The Precautionary Principle in Zoonotic Disease Control

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The COVID-19 pandemic has shown that zoonotic diseases are a great threat for humanity. During the course of such a pandemic, public health authorities often apply the precautionary principle to justify disease control measures. However, evoking this principle is not without ethical implications. Especially within a One Health strategy, that requires us to balance public health benefits against the health interests of animals and the environment, unrestricted use of the precautionary principle can lead to moral dilemmas. In this article, we analyze the ethical dimensions of the use of the precautionary principle in zoonotic disease control and formulate criteria to protect animals and the environment against one-sided interpretations. Furthermore, we distinguish two possible conceptions of the precautionary principle. First, we notice that because of the unpredictable nature of zoonotic diseases, public health authorities in general focus on the idea of precaution as preparedness. This reactive response often leads to difficult trade-offs between human and animal health. We therefore argue that this policy should always be accompanied by a second policy, that we refer to as precaution as prevention. Although zoonotic diseases are part of our natural world, we have to acknowledge that their origin and global impact are often a consequence of our disturbed relation with animals and the environment.

Introduction

In recent years, it has become evident that animal husbandry can have a negative impact on public health. These public health risks vary from zoonotic diseases like Avian Influenza and Q-fever, to antimicrobial resistance and particulate emissions (Anomaly, 2015; O'Neill, 2016; National Institute for Public Health and the Environment, 2017). Moreover, not only the health of animals and humans is involved. Intensive livestock production has proven to have a detrimental effect on our ecosystem as well (Seinfeld *et al.*, 2006). For this reason, intensive animal husbandry has received most of the attention. However, public health risks like zoonotic diseases are also associated with organic farming, and keeping of companion animals and horses (Vlaanderen *et al.*, 2019).

The international standard to address these health issues is called One Health. Within a One Health perspective, it is recognized that the health of animals, humans and the environment is inseparably intertwined. Therefore, all health issues at the human–animal-environmental interface should be tackled in a collaborative effort of multipledisciplines—working locally, nationally and globally—to attain optimal health for people, animals and our environment (American Veterinary Medical Association, 2008).

In the interest of public health, health professionals frequently employ the precautionary principle to justify drastic measures to counter zoonotic disease threats (Degeling *et al.*, 2020; van Herten *et al.*, 2020). The general idea of the precautionary principle is that scientific uncertainty should not stand in the way of actions to prevent potential grave harm to the health of humans, animals and the environment (cf. European Commission, 2000). However, zoonotic disease control measures to protect public health can have a negative impact on the health and welfare of animals. Examples of such measures are the culling of healthy animals, restricting the use of certain antimicrobials in animals or confining animals and implementing transport bans.

This raises questions about use of the precautionary principle in relation to the concept of One Health. Can precautionary measures still be justified when protection of public health harms animals or the environment? And what does a One Health perspective teach us about risk and prevention of zoonotic diseases?

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In this article, we illustrate how precautionary measures to combat zoonotic health problems can lead to certain moral dilemmas, especially within the One Health framework. Thereafter, we analyze the use of the precautionary principle in the context of public health and discuss its constraints. We argue that to respect the rationale behind One Health, the use of the precautionary principle in zoonotic disease control should be bound to specific criteria. Then, we will reflect on the societal perception of zoonotic disease risks and prevention strategies following the concept of One Health. Finally, we provide some guidance for the application of the precautionary principle in zoonotic disease control.

Ethical Issues of Precautionary Measures in Zoonotic Disease Control

There are many examples of the use of the precautionary principle to prevent or stop the spread of zoonotic diseases. Most recently, in the Netherlands and other European countries, all animals on infected mink farms were culled to prevent them becoming an animal reservoir for COVID-19. This was done after a comparison of viral DNA that suggested that mink had infected employees (Oreshkova *et al.*, 2020). Although there was no direct threat to public health and experts acknowledged that human–human transmission remained the most important driver of viral spread, mink were culled for precautionary reasons. Even though infected mink showed clinical signs of COVID-19, many of them did seem to recover from this illness. However, because it was not clear if they would then be permanently protected against COVID-19 and no longer infectious for humans, the government decided to take action.

