Bio-Hazard Disaster Risk Governance through Multi-Agency Cooperation

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1. Introduction

Our intention in this paper is to contribute to Sendai Framework Priority 1 “Understanding disaster risk” and Priority 2 “Strengthening disaster risk governance to manage disaster risk” (UNISDR, 2015: 14) by examining biological hazards and by proposing a structure for agencies to mitigate bio-risks. With regard to Priority 1, we aim, first, to develop an understanding of the characteristics that distinguish biological disasters from other disasters, and, second, to highlight the challenges of understanding risk in this area. Obviously a great variety of specific measures for disaster management and risk mitigation for each sort of disaster have already been developed and applied in practice on many occasions and in many countries. Here we wish to underline that biological hazards differ from other hazards in that it is not only hard to predict when an event will occur, but also what sort of biological agent will cause a disaster, leading to which specific kind of scenario and whether it will be induced naturally, accidentally, or intentionally. Hence, “biological hazard” describes a far broader and more loosely defined field than is the case for hazards where the mechanisms can be anticipated more easily.

Under priority 2 we address the specific challenges for multi-agency coordination in bio-hazard disaster risk reduction. To that end, we have drawn up a catalogue of relevant elements and actors, derived from a review of literature. Building on this, we propose an *Arena Approach*, which allows the creation of clusters of relevant actors for each element by applying *Disaster Risk Governance Dimensions*. Our main focus is not at policy level but concerns rather the more hands-on aspects of disaster risk management and disaster management, as these involve numerous agencies – from the national to the local. It is our aim to provide a generic approach, which could be easily adopted to specific national requirements. The Arena Approach builds on other existing concepts, but systematically allocates and organizes the elements and dimensions of risk management and the accordant institutions on various levels to cover multiple complex disasters, such as those of biological origin.

2. Framing the Issue – What Are We Talking About?

Talking about issues such as hazards, threats and risks reliably prompts confusion about usage and the understanding of such terms. Since experts and practitioners in fields from public health, via animal health, consumer protection, life sciences to security policy approach these issues from their own particular perspectives, we wish to start by calibrating terms. Before analyzing stakeholder activities, we will therefore first clarify our understanding of what a disaster is, then show how we use the term hazard and how closely it is linked to risk.

Finally, we will discuss the specific challenges of risk assessment in the bio area that complicate multi-agency governance in this field.

2.1 Disaster

There are many definitions of a disaster. Here we will use the definition of the Sendai Framework which states that a disaster is "a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts." That alone, however, does not sufficiently describe disaster. The following annotations, taken from the UNISDR Glossary (UNISDIR, 2017), characterize disasters more precisely:

Disasters can be distinguished in terms of duration – they may be immediate or last for a long period of time. On the geographical scale they can be distinguished by size, – they may be small-scale and localized, requiring assistance from neighboring jurisdictions, or large-scale and national or international and thus requiring national or international assistance. Disasters also differ by frequency and have different onset modes – they may be slow or sudden. Slow (and sometimes silent)-onset disasters are often associated with epidemic disease. However, the speed at which disease spreads may differ considerably. All the definitions that we found also do not restrict disasters to their effects on humans, but also include affected animals or plants. Depending on the scenario, bio disasters might fall into any of these categories. We would like to stress further that disasters may be highly dynamic and self-sustaining situations that develop into unpredictable situations and often result in cascading effects, which might induce other sorts of disaster, such as disasters from contagious disease as side effects of catastrophic floods.

Before we go into details of some of the above characterizations, we think it is important to stress that the occurrence of a disaster is never announced on the basis of scientific estimations, but is always declared as an ad hoc decision by authorities – at the local, national, or global level. Only such official announcements can turn an emergency situation into a disaster. Having said that, we think that the terms disaster and catastrophe can generally be used interchangeably and we will do so in this paper.

2.1.1 Special Characteristics of Biological Disasters

Bio disasters are one of many subsets of disaster. Often they are defined as "Processes or phenomena of organic origin or conveyed by biological vectors, including exposure to pathogenic micro-organisms, toxins and bioactive substances that may cause loss of life, injury, illness or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage" (NDMA, 2016). The world animal health organization OIE complements this definition by stating that biological disasters are a possible result of natural or intentional release of pathogens (OIE, 2015).

We have already seen the diversity of situations that can be termed disasters. In the following we show how biological disasters can differ fundamentally from other sorts of disaster and how widely biological disasters can differ from each other.

The first striking observation is the quantity and diversity of biological agents that can potentially cause disaster. A possibly incomplete list includes bacteria; viruses; toxins of biological origin, such as metabolites of bacteria (e.g. botulinum toxin), toxins from fungi (e.g. aflatoxin), and toxins from plant components (e.g. ricin); as well as cnidarian venoms, parasites, and prions. Some of these can cause contagious disease; others affect only contaminated individuals (humans, animals, plants, bacteria). This diversity goes even deeper, since, for example, not all bacteria cause contagious disease (anthrax, for example, similar to a toxin, generally only affects contaminated individuals). Many agents are specific to certain hosts (while different strains of one agent might be specific to different ranges of hosts). Bacteria and viruses mutate over time (some faster, and others slower) many are known, many are not, and some might not yet even exist. For some, vaccines or remedies are available, but not for others. They cause different symptoms and, if they spread, they do so by means of various mechanisms. There are approximately 1,400 different human pathogens out there (Nature, 2011). Many of them have never caused a disaster, although they may have the potential to do so. Some potentials for disaster have already been reduced: The potential for disaster caused by bacteria has been reduced by magnitudes with the intervention of antibiotics, though our careless use (or rather misuse) of these substances might reverse this development. These observations open two questions. First: What can be said about the relation of hazard and disaster in the bio area? And second: What can be said about the relation of natural and manmade biological disasters?

2.1.2 Hazard and Disaster

Biohazards can be understood very broadly as the presence of biological substances of all the kinds mentioned above (e.g. Princeton University, 2018). At the other extreme, the term biohazard is often used very narrowly to refer to substances in a laboratory setting that pose a threat and the relevant safety classes (Merriam-Webster dictionary, 2018). We understand bio-hazard as exposure to biological agents with a potential to cause disaster. By referring to probability and consequences, we discuss the usefulness of defining (biological) risk of biological along these parameters.

Naturally Occurring pan-demic	Reemer-ging Infect-ious Diseases	Unintend ed Conse-quences of Research	Labor atory Acci-dents	Lack of Awar enes	Policy Choices	Negli-gence (Failure to ollow SoPs)	Crime & Counter-feit Drugs	Sabo-tage	Attack leading to Release	Biowar -fare Terror-ism; State BW

Natural ⟵ Accidental

⟷ Intentional ⟶

Figure 1: Bio-Risk Spectrum (Taylor 2006)

As Shown by Taylor (figure 1) risks of biological disaster can come from a broad spectrum of sources, including natural hazards and those which are triggered or amplified by certain behavior and decisions. Human history is accompanied with biohazards that have caused biological disasters, including the "black death", cholera pandemics, severe influenza pandemics as in 1918, HIV, and smallpox (eradicated by 1980), to name just the most severe (Dobson and Carper, 1996).

