Adopting and Implementing a One Health Approach for Solving Complex Health Problems in China

Xiao Zheng¹, Jiahai Lu², Sarah K. White¹, Tara Sabo-Attwood¹, and Gregory C. Gray¹

¹ College of Public Health and Health Professions and One Health Center of Excellence, University of Florida, Gainesville, Florida
² School of Public Health, Sun Yat-sen University, Guangzhou, P. R. China

Correspondence: Gregory C. Gray, MD, MPH, FIDSA, Director, One Health Center of Excellence for Research and Training, and Professor, Department of Environmental and Global Health, College of Public Health and Health Professions, University of Florida, P.O. Box 100188, Gainesville, Florida 32610, Tel. 352-273-9188, gcgray@phhp.ufl.edu

Abstract word count: 311
Text word count: 3383
Running title: One Health Approach in China
Number of figures and tables: 2
Abstract

Some of today’s most challenging public health problems are exceedingly complex and cannot be resolved by a single discipline’s intervention. Food safety, emerging zoonotic diseases, and antimicrobial-resistance are some examples that call for interdisciplinary and often international teamwork; such collaboration that engages public health, veterinary health, and environmental health, have been termed the One Health approach. A growing number of professionals from numerous disciplines views One Health as the best way forward to reduce these complex threats. One Health embraces new thinking and partnerships, and building new bridges across disciplines and institutions. Examples of emerging infectious disease management using a One Health approach include: the 1997 response to highly pathogenic H5N1 avian influenza virus in Hong Kong, the reduction of bovine spongiform encephalopathy infections from 1993 to 2000 in the United Kingdom, the Nipah virus outbreaks during 1998 in Malaysia and 2001 in Bangladesh, the 2013 MERS-CoV outbreak in Saudi Arabia, and the 2013 H7N9 avian influenza epizootic in China.

China has suffered from a number of recent emerging zoonotic diseases, food safety outbreaks, and large environmental disasters; suggesting that the nation could greatly benefit from embracing a One Health strategy. Methods for development of a One Health approach have been demonstrated by the Danish Integrated Antimicrobial Resistance Monitoring Programme (DANMAP) and the Danish Zoonosis Center. DANMAP engages local veterinary and medical practices and supporting laboratories in conducting surveillance and confirmation of antimicrobial resistant pathogens, then aggregates national data for processing, analysis, and intervention development. China has the necessary clinical and laboratory networks to follow the Danish model. These networks would engage government, academic, and private sector agencies in organizing One Health approaches to respond to China’s food safety, zoonotic disease, and environmental health problems. In short, China is well-equipped to formally adapt a One Health approach to its complex problems and thus set an example for the rest of Asia.
Embracing the concept of One Health

In recent years, globalization has markedly changed the world in which we live. Globalization provides a rapid exchange of ideas, natural and man-made resources, and even diseases. Today, people are interconnected more than ever, with daily activities often spanning continents. The challenges of globalization are demanding new, innovative solutions. As the global human population is increasing and rapidly reaching into new geographic areas, complex public health and animal health problems are also increasing. These complex problems include food safety, zoonotic diseases, antimicrobial resistant pathogens, and environmental contamination. One organization or one discipline alone cannot efficiently respond to these modern globalization problems as they are far too complex. The realization is growing that an interdisciplinary, inter-institutional, and often international approach is required. One such approach is called One Health. It forges inclusive collaborative efforts of public health, veterinary health, and environmental health communities to attain optimal health for all. Through this approach, organizations and agencies cooperate and exchange data at local, national, and global levels to create efficient interventions with the greatest impact. The One Health approach is increasingly embraced by national and international professional groups (Table 1), including the Food and Agriculture Organization of the United Nations (UN), the World Organization for Animal Health (OIE), and the World Health Organization (WHO) (1). It is also supported by national agencies and professional individuals across multiple disciplines in several countries (2).

The United States Centers for Disease Control and Prevention (CDC) embraces a One Health approach by encouraging physicians, ecologists, and veterinarians to join together to comprehensively understand how diseases spread among people, animals, and the environment (3). Additionally, the US Department of Agriculture (USDA) is developing a One Health Coordination Office to be fully functional by 2015. Recognition of the complex issues previously mentioned initiated the development of an office that will unite different departments
involved in veterinary services, laboratory services, agriculture systems, public health, and ecosystems specialists (4).

