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UNDERSTANDING
EBOLA VIRUS AT THE
ANIMAL-HUMAN INTERFACE

Technical meeting
Rome, Italy
19-20 January 2016
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Acknowledgments

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## Abbreviations & Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>BSL</td>
<td>Biosafety Level</td>
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<tr>
<td>CDC</td>
<td>Centers for Disease Control and Prevention, USA</td>
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<tr>
<td>CFIA</td>
<td>Canadian Food Inspection Agency</td>
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<tr>
<td>CIRMF</td>
<td>International Centre for Medical Research of Franceville, Gabon</td>
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<td>EBOV</td>
<td>Ebola Viruses</td>
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<tr>
<td>ECTAD</td>
<td>Emergency Centre for Transboundary Animal Diseases, FAO</td>
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<tr>
<td>EFSA</td>
<td>European Food Safety Authority</td>
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<tr>
<td>EPT</td>
<td>Emerging Pandemic Threats</td>
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<td>EVD</td>
<td>Ebola virus disease</td>
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<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
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<tr>
<td>FLI</td>
<td>Friedrich Loeffler Institute, Germany</td>
</tr>
<tr>
<td>GHSA</td>
<td>Global Health Security Agenda</td>
</tr>
<tr>
<td>GOARN</td>
<td>Global Outbreak Alert and Response Network, WHO</td>
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<tr>
<td>IAEA</td>
<td>International Atomic Energy Agency</td>
</tr>
<tr>
<td>ILRI</td>
<td>International Livestock Research Institute</td>
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<tr>
<td>IRD</td>
<td>Research Institute for Development</td>
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<tr>
<td>OIE</td>
<td>World Organisation for Animal Health</td>
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<tr>
<td>P&amp;R</td>
<td>Preparedness and Response</td>
</tr>
<tr>
<td>PCR</td>
<td>Polymerase Chain Reaction</td>
</tr>
<tr>
<td>PPE</td>
<td>Personal Protective Equipment</td>
</tr>
<tr>
<td>PVS</td>
<td>Performance of Veterinary Services, OIE</td>
</tr>
<tr>
<td>RKI</td>
<td>Robert Koch Institute</td>
</tr>
<tr>
<td>RT-PCR</td>
<td>Reverse Transcription Polymerase Chain Reaction</td>
</tr>
<tr>
<td>SAR</td>
<td>Special Administrative Region</td>
</tr>
<tr>
<td>SOP</td>
<td>Standard Operating Procedure</td>
</tr>
<tr>
<td>USAID</td>
<td>United States Agency for International Development</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
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Introduction

The Technical Meeting on Understanding Ebola Virus at the animal-human interface was convened by the Food and Agriculture Organization of the United Nations (FAO) to determine the current status of the scientific knowledge on Ebola Viruses (EBOV), identify major gaps that require further research studies in order to better understand the disease dynamics at the interface between animals and humans, identify factors that potentiate the emergence, transmission and spread of EBOV, and develop practical approaches to better prevent and minimize the impacts of this virus. It was also aimed at fostering collaboration and partnerships between institutions and organizations working on Ebola viruses at the human-animal interface.

The meeting was organized by FAO and the United States Agency for International Development (USAID), from 19-20 January 2016 in Rome, and was attended by 59 participants from Cameroon, Canada, Democratic Republic of Congo, France, Gabon, Germany, Guinea, Hong Kong Special Administrative Region (SAR), Italy, Kenya, Liberia, Senegal, the United Kingdom and the United States, as well as from EcoHealth Alliance, Metabiota, the International Medical Corps, the World Organisation for Animal Health (OIE), the International Atomic Energy Agency (IAEA), the International Livestock Research Institute (ILRI), the European Food Safety Authority (EFSA), the World Health Organization (WHO) and FAO. This report provides the key objectives for the meeting, summarizes the gaps and needs identified, and presents the conclusions reached by the meeting participants.

BACKGROUND

The Ebola virus causes severe viral haemorrhagic fever in humans often with a fatal outcome, and is considered a global public health threat. As of 17 January 2016, the World Health Organization (WHO) has been notified of 28,638 laboratory-confirmed human cases in the ongoing West African outbreak (Ebola Zaire species), which includes 11,316 fatalities since 2014.

