathogens, 'cross over into healthy lives as if a pure space can somehow exist in contrast to an impure, diseased space' (Hinchliffe et al., 2013: p. 531). Ethnographic work has further shown how biosecurity measures can dictate the form that farms can take, creating farming models in which farmers are encouraged to follow and/or adopt certain standards in order to maximise profits and be successful (Porter, 2019). The push for biosecurity measures, therefore, often standardises farms and suggests that there is an optimal design for preventing and controlling diseases in farmyard animals. Thus, for farmers, biosecurity, and its consistent use, has real consequences. This becomes particularly evident when considering how as a term it has increasingly come to act as a global yardstick for measuring the success of farmyard and disease management.

The fact that biosecurity has become a universal term, which homogenises policy, regulations, and practices, suggests it has become part of a global hierarchy of value (cf. Herzfeld, 2004), promoted worldwide despite the noted ambiguities around its definition. Biosecurity is, as Herzfeld writes about a number of supposed other 'universal' concepts, 'everywhere present but nowhere clearly definable. Its very vagueness constitutes one source of its authority' (2004: p. 3). In accordance, biosecurity has been adopted as part of a system that assumes a shared understanding of its interpretation, and yet this overlooks and marginalises local differences (cf. ibid).

Herzfeld's notion of a 'global hierarchy of value' has been used by other social scientists, particularly those working on food and drink systems (Grasseni, 2011; Jung, 2014). Grasseni's study (2011) on alpine cheese-making, for example, shows how the emergence of a global set of cheese-making practices requires traditional cheese producers to negotiate between standardisation and authenticity, in order to offer their products to an increasingly global market. This, however, often has contradictory consequences, as it marginalises tacit knowledge and local experience (ibid). The emergence of global, standard practices, therefore, devalues local ways of doing and being. Applying the same logic to biosecurity, the notion of a standardised method to managing diseases, means that the knowledge and practices of many farmers, particularly small-scale farmers, is not valued at a global level. Thus, the issue is not just that biosecurity is an ill-defined term with multiple meanings, but that the term also creates and promotes a homogenous value system that is incapable of recognising or responding to local farming practices.

In light of the evidence above, in the remainder of this paper we will show why it is important to look beyond biosecurity as term, and instead consider how important local differences are for disease prevention and control. In order to do so, we will explore the development and use of a participatory visualisation tool in our research on poultry in southern India.

The need for a participatory visualisation tool: reflections from within our multidisciplinary project. The idea to visualise biosecurity first emerged as a result of working in a multidisciplinary project. Our team consisted of veterinary scientists, microbiologists, economists, public health professionals, social scientists and design researchers and each different discipline brought their own understanding and interpretation of biosecurity. It was in this context that we set out to explore what the term biosecurity meant to the people who promote and apply it in practice, particularly as it became apparent that even within academic institutions, the term itself was unstable and shifting meaning over time. We, therefore, agreed that one way to understand biosecurity as a team, without drawing upon a specific definition as defined by one discipline alone, was by visualising the practices and techniques that individuals associated with the term.

In response, we adopted a participatory and design-led approach to the visualisation process. Design researchers widely agree that the use of visualisation, particularly in the context of health communication, can contribute towards addressing global health challenges (Macdonald, 2017; Walker, 2019). Most of these examples use visualisation as a way of presenting information, such as scientific content, in an accessible format to reach a wider audience. As Walker writes on the role of graphics and visual information in communicating effectively both about Tuberculosis in the past, and AMR today, 'design has the potential to disrupt expectations and to trigger curiosity and engagement, leading to understanding in other circumstances' (2019: p. 15). Yet, visualisation as a technique cannot be adopted without caution and studies have shown the ways in which visualisation can create partial or abstract interpretation of contested terms. Manzo (2010a), for example, highlights how visualising climate change through polar bears, melting glaciers, and ice-caps no longer fosters meaningful understanding of the situation. While Ram (2020), illustrates how posters that visually depict ill-defined terms or topics, such as biosecurity, can cause confusion, particularly when individuals do not have prior knowledge of the subject and therefore have difficulty engaging with, or understanding, the visual material. Despite these limitations, and as Manzo concludes, 'all visual images have the capacity to draw attention to messages…to draw attention to their limitations is not to write off their value' (2010: p. 207).

Unlike the visualisation techniques described by Ram (2020), the visual imagery we used was not intended to promote understanding or awareness of biosecurity as a subject. Rather we developed a participatory visual tool, to simplify and translate information about disease control, into a format that would make it easier to enhance participation and capture people's individual interpretations.