Culling (healthy) animals has become a standard in zoonotic disease control (Degeling *et al.*, 2016). Often this practice is justified on the basis of the precautionary principle. During the outbreak of Bovine Spongiform Encephalopathy (BSE) in the United Kingdom, for instance, 4.7 million cattle were culled as part of an eradication programme to protect public health. This was done because there were indications that by eating meat from cattle affected by BSE, commonly called 'mad cow' disease, humans could acquire Creutzfeldt Jakob's disease. Although at that time the complete aetiology of Creutzfeldt Jakob's disease was not fully clear, policymakers decided that the death of approximately 200 people in that period (1985–1999) justified such drastic measures (Jones, 2001). In other European countries, precautionary measures were implemented too. In the Netherlands, where the incidence of BSE was much lower, the government resisted an EU proposal to cull healthy cows to ensure public trust and to prevent a drop in meat prices (Oosterveer, 2002). However, the Dutch government did implement measures like post-mortem BSE testing and removal of risk material from slaughter cattle. In hindsight, mainly the cost-effectiveness (in euros per life year saved) of BSE control was debated (Benedictus *et al.*, 2009). This shows that political and economic considerations are often dominant in the risk management of zoonotic diseases in livestock that threaten human health.

A similar situation occurred during the Q-fever outbreak in the Netherlands. From 2007 to 2012, approximately 4000 people became infected with *Coxiella Burnetii*, the bacterium that causes this disease. Moreover, in that period the death of 74 people was related to Q-fever. Before long, goat farms in the South East region of the Netherlands were identified as the probable source of the infection. To stop the outbreak, in 2008 the government started with the introduction of strict hygiene protocols and vaccination of the animals. However, the number of infected patients kept rising. On the basis of the precautionary principle, the Dutch Institute for Public Health and the Environment therefore advised to kill all the goats on 90 goat farms in this region at the end of 2009 (Bruschke *et al.*, 2016). In total 50,000 animals were culled, many of them in gestation. Although it was not clear if all of them were infected, authorities decided to make no exemptions because testing was too time-consuming and costly. In the Netherlands, the government was subject to strong public criticism about their (slow) response to this zoonotic disease (Van Dijk *et al.*, 2010). This indicates that according to societal opinion, public health generally trumps other values.

Apart from culling healthy animals, the use of the precautionary principle has other problematic implications as well. For instance, to prevent outbreaks of Avian Influenza, free range poultry is regularly confined for several months a year. This can seriously impact animal welfare because the housing system in these free range farms is often not adapted for this. Another example are (European) policies to reduce antimicrobial use in animal husbandry in order to fight antimicrobial resistance. These include restrictions of the use of certain antimicrobials in animals because they are critically important for public health. Although over- and misuse of antibiotics in livestock is acknowledged as a public health

threat, veterinarians as well as farmers address concurrent health and welfare risks for animals. They point at a rise of mortality and morbidity rates because animals receive suboptimal medical treatment. In this perspective, the Dutch Council on Animal Affairs warned that: 'the wish to achieve major reduction in antibiotic use in animal husbandry should never lead to the attitude that higher disease incidence and mortality are acceptable' (Council on Animal Affairs, 2016: 9).

Ethical questions regarding the use of the precautionary principle do not only arise in animal husbandry. In 2019, the Dutch Food Safety Authority detected *Brucella Canis* in dogs that were bred in the Netherlands. Until then, this zoonotic infection only occurred in dogs imported from Eastern European countries, where the disease is endemic. As a precautionary measure, authorities decided to euthanize all dogs in the breeding kennel that was the source of infection. *B. Canis* is a bacterial infection that can cause inflammation of reproductive organs and abortion in dogs, sometimes with ocular disease or discospondylitis. The bacteria usually persists in these animals even after treatment with antimicrobials. Experts therefore advice neutering, isolation or euthanasia (in breeding kennels) (Spickler, 2018). In humans *B. Canis* infections cause flu-like symptoms that normally respond well to antimicrobial treatment. Especially immuno-supressed people and young children are vulnerable. Because the number of human *B. Canis* cases is low, even in regions where the disease is endemic, not many countries have developed control plans. Instead of culling infected dogs, vaccination could significantly reduce the health risk for dogs as well as humans (Hensel *et al.*, 2018). However, because of the low zoonotic risk, the disease receives low priority from institutions such as the World Health Organisation. As a result pharmaceutical companies do not recognize a commercial interest in vaccine development for dogs, contrary to cattle for which Brucellosis vaccines are available.