2.2 Risk

2.2.1 Natural Risks

Disasters can have natural or manmade sources. A closer look, however, reveals that most of what are generally considered to be "natural disasters" cannot be regarded independently of human activities. Disastrous floods in the aftermath of heavy rainfall might only develop disastrous consequences when dams were poorly constructed or necessary flood zones were destroyed. Hence, potential disastrous effects from natural sources can be managed by acting in accordance knowledge and awareness of the risks: We can avoid building in zones of risk, adapt buildings to hazards, etc. Yet it would be unrealistic to expect political and societal decisions to be based only on risk assessment; risk reduction is not the only motive in complex decision-making processes. As with decisions to live with many other hazards (e.g. urban development in earthquake areas), decisions on how to deal with biological hazards are often multi-layered (Francesca et al, 2002).

While some diseases can still literally creep out of the jungle, some sort of human activity is still needed to induce the infection mechanism, be it by the consumption of bush meet or by eating fruit that infected animals had contaminated (Beeching et al, 2014). But wild animals are not the only source of zoonotic disease, and there has been an intense relationship between human activities and contagious diseases ever since the development of animal husbandry (Wolfe et al, 2007). Not only did smallpox spread from domestic animals in prehistoric times, but most current strains of influenza (A) have their origin in birds (Webster et al, 1992). It is also plausible that the H1N1 influenza strain, known in the public sphere as swine flu, spread from pig farms (Mena et al, 2016).

Another complicating factor is that biological disasters are often highly dynamic events. Since the lack of control is part of the definition of disaster, clearly all sorts of disasters might develop unexpectedly – dams break, bush fires spread, volcanos behave differently from expected, technologies fail, etc. Biological events, however, can develop dynamics that outshine those of many other catastrophic events. For most other disasters, we know for example the magnitude or the area of possible geographical spread: How much water will seek its way downstream after heavy rainfall? How much radioactive inventory has been released into the environment and how will it be distributed by wind and water? While some pathogens are also dependent on specific vectors or climate conditions, can others potentially spread over large distances or even worldwide. Moreover, in doing so they reproduce, which means that the load of hazardous material is virtually unlimited.

Probability of natural biological hazards

The occurrence of most contagious disease is difficult to predict. We know that annual influenza will travel around the world and that diseases such as malaria, dengue fever, and HIV are continuous catastrophes in large regions of the world. Figures for the probability of outbreak of contagious disease are in general rare and limited to diseases that occur with high frequency.[1] In all these cases and others, such as nosocomial infections with multiresistant bacterial pathogens, behavior and cultural practices heavily influence an individual's chance of being infected, but prediction is impossible. For most contagious disease, it is possible only to try to monitor global, regional and local developments as closely as possible. Authorities thus check real time databases on disease outbreaks keep a close eye on local events, and exchange information to identify the "bug of the week" on an ad hoc basis. In the recent past, the diseases with the greatest potential for regional or global pandemic and potential for disaster were previously unknown, particularly MERS and SARS (McCloskey et al, 2014). But we

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[1] There is, however, neither a common database, nor represent figures for disease such as influenza, malaria, dengue fever, norovirus infections and other often diseases ultimate truth. The environments for the development of disease are much too complex for general data (both in their timely and geographical dimensions).

cannot make predictions even for known diseases, such as Lassa or Ebola, and certainly not for “Disease X” that the WHO has put on their list of most threatening diseases (WHO, 2018) as a marker for the known unknown.[2] In any case growing population density and travel activities increase probabilities; methodologies for scaling are, however, to be developed yet (Brockmann and Helbing, 2013).

The effects of natural hazards

In most cases, the consequences are as difficult to predict as the event itself. The WHO, in a modelling exercise for the insurance industry, concluded that the annual risk of an influenza outbreak on the scale of the 1918 pandemic lies between 0.5 and 1 percent (Fan et al, 2018). There are also rough figures on the consequences of historical or current outbreaks: The CDC (2017) calculates that between 291,000 and 646,000 people worldwide die from seasonal influenza-related respiratory illnesses each year. Data on the economic cost of disease, including effects on absence from work, are also available. Similarly data on the cost and casualties of HIV, Zika, Ebola, and others are available at least for selected countries.[3] The costs of disastrous outbreaks of disease among domestic animals are very hard to aggregate, compare and calculate. To give just one example in an industrialized country, the FMD epidemic in Japan 2010 led to the culling of a number of herds and led to losses of 73 million US dollars (Hayama, 2017). Plant diseases can also cause catastrophic events: The FAO (2018) reports annual losses from biological disasters, “such as diseases and infestations” in the amount of 9.6 billion US dollars. However, extrapolating these figures to estimate single future disastrous events with sound methodology is virtually impossible.

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[2] Consequently for policy makers prediction and knowledge about probabilities might not the primary approach for risk reduction. Sometimes it seems to be most effective to try to prevent further infections with behavioural advice (including calls for vaccination, hygienic standards, safer sex, etc.).

[3] Cost of Zika in Brasil in 2016: 3.5 billion US dollars (World Bank, 2016); costs for Ebola recovery: >800 million US dollars for each Liberia and Sierra Leone and 2.89 billion US dollars for Guinea (Mullan, 2015); for HIV costs for first-line treatment of infection has decreased from 10,000 US dollars/patient to 100 US dollars in Sub-Saharan-Africa in 2012 (UNAIDS, 2012).

2.2.2 Accidental Release

While human behavioral patterns play a role in the spread of disease from natural sources, for other biological hazards, the role of man is far more direct. This is true for accidents in laboratories or production sites that lead to the failure of containment and the subsequent release of pathogens into the environment. The facilities in question could be, for instance, public health labs in the forefront of detection and diagnosis, research labs or vaccine production plants.