In 2013, the 2nd International One Health Congress was held in Thailand to promote the development of effective policy related to human, animal, and environmental health through trans-disciplinary collaboration. With over 1,000 attendees from more than 70 countries, it was the largest One Health conference to date (1). Looking toward the future of One Health, universities worldwide are accepting and practicing this interdisciplinary approach in research and teaching.

While there are numerous of definitions of One Health(5), perhaps the most widely recognized definition is that adapted by the American Veterinary Medical Association "One Health is the collaborative effort of multiple disciplines – working locally, nationally, and globally – to attain optimal health for people, animals, and our environment(5)." This definition fits well with most of today’s One Health activities and is the framework for this discussion.

Health issues in China which can benefit from a One Health approach

With the world’s largest population and a rapidly growing industrial sector, China is facing serious health problems. Since 2002, people in China have faced numerous emerging zoonotic diseases, including severe acute respiratory syndrome (SARS) and a series of swine and avian influenza infections, such as influenza A virus subtypes H1N1 and H7N9. Some of these recent outbreaks have found China unprepared. SARS caused the most serious outbreak seen in decades, which resulted in more than 5,300 human infections and killed 349 nationwide with economic losses of more than $US 41 billion (6, 7). Since the mid-2000s China has been engaged in two regional surveillance and response systems: The Mekong Basin Disease Surveillance Network and the Asian Partnership on Emerging Infectious Disease Research. Integrating these systems and China’s own infectious disease surveillance systems is quite challenging(8). Classically these systems have largely focused upon human diseases and they
have had difficulty sharing timely and reliable disease information. Additionally, comprehensive surveillance and protection systems for farm animals, wildlife, and companion animals are not well-established and not well integrated with the human surveillance systems(8).

Joining human and animal sectors in problem solving is challenging but there have been some examples of success. Certainly the recent worldwide collaboration in influenza surveillance between people and poultry is China’s best example. China is highly considered a model for influenza information sharing. There are other examples as well. An interdisciplinary team of Chinese scientist jointly tackled a schisotosomiasis problem in the Poyang Lake region and working together markedly decreased the incidence of human Schistosomiasis japonica infections by treating both humans and buffaloes between 1998 and 1999 (9). The infection rates and environmental pathogen loads were also significantly reduced after adopting environmental interventions including: improved sanitation, health education, and regulation of grazing cattle in grasslands(9, 10). These examples highlight how an interdisciplinary approach can reduce disease burden.

Zoonoses

A 2011 World Bank report estimates that zoonotic disease outbreaks have cost $US 200 billion globally in the previous 10 years; the majority due to the loss of external revenues such as trade, tourism, and taxes(11). China provides a unique location for the emergence of zoonotic influenza viruses with the presence of live animal markets and intense human exposure to market animals. China has recently experienced the emergence and spread of novel zoonotic influenza viruses such as H5N1 (12) and H7N9 that has highlighted the importance of One Health as an integrated key for an effective, comprehensive response to such outbreaks. Following the occurrence of this novel H7N9 influenza virus in early 2013, Chinese scientists rapidly identified and sequenced the viral genome which was quickly made public (12). As of May 2014, a total of 430 humans have experience laboratory-confirmed infections(13),
and while human-to-human transmission remains unsustainable, close contact with an infected case poses a transmission risk (14). Additional research supports the high pandemic potential of the H7N9 influenza virus (12). Current surveillance of human H7N9 cases and monitoring of live poultry markets continue on a global stage. National and provincial surveillance and monitoring have been conducted by the Department of Health’s Centre for Health Protection, and the Health and Family Planning Commission of Guangdong Province (13).

Many researchers and scientists are shifting focus to pathogen discovery – seeking to identify novel pathogens which may pose a threat to human health. Thanks to modern molecular diagnostics, genetic sequencing, metagenomics, and phylogenetic analysis it is possible to identify such pathogens and determine their ability to replicate in human and animal hosts. Many agencies are endorsing this proactive surveillance approach including the WHO’s Global Outbreak Alert and Response Network, the European Food and Waterborne Disease and Zoonoses Network, the US CDC’s Global Disease Detection program, the US Department of Defense’s Global Emerging Infections Surveillance and Response System, and Canada’s Global Public Health Intelligence Network (15). Vigilance among these groups and their partnerships with scientists from developing countries will enhance early identification of zoonotic pathogen threats and ultimately reduce the severity of their outbreaks.