Ebola viruses affect a range of mammalian species, from humans to wild and domestic animals. Fruit bats are considered as probable natural hosts for the Ebola virus in Africa. People likely to be exposed to EBOV in its natural environment are (bushmeat) hunters and those in contact with contaminated animal products. However, the precise factors that result in EVD outbreaks remain unknown and require a better understanding of the linkages between ecological and socio-economic factors as well as the constantly evolving interface between humans, animals and their ecosystems.

Critical gaps remain in our knowledge of the routes of EBOV transmission to humans and other potential animal host species. Addressing these gaps is crucial for developing and implementing measures to reduce the risks to public and animal health.

MEETING OBJECTIVES

1. Share information on ongoing research projects and studies on the role of livestock and wildlife in the epidemiology of EVD.
2. Identify and prioritize knowledge gaps in disease dynamics at the human-wildlife-domestic animal interface.

3. Peer-review scientific and technical approaches that aim at better understanding the Ebola virus disease at the human-animal interface, including the dynamics of viral emergence and evolution, surveillance design, laboratory diagnostics, and risk factors along animal value chains.

4. Analyse complementarities and synergies between programmes and projects implemented by various partners, and explore opportunities for collaboration and partnerships.

The meeting was structured around these objectives, and followed the same format as the framework of the collaborative approach between FAO and PREDICT-2 under the Emerging Pandemic Threats Programme – Phase 2 (EPT-2), organized under three “pillars”:

- Epidemiology and risk factors;
- Laboratory diagnosis;
- Value chains and behavioural studies.
Knowledge gaps

The key needs and knowledge gaps identified by the participants during the meeting are summarized below.

EPIDEMIOLOGY AND RISK FACTORS
Before the spillover: animal reservoir, sensitive species and distribution
1. What is the animal reservoir? What are the intermediate and/or amplification hosts?
2. What is the geographic distribution of the virus and the animal reservoir? Which countries are at risk?
Spillover: animal to human transmission
3. What are human (and animal) behaviours that favour transmission?
4. What are the mechanisms and routes of transmission between animals and from animals to humans?
5. What are the other (ecological, economic, social) drivers for emergence and spillover, such as: seasonality, temperature, rainfall, poverty, landscape, etc.
After the spillover: mostly human to human transmission and (potential) spillback to animals
6. What is the role of animals during an ongoing epidemic? Is there a possibility of reverse zoonosis?
7. Is there potential impact of persistence in, and shedding of, the virus in humans or animals (including domestic species)?
8. What are the peri-urban / urban dynamics and consequences of introduction into urban areas in the 2014-15 outbreak: is there now a new ecology of the virus?

LABORATORY DIAGNOSTICS
Test development and validation
1. There is a need for validation and standardization of serological assays for EBOV in different animal species:
   a. Screening assays with sufficient sensitivity (for which more knowledge on cross-reactivity of filovirus antibodies is required)
   b. Reliable confirmatory tests
   c. Positive control panels
2. There is a need for development and validation of rapid field diagnostic tests
3. What testing methods are optimal for diagnosing infection in the different species at different stages of an outbreak or in a surveillance situation?
4. What tests are most appropriate for screening tests? What tests are suitable to confirm results?
5. There is a need to develop optimized and standardized tests and protocols and to advocate for their wide usage to facilitate comparing results of different surveillance activities/projects.
**Laboratory and diagnostics for surveillance and outbreak investigations**

1. There is a lack of knowledge on transmission/shedding routes, and a need for experimental infection studies to understand pathogenesis of infection in suspected hosts (dogs, goats, pigs), as well as field studies to identify antibodies/viruses in different putative hosts.

2. More information on viral shedding is required not only to identify which animal species should be sampled, but also what the optimal sample types/times are for diagnosis. Until this is known, should sampling be broad, so as not to miss any potential transmission routes?

3. What samples, transport and preservation modalities are optimal for diagnosing infection in the different species?

4. Sampling protocols and algorithms for both surveillance and outbreak situations are needed.

5. Biosafety and biosafety, especially for field sampling: which precautions to take? There is a need to assess the risk of sampling activities.

6. Are animal samples available that were taken in/around human outbreak areas, and if so, are these available for testing?

**VALUE CHAIN AND BEHAVIOURAL STUDIES**

1. What are the interface points between wildlife, livestock and humans (e.g. at various points along the livestock value chain), what human behaviours and practices result in higher contact rates? What socio-economic aspects drive this change?