Probability of accidental release

Only severe accidents become public. Such cases include the containment loss in a Belgian vaccine producing company that caused a contamination of river Lasne with polio in the city of Rixensart in 2014, the shipping of live anthrax from the US bio defence programme facility Dugway Proving Ground in 595 cases over a period of 10 years to labs around the world, the possible exposure to ineffectively inactivated anthrax at US-Centers for Disease Control (CDC) laboratories and the contamination of another CDC lab with a strain of highly pathogenic bird flu (Connell and Rappert, 216: 255). As far as we know, none of the events has led to any negative consequences. But to estimate the chances of such an event (including a disastrous outcome) one would have to know parameters such as the number of relevant facilities, the pathogens that are handled inside and their (possibly altered) characteristics, and the frequency of occurrence of hazardous incidents in typical facilities. In fact there is very little aggregated knowledge that would facilitate the analysis of failure probabilities. Gryphon Scientific has tried to calculate the probabilities for accidental containment failure in labs working with influenza. Their analysis suggests that a global pandemic would be caused by a laboratory accident in the US once every 2,000-50,000 years (Gryphon Scientific, 2015: 163). The calculation is, however, based on assumptions about human and technical failures that are not based on concrete experiences. In many countries, moreover, central overview mechanisms are underdeveloped or entirely non-existent for sites that are not operated by the states themselves. This is also true for the systematic accumulation of knowledge about accidents. This distinguishes bio-hazard research from other areas: While many countries (e.g. Germany) have central public registers about failures in nuclear sites, no such database is available for biotechnology facilities or incidents.

The effects of accidental release

There is thus also almost no knowledge about the consequences of containment failures. It is possible that the effects would be minimal, since many pathogens have low chances of survivability in the external environment, which would mean that rapid infection would be required for the spread of disease (Gryphon Scientific, 2015). Some pathogens, such as polio or anthrax, however, could sustain themselves more easily.

Should loss of containment lead to an outbreak and the pathogen find good conditions for survival, it is sensible to assume a pattern not much different from a natural outbreak (though there is little knowledge of the effects of releasing large volumes of pathogens). Only one thing is certain: As with other technical facilities, a certain risk of failure will always remain.

2.2.3 Intentional Release

Another type of man-made biohazard (see figure 1) is the use of disease as a weapon.[4] The worst use of bioweapons dates back to medieval times: Although medical and public health standards were poor at the time and the numbers thus differ from what could be expected today, the plague spread throughout Europe in just few years after the Tatars catapulted plague victims into the city of Caffa (Feodosia today) in 1346 following the outbreak of severe disease among their ranks – causing up to 25 million fatalities (one third of the whole population). More recently, British troops distributed blankets contaminated with smallpox as "generous gifts" to the American Indian population during the Siege of Fort Pitt in 1763. A large percentage of the native population died of the disease in the following years, though a direct causal link cannot be established (Wheelis, 1999).

A more systematic development of bioweapons became feasible with the discovery and development of microbiology. And indeed, a number of states did set up programs of various degrees of sophistication. In total more than a dozen viruses, bacteria and were manufactured and weaponized (Dando, 2006). Most of the states disarmed with the entry into force of the bioweapons convention (BWC) in 1975 at the latest, though South Africa, Iraq, and the Soviet Union continued or set up their bioweapons programs in breach of the convention after that date (ibid.). The USSR *Biopreparat* program, which ran from approximately 1973 to 1992 had the dimensions of a large-scale industrial enterprise with some 10,000 staff involved in research and production at dozens of facilities. This was the first time that genomes and thus the characteristics of pathogens had been artificially edited to enhance the suitability of bacteria for weaponization. About a dozen agents were weaponized and the USSR stockpiled hundreds of tons of anthrax, and dozens of tons of plague and smallpox (Alibek, 1999).

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[4] Again due to the limited space the issue is here only exemplified at human disease, but bioweapons could of course also be used against crop-farming or livestock, and cause economic disaster.

Today, more than 25 years after the termination of *Biopreparat*, scientific progress in genetics continues to accelerate and with it comes the fear that bioweapon manufacture could become so easy that terrorist groups could acquire dangerous new bioweapon capabilities (Tucker, 2012).

The consequences of intentional release

By far the largest death toll to bioweapons use in the 20th and 21st centuries was the responsibility of Japan's Unit 731 in World War II, which was responsible for mass casualties through human testing and the release of plague and possibly other agents. Estimates of the number of victims vary from 50,000 to 580,000 (Harris and Paxman, 2002, Barenblatt 2004: 174). Had the USSR deployed their bioweapons, they would likely have resulted in mass destruction, possibly comparable to the effect of nuclear weapons (Danzig, 2006). Little information is available in public sources about the distribution systems and military scenarios envisaged for the use of those weapons, though it is known that dissemination would have been carried out by medium-range bombers and spraying systems, not by missiles (Leitenberg and Zilinskas, 2012).

Since World War II we know of "only" 21 casualties of bioweapons. All died from the effects of state-made bioweapon agents, but not in war. This includes the 14 anthrax victims of an accident in the Soviet bioweapons production site at Sverdlovsk in 1979 and the five victims of the 2001 anthrax letters in the US (Riedel, 2014). The latter is often called a bio-terrorist attack, but due to the supposed personal motivation the term bio-crime might be more appropriate. In any case, this case indicates the threat that can be posed by theft of agents from governmental biodefence facilities and demonstrates the possible disruptive consequences of bioweapons use: Decontamination of affected buildings took up to three years and total cost was almost 250 million US dollars (Danzig, 2006: 67). And the (technically easy) dissemination of animal disease such as FMD could have similar costs. Disruption might also include political and psychological effects. To date, however, no other bioterrorist attacks have led to fatalities (Jansen et al, 2014).[5]

[5] In Lentzos (2016) a number of chapters give a good overview of past bioterrorist attacks.

The probability of intentional release

Although the BWC does not possess any verification mechanisms, there are few if any facts indicating that any state (including BWC non-members) actually owns a bioweapons program of any size. Allegations of programs in non-member states generally remain unproven.[6] The internet is full of allegations against North Korea – yet validation has not been demonstrated in any public sources. The knowledge required to setting up a program and the necessary technical standards are becoming available in an ever-growing number of states with the spread of microbiology and progress in that field.

At least since the 2001 anthrax letters, bioterror is an issue that contributes to the securitization of health (and to the proliferation of actors in biological disaster management). The fact that there are so few historical cases makes it particularly hard to predict the motives and capabilities of terrorist organizations when it comes to bioterrorism. Since the issue is a matter of intense debate in the absence of hard facts, experts have recently conducted a Delphi survey to solicit informed guesses about the phenomenon. But the main result of this was that there is high level of aleatory uncertainty on the issue: Gronvall (2016) asked "59 U.S. experts in biosecurity, from the U.S. government, academia, nongovernmental sector, and industry organizations […] to estimate the percentage likelihood of a large-scale biological weapons attack occurring within the next ten years in any country". The experts' estimates of the likelihood ranged from 1 percent to 100 percent with a mean of 57 percent – a very clear case of we haven't a clue. Danzig (2006: 67) ranks bioterrorism activities, in terms of the effort they require, their possible effects and their probability, along a continuum from *campaign terrorism*, which would require relatively small amounts of agent that could be produced and weaponized with trained staff and equipment available in many places (though still no easy task) to scenarios involving creating and weaponizing a pathogen unknown in nature, which is "yet more difficult and more dangerous than preparing nuclear weapons".

