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Public Health Implications of Emergencies and Disasters

By

Amanda Culver
Master of Public Health

Environmental Health

Susan Cookson, MD, MPH
Committee Chair

William Michael Caudle, PhD
Committee Member

Roger Rochat, MD
Committee Member

Paige Tolbert, PhD
Committee Member

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By

Amanda Culver
BSN
East Tennessee State University
2003

Thesis Committee Chair: Susan Cookson, MD, MPH

An abstract of
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Rollins School of Public Health of Emory University
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Abstract

Public Health Implications of Emergencies and Disasters
By Amanda Culver

Background: The last ten years have seen an unprecedented rise in the number of persons displaced from their home due to conflict or natural disasters. Loss of infrastructure and large population displacements often lead to environmental conditions ripe for infectious disease outbreaks. While it is widely acknowledged that infectious disease epidemics play a major role in morbidity and mortality in complex emergencies and natural disasters, there has been limited published literature comprehensively examining this relationship.
Methods: Events were collected for the years 2005-2014. Complex emergencies (CE) were identified using the Center for Research on the Epidemiology of Disasters (CRED) Complex Emergency Database and United Nations (UN) Flash and Consolidated Appeals archive. Natural disasters (ND) were identified using the CRED International Disaster Database and UN Flash and Consolidated Appeal archive. Infectious disease outbreaks were identified from the World Health Organization (WHO) outbreak archive. Individual databases were created for each type of event then compared for overlap. Descriptive and inferential statistics were performed.
Results: There were 169 unique complex emergencies, 913 natural disasters, 118 events linked to both complex emergency and natural disaster, and 384 outbreaks were identified for the specified years. 43% of CEs were linked to outbreaks, 24% of NDs were linked to outbreaks, and 36% of 'both' events were linked to outbreaks. The OR of a vaccine-preventable outbreak occurring in a CE setting versus an ND setting was 6.66.
Conclusions: Outbreaks were more likely to be linked to a CE event and more likely to occur in developing countries. When an outbreak was associated with a CE, it was much more likely to be a vaccine preventable disease. Focus on better vaccine coverage in developing countries could reduce the morbidity and mortality associated with CEs when they do occur.

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1. Introduction

The last ten years have seen an unprecedented rise in the number of persons displaced from their home due to conflict or natural disasters. The United Nations High Commissioner for Refugees (UNHCR) estimates that in 2014, 59.5 million individuals were forced to flee their homes dues to conflict, violence, persecution, or human rights violations [1]. These numbers are further increased when natural disasters such as floods, typhoons, earthquakes, and droughts are taken into consideration. The Internal Displacement Monitoring Center estimates that an additional 19.3 million persons were displaced by natural disasters in 2014 [2]. Large population displacements are frequently associated with increases in mortality rates, usually from infectious disease and malnutrition. People forced to flee often relocate to informal settlements or refugee camps where poor environmental conditions (i.e., overcrowding, water shortages, and lack of sanitation) create situations ripe for infectious disease outbreaks. However, it is not just displaced persons who are at increased risk due to conflict and natural disasters. Large-scale emergencies and disasters cause damage to national and local infrastructure that limits residents' access to resources such as potable water, as well as potentially crippling a country's ability to cope if a secondary disaster occurs. All of these factors combine to put already vulnerable populations at risk for infectious disease outbreaks.

1.1 Background

Complex Emergencies

A Complex Emergency (CE) is defined as "a humanitarian crisis which occurs in a country, region[1], or society where there is a total or considerable breakdown of authority resulting from civil conflict and/or foreign aggression [3]." Infectious diseases have historically played a significant role in the morbidity and mortality associated with these events, in some cases accounting for up to 95% of recorded deaths [4]. While causative agents can vary regionally, the most common types of infections contributing to mortality in CE settings historically are measles, diarrheal disease, malaria, and acute respiratory infections.

For several unique reasons, CE situations put populations at particular risk for outbreaks. First, by definition, CEs lead to large-scale displacement of populations, who often end up in camps or informal settlements. Population density, lack of access to clean water, and poor sanitation in these settings each increase the risk of an outbreak occurring. Second because CEs are also more likely to occur in developing countries, this risk is compounded by lack of water and sanitation infrastructure, poor nutritional status, and low vaccine coverage, especially in areas of conflict [4, 5]. Third, CE events are ongoing for months or even years leading to long-term deprivation of services for those affected, such as in Sudan where conflict has been ongoing since the 1980's [6]. Fourth, large-scale displacement may also lead populations into areas where they encounter diseases to which they may have no immunity. Fifth and conversely, large refugee populations may also introduce diseases, such as malaria, into previously non-endemic areas [7].

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[1] Regional categories defined by United Nations Statistics Division

Natural Disasters

A Natural Disaster (ND) is a naturally occurring physical phenomena caused either by rapid or slow onset events which can be geophysical, hydrological, climatological, meteorological or biological [8]. Historically, people have associated NDs with a risk for infectious disease outbreak, primarily due to fear of increased numbers of dead bodies posing various health risks. While this belief has been persistently purveyed in media outlets, there is a lack of evidence that dead bodies increase risk for epidemics except in very specific cases such a dead bodies infected with Ebola or when NDs lead to very similar circumstances as CEs [9, 10] . This occurs when NDs cause population displacement and destruction of infrastructure, leading to poor sanitary conditions, lack of potable water, and overcrowding. Much like CEs, if the ND occurs in a low resource setting, pre-existing malnutrition, poor health status, and low vaccine coverage can further increase the risk of outbreak.

An article published in 2007 identified the likely causative agents of outbreaks in ND settings. Flooding can lead to water contamination and outbreaks of diarrheal disease from agents such as *Vibrio cholerae* and *Escherichia coli.* Hepatitis E outbreaks have also been associated with massive floods, which lead to contaminated water. Flooding and heavy storm seasons have also been associated with an increase in vector-borne illnesses like malaria and dengue fever. Cases of measles and meningitis have been associated with overcrowding that occurred following displacement due to NDs [9].

Of course, emergencies and disasters do not occur in isolation. One occurrence can precede another or events can also occur concurrently, such as in the case of Sudan and South Sudan where ongoing conflict has been exacerbated by long-term drought. Outbreaks can occur in any of the above situations or related to no other events at all.

1.2 Literature Review

To date, only one article has been published examining the relationship between CEs, NDs, and infectious disease outbreaks [5]. This study by Paul Spiegel, *et al*. identified the 30 largest events (based on mortality) in each category (CEs and NDs) for the years 1995-2004. They then examined these for overlap with concurrent events within their designated time frame. The authors performed descriptive statistics to analyze the relationship between the three events. They found that during the 10 years examined, 63% of the largest CEs had at least one epidemic and 23% of the largest NDs had at least one epidemic. They also found that 87% of CEs had at least one ND reported in the same time frame and 27% of the reported NDs occurred in areas with a reported concurrent CE.

While that article was valuable in that it was the first to examine this relationship, it was limited in its scope by only examining the 30 largest events by mortality. This review will attempt to control for more potential contextual biases such as ongoing years of conflict and ongoing effects of NDs as well as broaden the scope of study to all events in a 10-year period and look at the most recent 10-year period.