**Food safety**

Up to one-third of the population in developed countries, and even more in developing countries, suffer from foodborne illness every year (16). According to the bulletin of the Chinese Ministry of Health (MOH), 2305 food poisoning cases were reported in 2004, of which 255 (11%) people died. These data likely represent just the tip of the iceberg because they fail to take into account the broad spectrum of food-borne illnesses and individuals who did not seek medical care. Although, from 2001 to 2004 the mortality rate of food poisoning dropped by half, the aggregate foodborne infection incidence rate increased nearly four times (17).
Microorganism contamination caused most illness, followed by poisonous animals or plants, and chemical residues on crops (18). Based upon 2002 data from the WHO, in 1988 China suffered the largest known food-borne epidemic on record when hepatitis A infected more than 300,000 Chinese people (19).

Globalization of the food supply has exacerbated the spread of foodborne pathogens. For instance in 2001 peanuts from China that were contaminated by *Salmonella enterica* serotypes Stanley and Newport caused outbreaks in Canada, the British Isles, and Australia (20). Similarly, between 2006 and 2009, an outbreak of *Vibrio cholera* subtype O139, spread throughout China and Southeast Asia via soft-shelled turtles and shrimp (21, 22).

Illicit use of toxic chemicals is the other main source of food contamination which is especially problematic in China. In 2008 melamine contamination of baby formula was discovered after affecting 39,965 infants, hospitalizing 14,471, and causing 4 deaths (23). Following numerous incidences of product recalls for microbial or pesticide contamination, poor packaging, or selling expired products, the need for a better organized surveillance and regulatory system was acknowledged. China has since established a food safety control system based on the Food Safety Law (FSL) which aims to unite surveillance systems with food safety standards and evaluations. All collaborations are among government entities which will be involved in food safety surveillance, enforcement and regulation of policy, and the development of intervention strategies. With the adoption of a One Health approach, co-regulation will likely achieve higher food quality standards (24).

In the United States, the national Institute of Medicine (IOM) recently hosted a One Health workshop on food safety encompassing human health, epidemiology, veterinary medicine, and government entities such as the US CDC, US (USDA), the Food and Drug Administration (FDA), and the Environmental Protection Agency (19). While such federal agencies have their own unique responsibilities to food safety, currently they do not always work well together. There are barriers to sharing data and working across lanes of responsibility. This IOM workshop
reinforced the need for all organizations involved in food safety to work together towards a common goal of prevention versus reaction (19). Also through this workshop anew international strategy was introduced that encourages countries to publically document their food safety problems and investigations such that the knowledge will benefit other countries (19). The workshop also discussed the large role prevention plays in food safety, but recognized the means to achieve effective prevention are expensive and time-consuming. A strategy to build a united front among multiple public and private entities is required to better respond to foodborne problems (19).

Antimicrobial resistant pathogens

Antibiotics are the primary treatment for many infections, but with limited antimicrobial development and the rapid evolution of drug-resistant pathogens, it is becoming increasingly more challenging to protect humans and animals from infectious agents. As the largest antibiotics manufacturing nation and consumer in the world, China produced approximately 210,000 tons of antibiotics in 2007; an estimated 46.1% of which was used in livestock industries (25). Worldwide most antimicrobials produced are similarly not consumed by humans, but rather used as additives to treat or avoid disease among production and companion animals and crops, and other industries (26). A 2014 Environmental Health Perspectives report stated in 2011, that “the US livestock industry consumes more antibiotics per kilogram of meat and poultry produced than any other developed country” (27). Unmonitored and uncontrolled use of antibiotics for animal disease prevention and treatment in China have resulted in high concentrations of antibiotic residues in animals’ bodies and their manures (28, 29). Multi-drug resistance, especially to ciprofloxacin and tetracycline, have been frequently observed among Campylobacter and Escherichia coli isolates collected from pig farms and slaughter houses (30, 31). Diverse and abundant antibiotic resistance genes (ARGs) directly correlate with antibiotic levels detected in swine farms, indicating the expansion of antibiotic-resistance
ARGs may be transferred from livestock-associated microorganisms to microorganisms that colonize or infect humans (33, 34). The antibiotic residues accumulate in the sewage and run-off, and influence the emergence of antimicrobial-resistant strains (35). Additionally, frequent misuse of antibiotic agents in human healthcare systems due to overprescribing and self-medication with over-the-counter antibiotics increases the emergence of pathogens with antimicrobial properties (36). In many countries of the world, including China, the prevalence of antibiotic-resistant microbes in hospital environments markedly increased from 1990s to 2000s (37-39).