[6] An important exception is Syria. The country had declared and later disarmed a program to weaponize ricin. This happened under the Chemical Weapons Convention; as a bio-toxin, however, ricin is a bioweapon agent, too (Jeremias et al 2016).

2.2.4 Enhancing Biohazard Risks through Research?

Considerable attention has been paid to risk-related biological research in recent years. This debate is being carried out in the frameworks of gain-of-function research (GoF) or dual-use research of concern (DURC), the latter referring to directly occurring misuse potential (which is quite hard to define) (Suk et al 2011), the former more generally being a risk-benefit debate (NRC, 2015). The rapid advances being made in modern biotechnology research and development (understanding microbial mechanisms, developing ever faster, cheaper and easier technologies for genome manipulation, etc.) bring benefits (discovering cures, enhancing preparedness) while simultaneously enhancing the risk potential of the man-made hazards described above, whether by accidental release or unintended production of risk (sourcing from hazardous agents, or knowledge or both) (Connell and Rappert, 2016: 245 ff). To date no majority view on the issue of weighting risks and benefits has emerged in the expert community (NRC, 2015). A list of seven sorts of experiments (NRC, 2004) defines what is widely considered the core of DURC activities. Examples include reconstructing the 1918 flu virus (Tumpey et al, 2005), the de novo synthesizing of the polio (Cello et al, 2002) and, more recently, horsepox (Noyce et al, 2018) viruses. With these syntheses, it became clear that smallpox, though eradicated, could re-enter the scene – the genetic code is freely available in open internet databases (e.g. NCBI database).

A very recent technological development with potential for enhancing biological risks or even misuse is the technology known as gene drives. Gene drives literally suspend Mendel's laws and might, e.g. in combination with gene-editing methods that have also been developed recently, such as CRISPR, lead within a few generations to the manifestation of genetic characteristics in an entire population. This might enable the elimination of disease – the possibility of altering mosquito populations in a way that means they are longer vectors for the spread of malaria, for instance, has been widely discussed, but at the same time it opens the potential for misuse or unintended consequences affecting large-scale ecosystems (Nature, 2017).

2.2.5 Challenges for Risk Assessment as the Driver of a Specific Disaster Governance Approach

Biological disasters are a heterogeneous mix of scenarios that differ tremendously in various ways. There is heterogeneity of agents, host range, geographical scope, degree of human influence, expected consequences (sickness, death, disruption on various levels), likelihood, (non-)existing experience and many more. The term biological hazard thus describes a far broader set of scenarios than is the case with regard to other natural or man-made hazards.

For actors in disaster management (including prevention and preparedness) it is especially challenging to understand this complexity and to take appropriate action. Decision makers have to justify their decisions as well as possible. The means acknowledged to be best suited for doing this are objective, scientific (positivistic) approaches. Actors in risk and disaster management have been developing and using such approaches for many years. The methodology they employ is Probabilistic Risk Assessment (PRA), which is based on calculating risk as a function of the expected consequences (positive and negative) and likelihood of the event. It is not surprising that actors also wish to apply such methodology in the field of biological risks. PRA, however, is not applicable when any of the two parameter-sets (likelihood and consequences) cannot be sufficiently defined. And while this would indeed be possible for some biological disaster scenarios (namely frequently occurring events, such as annual influenza), for most of them it is not. For a wide range of conceivable scenarios, PRA would conclude that there is some risk but could not scale these risks against each other. In a world of limited resources, however, decision makers are dependent on being able to make some kind of ranking. Hence, they need an approach that makes them capable of acting. Since blurry risk parameters and the non-applicability of statistics and reliability theory also apply in other fields, especially in the analysis of the safety of large industrial facilities, alternative approaches have been developed. Further reading would include literature about Bayesian methods of risk assessment (defining probability as a degree of belief) where aleatory uncertainty (variability in known parameters) and epistemic uncertainties (lack of knowledge about fundamental phenomena) are typical (e.g. Hoffmann and Hammonds, 1994), and Dempster-Shafer methodology that defines belief as subset of plausibility (e.g. Sentz and Ferson, 2002), but for the development of a more practical approach for organizing multi-agency disaster risk governance, we can put epistemological theory aside for a moment.

3. Multi-Agency Disaster Risk Governance

3.1 Disaster Risk Governance

As indicated above, when it comes to biological hazards actors are confronted with a kaleidoscope of disaster risks. One way to assess and manage complex issues of this kind is to apply the concept of governance. The UNISDR understands disaster risk governance as "the system of institutions, mechanisms, policy and legal frameworks and other arrangements to guide, coordinate and oversee disaster risk reduction and related areas of policy" (UNGA, 2016:15).

Part of the discourse on governance concerns the concepts of “good” and “bad” (or “poor”) governance. “Good” (risk) governance complies with the principles of participation, accountability, transparency, equity and effectiveness in public management (Kapucu, 2010:27; UNDP, 2015:22). Disaster risk governance can stimulate those elements, for example when it includes civil society engagement and community-based approaches (UNDP, 2015:8–9). In contrast, “poor” governance is one of the major causes of increasing levels of disaster risk (UNDP, 2015:vii). The concept of “underlying disaster risk drivers” also includes a social dimension as it considers the circumstances of different groups in terms of their exposure and vulnerability (UNGA, 2016:24).

A risk governance approach demands that a wider array of institutional actors and mechanisms be taken into account to promote disaster risk management (Tierney, 2012:358), which is also reflected in the Sendai Framework: “Disaster risk governance at the national, regional and global levels is of great importance for an effective and efficient management of disaster risk. Clear vision, plans, competence, guidance and coordination within and across sectors, as well as participation of relevant stakeholders, are needed. Strengthening disaster risk governance for prevention, mitigation, preparedness, response, recovery and rehabilitation is therefore necessary and fosters collaboration and partnership across mechanisms and institutions for the implementation of instruments relevant to disaster risk reduction and sustainable development” (UNISDR, 2015:17).

While this requirement is consensus at the policy level, in reality, disaster risk governance tends to be fragmented due to the isolated approaches of actors, as shaped by their competences and jurisdictions (BBK, 2013:48; Tierney, 2012:348; Toner et al, 2018:6). In this context, Jonathan Lassa concludes that “the problem is not the risks but the institutions and types of institutionalism that shape the modes of disaster risk governance” (Lassa, 2014). The Arena Approach developed here addresses this challenge by organizing the activities of institutions with a possible role in risk governance more effectively.

3.2 Multi-Agency Cooperation

This insight leads to the question of how best to assess and govern the institutions dealing with bio-hazards and their mechanisms of interaction.

Even in the narrower field of emergency and disaster management agencies, there has been a partial shift from war-focused, top-down civil defense to a disaster-focused, bottom-up civil protection system, which relies more on coordination and cooperation than on clear chains of command (Alexander, 2015:3,21).