2. How important is bushmeat in Ebola transmission, and how is risk of transmission characterized (e.g. species, type of meat, preparation, etc.)?

3. There is a need for mapping bushmeat and livestock value chains, practices and drivers and understanding the interface between animals and humans in their habitats.

4. What are the drivers and patterns of bushmeat consumption and where can we intervene? What is the social value of bushmeat? How do cultural events affect consumption?

5. What is the impact of cross-border movements, migration, refugees, wildlife interactions, on the dynamics of livestock and bushmeat value chains?

6. What are the roles and perceptions of communities, and how can they be included in decision-making and communication strategies (both risk mitigation and public health interventions)?

7. How are cultural and religious practices linked to value chains and behaviours (both livestock and wildlife)?

8. How do changes in the value chain (through food insecurity, poverty, climate change, etc.) impact transmission risk?

**OVERARCHING NEEDS**

In addition to the topic-specific knowledge gaps, the following overarching needs were identified:

1. One health-driven investigation of human outbreaks, involving public health, animal health and social scientists: there is a need to establish standard operating procedures (SOPs) and lists of focal points with contact details, roles and
responsibilities. These latter can be facilitated through high-level advocacy by international organizations such as FAO.

2. Focused animal studies around human outbreaks: there is a need for guidelines and tools for animal surveillance during human outbreaks.


4. Capacity building and training for local partners.

5. Coordination of Ebola virus research field activities at national level.
Addressing needs and knowledge gaps

Conclusions by meeting participants are summed up by topic area below. In addition, participants were encouraged to discuss and propose their involvement in addressing the needs and knowledge gaps and to liaise with each other and FAO for future collaboration.

EPIDEMIOLOGY AND RISK FACTORS

- Focus research to identify host infection dynamics, reservoirs and intermediate hosts.
- Conduct additional research to identify environmental and other ecological factors, and the geographic range of virus incidence and persistence.
- Conduct additional research to identify human behaviours that affect transmission.
- Under the Tripartite Agreement, FAO, OIE and WHO should work together to improve/strengthen the capacities of the public health and veterinary services to detect, diagnose and respond to the emergence of Ebola viruses and other diseases originating from animals.

LABORATORY DIAGNOSTICS

- Standardize protocols for sampling and testing of filoviruses across species and countries.
- Develop/validate better (rapid) diagnostic tests for use in the field, with reliable confirmatory tests.
- Develop and validate serological assays for domestic animal species for use in the investigation of their potential roles in EBOV epidemiology.

VALUE CHAIN AND BEHAVIOURAL STUDIES

- Identify critical intervention points along livestock and wildlife value chains to inform surveillance, policy, risk management and communication.
- There is a need for tools and training to guide entry of researchers, surveillance teams, etc. into sensitive communities post-Ebola.
- Identify appropriate behaviour change options to reduce spillover and disease transmission risk.
- Explore options for individual animal identification to facilitate longitudinal surveillance.
Activities undertaken by participating partners

- United States Centers for Disease Control and Prevention (CDC): epidemiological and laboratory capacity, ecology (One Health), outbreak investigation, risk assessment, rapid response, capacity building for EBOV detection (36 countries).
- Canadian Food Inspection Agency (CFIA): reagent production for diagnostic tests (including positive test controls), experimental animal infections (swine) in BSL4 laboratory facilities, confirmatory testing (virus isolation, virus neutralization), development of ELISA for swine serology, real-time reverse transcriptase polymerase chain reaction (rRT-PCR) and immunohistochemistry.
- PREDICT-2 (Metabiota, EcoHealth Alliance, UC Davis): supporting governments (national response), rapid response, monitoring agriculture intensification and land use, biological surveillance, diagnostic capacity development.
- International Medical Corps: training in personal protective equipment (PPE) usage and Ebola response, supports Global Health Security Agenda (GHSA) in prevention and response.
- International Centre for Medical Research of Franceville (CIRMF): a.) Field surveillance: Risk factor and disease dynamic at the animal-human interface; viral emergence and evolution; virology and serology; samples: whole blood, serum, (faeces); viral emergence and evolution; route of transmission; surveillance design. b.) Laboratory research: routes of transmission; molecular determinants of Ebola pathogenesis; routes of transmission to humans. c.) Other: BSL-4 laboratory facilities.
- University of Hong Kong: studies on infection at the animal-human interface, development of serological assay on Ebola (based on pseudoparticles).
- OIE: capacity building in emerging disease control, Performance of Veterinary Services (PVS) pathway, training for disease notification.
- Robert Koch Institute (RKI): laboratory confirmation and diagnostics, animal experimental infections in BSL4 laboratory facilities, assay development, laboratory capacity building in biosafety, field studies.
- University of Marburg: laboratory support in West Africa (under WHO/Global Outbreak Alert and Response Network - GOARN umbrella), research on sample stability (e.g. swabs samples), training in PPE usage, diagnostics, inactivation of viruses for immunization studies (antibody production).
- IAEA: training courses (PPE usage, laboratory diagnosis, wildlife sampling), provision of field sampling SOPs.
- EFSA: risk assessment, literature review on risk factors for spillover.
- ILRI: slaughterhouse surveillance in pigs (serology and virus isolation), mapping of pig trade volume and routes, description of pig trader knowledge and practices around biosecurity.
• Research Institute for Development (IRD)/CIRAD (Agricultural Research for Development): testing of human, primate, bat, bushmeat samples (Cameroon, Democratic Republic of Congo, Guinea), ELISA development (bats), development of Luminex technology, Bayesian modelling of test performance evaluation.
• WHO: supporting governments; guiding community entries.
Action points