In response to this critical issue, China has developed multicenter surveillance networks, such as the Ministry of Health National Antimicrobial Resistance Investigation Net (Mohnarin), Gram-Positive Cocci Resistance Surveillance (GPRS) program, and the Nosocomial Pathogens Resistance Surveillance (NPRS) to track clinical trends of antimicrobial resistance. Based on the infection control policy in China, most hospitals have set up a department of epidemiology to monitor minor outbreaks and clusters of nosocomial infections (37, 38). The Chinese government also carried out the most stringent policy in its history to manage the clinical use of antibiotics in 2012 (40); however, the true prevalence of antibiotic resistance strains likely has been underestimated, especially in rural areas because of sparse coverage of the surveillance system. Additionally, the molecular epidemiology and resistance mechanisms of the antibiotic resistance pathogens seem to be region-specific and influenced by international clonal complexes (39, 41). Finally, integration of surveillance for resistant pathogens in human and animal systems is lacking. The WHO is advocating for countries and regions to work together to maintain pathogenic sensitivity to antibiotics. China may wish to adopt software developed for antimicrobial-resistance surveillance and increase collaborations with other countries engaged in such surveillance programs. China might also further engage in One Health partnership development to: 1) mandate more prudent use of antibiotics among both human and livestock
populations, 2) manage the environmental effects from residual antimicrobials, and 3) fill the gap between policy and implementation.

The Danish have set up an extraordinary One Health model in constructing the Danish Integrated Antimicrobial Resistance Monitoring Programme (DANMAP) and the Danish Zoonosis Center (42). Local veterinary and medical practices, laboratories, and slaughterhouses report cases of antimicrobial resistance to national institutions which relay data to DANMAP. The combination of continued human and animal surveillance, evaluation of associations and risk assessments, and multi-target intervention strategies by DANMAP have led to decreased use of antimicrobials resulting in fewer reports of resistant pathogens. Through this program, from 1992 to 2008 the antibiotic use in swine farming practices dropped by over 50%, yet production increased by over 8 million weaning pigs in the same time period (27). Pork products were additionally valued more highly as produced with limited or no antibiotics.

**Environmental pollution and contamination**

In considering One Health approaches to complex problems one must embrace environmental influences. The role of contaminated soil, water systems and polluted air should be considered in interdisciplinary One Health research and interventions. The WHO reports that 25% of the global disease burden is tied to environmental hazards (43). China is now experiencing some of the world’s worst air pollution problems (44). Outdoor air pollution due to vehicle exhausts and industrial emissions, affects most all residents in cities (~580 million) and has been estimated to annually cause 300,000 premature deaths (45). In China, indoor air pollution due to fumes from cooking with biomass fuels also impacts many rural (~740 million) and approximately one-third of urban residents (~200 million), leading to approximately 420,000 premature deaths each year (45). In contrast, the total number of premature deaths caused by air pollution is estimated at 30,000 each year in all other countries combined (46). Air pollution
has been associated with numerous diseases including: chronic obstructive pulmonary disease, respiratory infections, lung cancer, and possibly low birth weight infants (45). Exposure to traffic-related or household air pollution has been strongly associated with severe acute lower respiratory infections, particularly for pneumonia, which in China is the leading cause of death among children under 5 years of age.

Industrial water pollution has replaced water sanitation as a major health concern in China. Approximately half of China’s water resources are deemed unsafe for human consumption and contaminated water is estimated to cause 11% of China’s digestive system cancer cases (~954,500 per year) (47-49).

