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Biological threats from a 'One Health' perspective

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Summary

Biological threats are a prime example of an issue that needs the 'One Health' approach. Such an approach would facilitate the prevention and mitigation of these threats. 'One Health' is defined as any added value in terms of the health of humans and animals, financial savings or environmental services achievable through the cooperation of human and veterinary medicines when compared to the two disciplines working separately. This principle also applies to the involvement of other disciplines from the natural sciences and humanities. This paper is not an exhaustive survey of integrated approaches but discusses concepts and methods and provides key examples of the benefits of a 'One Health' approach when applied to biological threats. Zoonoses and vector-borne diseases (i.e. diseases transmitted between animals and humans and by insect or acarian vectors) remain central biological threats in highly dynamic social and environmental conditions. Such diseases are not always directly transmitted. Contaminated food, water, air and soil represent important sources of transmission for foodborne and environmentally related diseases. Therefore, this paper treats environmental sanitation separately because of the importance of the excreta management of humans and animals. Integrated syndromic surveillance and antimicrobial resistance surveillance link the above aspects and are showcases for a 'One Health' approach to biological threat reduction. Biological threats are not only related to natural conditions but may also be exacerbated by large development projects such as dams, mining and infrastructure. Consequently, it is recommended that the health impact assessment (HIA) approach be implemented as early as the planning stage of any large infrastructure project located in a complex socioecological system. This paper extends the HIA approach to an integrated 'One Health' impact assessment approach.

Keywords

Antimicrobial resistance – Biological threat – Foodborne – Health impact assessment – One Health – Syndromic surveillance – Vector-borne – Zoonosis.

Introduction

Biological threats are a prime example of an issue that would benefit from a 'One Health' approach to ensure its prevention and mitigation. The term One Health came into use at the beginning of the 21st century in relation to integrated wildlife conservation as 'One World – One Health™' (1), which was an extension of Calvin Schwabe's 'One Medicine' (2). For a detailed history of the convergence of human and animal health, the reader is referred to Bresalier *et al.* (3). This paper concentrates on the meaning and theoretical foundation of One Health, which the authors define as any added value in terms of the health of humans and animals, financial savings or environmental services achievable through the cooperation of human and veterinary medicines when compared to the two types of medicine working separately (4). This principle also applies to the involvement of other disciplines from the natural sciences and humanities.

What are the potential benefits of One Health in terms of reducing biological threats? Why does it make sense and save resources when physicians, veterinarians, microbiologists and others from related disciplines cooperate as closely as possible rather than work separately? An almost perfect example, which answers these questions, is the poor early communication between public and animal health authorities that contributed to the recent Q fever outbreak in the Netherlands, leading to thousands of avoidable human cases (5). But anecdotal evidence is not enough. Closer cooperation also requires more resources and therefore the authors must demonstrate that a One Health approach yields faster and better results, and saves more lives or financial resources than it requires to prevent or

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mitigate biological threats. For this, new integrated methods quantifying such benefits against separate approaches are needed. This paper is not an exhaustive survey of integrated approaches but provides concepts and methods and key examples of the benefits of a One Health approach when applied to biological threats. Zoonoses and vector-borne diseases, diseases which are transmitted between animals and humans or by insect or acarian vectors, remain central biological threats in highly dynamic social and environmental conditions. Such diseases are not always directly transmitted. Contaminated food, water, air and soil represent important sources of transmission of food-borne and environmentally related diseases. Therefore, the authors treat environmental sanitation separately because of the importance of the management of human and animal excreta. Integrated syndromic surveillance and antimicrobial resistance surveillance link the above aspects and are showcases for a One Health approach to biological threat reduction. Biological threats are not only related to natural conditions but may also be exacerbated by large development projects such as dams, mining and infrastructure (6). Consequently, it is recommended that the health impact assessment (HIA) approach be implemented as early as the planning stage of any large infrastructure project located in a complex socioecological system (7). Taking an integrated approach to human and animal health considerations in the HIA has significant potential. Against this background, in this paper the authors extend the HIA approach to an integrated One Health impact assessment (OHIA) approach.