Decision making in zoonotic disease control can cause value conflicts, for instance between values like animal welfare, public health or economy (Capps *et al.*, 2015; Degeling *et al.*, 2017; van Herten *et al.*, 2020). The use of the precautionary principle raises ethical questions, especially in the light of current One Health thinking. First of all, from a One Health perspective, one could question whether it is justified to apply the precautionary principle in such a way that it harms animals or the environment. Or does the One Health paradigm prescribe certain restrictions to prevent this? Furthermore, the precautionary principle is normally evoked concerning human actions that could possibly harm public health or the environment. For instance, to justify regulations on genetic modification of crops, like the EU ban on CRISPR-Cas gene editing in plants. In those cases, the principle prescribes to refrain from these actions or to adjust them to prevent this harm. But as we have seen, the precautionary principle is also used in case of zoonotic infectious diseases that often arise suddenly and unpredictably. What is the role of human actions in these situations? Does it make a difference if the cause of a zoonotic disease outbreak is anthropogenic instead of 'natural'? We will address these issues in the rest of this article, and offer some guidance in applying the precautionary principle in the context of zoonotic disease outbreaks, but first we will elaborate on the use of the precautionary principle in public health policies.

The Precautionary Principle and Public Health Policies

How should we act to prevent potential harm in times of scientific uncertainty? This is basically the question that underlies the idea of the precautionary principle. In the light of possible future environmental damage through human actions, the first formulation of the precautionary principle was coined during the United Nations 'Rio' conference in 1992: 'Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost effective measures to prevent environmental degradation' (United Nations, 1992). The 'Wingspread' conference in 1998 developed another yet similar version, including the notion of public health: 'when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically' (Science and Environmental Health Network, 1998). Since then many different versions and interpretations have evolved. To date no specific definition is formulated for the application of the precautionary principle in zoonotic disease control. There are however, more tailored descriptions of the principle in the public health setting.

Horton (1998: 252) for instance, interpreted the principle as follows:

> We must act on facts, and on the most accurate interpretation of them, using the best scientific information. That does not mean that we must sit back until we have 100% evidence about everything. Where the state of the health of the people is at stake, the risks can be so high and the costs of corrective action so great, that prevention is better than cure. We must analyse the possible benefits

> and costs of action and inaction. Where there are significant risks of damage to the public health, we should be prepared to take action to diminish those risks, even when the scientific knowledge is not conclusive, if the balance of likely costs and benefits justifies it.

In 2000, the European Commission has published guidelines for the use of the precautionary principle (European Commission, 2000). In this document, it is stated that the principle is applicable to prevent harm to the health of humans, animals, plants and the environment. The Commission stresses the importance of structured decision procedures and the use of all available scientific evidence. Although helpful in some aspects, these EU guidelines leave many ethical questions unanswered. For instance, how to deal with conflicting values? Is public health always dominant over animal and ecosystem health? Or how to weigh the benefits of prevention of public health harms on the short term, against long-term negative effects of disease control measures on animal and environmental health?