Design researchers often use participatory tools as a provocation in order to recognise and respond to the tacit, often invisible, knowledge that people acquire through interacting with the world (Sanders and Stappers, 2014). Participatory tools often use external stimuli to provoke and explore people's knowledge, values, and behaviours (ibid), this encourages people to reflect on, rather than simply recall, their knowledge and experiences (cf. Van Braak et al., 2018). Studies on qualitative methods have shown, for instance, that widely used research tools such as the survey or interview are limited in their ability to elicit tacit knowledge (Van Braak et al., 2018). This is because unlike explicit knowledge, tacit knowledge is often abstract and difficult to address, verbalise, or reveal.

Participatory tools often use visual stimuli in order to provoke discussion and to generate a deeper understanding of contexts (Segelström and Holmlid, 2009). As Schoffelen et al. (2015) contend, visualisation allows people to interact with complex issues through sensemaking and reflection. In this process, words and pictures are used as stable reference points to engage participants in the mapping and visualisation process and this in turn contributes to knowledge development (Whyte et al., 2007). As a result, visual methods are often discussed positively within design literature as they have been observed enhancing empathy, supporting engagements and allowing for the successful transfer of knowledge (Kallus, 2016).

Despite the benefits of using visual tools in research, it is important to note that visual tools also have their limitations. For instance, visual tools have the power to portray a particular point of view, often as dictated by the Global North. This, researchers have shown, can lead to the marginalisation of those living in the Global South (Manzo, 2010b). We, however, in line with Escobar, believe that design can enable better domains of interpretation and action to emerge, without overlooking this power dynamic

(2018: pp. 133–134). Consequently, and as discussed next, the purpose of our visualisaltion tool was to foster participation and inclusion and to open up and understand how individuals interpreted disease control, without the need to rely upon or perpetuate the use of biosecurity as a term.

Our approach to designing the visualisation tool. The following section discusses the design of the 'disease control map' and its use in three states of southern India (Karnataka, Telangana and Tamil Nadu). Qualitative research was conducted in India for five months in 2019 (March–April, July–September, November–December) and for one month in 2020 (February–March).

At the beginning of the research, a preliminary visual tool developed by UK-based service design academics was tested with seventeen participants in a focus group with veterinarians, poultry nutritionists, poultry integrators, and policy makers at the 7th Pan Commonwealth Veterinary Conference (PCVC) in Bangalore in March 2019 (see visualisation tool development section). The tool was then refined and used by the team on six broiler farms (average flock sizes of between 2000 to 8500 birds) in and around the town of Namakkal in July–September 2019. These farms were selected by project partners located in Namakkal and were selected based on the farm's location, the start date of the crop cycle, and the size of the flock. In Namakkal, the materials were translated into Tamil by the research team in India in order to facilitate discussions. Indian members of the team acted as English to Tamil translators during research on the farms.

When visiting the farms, researchers often interacted with more than one person, as families cared for poultry together. As a result, research was conducted with thirteen people across the six farms (see Table 1 below).

Visualisation tool development. The first iteration of our visualisation tool was designed prior to starting research in India. As discussed, the tool was designed in response to initial conversations with members of our multidisciplinary team and looking at how guidelines were presented in poultry manuals. As noted earlier, visualisation tools can offer partial or selective representation that may lead to miscommunication of contested terms (cf. Manzo, 2010a; Manzo, 2010b). Thus, we approached designing the visualisation tool with three main motives: one, as a tool to translate scientific guidelines into a relatable and accessible format; two, to act as a participatory tool for engagement; and three, as a visual representation of the farmyard and the multiple species living within it. Our approach to the design, therefore, took seriously, 'that design situations always involve encounters between human and nonhuman actants of allkinds' (Escobar, 2018: p. 133).

In order to create the visualisation tool, the team first identified components of disease control and prevention measures as described both by researchers within the team, and within the scientific literature (Lister, 2008). In this literature, disease control and prevention were typically first defined as biosecurity and included general on-farm hygiene requirements, disease monitoring, and the effective use of disinfectants (ibid). After a broader review of the scientific literature, we identified three interrelated components from which to understand disease control and prevention measures. The first focused on the bird, for instance treatment regimes; the second related to the farm, for example housing and water supply and the third; external factors such as standard operating procedures (SOPs) introduced by integrators [see Fig. 1].