Zoonoses and vector-borne diseases

For many zoonotic and vector-borne disease outbreaks, cases occur first within wildlife and livestock before spilling over to humans (8). At onset, however, the animal source of the human infection is often unknown. Integrated One Health study designs, investigating human and potential animal reservoirs at the same time, allow for the identification of animal sources of human infection. In this way, cattle were identified as the source of human brucellosis and dromedaries as a likely source of human Q fever infections in nomadic pastoralists in Chad (9). Table I shows the results of a study on representative brucellosis seroprevalence in humans, sheep, goats and cattle in Kyrgyzstan. This study allowed sheep to be identified as the main reservoir for human brucellosis (10). Sheep were later confirmed to be the main reservoir for brucellosis (11). Unfortunately, the Kyrgyz public health authorities did not share their human brucellosis strains with the authors for comparative molecular typing. This would have allowed the observations from the representative serological study to be confirmed. Similarly, in a recent molecular epidemiological study on bovine tuberculosis in Morocco, its public health authorities refused to share their tuberculosis strains for comparative analysis between humans and cattle. These examples show how the time to detection of the reservoir of zoonotic diseases can be shortened by using a One Health approach. However, they also illustrate the problem of persistent poor communication between the human and animal health domains, which results in illness and loss of life. Ironically, this also demonstrates the potential advantage of One Health. At the same time, human–animal linkages in zoonotic diseases are not always straightforward. For example, in a human/livestock brucellosis serological study in Mongolia, the direct link between humans and specific livestock species could not be demonstrated (12). This might be due to spatial aggregation: statistical linkages between humans and animals often appear to be more obvious at the provincial level rather than at the district or village level (10). Interestingly, for rabies the authors could demonstrate a close link between the disease and human exposure to rabid dogs within the same household in N'Djamena, Chad (13).

The transmission of vector-borne diseases depends highly

Table I
Sampling plan of the integrated human and animal brucellosis serology study in Kyrgyzstan
Source: Modified from Bonfoh *et al.* (10)

Species	Total	RBT (Biorad)	RBT (Ukraine)	ELISA IgG (ruminant)	ELISA IgG (human)	ELISA IgM (human)	FPA	Huddleson test
Cattle	1,813	737	1,560	1,698	0	0	1,691	0
Sheep	2,076	761	1,855	2,029	0	0	2,029	0
Goats	1,286	764	1,082	1,209	0	0	1,176	0
Humans	1,775	644	0	0	1,762	369	0	1,774

ELISA: enzyme-linked immunosorbent assay
FPA: fluorescence polarisation assay
IgG: immunoglobulin G
IgM: immunoglobulin M
RBT: Rose-Bengal test

on the abundance of vectors (e.g. mosquitoes, flies and ticks), which in turn depends on ecological factors and climatic conditions. Therefore, the combined study of mosquito species and disease cases in sheep and humans is warranted in order to prevent periodic outbreaks of Rift Valley fever (RVF) cases in humans. This type of integrated study would also have prevented the mistaken identification of a Mauritanian RVF outbreak in humans, initially classified as yellow fever. In this case, the correct diagnosis was only made after national public health services contacted livestock services and learned about the occurrence of abortions in cattle (14, 15). Another example is a recent RVF outbreak in Kenya, where the public health authorities reported human cases before the veterinary authorities reported animal cases, showing the poor sensitivity of RVF surveillance in livestock and vectors. Today, Kenya is one of the first African countries to have a permanent Zoonoses Control Commission under the Ministries of Health and Livestock Services (16). Modern RVF prediction includes sea surface temperature and vegetation index data (17) and consequently extends towards an ecosystem health approach (18).

Environmentally related diseases

As with directly or vector-transmitted zoonotic diseases, integrated methods for the assessment of foodborne and environmentally related diseases allow for the detection of biological threats sooner than if a health-facility-based study alone were employed. For foodborne diseases, this is already largely done through extensive food safety control systems. For environment-related hazards like anthrax or leptospirosis, similar frameworks can be applied to identify the most important locations and sources (19, 20).