Meeting participants highlighted the need for the following actions:

- **FAO** to engage with OIE and WHO to develop a decision-support tool to aid countries in the decision-making process in the case of the detection of positive cases in domestic animals, through sampling and surveillance activities.
- Collaborate with EPT2 Preparedness and Response (P&R) to assist the creation/strengthening of national One Health platforms and reinforce networks by running simulation exercises for different scenarios, etc.
- Promote regular international scientific and field consultations (physical and virtual) to fill in EPT2 knowledge gaps, develop guidance documents, share information and standardize approaches.
- Develop and test a Risk Communication Toolkit, in collaboration with OIE and WHO.
- Engage local research institutions in EPT2 country consultations.
- Facilitate policy dialogue on filovirus surveillance-related issues at different levels.
- Continue to strengthen national capacity building of veterinary services for early detection.
- **FAO** to coordinate and foster collaboration for the development, validation and refinement of diagnostic tests for livestock.
- Establish a multi-laboratory collaboration between IAEA, RKI, FLI, and the University of Marburg, Germany, the Canadian Food Inspection Agency (CFIA) and ILRI for the generation of Ebola antibodies in dogs, pigs, sheep, goats, cattle, and bats, through animal inoculation with inactivated virus. In this regard, IAEA will assist in the generation of antibodies in dogs, CFIA in pigs, sheep and goats, ILRI in cattle, and RKI and FLI in bats. The CFIA has also agreed to explore infecting pigs, sheep and goats with live Ebola virus.
- Ensure that the defined positive antisera against the Ebola virus are available as a global resource for development and validation of serological tests in targeted domestic animals. The University of Marburg to provide a defined dose of gamma-irradiated inactivated Ebola virus for this collaborative work.
Annex 1

Agenda

Understanding *Ebola Virus* at the *animal-human interface*

*Technical Meeting*
Rome, Italy • 19-20 January 2016
<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>08:30-09:00</td>
<td>Morning coffee and registration</td>
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<tr>
<td>09:00-09:30</td>
<td>Welcome, introductions and expectations</td>
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<tr>
<td>09:30-10:15</td>
<td>Scientific overview presentations:</td>
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<tr>
<td></td>
<td>• Epidemiology and risk factors (15 min.)</td>
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<td></td>
<td>• Laboratory diagnosis (15 min.)</td>
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<td></td>
<td>• Supply chains and behavioural studies (15 min.)</td>
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<tr>
<td>10:15-10:45</td>
<td>Coffee break</td>
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<tr>
<td>10:45-11:15</td>
<td>Plenary discussion</td>
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<tr>
<td>11:15-12:35</td>
<td>Break up into groups to discuss knowledge gaps, by thematic area as follows:</td>
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<tr>
<td></td>
<td>• Epidemiology and risk factors</td>
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<tr>
<td></td>
<td>• Laboratory diagnosis</td>
</tr>
<tr>
<td></td>
<td>• Supply chains and behavioural studies</td>
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<tr>
<td>12:35-13:45</td>
<td>Lunch</td>
</tr>
<tr>
<td>13:45-14:00</td>
<td>Collect results from group discussion</td>
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<tr>
<td>14:00-14:30</td>
<td>Plenary debriefing from group discussions (15 min. each)</td>
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<tr>
<td>14:30-15:00</td>
<td>Q&amp;A, wrap up of knowledge gaps, plenary discussion, agreement on final statements</td>
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<tr>
<td>15:00-15:30</td>
<td>Mapping of ongoing and planned activities of participating institutions</td>
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<td>15:20-15:30</td>
<td>Plenary session</td>
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<tr>
<td>15:30-16:00</td>
<td>Coffee, networking + review/completion of mapping exercise</td>
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<tr>
<td>16:20-17:20</td>
<td>Q&amp;A and open discussion on opportunities for collaboration:</td>
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<tr>
<td></td>
<td>• Field surveillance</td>
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<td></td>
<td>• Behavioural studies</td>
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<td></td>
<td>• Capacity building, training</td>
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<td></td>
<td>• Test development and validation</td>
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<td></td>
<td>• Laboratory research</td>
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<td></td>
<td>• Other</td>
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<tr>
<td>17:20-18:00</td>
<td>Wrap-up</td>
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<tr>
<td>18:30-20:00</td>
<td>Poster session and aperitivo</td>
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## Understanding Ebola Virus at the Animal-Human Interface