Testing the first iteration of the visualisation tool. We initially used the tool as part of a participatory exercise at the 7th Pan Commonwealth Veterinary Conference. The tool was used both with individuals during key informant interviews (poultry integrators, poultry nutritionists and veterinarians) and as a group during a focus group discussion (poultry integrators, policy makers, university lecturers and veterinarians). In this context, we asked participants to identify points they believed could cause disease in poultry. Participants, in turn, described the visual prompts in terms of biosecurity, so we as a team also began to describe the map as a 'biosecurity map' (see Fig. 2).

Nevertheless, when we subsequently conducted research on poultry farms in Namakkal, farmers did not respond to the map by using the term 'biosecurity'. We also observed that there was no direct translation of biosecurity into local languages. Rather, the concept was often described by Indian veterinarians in terms of 'protecting lives' (*Uyir Paadhugaappu* in Tamil and *Jaiv suraksha* in Hindi). Furthermore, when probed, veterinarians never had a clear or consistent set of practices on how best to protect chickens' lives. Instead, they often spoke of the importance of cleaning and the use of disinfectants. This difference in interpretation of the visualisation tool and translation of the word biosecurity itself, further emphasised how important it was to design tools that allow participants to talk about disease control without using language that is defined and imposed from other contexts. Thus, in line with our research participants' responses to the tool, we also moved away from using the term 'biosecurity'.

As we gained a deeper insight into the attitudes and knowledge of different stakeholders we refined and developed the map accordingly. For example, we translated the map into Tamil, and we added and removed components based on discussions with farmers. For instance, due to its presence in scientific literature, we included Hazard Analysis and Critical Control Points (HACCP) in our initial map. However, we found it difficult to visualise HACCP as a concept and as a result the term had to be written on the map and explained verbally to participants at the focus group. When discussing the map, not one participant mentioned HACCP and only when probed did one claim that HACCP was necessary in food processing plants. Our inclusion of

Table 1 An overview of characteristics of farms in this study.

Farm	Farmers interviewed	Who cares for the chickens?	Flock size (current cycle)	Year broiler farm was established
Farm 1.	Husband and Wife	Husband and Wife (occasional employed labourer)	8200 (Own shed: 3700 Rented shed: 4500)	2011
Farm 2.	Father and Son	Father and Son	2200	2000
Farm 3.	Husband and wife	Husband, wife, eldest son and daughter in law	2300	2008
Farm 4.	Two brothers	Two brothers	1495	2010
Farm 5.	Husband and Wife	Wife and two employed labourers paid 150 Indian Rupees (£1.58) per person, per day.	5000	2005
Farm 6.	Husband and Wife	Husband and Husband's brother	3500	2002

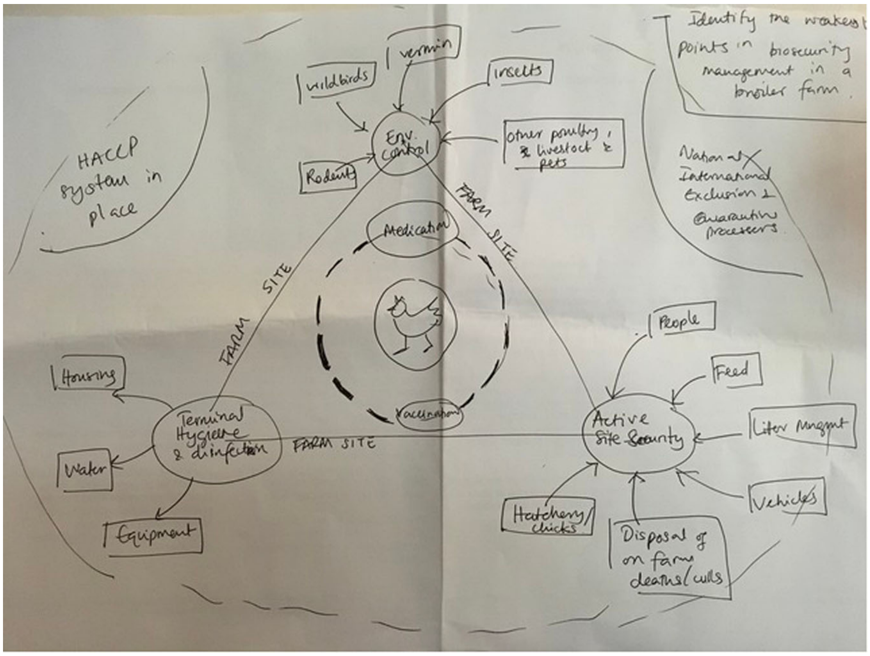

Fig. 1 An initial sketch of the the visualisation tool. Initial sketch of the disease control/biosecurity participatory tool prepared by service designers.