Environmental sanitation

Environmental sanitation is a special type of biological threat because of its relationship to human hygiene practices and the recycling of nutrients (21). In many rural areas, integrated environmental sanitation addresses human and livestock excreta management. Nguyen *et al.* have developed a broader intervention framework that identifies the most critical contamination points. This is achieved in a similar way to the hazard analysis and critical control point (HACCP) system for the material flow analysis of environmental sanitation systems, combined with quantitative microbial risk assessment (MFA-QMRA) and a socio-economic analysis of the most profitable interventions in Vietnam (Fig. 1) (22). Similarly, the World Health Organization (WHO) has recently developed a sanitation safety planning (SSP) manual for the promotion of the safe use and disposal of wastewater, grey water and excreta (23, 24).

Integrated syndromic surveillance

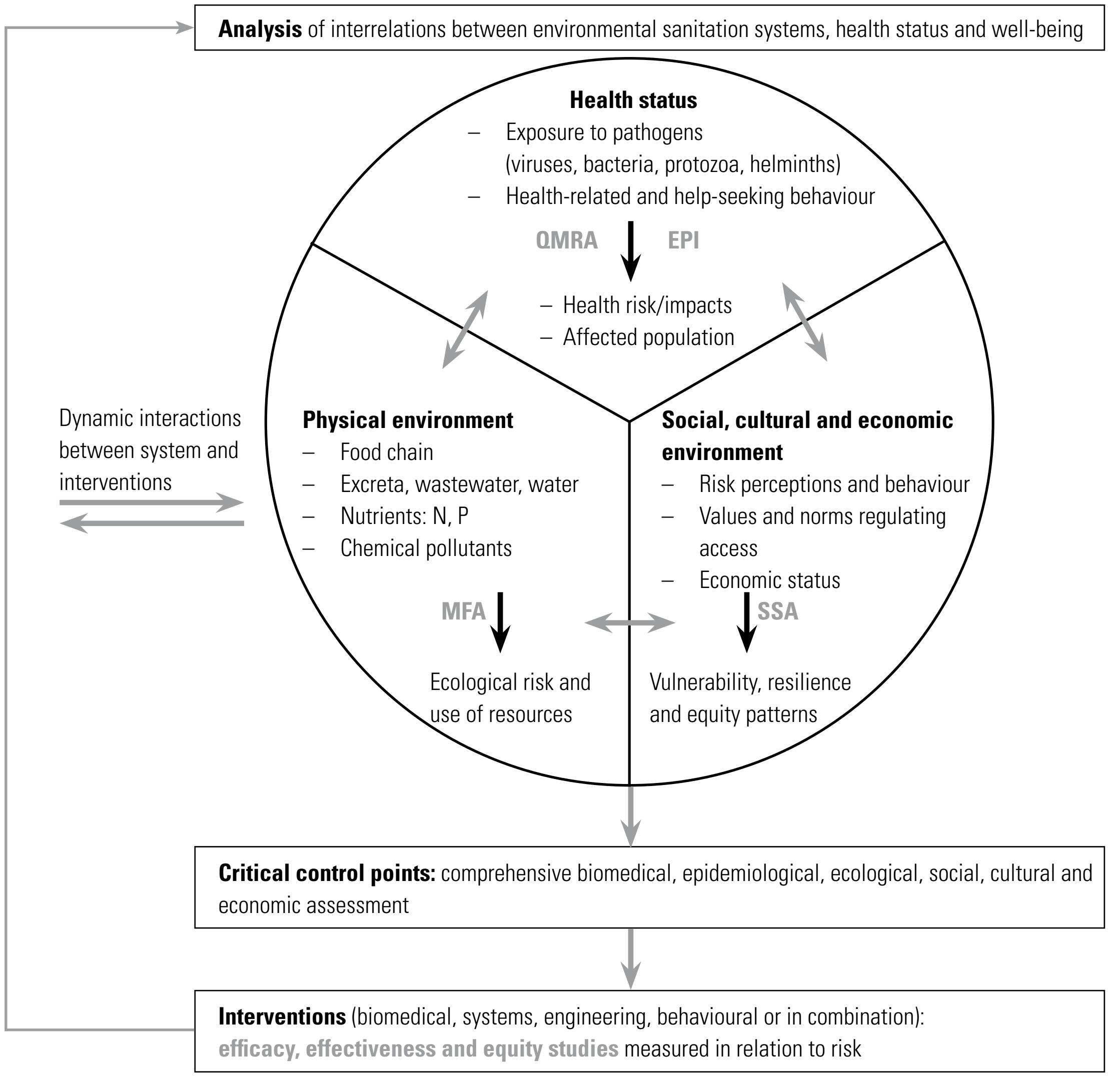
Owing to the vital importance of registering nomadic pastoralists and their animals in this surveillance, the authors developed a mobile-phone-based call system that accurately recorded livestock and human population data in the area of Lake Chad (25). This system is currently being extended to integrated syndromic disease surveillance in humans and their livestock with the aim of achieving a timescale of less than 24 hours from reporting to aetiological diagnosis. Syndromic One Health surveillance can be defined as the regular collection, analysis and interpretation of real-time and near real-time indicators of diseases and outbreaks by public health organisations (26). There are other One Health surveillance systems oriented more towards endemic diseases in resource-poor settings (27).