In the context of public health, the impact and consequences of using the precautionary principle has been debated extensively. Some authors consider the principle not applicable in clinical human medicine nor public health policy. According to Ter Meulen (2005), physicians have an obligation to do good to their patients and have to weigh the benefits against possible harms and burdens. The basic virtue of medical decision making is not avoidance of risks, as stated in the precautionary principle, but the prudent assessment of benefits, burdens and harms, in relation to other ethical principles like respect for autonomy and justice. Ter Meulen believes the precautionary principle does play a role in health care, but it should never rule medical decision making as an absolute principle. In contrast, Resnik (2004) thinks the precautionary principle can offer physicians and patients a useful tool in making decisions about treatments. When physicians lack adequate scientific proof relating to the potential outcomes associated with various choices, they should take reasonable measures to avoid health threats that are serious and plausible. According to Resnik, the reasonableness of a response to a health threat depends on several factors, including benefit vs. harm, realism, proportionality and consistency (Resnik, 2004). The precautionary principle is also widely adopted in drug development to prevent unwanted negative side-effects on human, animal and environmental health. As a consequence of this risk averse attitude, the introduction of new therapies could be slowed down and therefore harm patients (Bailey, 2001). In the race to develop an effective vaccine against COVID-19, we have seen that these precautionary regulations are stretched when needed (European Commission, 2020). Finally, some authors warn that careless use of the precautionary principle to protect public health could result in the opposite. It is claimed, for example, that the ban on insecticides like DDT has caused a resurgence of malaria in developing countries (Bate, 2003).

The main reason for public health professionals to appeal to the precautionary principle is to prevent harm to public health, since this is the primary objective of public health policies. In practice, the precautionary principle functions as a decision-making tool. When public health professionals, due to a lack of scientific evidence, cannot base their decisions on the basis of a standard cost-benefit analysis, they often use the precautionary principles as a guideline. An example of this is the advice to wear face masks to prevent COVID-19 transmission. Although it is scientifically contested whether it will reduce viral transmission significantly or not, health authorities in many countries think that the seriousness of the COVID-19 pandemic justifies an obligation to wear non-medical face masks in public (Greenhalgh *et al.*, 2020).

In such cases, the function of the precautionary principle can best be described as an heuristic tool for decision-making under uncertainty (Tickner, 2002). Often without explaining the rationale behind their decisions, public health professionals tend to justify disease control measures by referring to the precautionary principle (Rosella *et al.*, 2013). However, an appeal to the precautionary principle is not a carte blanche. Several scholars have pointed out that there are certain constraints around the use of the principle in health settings. In the next paragraph, we will discuss these limitations.

Conditions and Constraints for the Precautionary Principle

As seen earlier, the precautionary principle comes in many forms and applications. In general, for each version of the precautionary principle at least three conditions must be met (Kramer *et al.*, 2017).

First, there must be some kind of *harm*, that does or might occur. Within the context of zoonotic disease control and public health policies, this harm is often primarily understood as harm to human health. However, starting from the concept of One Health, harm to the health of animals and the environment should be taken into account too, especially, because the health of living beings and ecosystems is inextricably linked. One Health

teaches us that preventing animal and environmental health damage will eventually benefit human health too. Traditionally, the precautionary principle was directed to anthropogenic actions in order to prevent harm to the health of humans, animals or the environment. Typically in the case of a zoonotic disease outbreak such a harm can also originate as a non-anthropogenic event. However, in many cases the drivers of these outbreaks are in fact traceable to human activity, such as deforestation, climate change, wildlife trade, etc.[1].

Second, to evoke the precautionary principle, it has to be (theoretically) plausible that without interference the health of humans, animals or the environment is indeed harmed. This *knowledge* condition requires that there is at least a minimal amount of scientific evidence that with taking precautionary measures health harms can be prevented. This approach contains the risk that a theoretical and minimal chance of a serious health threat, would immediately lead to the implementation of drastic precautionary measures. Wilson and Atkinsons recognized this danger of overreaction where the measures to prevent the harm might be more harmful than the event itself. They proposed a framework for calibrated precaution where the theoretical risk is balanced against the potential harm of the risk mitigating policy (Wilson and Atkinson, 2017). From a One Health perspective, this assessment should also include the health risks for animals and the environment. In this respect, the emphasis should not only be on the impact of the zoonotic disease itself but also on the effect of disease control measures.