With the intensity of a biological event, the number of involved actors increases and agencies that have no formal relationship under normal circumstances have to cooperate (Alexander, 2015:11; Gronvall, 2012:42).

Applying the broader concept of governance to biological hazards subjects the network of actors to two key multi-sector extensions:

Firstly, in contrast to the response to non-biological disasters, which is mainly carried out by the disaster-related bureaucracy or "disastocracy" (Lassa, 2014) (civil protection, health, military and law enforcement agencies), biological disasters also involve "disaster-distant" authorities – at all levels, from international to local – concerned with matters such as animal health, food, the environment and agriculture (DHS, 2008:9; EUCOM, 2007:16).

Secondly, in contrast to classic chain-of-command processes, governance not only addresses state institutions but also the engagement of all relevant stakeholders such as civil society, private businesses, non-governmental organizations and academia (Gall, Cutter and Nguyen, 2014:4).

Of course, no single authority can order compliance among this variety of actors. Instead governance is carried out by instruments such as "state regulation and self-regulation; market mechanisms; and other processes, such as negotiation, participation, and engagement, which facilitate collective decision making and action" (Ahrens and Rudolph, 2006:213; see also Tierney, 2012:342).

The multisectoral approach can lead to continual improvements in planning by identifying changing mutual tasks (UNDP, 2015:X). This will not only improve the outcome of integrated disaster risk reduction, but also give those involved a broader view and a better understanding of the issues, while enhancing inter-agency understanding and streamlining inter-agency interactions (Atkinson et al, 2002:8). Establishing multi-agency perspectives is important because otherwise the different institutional frames could lead to "competing understandings of the nature of the problem and the means of resolution" (McInnes and Roemer-Mahler, 2017:1319).

Consequently, the governance approach is a central guiding principle of the Sendai Framework: "Disaster risk reduction and management depends on coordination mechanisms within and across sectors and with relevant stakeholders at all levels, and it requires the full engagement of all State institutions of an executive and legislative nature at national and local levels and a clear articulation of responsibilities across public and private stakeholders, including business and academia, to ensure mutual outreach, partnership, complementarity in roles and accountability and follow-up" (UNISDR, 2015:13).

4. Multi-Agency Cooperation in Bio-Hazard Disaster Risk Governance: The Arena Approach

Disaster risk governance involves a complex pattern of dimensions and elements, which might be linked to well-established activities. The Arena Approach, however, seeks to structure those different efforts.

4.1 Dimensions of Disaster Risk Governance

Although disaster risk reduction is always a complicated cross-cutting field, bio-hazards make it even worse by multiplying the variety and complexity of risks, as we stated above. This complexity is also reflected in the number of actors involved. Ergo, even if there are many isolated efforts to contain bio-hazards, the linkage between them is often weak.

One obvious suggestion of how to foster bio-hazard disaster risk governance is to bring together all the actors involved. The European Commission, for example, recommended a European Bio-Network (EBN), which "would be an advisory structure which would pull together European expertise on bio-preparedness from different sectors – the research community, private and public sectors (including the security and intelligence community, civil protection authorities and first responders)" (EUCOM, 2007:8).

While formats of this kind may be sufficient in many areas, we consider the field of actors in bio-hazard disaster risk reduction too broad and heterogeneous for one-size-fits-all structures of this kind.

This is why we developed the following *Arena Approach*, which may overcome some of those pitfalls via a systematic assessment and clustering of elements and actors of bio-hazard disaster risk reduction. The simple idea is to categorize every element and actor using a set of *Disaster Risk Governance Dimensions*, allowing sorting according to more than one criterion (see table 2). The overlap of elements and actors creates *Disaster Risk Governance Arenas* for each element, consisting of all relevant actors.

Table 2: Dimensions of bio-hazard disaster risk governance

(Geo-) Hierarchical[7]	Sector[8]	Planning level[9]	Field of Actors[10]
• International • National/federal • Regional/state/ district • Local/community	• Health • Food • Animal health • Environmental • Agricultural • Fire & rescue • Civil protection • Law enforcement • Intelligence • Military • Information	• Strategic • Operational	• Governmental organization • Non-governmental organization • Private sector • Academia/research institution

The clustering could be accomplished in three stages:

1. Identifying and categorizing relevant elements of bio-hazard disaster risk reduction by their *Disaster Risk Dimensions* (section 4.2).
2. Identifying relevant actors and categorizing them by the same *Disaster Risk Dimensions* (section 4.3).
3. Building *Disaster Risk Arenas* for each element, including all actors that intersect with at least one of the same categories in each dimension.

After clustering the actors, one could choose the appropriated model of multi-agency cooperation for the arena to enhance bio-hazard disaster risk reduction (section 4.4).This procedure ensures a comprehensive answer to those types of risks while at the same time taking into account specific national structures.

[7] Cf. Alexander (2015:13)
[8] Cf. EUCOM (2007:16)
[9] Cf. Alexander (2015:20)
[10] Cf. DHS (2008:13); Gall, Cutter and Nguyen (2014:4); ODI (n.D.:1)

4.2 Elements of Multi-Agency Bio-Hazard Disaster Risk Reduction

4.2.1 Applying the Disaster Risk Management Framework

In this section we present relevant elements of multi-agency bio-hazard disaster risk reduction derived from a literature review.

For the sake of clarity and the integration in existing disaster risk reduction methods, the elements are arranged systematically using the Disaster Risk Management Framework (FAO, 2008:6), though we acknowledge that a distinct allocation of elements is not always possible. This is why some elements are associated with the response period, which is usually not part of disaster risk reduction.

Following the presentation of elements, they are categorized by *Dimensions* in Table 3 in section 4.2.5.

4.2.2 Pre-Disaster

Risk assessment – a diagnostic process to identify the risks that a community faces

As noted above, **risk analysis** of bio-hazards is challenging in many ways. Nevertheless, to prepare for disaster and to prioritize resources, some kind of preliminary risk assessment is necessary. To analyze the possible occurrence of a threat, its consequences, and adequate countermeasures, a variety of actors should be involved. Scenario techniques could be used to identify relevant actors for the assessment of specific foreseeable risks. Going through the risk management process with those risks will very likely also strengthen resilience against other, unforeseeable or unexamined risks (Alexander, 2015:1). There are several multi-hazard risk assessment approaches as well as specialized tools, for example in the field of food defense (EUCOM, 2010; FDA, 2009; WHO, 2003:15–16).

Due to the broad approach necessary in the field of bio-hazards, it could be useful to concentrate on a few prototypical risks – covering a wide and diverse risk spectrum – and analyze them in detail. This method can be understood as a kind of stress test for the whole disaster risk governance system (BBK, 2015:20).

Although unexpected biological threats and game-changing developments will always occur, academia and designated governmental agencies should undertake "**horizon scanning**" to estimate the impact of emerging pathogens and new (bio-)techniques (NRC, 2002:53). Given the fact that there is a tendency to "plan for the last event, not the next one", this method is particularly important (Alexander, 2015:9).