Antimicrobial resistance surveillance

The growing risk of antimicrobial resistance requires extended surveillance of antimicrobial-resistant bacteria in humans, livestock, the food chain, waste and surface water, and other environmental sources. The Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS) (www.phac-aspc.gc.ca/cipars-picra/index-eng.php) has been implementing a similar integrated process for the last decade and is thereby spearheading the One Health and ecosystem approaches to health. These concepts connect human and animal health and the environment (www.ecohealth.net) (Fig. 2). By using one laboratory for all microbiological work and standardised sampling procedures, financial and programmatic savings can be made at the following levels:

– sample collection
– laboratory analysis and infrastructure
– data warehousing and analysis
– communication with stakeholders and authorities
– risk management.

Many countries establish similar frameworks today. For example, the Strategy on Antibiotic Resistance (StAR) (www.star.admin.ch) in Switzerland explicitly follows a One Health approach.



EPI: epidemiology
MFA: material flow analysis
N: nitrogen
P: phosphorus
QMRA: quantitative microbial risk assessment
SSA: social science analysis

Fig. 1
Conceptual framework of the integrated assessment for health, environmental sanitation and society
Source: Nguyen-Viet *et al.* (22)

Towards a One Health impact assessment

The One Health impact assessment is an extension of the typical HIA, placing particular emphasis on the interlinkages between human, animal and ecosystem health, as well as animal health separately (28, 29). From an ecosystem health perspective, this should also extend to the socioecological system as a whole (30). The OHIA approach builds on the prospective nature of the HIA approach, meaning that the HIA process is initiated at the planning stage of a project, programme or policy, and is followed by impact surveillance and evaluation. Thus, the OHIA approach promises to address One Health issues in a preventive manner rather than in the form of disease detection and management, as is generally the case. Moreover, the OHIA process promotes a broad consideration of potential human and animal health impacts. For example, the construction of a new road should not only be planned in such a way as to prevent road traffic accidents and promote human safety, but also to consider how to reduce the death of wildlife and prevent the loss of livestock which stray into the road. Modern road construction addresses this need already, but impact assessment would extend its indicators to the risks for humans and animals and express the impact in terms of human and animal mortality. Similarly, the construction of a new dam in Africa potentially results in higher exposure to schistosomiasis for humans as well as livestock. In addition,