1.3 Research Objectives

This research has two aims. The first is to provide an analysis of the number of complex emergencies, natural disasters, and infectious disease outbreaks that have occurred in the years 2005-2014 and examine the overlap of the three categories. The second is to identify the public health implications of these data and their potential to impact planning, response, and interventions.

2. Methods

2.1 Complex Emergencies

Two primary sources were used to create a database of Complex Emergencies (CE): The Center for Research on the Epidemiology of Disasters (CRED) Emergency Event Database (CE-DAT) and The United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) Consolidated and Flash Appeal archives. A tertiary source was used for verification: The United Nations High Commissioner for Refugees (UNHCR) archives and records. Inclusion criteria were: events that occurred between 2005 and 2014, CE-DAT surveys meeting complex emergency threshold criteria of mortality rate of > 1/10,000/day, country specific appeals, and number affected of 10,000 persons or greater. For events spanning multiple years, each year was counted as one occurrence. Multiple reports for the same country in the same year that were of the same type of emergency were counted as one occurrence.

CRED's CE-DAT stores surveys of nutrition and mortality data of CE affected countries. These data are publicly available at http://www.cedat.be/. A database query was run for the years 2005-2014 using the 'Tables' function on the website. Each country in the database was queried individually. For each query, the following search criteria were used: country name, all available Admin Div 1 (referring to provinces or districts), and the indicator of Crude Mortality Rate (CMR). All returned entries were exported and organized in Microsoft Excel (Microsoft©, Redmond, WA). CRED acknowledges that this database has inherent limitations. The surveys upon which it is based are submitted voluntarily, so gaps in reporting may exist. Additionally, they state that validity is a concern, as the submitted surveys are not compared to raw data [11]. For these reasons, a secondary source of CEs was used.

UNOCHA maintains a Central Emergency Response Fund (CERF) to which countries can appeal for rapid humanitarian response and funding to support populations affected by natural disaster or armed conflict [12]. In order to receive assistance, countries must file a Flash Appeal or Consolidated Appeal to UNOCHA. These appeals are maintained in a public searchable archive on UNOCHA's website at http://www.unocha.org/cap/appeals/by-year/results. Appeals were searched by year and all appeals filed between 2005 and 2014 were collected and organized in Microsoft Excel. Inclusion criteria were the same as those used for the CE-DAT database. The appeal archive entries include attached PDF copies of the original filed document. These were examined individually by a single reviewer for each event to ascertain the nature of the appeal and the number affected. Entries were categorized as armed conflict, natural disaster, or other.

CE-DAT surveys and UNOCHA appeals were then cross-referenced by year and country to identify concordant and discordant reports. If observations were concordant between data sets, they were recorded as a single event in a new database. If observations were discordant, they were recorded as separate events and verified using a tertiary source, the UNHCR archives and records. These are also publicly available at http://www.unhcr.org/pages/49da066c6.html. Yearly country reports were searched for each discordant entry to confirm event occurrence as well as number affected. Additionally country reports were used to verify number affected in all CE-DAT surveys, as this information was not available in those surveys.

2.2 Natural Disasters

Two sources were used to collect ND data: The CRED International Disaster Database (EM-DAT) and the Flash and Consolidated Appeal archives described above. Inclusion criteria were as follows: events that occurred between 2005 and 2014, country-specific appeals, and number affected of 10,000 persons or greater. For events spanning multiple years, each year was counted as one occurrence. Multiple reports for the same country in the same year for the same type of emergency were counted as one occurrence.

The CRED EM-DAT is considered to be comprehensive and is widely cited by government and private organizations like International Monetary Fund (IMF) and Oxfam [13-15]. The data are publicly available at http://www.emdat.be/. An EM-DAT database query was run using the Database, Advanced Search function on the website. Search criteria were as follows: Period: 2005-2014, Country: all included, Disaster Classification: Natural, Group Results by: Year, Country Name, Disaster Group. All entries returned were exported and organized in Microsoft Excel.

Flash and Consolidated appeals for NDs were collected by the methods described for CE Flash and Consolidated appeals. These were used in addition to the EM-DAT data in order to identify countries with ongoing disaster status in the year(s) following the original event. One example of this is Haiti, where an earthquake occurred in 2010. The original event is counted once in 2010. However due to extensive damage of infrastructure, flash appeals were filed for 3 additional years related to the original event. These were each counted as separate annual occurrences. Additionally, if more than one ND occurred in a country during a single year, each occurrence was counted as a single event. ND events were then categorized into 5 categories: drought, earthquake, extreme temperature, flood, storm, and other. The 'other' category included events classified as landslides, wildfires, and volcanic activity and were grouped together due to their relatively infrequent occurrences.

2.3 Infectious Disease Outbreaks

Data on infectious disease outbreaks were collected from the WHO disease outbreak archive, which is publicly available at http://www.who.int/csr/don/en/. This archive contains all outbreaks reported to WHO from their field country offices. Inclusion criteria were as follows: outbreaks occurring between the years 2005 and 2014. For outbreaks spanning multiple years, each year was counted as a separate occurrence. A single reviewer examined and recorded each report for the included years. Disease type, number affected and number of deaths were extracted from each report. Ongoing status reports for individual outbreaks were linked to the original report and counted as one occurrence. Outbreaks were then examined by year, region, numbers affected and disease type of outbreak. Due to the 2009 H1N1 pandemic, outbreaks spiked three times higher that year than any other year in the study. Because of this, data analysis was also performed controlling for H1N1. The outbreaks with highest case fatality rates (CFR) were examined in several fashions:

total outbreaks, outbreaks excluding influenzas, and outbreaks affecting 100 persons or greater. This was done because many of the outbreaks were diseases with very low infection numbers but high mortality rates (ex: influenza and Ebola). Because vaccine-preventable diseases have the clearest implications for public health interventions, the outbreaks caused by these diseases were also analyzed individually.

2.4 Data Organization and Statistics

Once data were collected into each appropriate category and cleaned, CEs and NDs were cross-referenced. If a CE and ND occurred in the same year, this was categorized as 'Both' and was removed from the individual category. These three separate categories (CE, ND, Both) were then cross-referenced with the WHO outbreak archive. Events that occurred in the same year of an outbreak were then linked.

Basic descriptive statistics were performed including mean, standard deviation (SD), median, as well as proportional calculations for each separate event (CE, ND, and Outbreaks). This included total number of cases worldwide as well as regional calculations for all categories. All outbreak descriptive statistics were calculated including and excluding H1N1. Outbreaks were then further stratified by disease and vaccine-preventable status, and then additionally broken down regionally. CFRs were calculated and compared by total number of affected, total number of cases excluding all influenza cases, and finally total numbers in outbreaks affecting 100 or greater persons.

Once outbreaks were linked to events, basic descriptive statistics were again performed on total numbers of outbreaks and regions. Mantel-Haenzel chi square odds ratios (OR) with a 2-tail p value and 95% confidence interval (CI) were then calculated using OpenEpi software comparing outbreaks in CEs with NDs as well outbreaks stratified on vaccine-preventable status in CEs and NDs. The same calculations were then performed controlling for H1N1.