This brings us to the third condition of the precautionary principle which is focused on the element of *precautionary action*. This condition concerns the precautionary measures that are indicated when the harm and knowledge condition are met. Logically, the consequences of these actions may not be worse than the harm they should prevent. Kramer *et al.* (2017) proposed three criteria to evaluate possible mitigating measures. To begin with, they argue that the precautionary principle cannot prescribe safety measures and, considering the potential harms involved in those measures themselves, advise against them at the same time. In other words, the precautionary principle has to be applied in a *consistent manner* and one cannot simultaneously prescribe and forbid certain safety measures. However, in the case of zoonotic disease control this often seems more or less inevitable. As we have seen earlier, many common disease control measures, like culling or containing, do have a negative impact on animal health or welfare. Moreover, the broader the definition of harm, the more difficult it will become to prescribe disease control measures that don't have any negative consequences.

This leads us to the second criterion for precautionary measures, which is to *avoid counterproductivity*. Precautions should not cause more harm than they ought to prevent. For instance in the case of COVD-19, effective disease control measures such as a lockdown have led to serious socio-economic harms. Some studies even suggest that the numbers of lives saved by measures, like a total lockdown, are overridden by the number of lives lost by the consequences of these policies (Gupta Strategists, 2020). And although at first sight, the environment has seemed to benefit from the shutdown of human activity, it is unclear what the effects in the future will be. Further steps to mitigate the effects of climate, for instance, will require major financial investments. In times of economic depression this could be difficult for many countries.

Finally, the criterion of *proportionality* forbids precautions that are more harmful than other alternatives. In a One Health approach, this implies that the effect of certain measures to protect public health on animals and the environment, should be taken into account. Along this line of argumentation, an intervention such as vaccination of humans and/or animals is a better alternative than culling practices. Again, this assessment will be more difficult when the definition of harm is considered broader than direct health effects. At the same time, it will imply difficult trade-offs between short- and long-term interests of humans and animals. To let the precautionary principle function as a useful instrument for policy makers addressing zoonotic disease risks these criteria provide some guidance. However, as Kramer *et al.* (2017) state, accepting these constraints will imply that a certain degree of risk has to be accepted. In the case of safety of donor blood, for instance, this can imply that a small risk on certain transferable diseases is tolerated because the costs of complete testing are irrationally high. In the next paragraph, we will explain that in case of zoonotic disease risks this can be complicated.

Ethical Acceptability of Zoonotic Disease Risk

On the ethical acceptance of risk, Hansson (2003) posed that in principle everyone has a prima facie right not to be exposed to risk. However, this right can be overridden if the risk-exposure is part of an equitable system for risk-taking that on balance works to the advantage of the individual risk-exposed person as well. In many parts of the world the practice of animal husbandry for the

production of food is, to a certain extent, socially accepted and sometimes even necessary for survival. The vast majority of the global human population benefits from this social system. This could imply that the exposure to public health risks associated with livestock production, like zoonotic diseases, is likewise acceptable.

However, in a number of (Western) societies there are a considerable number of people who oppose the consumption of animal proteins for moral and/or environmental reasons. In Europe approximately 5 per cent of the population follows a vegetarian or vegan diet (Nielsen, 2016). Besides that, in most parts of the world animal protein is no longer a necessary ingredient of a healthy diet. On the one hand, this could imply that in these societies public health risks of farm animal husbandry are not ethically acceptable after all. On the other hand, most people accept that we use animals for other reasons like companionship or sport. As said earlier, zoonotic diseases are associated with these types of animal keeping too. Moreover, the greatest risk for emerging zoonotic diseases comes from the wildlife reservoir (Jones *et al.*, 2008). This implies that where (domesticated) animals and humans live closely together, there will always be a certain risk of zoonotic disease transmission. As a matter of fact, zoonotic diseases are and always will be a natural part of any ecosystem on the planet.