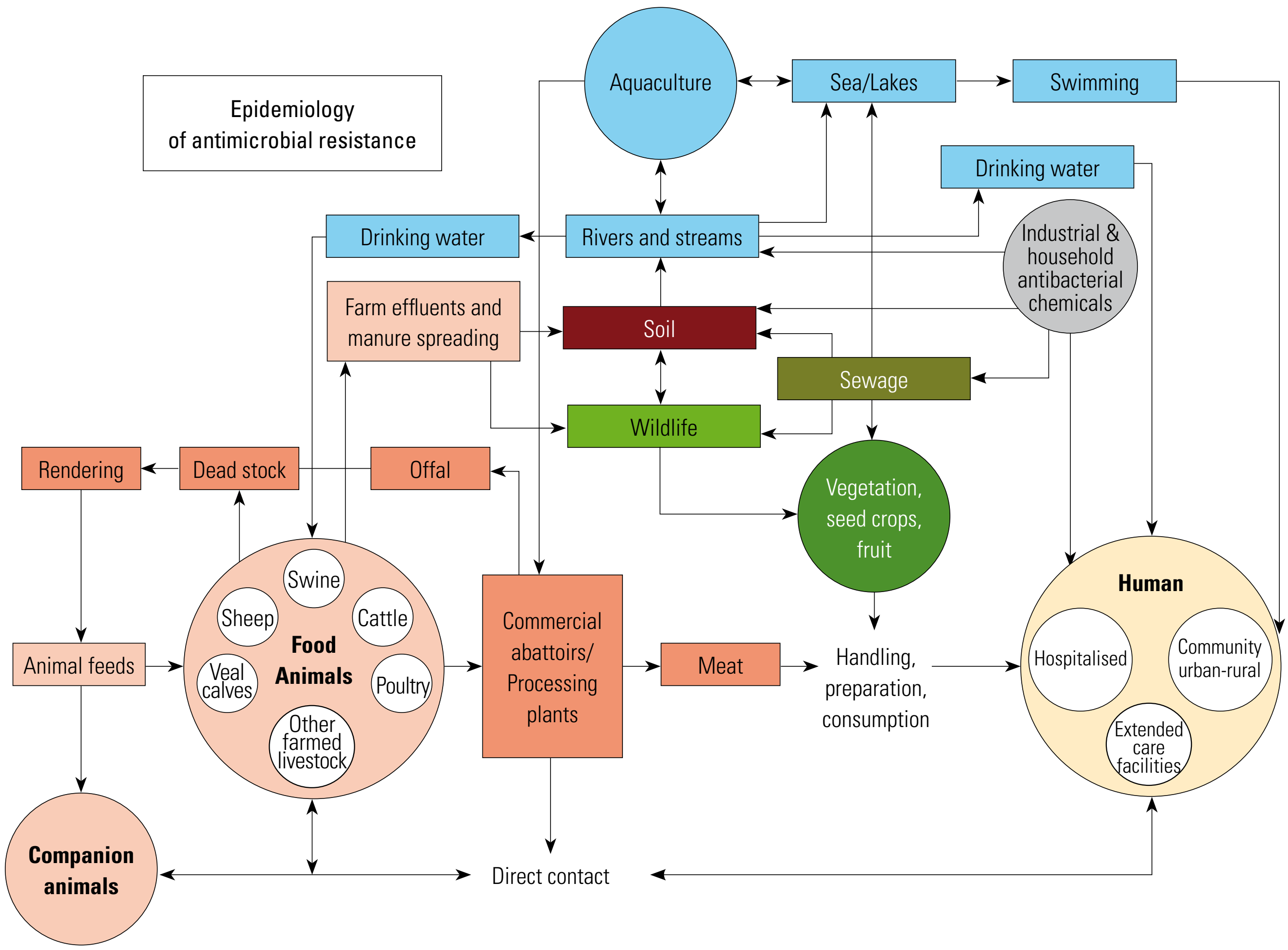


Fig. 2
Flow chart of the Canadian Integrated Program for Antimicrobial Resistance Surveillance
Source: Greter *et al.* (31)

livestock are likely to be exposed to liver flukes (e.g. *Fasciola* spp.). Such an integrated approach has been tested on the shores of Lake Chad for humans and livestock (31).