Part of risk management is deciding to what extent risks are considered to be acceptable. Since it is the general public that is affected in a disaster situation, local communities should be integrated in the process in a way that allows them to collaborate in taking the relevant decisions (Tierney, 2012:356).

Prevention – activities to avoid the adverse impact of hazards

To reduce the chance of accidental pathogen release, misuse and to induce a careful handling of of dual-use knowledge, **awareness raising** is a key concept. Establishing a professional code of conduct in conjunction with mandatory training on dual-use consequences of bio-research and on ethics of bio-research for life science and biotechnology students could be sufficient for academia and bio-companies (EUCOM, 2007:13; NRC, 2002:54), while awareness raising in the area of food production should focus on food defense programs[11] (BBK, 2013:16).

To prevent the intentional release of pathogens by criminal, terrorist, and even state actors, a multi-agency approach is needed to **reduce access** to those agents and dual-use goods (WHO, 2003:20), to **monitor facilities** capable of producing such agents and to **track and disrupt groups** with plans for hostile use of pathogens (Grundmann, 2014:182). A joint risk assessment of biological agents by public health and law enforcement authorities could help with prioritizing resources (BBK, 2012:35).

While the police usually lead the response to terrorist attacks and crimes generally, other emergency responders with CBRN capabilities are also likely to be deployed to an incident. In those cases, it is beneficial for all sides to know each other's tactics and skills (BBK, 2012:32).

Preparedness – activities and measures taken in advance to ensure effective response

It is inherent to disasters that the response will always contain a degree of improvisation, but this needs to be reduced by preparedness (Alexander, 2015:4).

Multi-agency **disaster response plans** are a mighty instrument for raising bio-hazard preparedness. They determine the roles and responsibilities of actors in a specific setting, which can then be tested under hypothetical conditions (Alexander, 2015:17). While there is a general need for overall strategic planning, in some

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11 e.g. FIRST (follow, inspect, recognize, secure, tell) and ALTERT (assure, look, employees, report, threat)

cases operational cooperation demands detailed guidelines and standard operating procedures (SOPs) (Grünewald, 2015:663; Raber, Hibbard and Greenwalt, 2011:272).

Besides a finalized plan, there is another (maybe more) important outcome of joint planning processes: The multi-agency interaction that derives from the planning process generates knowledge about the routine functions and preplanned disaster functions of other actors while also creating trust and informal contacts (Alexander, 2015:7; Atkinson et al, 2002:10; Auf der Heide, 1989:88–89).

The same is true for **joint training and exercises**, which can reveal mistakes, inefficiencies, areas where a lack of planning creates the need for improvisation and other shortcomings of the current disaster response planning (Alexander, 2015:4; Auf der Heide, 1989:87; BBK, 2013:23).

Structured **audits** can also help to clarify strengths and weaknesses of crisis plans. When multiple actors take part in the same audit, the results can be compared and jointly reflected on to enhance multi-agency preparedness (Ruggiero, Vos and Palttala, 2014:4).

Standardization is a key general preparedness measure that can enhance multi-agency communication and the response to biological disasters. It should be applied to terminology, mapping systems, procedures, resources, and performance criteria (Auf der Heide, 1989:85-87,100; DHS, 2008:29). At the technical level, communication systems should enable the automatic exchange of information (Krause et al, 2013:62; Schaub, 2016:294).

Large aspects of disaster management is the **management of resources** (Alexander, 2015:2). Specialized databases for biological incidents, perhaps maintained by designated coordination centers, could help to use bottleneck resources efficiently (BBK, 2012:15,47; Krause et al, 2013:61). For some resources – such as vaccines and antibiotics – **strategic stockpiling** will enhance disaster response dramatically. They could be used not only for treatment, but also as a preventive measure in ongoing outbreak situations (Grundmann, 2014:181).

Given the importance of rapidly identifying pathogens and clearing patients, there is a need for **laboratory response networks**, including private and commercial laboratories, to speed up initial and reference investigation (Grundmann, 2014:182).

Hospitals should prepare disaster response plans for a mass casualty influx (Alexander, 2015:15). In the field of infectious diseases, there is a need for special isolation facilities, trained personal and laboratory infrastructure (BBK, 2013:108). Those resources are costly to maintain, which is especially challenging in “fee-for-service” healthcare systems (Toner et al, 2018:5). One solution could be the implementation of special competence and treatment centers for highly infectious diseases (Grünewald, 2015:662). To strengthen bio-disaster resilience more generally, the centers could be the core of "health care coalitions" for the coordination of preparedness measures in a region, working together with smaller hospitals, other health care facilities, emergency services and pharmacies (Toner et al, 2018:18).

Alongside the integration of private service providers in the governance of bio-hazard risk reduction, **private sector preparedness** itself plays a significant role in building resilience against economic and social disruption (RKI, 2017). There is a wide array of voluntary standards that could be used to prepare businesses for disasters of all types (Tierney, 2012:356). Ensuring critical and vital infrastructure may also require legislative efforts.

The need for **legislative and regulatory frameworks** could apply to various fields – from food safety to bio safety – and also includes security guidelines in scientific facilities and bio-companies (EUCOM, 2007:12; WHO, 2003:14). When planning disaster risk reduction, it is useful to define legally binding structures, jurisdictions, mandates and procedures for the disaster response phase (BBK, 2012:16; Krause et al, 2013:62), including emergency use authorization for vaccines and other medication (UNDP, 2015:99). Establishing and following both legally binding and voluntary agreements will also promote the governance principles of transparency, reliance and accountability (UNDP, 2015:99). This is especially required for state-of-emergency laws, which affect individual (human) rights and could be subverted towards forms of dictatorship (Alexander, 2015:22).

Early warning – provision of timely and effective information to avoid or reduce risk

Bio-related disasters tend to have a slow and "silent" onset, which makes **surveillance systems** crucial for early warning (Grundmann, 2014:180; Krause et al, 2013:61). These consist of means to gather voluntary or legally required reports of single infections and to merge them to create a big picture, enabling a quick response that can contain disease in an early stage. Although such systems are a widely accepted standard in the field of public health, they seem to be underdeveloped when it comes to (wild) animal and crop diseases (Cook et al, 2002; EUCOM, 2007:14; Friend, 2006:263).

Another important factor is **raising awareness and building knowledge** about man-made and natural infectious disease outbreaks among frontline responders to biological incidents. These could be – depending on the context – paramedics, firefighters, police officers, farmers, hunters, wild life rangers, resident physicians and other health care professionals (Friend, 2006:259; Grundmann, 2014:183; Lathrop and Mann, 2001:220).