Therefore we have to conclude that as long as we live in a world with wild and domesticated animals, a certain level of zoonotic disease risk is unavoidable and should be considered as a fact of life. Of course, this does not exempt animal keepers from their duty to prevent zoonotic diseases to spread. In principle, this duty is equal for farmers, horse-keepers or owners of companion animals. In this respect, all animal owners have a moral obligation to take preventive measures like securing biosecurity, vaccination and veterinary care. In situations where zoonotic disease risk is considered higher, for instance in intensive animal husbandry, a greater effort and perhaps stronger regulations to prevent zoonotic spill over are justified. At the same time, this implies a moral obligation of society as a whole to protect the natural habitat of wildlife. Not only to prevent the spill over of pathogens to humans, but from a One Health perspective also to safeguard the health and welfare of animals in the wild and our environment. Hinchliffe and Ward translate this as follows: 'biosecurity, or what we call the making of safe life, is constituted through an ability to work with rather than against a complex microbial environment' (Hinchliffe and Ward, 2014: 136)

So the question is how much—or little—zoonotic risk from animal husbandry should public health authorities accept before they can appeal to the precautionary principle and take control measures? In this respect, a general critique of the precautionary principle is that it can be unrealistically intolerant for risk and requires unreasonable sacrifices in the name of safety (Kramer *et al.*, 2017). It would be unreasonably for example, to cull a large number of healthy animals, only to avoid a small risk for humans of contracting a minor flu. To establish a reasonable threshold can be difficult. Depending on the ethical framework, the outcome of such an assessment will differ. In a utilitarian calculus, for instance, there will be a certain tolerance for human casualties, as long as overall utility of animal husbandry overrides these losses. A deontological perspective, on the other hand, may offer more support for a zero tolerance approach of zoonotic disease risk. In general, public health authorities will take an anthropocentric approach in such assessments. However, from a One Health perspective harm to animals and the environment should be included as well.

How difficult these considerations can be for the responsible authorities, can be illustrated by the debate about public health risks of residents living in the vicinity of (goat and poultry) farms in the Netherlands. Research has pointed out that there is a higher incidence of pneumonia (5–7 per cent) in people living close to these farms (< 2 kilometres) (National Institute for Public Health and the Environment, 2017). Although the exact cause of this effect is not identified yet, a higher level of endotoxins in the air is supposed to play a role. Besides an increased risk of pneumonia, researchers also found that people living close to farm had less asthma and less allergies. At the same time it is known that in certain regions in the Netherlands, 70–90 per cent of the farms lie within 250 metres from residential buildings. To banish the risk of pneumonia related to animal husbandry completely in these regions, drastic measures would be necessary and probably require a radical change in urban development and rural planning. This seems unrealistic in the short term. Furthermore, the trade-off between the risk of pneumonia and the prevalence of asthma and allergies, is something to take into account too.

Local governments, however, do have the authority to make decisions about land use planning and environmental licensing. In the Netherlands, this resulted in regional bans for goat farms to expand. The public concern about goat farms was already elevated because of the Q-fever epidemic (2007–2011) in the Netherlands. The results from further research concerning the public health risks of animal husbandry, established a new but unidentified relation with goat farming. Altogether this urged local governments to invoke the precautionary

principle and take preventive action. In the following decision-making process, human interests like public health and economics were balanced. However, the interests of the animals were hardly taken into account. The effect of withholding licenses to expand, confronted farmers with housing problems causing welfare problems, especially for young male goats. These animals are economically of little value and therefore worst off. As often in case of zoonotic disease control, it seems that animals are at the losing end.

Even if zoonotic disease risks might sometimes be inevitable, there is still a moral obligation to compensate and reduce zoonotic disease risks whenever possible, and to adequately inform the people at risk about the situation (cf. Hansson, 2003). This places a special burden on those responsible for potentially harmful activities (Raffensberger and Tickner, 1999). In the context of animal husbandry, it implies that farmers have to take all the preventive measures they possibly can to mitigate zoonotic disease risks. This includes inter alia: optimal biosecurity, housing and management that supports animal health, preventive veterinary care like vaccination. Furthermore, public health authorities should implement early warning systems to detect (unexpected) disease outbreaks. Living with uncertainties concerning zoonotic disease risk can be stressful and lead to societal tensions, for instance in communities with intensive animal husbandry. After analyzing the public health response against West Nile fever in the United States, Tickner therefore concluded that zoonotic disease control cannot remain the exclusive domain of experts (Tickner, 2002). Especially because zoonotic disease control can lead to value conflicts and experts' values are not necessarily more weighty than non-experts' values, policy-making will benefit from a broad and informative public dialogue, acknowledging unavoidable risks, uncertainties and trade-offs, because this creates transparency and hence trust and public support.