3. Results

3.1 Complex Emergencies

The CE-DAT database query yielded 1,555 surveys. Of these, 1,008 were excluded for not meeting the emergency threshold of a CMR of greater than 10,000 per day. Of the remaining 547 surveys, 477 were duplicate country surveys from the same year. After excluding those surveys that did not meet criteria as well as duplicate entries for the same year, there were 88 total CE events recorded from this database. The Flash and Consolidated Appeals archive yielded 249 appeal documents. Of those reports, 72 were categorized as natural disasters only and analyzed under ND criteria. 23 reports were excluded for falling into category 'other[2]' and 3 reports were duplicates. An additional 11 observations were removed for being regional reports rather than country specific. This resulted in a total of 140 Flash/Consolidated appeals being included in the CE database. The two sources were then examined for overlap and 52 events were identified as being reported in both databases. These were each combined as a single event. There were 7 events

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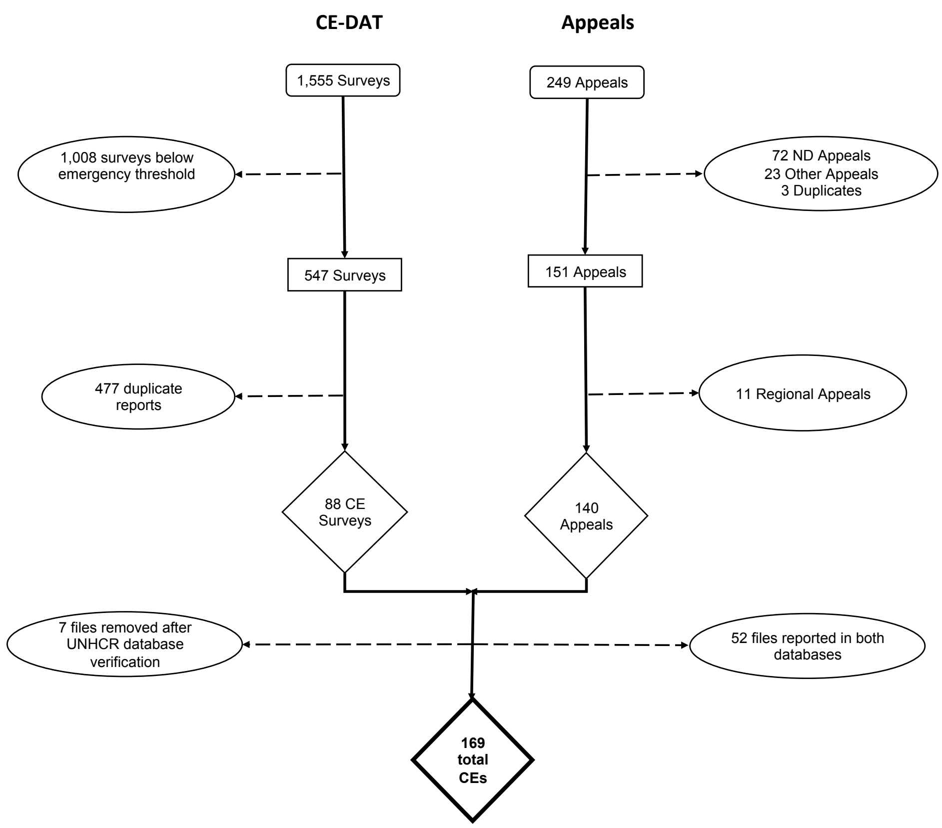
[2] Other reasons given included poverty and food insecurity not explicitly linked to ND or CE

reported only in the appeal archive that could not be verified through the UNHCR database and were thus removed.

Once the CE-DAT and appeal data were combined, there were a total of 169 complex emergency events between 2005 and 2014. Of these, 37 were reported only by the CE-DAT, 81 were reported only in Flash/Consolidated appeals, and 51 were reported in both databases. All of the single reported occurrences could be verified using UNHCR country report documents [Figure 1].

Figure 1. Complex Emergencies Process Diagram

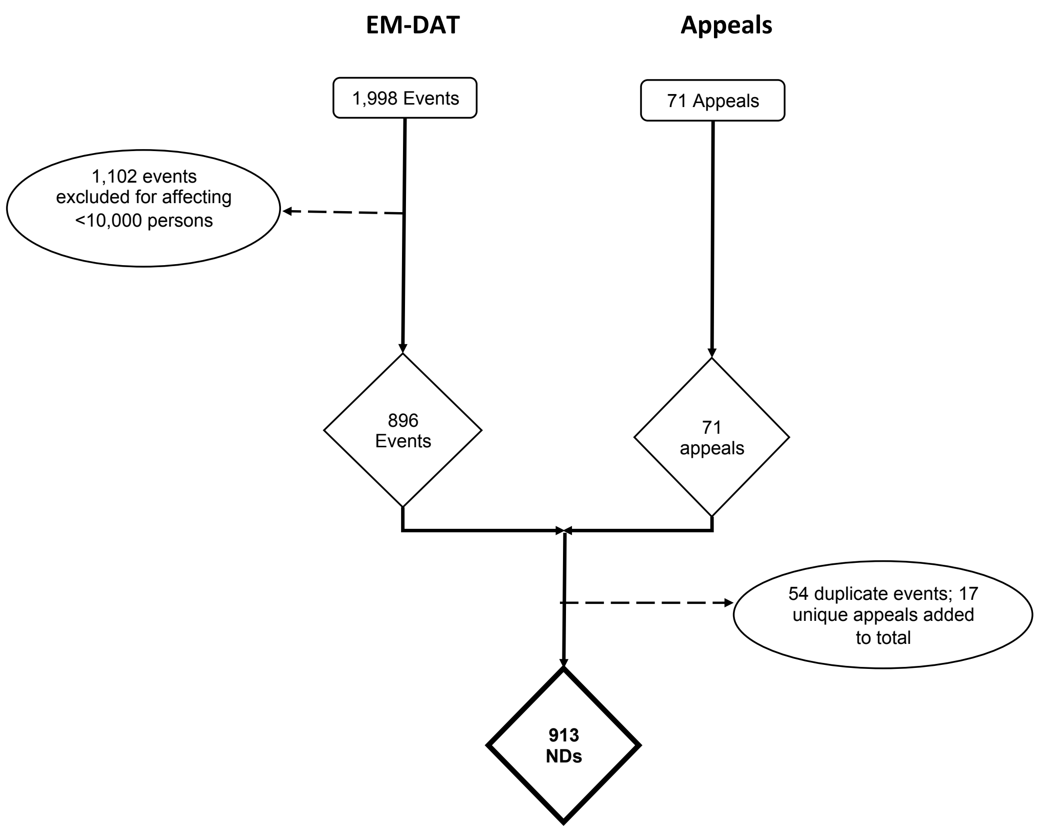


The 169 CE events occurred in 42 countries, primarily in three regions. The most affected region was Africa, which had 112 CEs (66%), followed by the Middle East with 37 CEs (22%), then Asia with 19 CEs (11%), and finally Eastern Europe with 1 CE (<1%) [Figure 2]. While Africa suffered the most CE events, the largest affected populations were primarily in the Middle East with 8 of the 10 largest events by population affected occurring in that region [Tables 1, 2]. The mean number of persons affected per individual CE was 1,102,780 with a SD of 1,336,428 and a range of 10,700 to 6,973,000.