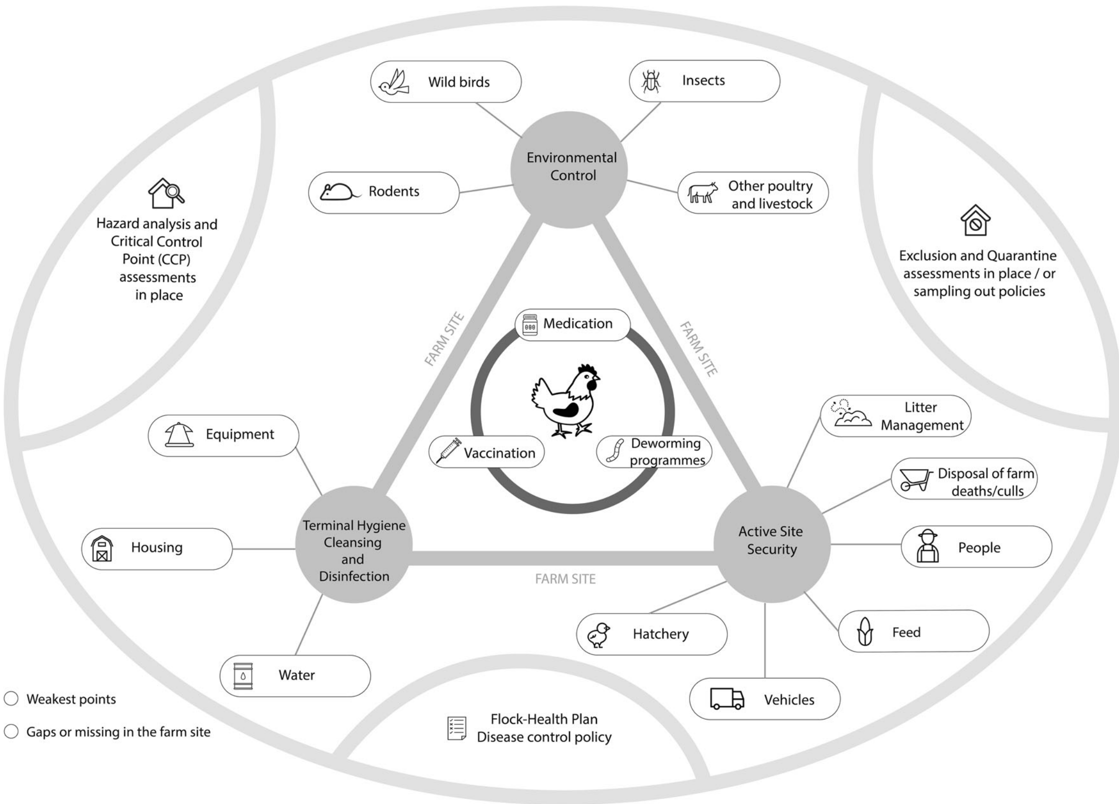

Fig. 2 The first version of the Disease Control Map. We used a version of this map with stakeholders at the PCVC conference.

HACCP was, therefore, underpinned by our own initial assumptions around what disease control should look like on a contracted poultry farm.

As we will show next, our visualisation tool enabled us to move away from talking about biosecurity—an already ill-defined and term—and towards re-thinking disease control in terms of local understandings of boundaries, spaces and relationships between humans and animals. This process allowed us to gain a deeper insight into the worlds of different stakeholders working along the poultry supply chain in southern India.

Findings

Separation on the farm: sharing experiences on disease prevention and control with animal health professionals and owners of large-scale poultry integrators. We first used the map in Bangalore at a focus group discussion conducted during the PCVC conference.

In this space, the map unanimously provoked participants to discuss the concept of biosecurity. For instance, upon presenting the group with the disease control map, an owner of a large-scale integrator asserted in English: '*Over the years, farming productivity has improved not just because of the medicines, but because of the good management practices. Good feed, good vaccinations and good biosecurity. This is called a triangle*'. He continued, '*The farmer is attracted to costs, to save the costs he should ensure that his birds do not get diseases. To make sure, he has to have a secure farm*'. Like the poultry integrator, other stakeholders at the PCVC and in the subsequent individual interviews, responded to the map in English and initial comments included the term biosecurity. In these conversations, biosecurity had positive connotations and was defined as the best way in which to prevent and control diseases on poultry farms.