A further extension of the OHIA is the economic evaluation of health impacts, including the expected cost to human and animal health. Considering the sustainable development goals (32), the One Health economic impact can be extended to include the social and ecological consequences of any large infrastructure development. In particular, mining projects have far-reaching consequences in this regard, affecting human and animal health (33). In Mongolia, for example, many herders and their animals have been displaced by mines, losing both pastoral resources and access to safe drinking water. On the other hand, large infrastructure developments are vulnerable to the threat of emerging infectious diseases (EIDs) – most EIDs are zoonotic in nature and can thus be passed between animals and humans – which have the potential to shut down entire operations (6). This has been demonstrated by the recent Ebola outbreak in West Africa, which not only resulted in enormous human suffering but also caused massive losses in economic productivity (34). The promotion of a One Health approach holds the potential to be beneficial to both the public and private sectors and populations in low- and middle-income countries (35).

Complementing the impact assessment at the planning stage of a project, the OHIA should monitor and evaluate impacts on human and animal health over the entire project cycle. In view of rapidly spreading diseases such as EIDs, moving from monitoring and evaluation towards surveillance and response should be even more beneficial (36). This approach means that the impacts on human and animal health are monitored during the construction, operation and closure phases of a project such as a mining operation, a hydro-power project or any other large development project (37) because health impacts are not only of concern in the early phases of project development, but also potentially in the long run and towards its devolution. For example, the closing of a nuclear power plant requires the implementation of careful and costly measures in order to avoid human and animal exposure to deleterious infrastructural and waste components. Indeed, nuclear energy is a prime example in this respect, demonstrating that the full societal and ecological cost is exorbitant, and thus it is not competitive with less efficient but cleaner energy systems. It must be noted that hospitals by themselves may also represent an environmental hazard when biological, chemical and radioactive wastes are not properly treated.

The level of HIA and OHIA use is not yet at this point and many countries, in particular countries in transition, have significant needs for HIA and OHIA approaches in the future, the aim being to prevent disease and promote health in the agriculture, industry, energy and transport sectors (29, 38, 39).

Conclusion

Efforts to reduce biological threats could potentially benefit strongly from a One Health perspective on foodborne and/or environmentally related diseases, environmental sanitation, integrated syndromic surveillance and antimicrobial resistance surveillance. Biological threats are not exclusively related to natural conditions, and many efforts are already being implemented at all levels of what the authors consider to be a complex socioecological system. However, in order to be justifiable from a financial perspective, closer cooperation between human and animal health should not only yield financial savings but also health benefits for humans and animals. Cross-sectional animal–human disease frequency studies, like those on brucellosis and Q fever presented here, may identify the animal source of human disease more quickly, therefore reducing the new-outbreak detection time. The development and promotion of an OHIA approach has the potential to ensure that animal health is included on the agenda during the planning stages of large infrastructure projects, programmes or policies, while fostering surveillance of and response to biological threats.

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Les menaces biologiques dans une perspective « Une seule santé »