3.2 Natural Disasters

The EM-DAT database query was run, yielding 1,998 events between 2005 and 2014. Of those observations, 1,102 (55%) were excluded for affecting less than 10,000 persons. The remaining 896 observations met inclusion criteria. When these were compared to Flash/Consolidated appeals for NDs, of the 71, there were no new events identified in the appeal archives. However, 17 additional events representing ongoing years of appeal related to a prior event were included based on criteria. These created a total of 913 Natural Disaster events between 2005 and 2014 [Figure 3].

Figure 3 Natural Disasters Process Diagram



ND events occurred in 139 different countries. Regionally, Asia (31%) and Africa (29%) were the most affected followed South America (11%), Central America (6%), and the Middle East (5%). The remaining regions comprised less than 5% each of the total [Figure 4]. The ten largest NDs occurred in Asia with 9 of them confined to China [Table 3]. The most commonly occurring events were floods (53%), storms (17%), and droughts (13%) [Figure 5]. The mean number of persons affected by all NDs was 1,935,519 with a SD of 8,773,964 with a range of 10,000 to 140,194,000.

3.3 Both

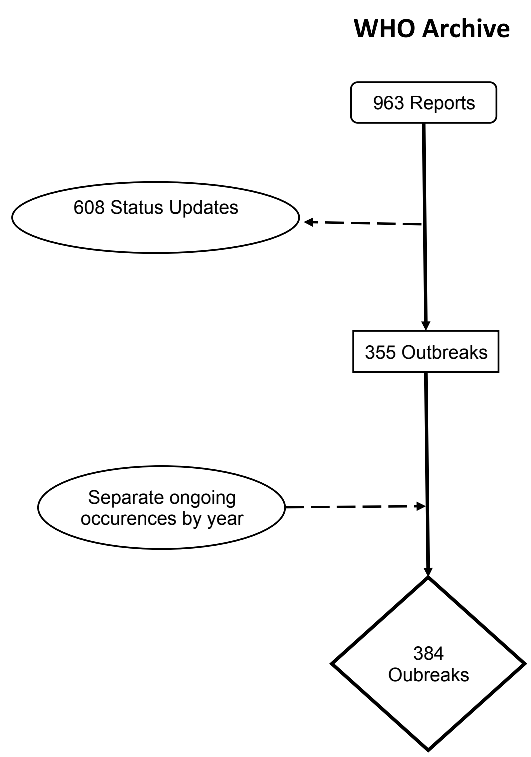
When CE and ND databases were compared, 118 observations fell into the 'both' category, meaning an ND and CE occurred in the same country, in the same year. This number appears larger than the basic sum for CEs or smaller for NDs because for 9 of the 10 years at least two NDs of different types occurred in the same country. Each of these events were linked to a CE, thus creating a larger number.

These events occurred in 29 different countries in only three regions: Africa (67%) Asia (20%) and the Middle East (14%) [Figure 6]. Of the ten largest dual occurrences, 7 were in Africa and were droughts with CEs [Table 4]. The mean number of person affected was 1,994,785 with a SD of 2,853,398 nd a range of 27,080 to 24,404,986.

3.4 Infectious Disease Outbreaks

The WHO outbreak archive was examined for each year included in this study and yielded 963 reports. Of these, 355 were new outbreak reports and the remaining 608 were status update reports. After separating ongoing occurrences by year, 29 additional outbreak events were identified. The final database included 384 outbreaks from 2005-2014 [Figure 7].

Figure 7. WHO Outbreak Process Diagram



The mean number of outbreaks per year was 38 with a SD of 31. The range of occurrences per year was between 24 and 124 with a median of 29. The largest number of outbreaks in one year occurred in 2009 due to the H1N1 pandemic influenza [Figure 8]. The mean number affected was 5,852 with a SD of 64,977 and a range of 1 to 1,250,000. When H1N1 was excluded from the analysis, the mean number of outbreaks per year was 28 with a SD of 5.5 and range of 24 and 37. The mean number affected was 7,758 with a SD of 76,056 and a range of 1 to 1,250,000.

Looking at overall regional trends of outbreaks, 46% occurred in Africa and 17% in Asia. All other regions accounted for less than 10% of outbreaks each [Figure 9]. The outbreaks with the highest total infected occurred in Asia, Africa, South America, and the United States [Table 5], the latter being because of the H1N1 pandemic. Of the ten largest, 5 were vaccine-preventable diseases. For the total outbreaks, 7 of the highest 10 CFR occurred in avian influenza outbreaks in Asia [Table 6]. When influenza was excluded from the analysis, outbreaks of hemorrhagic fevers, Middle Eastern Respiratory Syndrome (MERS-CoV), yellow fever, and poliomyelitis in Europe, Africa, and the Middle East had the highest CFR [Table 7]. Of the 10 highest CFRs in outbreaks affecting 100 persons or greater, 8 occurred in Africa, 1 in the Middle East, and 1 in Asia. These included Ebola, poliomyelitis, Rift Valley fever, avian influenza, and MERS-CoV [Table 8].

In terms of type of outbreak, 42% of those reported were acute respiratory illnesses (influenzas, MERS-CoV). The next largest numbers of reported outbreaks were all vaccine-preventable diseases (VPD): yellow fever (10%), poliomyelitis (9.1%), meningococcal disease (8.7%), and cholera (7.8%) [Figure 10]. Stratifying all outbreaks on vaccine preventable status revealed that 62% of reported outbreaks were non-vaccine preventable and 39% were vaccine preventable. This proportion held true regionally with the exception of Africa. Of the reported outbreaks in African region, 70% were vaccine preventable [Figure 11].

Five VPDs were reported in the outbreaks archives: cholera, measles, meningococcal disease, poliomyelitis, and yellow fever. Case numbers and CFRs for the largest events defined as most affected or highest CFR can be seen in the Tables addendum [Tables 9-18]. Of note, the highest case numbers and CFRs all occurred in Africa except for Tajikistan, which had the most case numbers for poliomyelitis.

Examining each VPD individually revealed the following: For cholera, the mean number of infected persons was 17,013 with a SD of 30,302 and a range of 99 to 143,030. The mean CFR for cholera was 4.1% with a SD of 5.5% and a range of 0% to 28%. For measles, the mean number of infected persons was 11,981 with a SD of 29,271 and a range of 3 to 103,000. The mean CFR for measles was 0.09% with a SD of 0.31% and a range of 0% to 1%. For meningococcal disease, the mean number of infected persons was 2,428 with a SD of 4,877 and a range of 53 to 22,255. The mean CFR for meningococcal disease was 9.3% and a SD of 5.2% and a range of 3.8% to 7.6%. For poliomyelitis, the mean number of infected persons was 54 with a SD of 100 and a range of 1 to 430. The mean CFR for poliomyelitis was 4.6% with a SD of 17% and a range of 0% to 86%. Lastly, for yellow fever, the mean number of infected persons was 55 with a SD of 146 and a range of 1 to 732. The mean CFR for yellow fever was 24.0% with a SD of 29% and a range of 0% to 100%.