After participants' initial responses, we encouraged them to develop their answers by identifying the weakest spots for disease prevention and control on the farm. In line with biosecurity guidelines, animal health professionals and poultry integrators responded to the map by pinpointing vehicles, people and wild birds as a disruption to the boundaries necessary for effective disease control (cf. FAO, 2008). For instance, when we presented the map to another large-scale poultry integrator and asked him to indicate what for him were the weakest spots for disease control on the farm, he immediately pointed and stated '*wild birds' ….[but] People are red. People are the most dangerous. People are the ones who spread disease. For everything else you can put a barrier and stop but for people they can move as they please*'. As another veterinarian similarly commented after examining the map, '*People are a problem, if people are there, there is always a chance of the chickens getting something*'.

In order to mitigate the effects of movement of vehicles and people and in line with biosecurity guidelines, many participants commented on the need to clean and use disinfectants. As a medium-scale poultry integrator commented, '*We maintain everything else by disinfecting, cleaning….vehicles you have to take care. People and vehicles. Even our people, the supervisor, he will go from farm to farm, so he has to take care. He has to wash his boots as he goes*'. Likewise, a poultry pathologist in an individual interview pointed to the vehicle icon and responded, '*We always advise the poultry farmers to avoid the vehicles from coming onto their farms….That is a risk. If any vehicles are coming, we advise them to thoroughly clean and disinfect, not just near the farm, elsewhere also*'. He later continued, '*after disease outbreaks, the governments have realised there will be huge economic loss if the outbreaks occur. So now most of the states are bringing in these kinds of regulations*'. Thus, for the research participants quoted above, disease control and prevention practices were based on a principle of separation. This transformed the farm into a bounded space. If the boundaries of the farm were compromised, then participants described cleaning and the use of disinfectant as essential.

When probed on cleaning and disinfection, veterinarians and integrators claimed that 'cleaning, disinfection and sweeping', 'Foot baths for vehicles' and 'Maintaining clean sheds' were all vital for preventing and controlling diseases. As a large-scale integrator commented; '*On my farms, biosecurity is 100% implemented. Once the batch is removed it will be cleaned properly. It will be fumigated properly….We are using phenolic for disinfectants. These are routine processes*'. The condition of poultry sheds was also often cited by poultry integrators as impacting on disease outbreaks. Integrators presented with the map regularly commented on the housing icon and distinguished between environmentally controlled, closed sheds and open sided sheds. In this discussion, the latter was deemed to be less 'biosecure'. As one integrator operating environmentally controlled sheds claimed: '*[My] Housing is also hygienic. It is not a weak spot*'.

It was not just cleaning that was described by animal health professionals and poultry integrators as essential for maintaining the boundaries that prevented the spread of disease. These participants also responded to the map by separating dead birds from live birds and poultry litter from the wider farm context. As an integrator stated, '*Disposal of the dead birds, day to day that is done…if it is not properly disposed, that can be an issue. The dead bird should be buried or burned, if it is buried there should be a standard pit for that*'. This separation between what was considered a disease risk and what was considered disease free extended to litter management. As another integrator commented, '*litter management, if this is not done properly there will be issues…Every batch we remove the litter, it goes to agriculture only…people buy a tractor load, 3000 INR (£30) per load*'. While many poultry integrators and animal health professionals commented on the use of litter on agricultural farms, none mentioned that poultry farmers may be simultaneously rearing other types of livestock or agricultural crops alongside their birds.

What we observed from the interactions with the visualisation tool was that when imagining disease prevention and control in terms of biosecurity, animal health professionals and poultry integrators conceptualised the poultry farm as a bounded space, removed from communities and other species of animals. As a result, uncontrolled movement (of wild birds, people and vehicles) was considered to be problematic. If transgressions were made, then cleaning and the use of disinfectants were described as vital. This notion of the farm as a bounded space, created hierarchies and distinctions, separating clean from unclean, and the perception of 'good farms' from 'bad farms'. Accordingly, biosecurity, although never described by participants as one consistent thing, was highlighted by all as something that had to be 'done right' or the farm would fail.

Nevertheless, as much as Indian animal health professionals and poultry integrators described biosecurity in terms of disease control practices and techniques, they also used the word to describe other visions and ideas they had about the farm. For example, participants also discussed productivity and profitability on the farm, as well as other farmyard management practices such as feed and medicine use. Thus, our findings show how participants often conflated multiple different ideas about poultry farming with the word biosecurity. The participants' responses indicate how biosecurity has become part of a global hierarchy of value (cf. Herzfeld, 2004), in which individuals are forced to conform to an undefined set of standards, or risk becoming marginalised within the system. By referring to biosecurity, participants were attempting to reinforce and become part of a global network of 'good' integrators, veterinarians and farmers. Moreover, as discussed next, the same visualisation tool opened up a radically different way of conceptualising disease control when used with contracted poultry farmers in Namakkal, Tamil Nadu.