Operationalizing the Precautionary Principle in Zoonotic Disease Control

What can we learn from these insights for the application of the precautionary principle in zoonotic disease control? To answer this question, it is helpful to distinguish between two rational approaches to risk: prevention and preparedness (cf. Lakoff, 2007). In situations where a standard cost-benefit analysis is impossible because of scientific uncertainties, authorities often fall back on precaution as the basis for decision-making. Precaution typically entails avoidance of risk by refraining from certain actions or taking measures to prevent associated risks. As we have seen, in case of zoonotic disease risks, this is not always feasible. Zoonotic diseases can strike unexpectedly and as COVID-19 has proven, it is nearly impossible to predict which pathogen will cause the next pandemic nor when or where this will happen. For these kinds of zoonotic disease risks, preparedness is probably a much better approach. As Lakoff states: 'Preparedness does not seek to prevent the occurrence of a disastrous event but rather assumes that the event will happen. Instead of constraining action in the face of uncertainty, preparedness turns potentially catastrophic threats into vulnerabilities to be mitigated' (Lakoff, 2007: 253).

In case of zoonotic disease control, we therefore propose to differentiate between two supplementary approaches, each with their own interpretation of the precautionary principle. The first policy is that of preparedness. This approach is applicable in the situation of an acute and/or unexpected zoonotic disease outbreak. In principle, it doesn't matter whether this disease emerges from animal husbandry, companion animals or wildlife. The goal of this strategy is to be prepared and to respond and mitigate the effects of such a zoonotic disease as effectively as possible. Depending on the scientific and empirical knowledge that is available, disease control measures in this approach are either based on a standard cost-benefit analysis or when uncertainty is too high on the precautionary principle. Within this approach there is a strong focus on short term risk management. We refer to this approach as 'precaution-as-preparedness'.

The version of the precautionary principle that is applicable here reflects the definition of the United Nations that: 'in case of threats of harm to human health, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically' (United Nations, 1992). To justify interventions on the basis of the precautionary principle, the harm and the knowledge condition have to be sufficiently met. For instance, to take measures that affect animals a plausible link between human disease and the animal population has to be established. Furthermore, to select and justify certain precautionary measures, the criteria of consistency, proportionality and counterproductivity have to be met. From the perspective of One Health, this implies that the effect of interventions on animals and the environment have to be taken into account as well. This could lead to the conclusion that the culling of animals is sometimes counterproductive and disproportional, like in the case of culling badgers to prevent the spread of zoonotic bovine tuberculosis in cattle in the United Kingdom. In

hindsight, this strategy has proven to be neither cost-effective nor effective and even counterproductive because of the consequential damage to biodiversity which is a key factor in zoonotic disease spread (Lederman, 2016). An assessment of the effect of precautionary measures should be integrated in the standard decision models of public health authorities. Moreover, to ensure societal support these considerations and the trade-offs they contain should be transparent and open for dialogue, with the involved stakeholders as well as with the general public.