3.5 CEs, NDs, and Outbreaks

The data were first examined by looking at the emergency event as the starting point. Doing this revealed the following: Of the 84 CE only events, 36 (43%) were linked with outbreaks. Of the 795 ND only events, 191 (24%) were linked with outbreaks. Of the 118 ‘Both’ events, 42 (36%) were linked with outbreaks. The odds ratio (OR) and 95% Confidence Interval (CI) of any outbreak occurring in a CE only setting versus an ND only setting was 2.42 (1.51, 3.84). The OR (95% CI) of any outbreak occurring in a 'Both' setting versus a non-emergency setting was 3.60 (1.93, 6.80). The OR (95% CI) of any outbreak occurring in a 'Both' setting versus an ND only setting was 2.24 (1.19, 4.25). The OR (95% CI) of any outbreak occurring in a 'Both' setting versus a CE only setting was 0.54 (0.22, 1.29). Excluding H1N1 outbreaks from the analysis, the OR (95% CI) of an outbreak occurring in a CE only setting versus an ND only setting was 2.27 (1.57, 3.25) [Table 20]. Stratifying regionally revealed no statistically significant odds with the exception of Africa where the OR (95% CI) of an outbreak occurring in a CE only setting versus an ND only setting were 3.50 (2.12, 5.84).

Examining the overlaps with outbreaks as the starting point showed that of the 384 outbreaks reported, 39 (10%) were linked by year to a CE event, 126 (33%) to an ND event, and 58 (15%) to a 'Both' event, with the remaining 161 (42%) linked to no event.

Further stratification of vaccine preventable status allowed for statistical testing to be performed, yielding the following results: the OR (95% CI) of a vaccine preventable outbreak occurring in a CE only setting versus a non-emergency setting was 6.66 (3.08, 15.1); The OR (95% CI) of a vaccine preventable outbreak occurring in an ND only setting versus a non-emergency setting was non-statistically significant at 1.61 (0.97, 2.67); The OR (95% CI) of a vaccine preventable outbreak occurring in a CE only setting versus an ND only setting was 4.14 (1.90, 9.43) [Table 19]. Examining these trends regionally revealed no statistically significant results with the exception of the Middle East where the OR (95% CI) of a vaccine preventable outbreak occurring in a CE setting versus a non-emergency setting was 14.19 (1.22, 268.8). The OR (95% CI) of a vaccine preventable outbreak occurring in a CE only setting versus an ND only setting was 4.14 (1.90, 9.43); but the OR (95% CI) of a vaccine preventable outbreak occurring in an ND only setting versus a non-emergency setting was not statistically significant at 1.66 (0.02, 38.7); [Table 19]. When H1N1 was controlled for, the OR (95% CI) of a vaccine preventable outbreak occurring in a CE only setting versus a non-emergency setting was 2.99 (1.31, 7.16); the OR (95% CI) of a vaccine preventable outbreak occurring in a CE setting versus an ND setting was 2.91 (1.29, 6.91); but the OR (95% CI) of a vaccine preventable outbreak occurring in an ND setting versus a non-emergency setting was 1.03 (0.58, 1.83); [Table 20].

4. Limitations

This research has a number of limitations that should be taken into consideration. The primary limitation is that these data are all correlational, linked by year and country; no causal relationship can be assumed. Events occurring in different regions within a country may be linked by inclusion criteria but may be, in actuality, unrelated. For example, the 2011 measles outbreak in the United States was linked to a drought that occurred the same year in this study. We know these two events were unrelated but they met inclusion criteria. To avoid bias, they were included as a linked event. Additionally, the time delineation based upon year is completely arbitrary and based on ease of data mining. Because of this some events may be linked in reality, but not for purposes of this study as they were recorded in different years. Additionally, for NDs, 9 of the 10 years examined had multiple reports of events for the same country in the same year. If these were different types of disasters, they were each counted as a single occurrence. Because of this, the number of 'both' events may be artificially inflated.

Reporting inconsistencies within databases is another limitation. The WHO archives are consolidated from individual country reporting offices and the way in which they collect and report data is different based on location. Inconsistencies included the following: some reports appear to be estimates or rounded numbers where other reports are more exact, some reports do not include mortality data, and reports do not always specify if case numbers are laboratory confirmed cases or just symptomatically diagnosed. Additionally, no other database was available for outbreak verification. For all categories, events may have been missed or mis-categorized. The various databases used were not considered to be exhaustive and some events were inevitably missed.

And finally, while this research can give a broad picture of correlations, many nuances of relationship are missed. One example of this is the cholera outbreak in Haiti after the 2010 earthquake. The epidemic was actually traced back to Nepalese UN Peacekeepers who brought the disease with them after the earthquake [16]. While one could argue that the epidemic would not have occurred if the earthquake hadn't happened, the opposite could be argued just as easily. The complexity of causality in these circumstances is not always clear.

5. Discussion

Overall, the data from this research indicate the odds of an infectious disease outbreak occurring are more associated with a CE than with an ND. When an outbreak does occur associated with a CE, it is much more likely to be a VPD. CEs were also highly associated with concurrent NDs: 51% of reported CEs had an associated natural disaster event. When examining the overlap of CEs and NDs, it would be natural to assume that concurrent events would place populations at higher risk for outbreak. Interestingly, this was not shown with the data. One possible reason for this is that the combination of CE and ND would actually drive more people across national borders in search of safety and resources not available in their home country. Their numbers would then be attributed to the host country as a refugee population. This could result in informational bias within the data captured in this study by attributing an outbreak to the host country and not linking it to the original event, thus decreasing the relationship seen between 'both' events and outbreaks. One example of this is Somalia where ongoing drought and conflict have driven millions into countries such as Ethiopia, Djibouti, Kenya, and Tanzania. While the original insult may have been a 'both' event, whatever occurs subsequently within that population will be attributed to their host countries. In spite of the potential for some misclassification, when all of the ORs are examined together, there is statistical evidence that overall, CEs are the driving force behind increased odds of a vaccine-preventable outbreak: the OR for CEs versus non-emergency was well above the null while in NDs versus non-emergency, the OR was the null; in the combined event, the OR again becomes significant [Table 19].

While the numbers for CEs are compelling, one cannot ignore the general context of poverty in which these events occur. One of the major trends that emerged from these data was that developing countries were disproportionately affected by CEs and outbreaks. This was especially true in Africa where 67% of total CEs, 67% of combined events (CE and ND), and 46% of all outbreaks occurred. The baseline risk of disease occurring in developing countries is going to be higher because they are, by definition, more vulnerable to these types of occurrences. This is especially clear when regionally stratifying diseases. While only 39% of globally reported outbreaks were VPDs, 70% of outbreaks reported in Africa were VPDs. Compare this to Europe and North America where only 11% of reported outbreaks were VPDs, and those numbers came almost exclusively from the 2011 measles outbreak. The low-level baseline distribution of infectious disease within developed countries combined with better surveillance infrastructure would increase reporting of many outbreaks that are not endemic. This would increase the number of outbreaks not associated with a CE or ND thus diluting the ORs closer to the null for these emergencies.

Public Health Implications

The causes of morbidity and mortality in the early phase of emergencies are widely understood. This study sought to look at the larger implications of disasters by examining all reported diseases in a country during the allotted time period. What emerged has implication both for public health interventions and areas of future study.