Entanglements on the farm: sharing experiences on disease prevention and control with poultry farmers in Namakkal. In contrast to the animal health professionals and poultry integrators cited above, on the poultry farms of Namakkal, farmers did not respond to the disease control map in terms of separation. Rather, farmers reacted to the map by discussing the entangled relationships between humans, animals and the environment. As a result, farmers were adamant that people and vehicles were not introducing diseases to the farm. As one farmer explained as he referred to the movement of people, '*The people in the sheds are me, my wife and the vaccinators. On the day of clearance, one or two people will enter…We have one tractor. Some other vehicles* *come. There is no compound here. The shed here is inside the community*' (see Fig. 3).

In order to see how people moved around their farms, we asked farmers to walk us around their premises and to verbalise how the disease control map related to each space. When designing the disease control map, we assumed that a major concern for poultry farmers would be the health of their chickens. However, none of the farmers we visited exclusively raised chickens and farmers' responses to the disease control map illustrated that they were equally as concerned about the health of other livestock and agricultural crops on their farms. In accordance, farmers responded to the prompt on 'other livestock animals' by directly showing us the placement and care of other livestock animals and agricultural crops around the farm as visualised in the spatial map (see Fig. 4).

Fig. 3 A picture of a broiler farm in Namakkal. People walking and driving past a broiler shed.

Alongside raising poultry, farmers also grew an assortment of agricultural crops (commonly sorghum, tapioca, pumpkin, sugarcane, cotton and coconuts) and reared dairy cows, buffaloes and goats. As all of the farmers raised crops, litter from the poultry sheds was consistently used directly on the farmer's own agricultural land. On poultry farms, the disease control map, therefore, opened up a wider discussion around other aspects of the farm such as the farm's boundaries, water sources, farm buildings, the placement of poultry sheds, disposal of litter and the placement of other livestock.

The disease control map allowed us to understand farmers' interactions with animals, natural resources and the environment, and this insight challenged normative assumptions around how relationships ought to be on the farm. This further shows, as Prendiville (2015) also emphasises, that place should be understood as an experiential landscape rather than a spatial distribution of things. Thus, unlike conventional methods such as surveys or interviews, the participatory visualisation tool acted as a prompt that opened up the often implicit and complex relationships that existed between farmers and their livestock.

The entangled and complex relationship between farmers and their livestock extended to other species. As a result, farmers did not describe the other species listed on the map—wild birds, insects, and rodents—as a cause of disease. Consequently, wild birds were regularly observed inside sheds, often a species of babbler that would eat the insects out of the coir bedding. Farmers did not believe that wild birds were a problem for chickens and one even claimed that broiler chickens could infect wild birds with diseases rather than vice versa. As he explained, '*Small birds will come sometimes. I have found them inside the*