J. Zinsstag, L. Crump & M.S. Winkler

Résumé

Les menaces biologiques sont un parfait exemple de problématique nécessitant une approche « Une seule santé » en matière de prévention et d'atténuation des risques. « Une seule santé » désigne toute valeur ajoutée en termes de santé humaine et animale, d'économies d'échelle ou de services écologiques obtenue grâce à la collaboration de la médecine humaine et de la médecine vétérinaire (comparativement à ce qu'elles auraient obtenu en travaillant chacune de son côté). Ce principe s'applique également à l'apport d'autres disciplines relevant des sciences naturelles ou sociales. Cet article ne passe pas en revue l'ensemble de ces approches intégrées mais examine les concepts et les méthodes qui les sous-tendent et donne quelques exemples forts des bénéfices apportés par l'approche « Une seule santé » dans le traitement des menaces biologiques. Les maladies zoonotiques (transmissibles entre l'homme et les animaux) et à transmission vectorielle (par un insecte ou un acarien vecteur) représentent une menace biologique particulièrement importante dans les situations fortement dynamiques au plan social et environnemental. La transmission de ces maladies est parfois indirecte. Ainsi les aliments, l'eau, l'air et le sol sont-ils d'importantes sources de transmission pour les maladies d'origine alimentaire ou environnementale. L'hygiène environnementale fait l'objet d'un examen particulier en raison de l'importance de la gestion des déjections humaines et animales. La surveillance intégrée syndromique et la surveillance de la résistance aux agents antimicrobiens relient ces différents aspects et illustrent le recours à une approche « Une seule santé » en matière de réduction des risques biologiques. Les menaces biologiques ne sont pas seulement dues à des évènements naturels ; certains projets de développement peuvent aussi y contribuer, par exemple les barrages, l'exploitation minière et les travaux d'infrastructures. Par conséquent, il est recommandé de procéder à une « évaluation de l'impact sanitaire » dès la phase de planification de tout projet d'infrastructure de grande ampleur situé dans un système socio-écologique complexe. Les auteurs préconisent d'élargir la portée des évaluations de l'impact sanitaire dans une perspective intégrée « Une seule santé ».

Mots-clés
Évaluation de l'impact sanitaire – Maladie à transmission vectorielle – Maladie d'origine alimentaire – Menace biologique – Résistance aux agents antimicrobiens – Surveillance syndromique – Une seule santé – Zoonose.

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Las amenazas biológicas desde la perspectiva de «Una sola salud»

J. Zinsstag, L. Crump & M.S. Winkler

Resumen
Las amenazas biológicas son un perfecto ejemplo del tipo de problemas cuya prevención y atenuación exige abordarlos desde los planteamientos de «Una sola salud». Se entiende por «Una sola salud» todo valor añadido, en términos de salud humana o animal, ahorro económico o servicios ambientales, que pueda deparar la cooperación entre la medicina humana y la veterinaria en comparación con el trabajo de ambas por separado. Este principio se aplica igualmente a la intervención de otras ramas de las ciencias naturales y las humanidades. Los autores no proponen un repaso exhaustivo de las distintas fórmulas de trabajo integrado, sino que examinan conceptos y métodos y ofrecen importantes ejemplos de los beneficios que se obtienen al aplicar la lógica de «Una sola salud» a la cuestión de las amenazas biológicas. Las zoonosis y las enfermedades de transmisión vectorial (es decir, respectivamente, las patologías que se transmiten entre animales y personas y las que se transmiten por intervención de un insecto o ácaro como vector) siguen constituyendo amenazas biológicas de primer orden en las condiciones de gran dinamismo social y ambiental que imperan hoy en día. Estas enfermedades no siempre se transmiten directamente. Los alimentos, el agua, el aire y los suelos contaminados son un importante vehículo de enfermedades de transmisión alimentaria o ligadas a factores ambientales. De ahí que los autores examinen por separado el saneamiento ambiental, subrayando la importancia que reviste la gestión de las excreciones humanas y animales. La integración de la vigilancia sindrómica y la vigilancia de las resistencias a antimicrobianos articula entre sí todos estos aspectos y permite abordar la reducción de las amenazas biológicas desde la óptica de «Una sola salud». Las amenazas biológicas no solo guardan relación con las condiciones naturales, sino que además pueden verse favorecidas por grandes proyectos de desarrollo como la construcción de represas o infraestructuras o la excavación de minas. Por ello se recomienda aplicar fórmulas de evaluación del impacto sanitario desde la fase misma de planificación de todo gran proyecto de infraestructura que se ubique

dentro de un sistema socioecológico complejo. Los autores hacen extensivo el método de evaluación del impacto sanitario a la idea de una evaluación integrada del impacto desde la perspectiva de «Una sola salud».

Palabras clave
Amenaza biológica – Evaluación del impacto sanitario – Resistencia a los antimicrobianos – Transmisión alimentaria – Transmisión vectorial – Una sola salud – Vigilancia sindrómica – Zoonosis.

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