One of the most obvious public health implications that emerged from these data is that increased and adaptable vaccine coverage in developing countries could reduce morbidity and mortality associated with CEs. While the Global Immunization Vision and Strategy (GIVS) campaign developed by WHO and UN Children's Fund (UNICEF), as well as the Global Alliance for Vaccines and Immunizations (GAVI) have made strides in increasing routine vaccine coverage worldwide, many countries involved in conflict have seen their healthcare infrastructure destroyed and vaccine coverage progressively dropping [17-19]. This loss of herd immunity has regional and global implications. The re-emergence of polio in Syria and Cameroon in 2014 brought the potential international impact into sharp focus. WHO recognized the risk in a statement issued that same year: "The consequences of further international spread are particularly acute today given the large number of polio-free but conflict-torn and fragile States which have severely compromised routine immunization services and are at high risk of re-infection. Such States would experience extreme difficulty in mounting an effective response were wild poliovirus to be reintroduced [20]."

This raises the question of how to increase coverage in areas with little to no infrastructure, where conflict is ongoing, and conditions may be too dangerous to hold vaccination campaigns. While it may seem impossible, successful vaccination campaigns have been carried out in places such as Afghanistan, Peru, and Democratic Republic of Congo in the midst of open conflict [21]. These campaigns are not without risk, however, as we have seen in Pakistan, Afghanistan, and Nigeria where healthcare workers carrying out vaccine initiatives have lost their lives [22].

Simpler and safer would be to target countries with no risk for instability. While CEs are true emergencies, they are not unforeseen in the same sense of most NDs. Conflict and instability can be brewing for months or years before it erupts. Prioritizing adaptable healthcare infrastructure and vaccine coverage in high-risk countries could mitigate the negative disease outcomes when a CE does occur.

An important public health issue raised by this research for future study is the complicated relationship between resource scarcity and conflict. More than 50% of the CEs in this study were linked by year to an ND and more than 90% of the NDs in this study are types of events linked to climate change [23]. This does not even account for the conflicts that were preceded by ongoing NDs but did not overlap by the inclusion criteria of these data. For example, the current conflict in Syria was preceded by a three-year drought that is considered the worst in recorded Syrian history [24]. Whether the drought and subsequent scarcity were linked is a matter of debate and beyond the scope of this study. However, with long term trends of natural disasters related to climate change increasing, the possibility for growing conflict related to food and water scarcity are real concerns [13].

Examining these events through a public health lenses, primary prevention would always be the goal. But, as the International Committee of the Red Cross stated, “Disasters and emergencies are a fundamental part of normal life. They are consequences of the ways societies structure themselves, economically and socially; the ways that societies and states interact; and the ways that relationships between the decision makers are sustained [25].” However, effective secondary prevention in this situation is possible. While it is obviously beyond the scope of this research to predict the future occurrence of disasters and emergencies, it is possible to use these data to mobilize future resources for mitigation, planning, and response strategies that do not just manage the consequence of disasters and emergencies but actually decrease the risk of epidemics associated with them.

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Appendix 1: Tables

Table 1. Populations affected by Complex Emergencies

Region	Population	Number of CEs	Population affected by CEs	Ratio Affected:Unaffected
Africa	1 billion	112	78.9 million	1:12
Asia	3.9 billion	19	12.8 million	1:300
Middle East	445 million	37	94.2 million	1:4
East. Europe	105 million	1	400,000	1:245

Table 2. Ten most affected countries from Complex Emergencies by number affected, 2005-2014

Date	Country	Total Affected
2013	Syria	6,973,300
2014	Democratic Republic Congo	5,400,000
2014	Syria	4,408,010
2014	Occupied Palestinian Territory	4,294,682
2013	Occupied Palestinian Territory	4,169,506
2012	Occupied Palestinian Territory	4,046,901
2011	Occupied Palestinian Territory	3,927,051
2010	Occupied Palestinian Territory	3,811,102
2009	Occupied Palestinian Territory	3,702,218
2006	Nepal	3,639,400

Table 3. Ten most affected countries from Natural Disasters by number affected, 2005-2014

Date	Country	Disaster	Total Affected
2010	China	Flood	140,194,000
2007	China	Flood	111,110,792
2011	China	Flood	93,360,000
2008	China	Extreme temperature	77,000,000
2009	China	Drought	60,160,000
2006	China	Storm	55,337,820
2008	China	Earthquake	47,437,647
2009	China	Flood	45,226,038
2005	China	Storm	40,782,831
2007	India	Flood	38,143,008

Table 4. Ten most affected countries from Concurrent CE and ND by number affected, 2005-2014

Date	Country	Disaster Type		Total Affected
2010	Pakistan	CE	Flood	24,404,986
2011	Philippines	CE	Storm	9,570,676
2011	Kenya	CE	Drought	8,971,990
2012	Philippines	CE	Storm	7,860,480
2008	Ethiopia	CE	Drought	6,485,300
2012	Niger	CE	Drought	6,450,200
2009	Ethiopia	CE	Drought	6,324,330
2009	Sudan	CE	Drought	5,726,400
2010	Somalia	CE	Drought	5,489,950
2012	Sudan	CE	Drought	5,348,200

Table 5. Ten most affected countries from Outbreak by numbers infected, 2005-2014

Date	Country	Disease	Total Infected	Total Mortality	CFR
2006	India	Chikungunya	1,250,000	Unknown	Unknown
2005	Guinea B.	Cholera	143,030	252	0.18%
2008	Brazil	Dengue	120,570	48	0.04%
2011	D.R. Congo	Measles	103,000	1100	1.07%
2009	Zimbabwe	Cholera	71,927	2758	3.83%
2010	Haiti	Cholera	60,240	1415	2.35%
2006	Angola	Cholera	43,076	1642	3.81%
2007	Iraq	Cholera	30,000	14	0.05%
2010	Nigeria	Cholera	29115	1191	4.09%
2009	United States	H1N1	27717	127	0.46%

Table 6. Ten most affected countries from Outbreak by highest case fatality rates, 2005-2014

Date	**Country**	**Disease**	**Total Infected**	**Total Mortality**	**Case Fatality Rate**
2012	Indonesia	Avian Influenza	8	8	100%
2012	Cambodia	Avian Influenza	6	6	100%
2011	Cambodia	Avian Influenza	5	5	100%
2008	Viet Nam	Avian Influenza	5	5	100%
2010	Cameroon	Yellow Fever	3	3	100%
2009	Indonesia	Avian Influenza	2	2	100%
2012	Jordan	MERS-CoV	2	2	100%
2005	Senegal	Yellow Fever	2	2	100%
2007	Cambodia	Avian Influenza	1	1	100%
2008	Cambodia	Avian Influenza	1	1	100%

Table 7. Ten most affected countries from outbreak by case fatality rates, excluding H1N1, 2005-2014

Date	Country	Disease	Total Infected	Total Mortality	Case Fatality Rate
2014	Spain	Ebola	1	1	100%
2011	Uganda	Ebola	1	1	100%
2007	Uganda	Marburg	1	1	100%
2012	Jordan	MERS-CoV	2	2	100%
2013	UA Emirates	MERS-CoV	1	1	100%
2010	Cameroon	Yellow Fever	3	3	100%
2005	Senegal	Yellow Fever	2	2	100%
2007	Angola	Poliomyelitis	7	6	85.71%
2009	CA Republic	Yellow Fever	4	3	75%
2012	Uganda	Ebola	24	17	70.83%