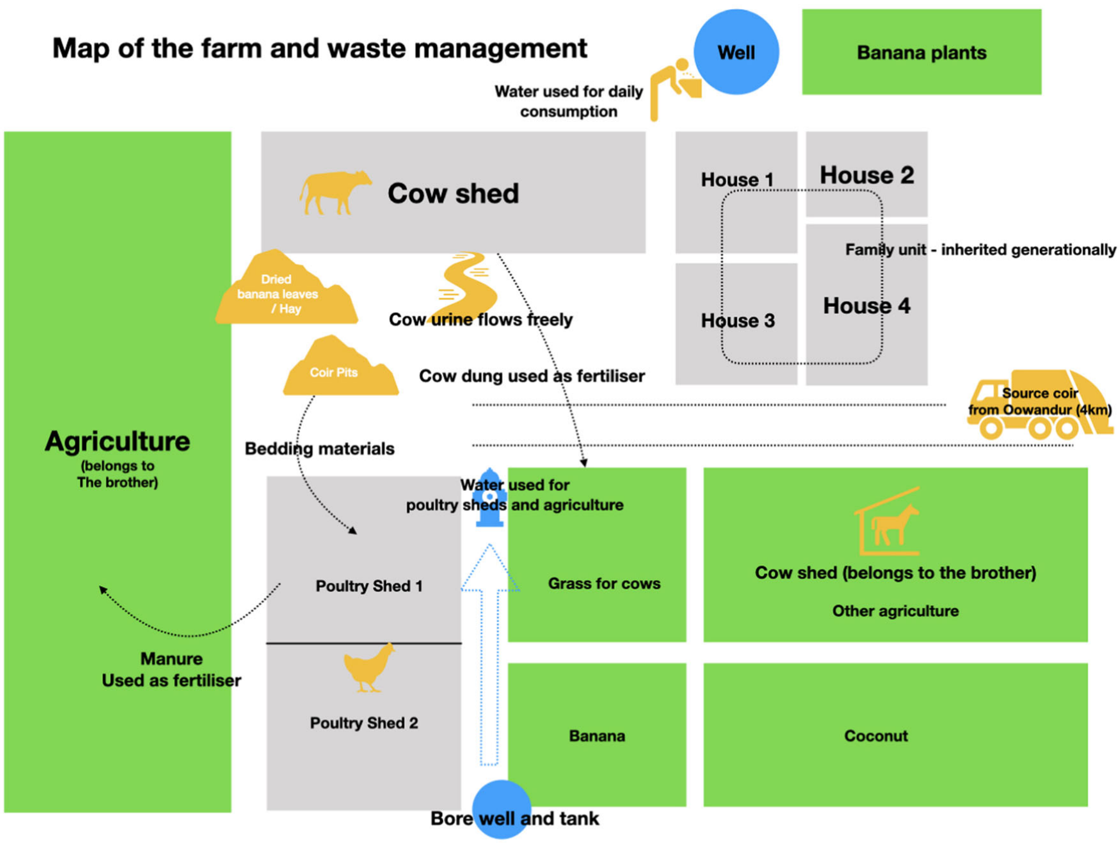

Fig. 4 Spatial map of a farm. This participatory map was designed by walking around and discussing aspects of the farm with the farmer. We carried out this mapping exercise on each farm visited.

shed. It is not a problem… [Actually] if the wild birds come into contact with the chickens then the wild birds will get diseases'. Referencing the map, farmers further presented insects and rodents as common on the poultry farm and as difficult to control. A farmer stated, '*I have no control over rodents. We have one cat…If the rats remain then that is the cat's problem*'. The farmers' comments indicate how the visual icons on the map acted as a lens on the nature of the farm as a living and entangled space where humans, animals and other species co-exist.

Beyond acting as a prompt to understand relationships between species, the map also demonstrated farmers' situated practices. When provided with the map, farmers all discussed farm management practices such as cleaning, waste management and disposal of dead birds. However, when probed further, farmers responded by discussing cleaning and waste management methods that differed to those recommended or expected by animal health professionals. For example, poultry integrators provided formalin spray and citric acid for cleaning the shed after the clearance of birds. Yet, when viewing the map, a wife of a farmer explained how she also used cow dung as a '*natural disinfectant*' to clean the poultry shed. Similarly, many farmers claimed that cow dung was a '*traditional*' disinfectant that could be used to clean the poultry shed.

The notion that everything on the farm was entangled, extended to the disposal of dead birds. Although many farmers had a covered pit, a minority left dead birds in an open pit. One farmer buried the bird into the manure in order to accelerate its decomposition. As another farmer clarified, '*There is no space in the old pit and there is no tank in the new pit, I have to dispose [of the dead bird] by leaving it outside*'. Thus, unlike the animal health professionals and poultry integrators discussed in the section above, in Namakkal, farmers' responses to the map provided an insight into the intricate relationships between humans, animals and the environment. This, in turn, provided an insight into how farmers conceptualised the farm boundaries as porous and fluid, rather than bounded and closed.

The farmers in Namakkal were described by local veterinarians as not following 'good biosecurity'. However, when the farmers were presented with the disease control map, many commented that they had never experienced notable mortality on their farms. They, therefore, did not believe that the visual prompts on the map were potential causes of disease. Rather, farmers asserted that heat stress, weak chicks from the hatchery and failed vaccinations were the real causes of sickness. As one farmer explained, '*Those diseases don't spread from these common things [wild birds, rodents, and insects]. If the birds die, it is from the high temperature in the summer seasons…. a delay in vaccination or if the vaccination is not properly given then the disease will come*'.