Major contributors of soil contamination in China include heavy metals derived from anthropogenic activity such as intensive mining, excessive fertilizer application, and unregulated electronic waste disposal. Heavy metal absorbance, either through direct dermal contact or bioaccumulation through the food chain, have been associated with a wide array of diseases, especially cancers (50, 51)(52). Due to severe cadmium (CD) contamination in rice, the level of which increased from 0.072 mg/kg in 2006 to 0.132 mg/kg in 2011 (53), China has converted from the number one rice exporter to the world’s top rice importer in 2013 (54). The problems of air, water, and land pollution intertwine, making them even more complicated to mitigate.

In an effort to monitor and regulate such environmental problems, China has developed an environmental protection system; however, the guidelines for environmental impact analysis and human risk assessment are underdeveloped and enforcement capacities are quite modest, especially in rural areas.

Implementation of One Health strategy

Facing many complex health issues, China could benefit from aggressively embracing the One Health strategy. Perhaps the best way to do this is to develop interdisciplinary working
groups that focus on a specific problem or theme, similar to the previously discussed DANMAP program in Denmark.

China has an existing systematic hierarchy to address problems in food safety, infectious disease, and environmental health. At the government level, the State Council branches into the Ministry of Environmental Protection (MEP), the Ministry of Agriculture (MOA), the National Health and Family Planning Commission (NHFPC), the China Food and Drug Administration (CFDA), the General Administration of Quality Supervision, Inspection, and Quarantine (AQSIQ), the National Development and Reform Commission (NDRC), and the State Administration of Grain (SAG). The State Council also manages the Chinese Academy of Sciences (CAS) representing the highest level of academic and research, and the National Natural Science Foundation of China (NSFC), which offers research funding. China’s Center for Disease Control and Prevention (CDC) is government-supported and consists of the National Institute for Communicable Disease Control and Prevention (ICDC), the National Institute of Viral Disease (NIVD), the National Institute for Non-communicable Chronic Diseases (INCD), the National Institute of Parasite Disease (NIPD), the Institute of Environmental Health and Related Product Safety (IEHS), the National Institute for Nutrition and Food Safety (NNFNS), and the National Center for Rural Water Supply Technical Guidance (NCRWSTG). Perhaps a national One Health parent organization or institute could link the numerous aforementioned institutions to engage specific complex problems with the interdisciplinary One Health teams necessary to reduce their morbidity; such a new One Health organization could better link with the One Health efforts of other countries and international organizations, such as the WHO, the United Nations (UN), and various non-governmental organizations (NGO) (Figure 1).

In conclusion, China will benefit from further adopting a One Health approach to solve its complex health problems. Such action could save millions of lives and prevent great economic losses by protecting China’s people, animals, and environment.
References


13. ProMED-mail. Avian influenza, human: China, H7N9, WHO. ProMED-mail 2014(20140317.2338505).


Table 1. A partial list of prominent "One Health" Organizations, sampled from the One Health Initiative website, www.onehealthinitiative.com(as of May 2014)