Table 8. Ten most affected countries from outbreak by case fatality rates in cases affecting 100 or greater persons

Date	Country	Disease	Total Infected	Total Mortality	Case Fatality Rate
2014	Guinea	Ebola	607	406	66.89%
2014	Liberia	Ebola	1082	624	57.67%
2007	Viet Nam	Avian Influenza	101	47	46.53%
2010	D.R. of Congo	Poliomyelitis	184	85	46.20%
2006	Somalia	Rift Valley Fever	114	51	44.74%
2007	D.R of Congo	Ebola	372	166	44.62%
2013	Saudi Arabia	MERS-CoV	160	69	43.13%
2014	Sierra Leone	Ebola	910	392	43.08%
2007	Tanzania	Rift Valley Fever	264	109	41.29%
2007	Sudan	Rift Valley Fever	601	211	35.11%

Table 9. Ten most affected countries from Cholera by case numbers, 2005-2014

Date	Country	Total Infected	Total Mortality	Case Fatality Rate
2005	Guinea-Bissau	143,030	252	0.18%
2009	Zimbabwe	71,927	2,758	3.83%
2010	Haiti	60,240	1,415	2.35%
2006	Angola	43,076	1,642	3.81%
2007	Iraq	30,000	14	0.05%
2010	Nigeria	29115	1191	4.09%
2008	Zimbabwe	26497	1518	5.73%
2005	Senegal	23325	303	1.30%
2006	Ethiopia	22101	219	0.99%
2012	Sierra Leone	20736	280	1.35%

Table 10. Ten most affected countries from cholera by case fatality rates, 2005-2014

Date	Country	Total Infected	Total Mortality	Case Fatality Rate
2010	Cameroon	1869	515	27.55%
2005	Mali	158	20	12.66%
2005	Niger	197	24	12.18%
2010	Niger	976	62	6.35%
2008	Zimbabwe	26497	1518	5.73%
2010	Chad	2508	111	4.43%
2008	Iraq	341	15	4.40%
2005	Liberia	703	29	4.13%
2010	Nigeria	29115	1191	4.09%
2009	Zimbabwe	71927	2758	3.83%

Table 11. Ten most affected countries from measles by case numbers, 2005-2014

Date	Country	Total Infected	Total Mortality	Case Fatality Rate
2011	D.R. of Congo	103,000	1100	1.07%
2011	Nigeria	17,428	0	0
2011	France	14,025	6	0.04%
2011	Zambia	5,397	0	0
2011	Ethiopia	2,902	0	0
2011	Quebec	742	0	0
2011	United States	213	0	0
2011	Ecuador	41	0	0
2011	Brazil	18	0	0
2011	Colombia	7	0	0

Table 12. Two most affected countries[3] from cholera by case fatality rates, 2005-2014

Date	Country	Total Infected	Total Mortality	Case Fatality Rate
2011	D.R. of Congo	103,000	1100	1.07%
2011	France	14,025	6	0.04%

[3] Only two countries reported fatalities related to cholera

Table 13. Ten most affected countries from meningococcal disease by case numbers, 2005-2014

Date	Country	Total Infected	Total Mortality	Case Fatality Rate
2007	Burkina Faso	22255	1490	6.69%
2009	Nigeria	17462	960	5.50%
2007	Sudan	6946	430	6.19%
2009	Nigeria	5323	333	6.26%
2012	Burkina Faso	5300	553	10.43%
2009	Niger	4513	169	3.74%
2006	Burkina Faso	3636	399	10.97%
2012	Chad	2828	135	4.77%
2010	Chad	1531	151	9.86%
2008	Burkina Faso	1422	204	14.35%

Table 14. Ten most affected countries from meningococcal disease by case fatality rates, 2005-2014

Date	Country	Total Infected	Total Mortality	Case Fatality Rate
2006	Cote d'Ivoire	130	40	30.77%
2006	Kenya	74	15	20.27%
2008	Burkina Faso	1,422	204	14.35%
2005	Chad	387	53	13.70%
2012	Cote d'Ivoire	399	49	12.28%
2005	India	405	48	11.85%
2008	Chad	922	105	11.39%
2007	D.R. of Congo	53	6	11.32%
2006	Burkina Faso	3636	399	10.97%
2012	Burkina Faso	5300	553	10.43%

Table 15. Ten most affected countries from poliomyelitis by case numbers, 2005-2014

Date	Country	Total Infected	Total Mortality	Case Fatality Rate
2010	Tajikistan	430	19	4.42%
2009	Nigeria	258	0	0
2005	Indonesia	251	0	0
2006	Somalia	215	0	0
2010	D. R. of Congo	184	85	46.2%
2005	Yemen	179	0	0
2011	Pakistan	84	0	0
2011	Chad	68	0	0
2014	Syria	57	0	0
2006	Namibia	34	7	20.59

Table 16. Ten most affected countries from poliomyelitis by case fatality rates, 2005-2014

Date	Country	Total Infected	Total Mortality	Case Fatality Rate
2007	Angola	7	6	85.71%
2010	D. R. of Congo	184	85	46.2%
2006	Namibia	34	7	20.59%
2010	Tajikistan	430	19	4.42%
2007	D. R. of Congo	27	1	3.70%

Table 17. Ten most affected countries from poliomyelitis by case numbers, 2005-2014

Date	Country	Total Infected	Total Mortality	Case Fatality Rate
2012	Sudan	732	165	22.54%
2005	Sudan	565	143	25.31%
2010	Uganda	226	53	23.45%
2014	D.R. of Congo	139	6	4.32%
2005	Guinea	114	26	22.81%
2011	Cote d'Ivoire	79	35	44.30%
2005	Mali	53	23	43.40%
2013	D.R. of Congo	51	19	37.25%
2008	Brazil	48	13	27.08%
2013	Sudan	44	14	31.82%

Table 18. Ten most affected countries from yellow fever by case fatality rates, 2005-2014

Date	Country	Total Infected	Total Mortality	Case Fatality Rate
2010	Cameroon	3	3	100%
2005	Senegal	2	2	100%
2009	C.A.Rebublic	4	3	75%
2012	Ghana	3	2	66.67%
2008	Liberia	3	2	66.67%
2009	Cote d'Ivoire	10	6	60%
2008	Burkina Faso	2	1	50%
2008	C.A.Rebublic	2	1	50%
2011	Cote d'Ivoire	79	35	44.30%
2005	Mali	3	3	43.40%

Table 19. Odds Statistics (H1N1 included)