### Wednesday

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>09:00-09:15</td>
<td>Recap of activities from day 1 and moving forward</td>
</tr>
<tr>
<td>09:15-10:45</td>
<td>Presentation of One Health implementation approach under Emerging Pandemic Threats Programme Phase 2 (EPT-2), by thematic area as follows:</td>
</tr>
</tbody>
</table>
|               | • Surveillance and risk factors  
|               |   (20 min. ppt + 10 min. discussion)  
|               | • Laboratory diagnosis  
|               |   (20 min. ppt + 10 min. discussion)  
|               | • Supply chains and behavioural studies  
|               |   (20 min. ppt + 10 min. discussion)  |
| 10:45-11:15   | Coffee Break                                                                                                                              |
| 11:15-12:15   | Facilitated discussion on cross-cutting collaboration:                                                                                       |
|               | • Stakeholder participation  
|               | • Information sharing  
|               | • Communication: awareness raising, disseminating information, and risk communication  
|               | • Capacity development                                                                                                                     |
| 12:15-12:45   | Implementation approach wrap-up                                                                                                             |
| 12:45-13:45   | Lunch                                                                                                                                     |
| 13:45-14:30   | Coffee over topic discussions                                                                                                              |
| 14:30-16:00   | Collaboration building and way forward (3 pillars: surveillance and risk factors, laboratory diagnosis, supply chains and behavioural studies): |
|               | • Technical  
|               | • Institutional  
|               | • Stakeholder Level                                                                                                                        |
| 16:00-16:00   | Coffee Break                                                                                                                             |
| 16:30-17:00   | Recommendations                                                                                                                           |
| 17:00         | Closure                                                                                                                                   |

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This meeting was made possible through financial support provided by the United States Agency for International Development (USAID).
Annex 2
List of participants

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ONLINE PUBLICATION SERIES
FAO ANIMAL PRODUCTION AND HEALTH REPORTS

1. Impact of animal nutrition on animal welfare – Expert Consultation, 26–30 September 2011, FAO Headquarters, Rome, Italy. 2012 (E)
   http://www.fao.org/3/a-i3148e.pdf

   http://www.fao.org/3/a-i3391e.pdf

   http://www.fao.org/3/a-i3622e.pdf

   http://www.fao.org/3/a-i3739e.pdf

   http://www.fao.org/3/a-i3381e.pdf

   http://www.fao.org/3/a-i4081e.pdf

   http://www.fao.org/3/a-i4146e.pdf

8. Regional workshop on brucellosis control in Central Asia and Eastern Europe. 2015 (E, R)
   http://www.fao.org/3/a-i4387e.pdf

9. The last hurdles towards Rift Valley fever control. 2015 (E)
   http://www.fao.org/3/a-i4466e.pdf

10. Understanding Ebola Virus at the Animal-Human Interface. 2016 (E)
    http://www.fao.org/3/a-i5670e.pdf

11. Understanding MERS-CoV at the Animal-Human Interface. 2016 (E)
    http://www.fao.org/3/a-i5682e.pdf

Availability: May 2016

E - English
Ar - Arabic
R - Russian
** - In preparation