<table>
<thead>
<tr>
<th>Organization</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agronomes et Vétérinaires Sans Frontières</td>
<td>Federation of Veterinarians of Europe</td>
</tr>
<tr>
<td>American Academy of Pediatrics</td>
<td>Global Alliance for Rabies Control</td>
</tr>
<tr>
<td>American Association of Public Health Physicians</td>
<td>Horizon International, Yale University</td>
</tr>
<tr>
<td>American Association of Veterinary Laboratory Diagnosticians</td>
<td>Immune Macro Biotic Technology</td>
</tr>
<tr>
<td>American Association of Wildlife Veterinarians</td>
<td>Immuno Valley Consortium in The Netherlands</td>
</tr>
<tr>
<td>American College of Preventive Medicine</td>
<td>Indian Veterinary Public Health Association</td>
</tr>
<tr>
<td>American College of Veterinary Microbiologists</td>
<td>Department of Animal Health, Institute of Tropical Medicine</td>
</tr>
<tr>
<td>American College of Veterinary Pathologists</td>
<td>Italian Society of Preventive Medicine</td>
</tr>
<tr>
<td>American College of Veterinary Preventive Medicine</td>
<td>National Academies of Practice</td>
</tr>
<tr>
<td>American Medical Association</td>
<td>National Association of State Public Health Veterinarians</td>
</tr>
<tr>
<td>American Nurses Association</td>
<td>Bhutan National Centre for Animal Health</td>
</tr>
<tr>
<td>American Physiological Society</td>
<td>National Environmental Health Association</td>
</tr>
<tr>
<td>American Phytopathological Society</td>
<td>US National Park Service</td>
</tr>
<tr>
<td>American Society for Microbiology</td>
<td>New Zealand Centre for Conservation Medicine</td>
</tr>
<tr>
<td>American Society of Tropical Medicine and Hygiene</td>
<td>Nigerian Biomedical and Life Scientists</td>
</tr>
<tr>
<td>American Veterinary Medical Association</td>
<td>Nigerian Veterinary Medical Association</td>
</tr>
<tr>
<td>US Animal Medical Center</td>
<td>One Health in Epidemiology, Massey University</td>
</tr>
<tr>
<td>Animal/Human Health for Environment and Development for Great Limpopo Transfrontier Conservation Area</td>
<td>Praecipio International</td>
</tr>
<tr>
<td>Association of Academic Health Centers</td>
<td>SAPUVET III Project</td>
</tr>
<tr>
<td>Association of American Medical Colleges</td>
<td>Silent Heroes Foundation</td>
</tr>
<tr>
<td>Association of American Veterinary Medical Colleges</td>
<td>Society for Tropical Veterinary Medicine</td>
</tr>
<tr>
<td>Association of Schools of Public Health</td>
<td>South Africa Society of Travel Medicine</td>
</tr>
<tr>
<td>Organization</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>College of Veterinary Medicine, Auburn University</td>
<td>SpayFIRST, Inc.</td>
</tr>
<tr>
<td>Bella Moss Foundation</td>
<td>State Environmental Health Directors</td>
</tr>
<tr>
<td>Biomedical Technology, Epidemiology and Food Safety Global Network</td>
<td>US Animal Health Association</td>
</tr>
<tr>
<td>CAB International</td>
<td>Veterinarians without Borders</td>
</tr>
<tr>
<td>College of Veterinary Medicine and Biomedical Sciences, Texas A&amp;M University</td>
<td>VeterinarniMedicina, the international journal for biomedical and veterinary sciences</td>
</tr>
<tr>
<td>Conservation through Public Health</td>
<td>Veterinary Bioscience Institute</td>
</tr>
<tr>
<td>Corporation Red SPVet</td>
<td>Volunteers for Intercultural and Definitive Adventures</td>
</tr>
<tr>
<td>Council for Agricultural Science and Technology</td>
<td>WILDCOAST/COSTASALVAJE</td>
</tr>
<tr>
<td>Council of State and Territorial Epidemiologists</td>
<td>Wildlife Disease Association</td>
</tr>
<tr>
<td>Croatian Society for Infectious Diseases</td>
<td>World Association of Veterinary Laboratory Diagnosticians</td>
</tr>
<tr>
<td>Delta Society</td>
<td>World Medical Association</td>
</tr>
<tr>
<td>Department of Molecular and Comparative Pathobiology, School of Medicine,</td>
<td>UK Zoonotic and Emerging Diseases</td>
</tr>
<tr>
<td>Johns Hopkins University</td>
<td></td>
</tr>
<tr>
<td>Exuberant Animal</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1. Potential organizational strategy for a national One Health Institute in China

ICDC = National Institute for Communicable Disease Control and Prevention
NIVD = National Institute of Viral Disease
INCD = National Institute for Non-communicable Chronic Diseases
NIPD = National Institute of Parasite Diseases
IEHS = Institute of Environmental Health and Related Product Safety
NINFS = National Institute for Nutrition and Food Safety
NCRWSTG = National Center for Rural Water Supply Technical Guidance
CAS = Chinese Academy of Science
NSFC = National Natural Science Foundation of China

CDC = China Centers for Disease Control and Prevention
MEP = Ministry of Environmental Protection
MOA = Ministry of Agriculture
NHFPC = National Health and Family Planning Commission
CFDA = China Food and Drug Administration
AQSIQ = General Administration of Quality Supervision, Inspection, and Quarantine
NDRC = National Development and Reform Commission
SAG = State Administration of Grain

Other countries

Organizations (WHO, UN, NGO, etc.)