Degeling *et al.* characterized the 'precaution-as-preparedness' approach as 'managing risk'. They recognized that under this regime policy-makers try to avoid the risk of over-reacting to the threat, such that precaution acts as an epistemic rule (Degeling *et al.*, 2020). This knowledge-driven strategy is reactive in nature because it bases decisions and interventions on the scientific evidence that is at hand. This in contrast to what they call the regime of 'managing uncertainty', which is directed towards promoting system resilience while at the same time protecting those at immediate risk from disease emergence (Lysaght *et al.*, 2016). In this respect, resilience can be defined as the capacity or ability of an individual or a system to react to an external force and to maintain or return to a state of equilibrium. Striving for resilience can have a stabilizing effect on pathogen behaviour (Heymann *et al.*, 2017). In the latter way of thinking, the focus is more on averting zoonotic disease outbreaks than on response. This brings us to a second approach of zoonotic disease control: prevention. Without underestimating the importance of a well-functioning mechanism to react to zoonotic disease outbreaks, we believe there currently is a lack of effort to address the causes of these events. To encounter the increasing risks of zoonotic diseases in our modern world, a more long-term approach is needed. This strategy should be aimed at improving and maintaining the resilience of ecosystems, of which animals and humans are inseparable elements.

As we have seen, applying the precautionary principle in zoonotic disease control can lead to trade-offs between human and animal health. From a One Health perspective this is problematic. In our non-ideal world, the consequences of zoonotic disease control are often distributed unequally between humans, animals and the environment. The policy we refer to as 'precaution-as-preparedness' is reactive in nature and disease control measures are sometimes detrimental to animals and the environment. Although such measures can be necessary to stop the disease, in our view such an approach is only justified in combination with a policy directed at 'precaution-as-prevention'. This implies that we should pay more attention to the underlying human drivers of zoonotic disease outbreaks. Moreover, because the risk of single zoonotic disease outbreaks cannot be completely eradicated, it is more effective to examine and address the root causes of zoonotic disease at the system level (Tickner, 2002).

In our view such an approach follows the core principles of One Health to promote the health of humans, animals and the environment (van Herten et al., 2019). Within this perspective, 'precaution-as-preparedness' should always be accompanied by 'precaution-as-prevention'. The focus of the latter should be on possible human activities that could potentially harm the health of humans, animals or the environment. It also requires that certain precautionary measures to prevent zoonotic disease risks should be taken even if some cause-and-effect relationships are not fully established scientifically. This implies inter alia that health authorities and governments should critically assess all human activities that could contribute to possible zoonotic disease outbreaks, like globalization, food production, land use, urbanization, etc. On a national level, such an impact assessment could be part of licensing systems, for instance for food production, transport or construction.

Conclusions

In this article, we have given many examples to illustrate that the use of the precautionary principle in the context of zoonotic disease outbreaks can have problematic ethical implications, particularly when we take the One Health perspective seriously. Currently, when the precautionary principle is applied, there often is a one-sided focus on human health and economic considerations, and precautionary measures can lead to unwanted outcomes or trade-offs. In other words, the application of the precautionary principle in zoonotic disease control can cause value conflicts. Appeal to the precautionary principle, furthermore, has certain limitations; it must be clear that there is a harm, there has to be a certain amount of scientific evidence for a cause and effect relation and the proposed precautionary measures should be effective, consistent, proportional and avoid being counterproductive. These limitations show that in practice, we have to accept a certain degree of risk. Establishing what level of risk is acceptable, amongst other things, calls for a public dialogue, as value judgements need to be made and this cannot only be left up to experts.

The fact that a certain level of zoonotic disease risk is unavoidable, forces us to think about managing these

risks. In our view it is not enough to be well prepared for (re-)emerging zoonotic disease threats. Such a reactive approach will inevitably lead to value conflicts and trade-offs that are often not consistent with the concept of One Health. We promote that this preparedness should be supplemented with a more fundamental approach that addresses the root causes of zoonotic disease risks. This strategy, that we call 'precaution-as-prevention' must be aimed at improving the health and resilience of animals and ecosystems primarily, to ultimately benefit the health of humans as well. That is what it implies when you take One Health seriously.

Note

1. We argue that human actions are often the direct or indirect cause for zoonotic disease transmission. Therefore, our conclusion is that zoonotic disease outbreaks often have anthropogenic drivers. However, the actual transmission from animals to humans is in many cases not directly anthropogenic. Examples of non-anthropogenic zoonotic disease transmission are West Nile virus, where humans become infected by a vector (mosquito bite) and rabies, where humans are bitten by an infectious rabid animal (dog, cat, raccoon, etc.)

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