Farmers, moreover, expected a small percentage of mortality per batch, up to 5% of the total flock over the lifecycle, as normal (5% was also the percentage set by the integrator). It was, therefore, common to see dead chickens in the first 10 days and after 30 days. Farmers linked the death of chicks in the first 10 days to issues with the hatcheries and weak chicks, while the death of chickens after 30 days was linked to *sali* (cold/flu). Across the farms, farmers described *sali* as a common sickness that was often treatable. Therefore, farmers did not believe it was necessary for the condition to be diagnosed by a veterinarian. As one farmer asserted; '*after 30 days they will get a cold (sali), at that time maybe 10 chickens will die in a day*'. Farmers claimed that *sali* was a problem with the birds' lungs and the main symptom was a change in the sound of the bird. Farmers explained that *sali* always came at the end of the cycle and that it was always treated with antibiotics, commonly Enrofloxacin [Fig. 5].

Although not visualised on the tool, farmers responded to the visual prompts by discussing daily mortality rates as 'normal' and caused by weak chicks, climate, improper vaccinations and *sali* (cold/flu). If *sali* was the cause, then farmers claimed that this could be successfully treated with antibiotics. Thus, what our findings show is that the term biosecurity when visualised, reduces disease control to a set of defined techniques and practices, and yet when these techniques and practices were presented to farmers in Namakkal, they spoke about different ways in which sickness occurred or could be prevented on the farm. Consequently, the visualisation tool, when used in different contexts, highlighted that not only is biosecurity ill-defined and open to interpretation, it is simultaneously a rigid term that does not reflect or allow for local variations or understandings of disease.

Fig. 5 Usage of Antibiotics on broiler farms. A farmer showing a bottle of Enrofloxacin being used on his broiler farm.

Conclusion

In this paper, we have shown that researchers, governments, and global health professionals need to move beyond discussing disease control on farms, in terms of biosecurity. As existing literature has shown, biosecurity is open to interpretation and is ill-defined despite its global prominence. The term has, as we have illustrated, become part of a global hierarchy of value, in which it is a universally present but never clearly defined (cf. Herzfeld, 2004: pp. 2–3). In accordance, we have demonstrated why it is important to develop tools that allow us to understand and deconstruct global hierarchies of value, rather than use language that reinforces and maintains them. In particular, we have described why we chose to design a participatory visualisation tool, as we believed the use of visual prompts would open up the multiple, and often implicit ways, in which different stakeholders conceptualised disease causation, prevention and control.

The use of our visualisation tool in southern India highlighted that even when biosecurity was adopted as a term, it never had a consistent meaning. As evidenced in our findings, amongst animal health professionals and poultry integrators, biosecurity was often conflated with other meanings that were not linked to disease control measures as stipulated in biosecurity guidelines and instructions. Thus, for these research participants, biosecurity was much more than a simple set of disease control practices and techniques. The variation in responses to our visualisation tool, suggests why biosecurity measures are so often not adopted in the same way, even by individuals that advocate for them.

The same tool on poultry farms in Namakkal, highlighted how interpretations of disease control and sickness on farms are often locally contingent. In Namakkal, the visualisation tool illuminated how farmers understood the farm as an entangled space, in which communities of people and different species of animals coexisted together without causing notable sickness in their birds. The tool further prompted discussions around causes of sickness not visualised, including weak chicks and hot temperatures. Thus, the tool showed that biosecurity instructions and guidelines are also too rigid and do not reflect the lived experiences of poultry farmers in southern India. Accordingly, we argue that even if global health organisations and governments produce standardised guidelines and instructions for disease control, there is still a need to understand what farmers think is causing sickness on their farms, and for disease control measures to be designed to embrace and reflect farmers' knowledge and lived experiences.

The term biosecurity reduces the complexity of disease control and farmyard management to a single term that can be transported around the world. Yet, social scientists have long illustrated that it is erroneous to assume that solutions crafted in one context will be applicable in another, and have subsequently encouraged researchers to include other ways of being and doing (cf. Hinchliffe, 2021). We, similarly, conclude that biosecurity has become increasingly meaningless, and rather than offering solutions, simply reinforces a value system that disregards other ways of understanding and controlling diseases on farms. Consequently, we argue that there is a need to move beyond global responses for disease control on farms, and towards designing disease control measures that reflect and respond to local farming contexts. The use of our participatory visualisation tool is one such attempt to capture various local responses and a step towards co-designing sustainable solutions for disease prevention and control on farms.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request and through UK data Service.

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Competing interests

The authors declare no competing interests.

Ethical approval

This research has received ethics approval from research ethics committees of participating universities. We confirm that all research was performed in accordance with relevant guidelines/regulations and have been performed in accordance with the Declaration of Helsinki.

Informed consent

Informed consent was obtained from all participants during focus group sessions and fieldwork in India.

Additional information

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