Compared to other hazards, there are only limited technical **detection capabilities** to verify bio-hazards. This should be addressed by joint research of practitioners and scientific institutions (EUCOM, 2007:14; NRC, 2002).

4.2.3 Disaster Response

Saving people and livelihoods – protection of people and livelihoods during emergencies

During disasters, **crisis communication** of the public authorities with stakeholders such as citizens, the news media, and other response organizations is indispensable (Ruggiero, Vos and Palttala, 2014:4). As contradictory statements will lead to a loss of trust, the objective should be for all the actors involved to speak with a single voice (Drews, 2018:277). Man-made biological events, in particular, can trigger rumors and scapegoating as well as other fear-based behaviors (Hall et al, 2003:142). Multidisciplinary and multisectoral national **risk communication strategies** will ensure more comprehensive information gathering, assessing, and sharing (Dickmann et al, 2016:438).

Immediate assistance – provision of assistance during or immediately after a disaster

A joint response in disaster situations requires a **multiagency coordination system** that integrates the elements personnel, procedures, protocols, business practices, and communications (DHS, 2008:64; Krause et al, 2013:62). The structure of the system depends on the level of strategic and tactical tasks. At the strategic level, meetings of joint crisis committees or councils that bring together different ministries could be adequate. At field level, common incident command systems and emergency operations centers under unified command seem to be necessary (Auf der Heide, 1989:129–130; BBK, 2014:23, 25; DHS, 2008:50; Irwin, 1989; Raber, Hibbard and Greenwalt, 2011:272). One low-threshold measure of cooperation is the exchange of liaison officers between agencies (DHS, 2008:52). Those structures can be established informally and ad hoc in the situation, but it is better to prepare them in mutual agreement beforehand (DHS, 2008:18).

For on-site investigation and handling of infectious diseases, **multiagency regional outbreak response teams** can be set up in advance to support local response structures (BBK, 2012:12; Krause et al, 2013:62).

Assessing damage and loss – information about impact on assets and loss to production

Disaster assessment should not be conducted in organizational silos. An **overall situation analysis** is a key element of comprehensive response (Auf der Heide, 1989:115–118). Some biological incidents may only be identifiable by gathering information from different actors (BBK, 2013:11).

For tactical and strategic planning of operations, a clear **overview of response resources** available at each agency is just as important as the assessment of damage and loss (Krause et al, 2013:57).

4.2.4 Post-Disaster

Recovery – actions taken after a disaster with a view to restoring infrastructure and services

Decontamination, which in most bio-hazard related cases would be disinfection, is part of daily routine in the health sector. However, when it comes to large-scale incidents, such as a significant release of anthrax in an urban environment, it would be a major challenge (Lesperance et al, 2011:310). The decontamination coordination could be prepared and managed by strategic and operational interagency groups in combination with scientific and technical advisory cells (GDS, 2017:11).

Economic & social recovery – measures taken to normalize economic and societal living

Biological incidents – especially but not only bioterror events – could lead to psychological effects that include stigmatization and marginalization, fear and trauma. Such effects can be of long duration (Hall et al, 2003:142). This is why it is important to maintain coordinated approaches to mental health among relevant agencies and care for **psychological recovery** (Hall et al, 2003:141).

4.2.5 Categorizing Disaster Risk Reduction Elements by Dimensions

Table 3 shows the allocation of all the elements mentioned above within defined *Disaster Risk Reduction Dimensions*.

Table 3: Elements of multi-agency bio-hazard disaster risk reduction – dimensions matrix

Elements of multi-agency bio-hazard disaster risk reduction	**Disaster risk reduction dimensions**																				
	Hierarchical				Sector											Planning		Field of actors			
	International	National/federal	Regional/state/district	Local/community	Health	Food	Animal health	Environmental	Agricultural	Fire & rescue	Civil protection	Law enforcement	Intelligence	Military	Information	Strategic	Operational	Government organization	Non-governmental	Private sector	Academia / Research
Risk analysis	X	X	X	X	X	X	X	X	X				X	X		X		X	X	X	X
Horizon scanning	X	X			X	X	X	X	X				X	X		X		X	X	X	X
Awareness raising – Dual Use Research of Concern (DURC)	X	X	X	X	X		X		X					X		X	X			X	X
Awareness raising – intentional and atypical events			X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	
Actor focused bioterror prevention	X	X	X		X	X	X	X	X			X	X			X		X			
Disaster response plan – strategic	X	X	X		X	X	X	X	X		X			X	X	X		X	X		
Disaster response plan – operative (SOPs)		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	
Joint training, exercise & audits – strategic	X	X	X		X	X	X	X	X		X	X	X	X	X	X		X	X	X	
Joint training, exercise & audits – operative		X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X	
Standardization	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Joint resource database	X	X	X		X		X	X		X	X	X		X			X	X	X	X	
Strategic stockpiling	X	X	X		X		X							X		X		X	X	X	
Hospital networks		X	X	X	X											X	X	X	X	X	
Laboratory networks	X	X	X		X	X	X	X	X					X		X	X	X	X	X	X
Private sector preparedness		X	X	X	X	X	X	X	X							X	X	X		X	
Legislative and regulatory frameworks	X	X	X		X	X	X	X	X		X	X				X		X			
Surveillance systems	X	X	X	X	X	X	X	X	X							X	X	X	X	X	
Enhancing technical detection capabilities		X	X		X	X	X	X	X	X	X	X	X	X			X	X		X	X
Joint crisis communication		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X			
Strategic multiagency coordination system	X	X	X		X	X	X	X	X		X	X	X	X	X	X		X	X		

Operational multiagency coordination system		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		
Multiagency regional outbreak response teams	X	X	X		X	X	X	X	X	X	X			X			X	X	X		
Overall situation analysis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Decontamination concept		X	X	X	X	X	X	X	X	X	X			X		X	X	X	X	X	
Psychological recovery concept		X	X	X	X					X	X				X	X		X	X		

4.3 Actors in Disaster Risk Governance

Following the categorization of elements by *dimensions*, the same needs to be done with the pertinent actors before the eventual clustering of elements and actors within certain *arenas*.

The most relevant actors in the field of disaster risk reduction are still government agencies, since they hold power, authority and financial resources (Gall, Cutter and Nguyen, 2014:16). Nevertheless, civil society actors such as volunteers, organized voluntary work organizations and community-based organizations, which could provide resources, specific knowledge and pragmatic guidance, should complement the leading role of governments (Lassa, 2014; UNISDR, 2015:23). Besides those direct benefits, the integration of civil society actors guarantees a higher degree of participation and legitimation.

The private sector is also increasingly important for holistic disaster risk reduction. On the one hand, it provides vital infrastructure, services and resources needed for disaster management and, on the other hand, it can be both the source and a victim of bio-hazard disasters (Röhl, 2016:175; Tierney, 2012:347).

For legislation relating to disaster risk management, lawmakers are, of course, also relevant actors. Given that laws are usually created or adapted on the basis of input from the relevant authorities, advocacy groups, etc., we do not consider the legislators themselves to be relevant actors in this framework.

Since actors and their jurisdictions vary strongly depending on the specific domain of reference (usually a national context), no categorization of actors by *dimensions* was possible in this paper. Table 4 shows a list of possible types of actors, which could be used to identify actors for the *Arena Approach*.

Table 4: Types of actors listed by sectors

Sectors	Types of actors
Health[12]	• Public health authorities • Hospitals • Registered/practicing physicians • Registered/practicing psychotherapists • Nursing homes • Mental health facilities • Blood banks • Hazardous material decontamination facilities • Medical laboratories • Pharmacies • Patient associations • Coroner/funeral services • Health research facilities • World Health Organization (WHO)
Food[13]	• Consumer protection authority • Public and private water suppliers • Food producers • Catering services • Trade associations • Consumer protection organization • Food research facilities • UN Food and Agriculture Organization (FAO)
Animal health[14]	• Animal/livestock control authorities • Veterinaries (domestic, farm and wild animals) • Animal clinics/hospitals • Animal feed producers • Animal health research facilities • UN World Organization for Animal Health (OIE)
Environmental[15]	• Environmental protection authorities • National park/wildlife refuge authorities • Forest administration/forestry • Environmental organizations/groups • Waste service providers/facilities • Environmental research facilities • United Nations Environment Programme (UNEP)

[12] Cf. Auf der Heide (1989:257–262); Grundmann (2014:183); Hall et al (2003:139); Tierney (2012:348); WHO (2003:33)
[13] Cf. Auf der Heide (1989:257–262); BBK (2013:11)
[14] Cf. Alexander (2015:156); Auf der Heide (1989:257–262)
[15] Cf. Auf der Heide (1989:56); Friend (2006:262); Lesperance et al (2011:311)

Agricultural[16]	• Agricultural authorities • Land management authorities • Agricultural research facilities • UN Food and Agriculture Organization (FAO)
Fire & rescue/first responders[17]	• Fire departments • Hazardous material response teams • Emergency medical services agencies • Air ambulance services • Fire marshals • Private manufacturing and storage facility fire brigades • Emergency research facilities
Civil protection[18]	• Civil protection authorities • Volunteer welfare and relief organizations • Psycho-social intervention units/crisis counseling services • Civil Protection research facilities
Law enforcement[19]	• Police authorities/constabulary • Criminal investigation authorities • Ranger/park police • Airport police/authorities • Treasury/custom authorities • Bomb squads • Forensic or body identification teams • Drug enforcement authorities • Law enforcement research facilities
Intelligence[20]	• Domestic intelligence services • Foreign intelligence services
Military[21]	• CBRN units • Laboratories/research facilities • Engineers corps • National guard • Military air rescue • Military hospitals • CBRN research facilities
Information[22]	• Communications/information authorities • Television and radio broadcasters • Newspaper publishers

[16] Cf. Auf der Heide (1989:257–262)
[17] Cf. Auf der Heide (1989:56,257-262); Grundmann (2014:183); Raber, Hibbard and Greenwalt (2011:274)
[18] Cf. Alexander (2015:3); Auf der Heide (1989:56,257-262); Hall et al (2003:139)
[19] Cf. Auf der Heide (1989:56,257-262)
[20] Cf. Grundmann (2014:182)
[21] Cf. Auf der Heide (1989:257–262); Tierney (2012:348)
[22] Cf. Auf der Heide (1989:56)

4.4 Organizing Multi-Agency Governance

After carving out the elements and actors of the different bio-hazard *Disaster Risk Reduction Arenas*, there are several different ways of establishing institutional cooperation within an arena. The appropriate model depends strongly on the task and context at hand.

To develop joint approaches for disaster risk reduction, three levels of bodies could be constituted. At the strategic level, these could be steering groups or boards where directors and senior professionals define the guiding principles for multi-agency cooperation and ensure political accountability (Atkinson et al, 2002:17; Chase, 1980).

The main coordination work will be done at the tactical level by decision making groups, operations teams and working groups (Atkinson et al, 2002:21; BBK, 2012:38). They implement board decisions and recommend new proposals for consideration or review (Chase, 1980).

For technical and other complex tasks, setting up specialist groups, task forces and technical advisory groups secures professional consulting mechanisms for the higher levels of multi-agency governance structures (Atkinson et al, 2002:24; Chase, 1980; Raber, Hibbard and Greenwalt, 2011:274).

The form of cooperation in those structures can vary from multi-agency panels, which meet on a regular basis to discuss relevant issues, to multi-agency teams, whose members are seconded, or even integrated services/agencies with permanent staff and tasks (ECM, 2005:1).

Multi-agency institutions need a conducive environment to be fruitful. Investigating health care coalitions as part of the U.S. Hospital Preparedness Program (HPP), Acosta et al (2015) identified promoters of success and barriers to success in multi-agency collaborative work (Table 3).

Table 5: Promoters of success and barriers to success in multi-agency collaborative work[23]

Promoters of success	Barriers to success
• Active member participation • Diversity of members • Sharing information and resources • Increases in members' capacity to respond to or recover from disaster • Coalitions perceived as a trendsetter or model for surrounding communities	• Lack of funding • Staffing shortages and leadership difficulties • Lack of trust • Cultural/organizational differences • Limited data collection

5. Conclusion

We have shown that biological disasters can derive from an extremely broad spectrum of agents and sources. So far, they have largely been natural events (heavily influenced for good and ill by how people live with and within their environment), but accidentally or intentionally triggered disasters may lie ahead. There are only a few scenarios where we can anticipate what a biological disaster will look like. But on the whole we do not know which agent will spread and on what scale; whether it will affect humans or agriculture; or if its status as a disaster will come from its lethality or from its potential to cause economic or societal disruption. While probabilistic risk analysis is already challenging for most other sorts of disaster, in the bio field, actors in risk mitigation can only make use of it for the very few scenarios of which we have aggregated knowledge from the past. Hence, complexity and ignorance make it necessary for actors in risk mitigation (including prevention, preparedness and response) to develop especially flexible mechanisms and network structures.

The approach developed here for the governance of bio-hazard risk reduction through multi-agency coordination could generate powerful and resilient structures that could also enhance governance principles such as transparence, accountability and participation. The *Arena Approach* presented here may be used to find the right actors in the right cooperative setting for the right tasks, considering national characteristics. Due its specific

[23] based on Acosta et al (2015:692–695)

focus on – and its broad understanding of - bio-hazard risk, this approach identifies actors far beyond the “old favorites” of disaster management in a systematic and comprehensive way.

In doing so, it builds upon well described concepts and established institutions, but provides the basis for a more holistic disaster risk governance.

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