Event	OR	CI (95%)	Chi Sq.	p value
Outbreak occurring in CE vs ND	2.42	1.51-3.84	14.6	<0.001
Outbreak occurring in Both vs. CE	0.723	0.41-1.29	1.24	0.267
Outbreak occurring in Both vs. ND	1.74	1.15-2.62	7.18	0.007
Outbreak occurring in Africa: CE vs ND	3.50	2.12-5.84	24.82	<0.001
Outbreak occurring in Middle East: CE vs ND	1.54	0.3073-7.78	0.39	0.530
VPD outbreak vs NVPD outbreak in CE vs non-emergency setting	6.66	3.08-15.1	26.38	<0.001
VPD outbreak vs NVPD outbreak in ND vs non-emergency setting	1.61	0.97-2.67	3.49	0.062
VPD vs NVPD outbreak CE vs ND	4.14	1.90-9.43	13.62	<0.001
VPD vs. NVPD outbreak Both vs non-emergency	3.60	1.93-6.8	17.07	<0.001

CE- complex emergency ND- natural disaster Both – concurrent CE and ND
VPD – vaccine preventable disease NVDP – non-vaccine preventable disease

Table 20. Odds Statistics (H1N1 excluded)

Event	OR	CI (95%)	Chi Sq.	p value
Outbreak occurring in CE vs ND	2.27	1.57-3.25	20.3	<0.001
Outbreak occurring in Both vs. CE	0.83	0.50-1.38	0.52	0.470
Outbreak occurring in Both vs. ND	1.88	1.21-2.88	8.47	0.004
VPD outbreak vs NVPD outbreak: CE vs non-emergency setting	2.99	1.31-7.16	6.97	0.008
VPD outbreak vs NVPD outbreak: ND vs non-emergency setting	1.03	0.58-1.83	0.01	0.923
VPD vs NVPD outbreak: CE vs ND	2.91	1.29-6.91	7.74	0.009
VPD vs. NVPD outbreak: Both vs non-emergency	1.75	0.88-3.51	17.07	<0.001

CE- complex emergency ND- natural disaster Both – concurrent CE and ND
VPD – vaccine preventable disease NVDP – non-vaccine preventable disease

Appendix 2: Figures

Figure 1. CE process diagram

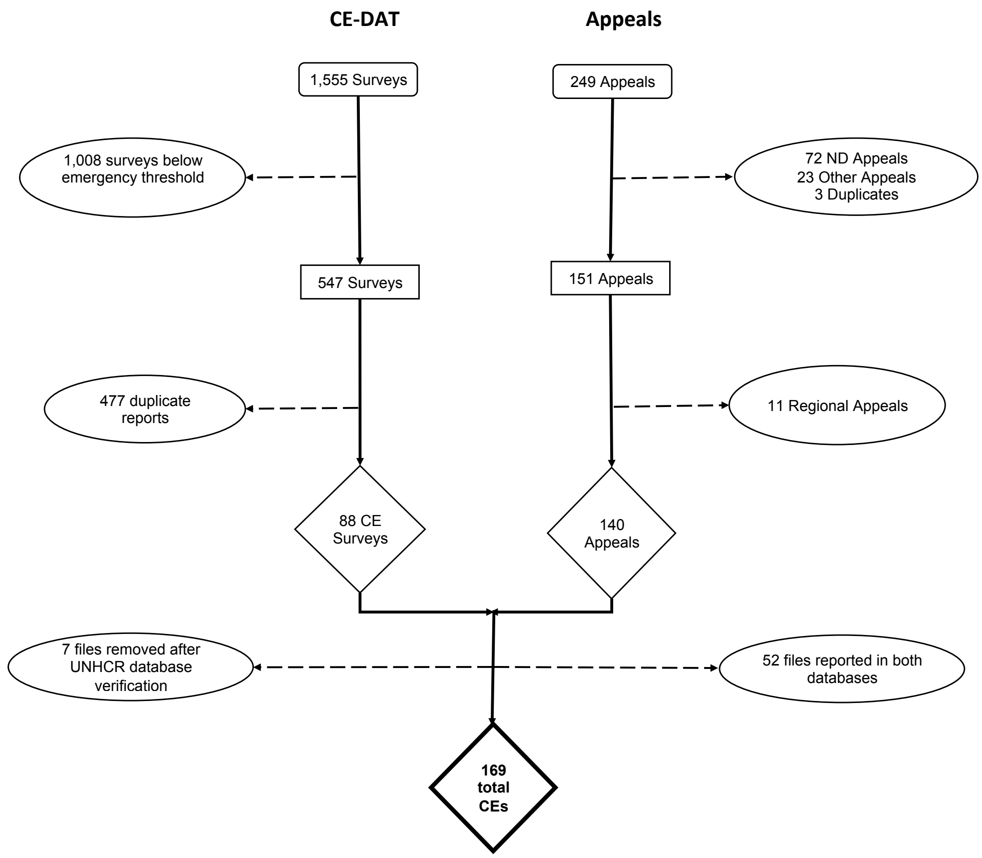


Figure 2. CE regional distribution (n=169)

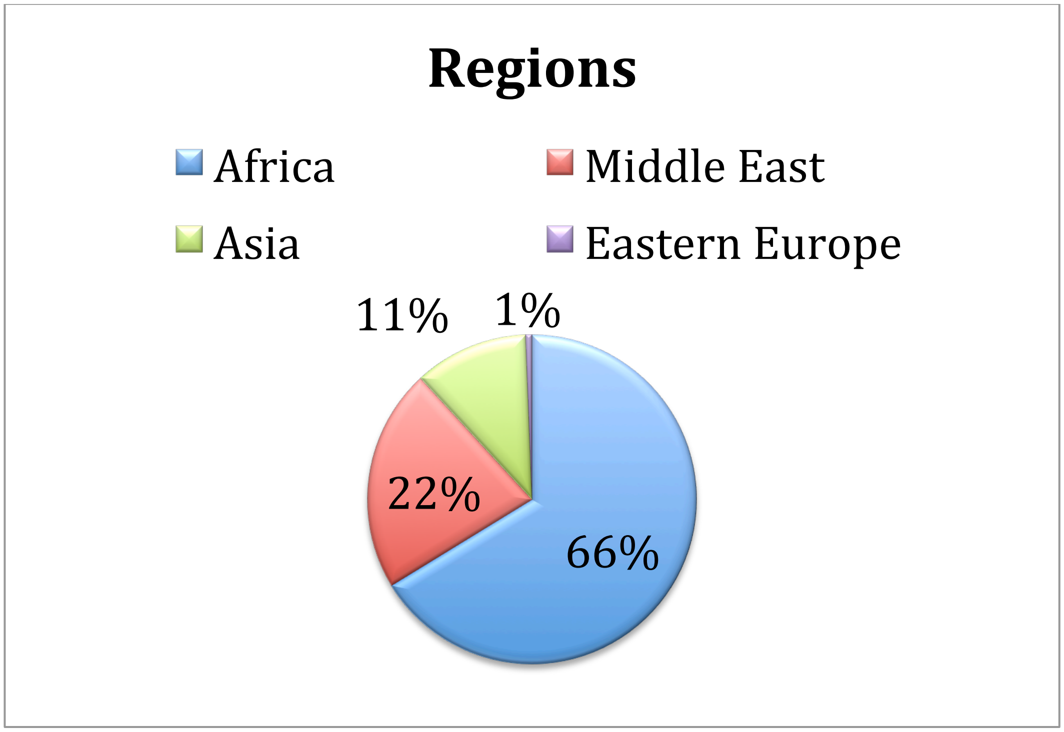


Figure 3. ND process diagram

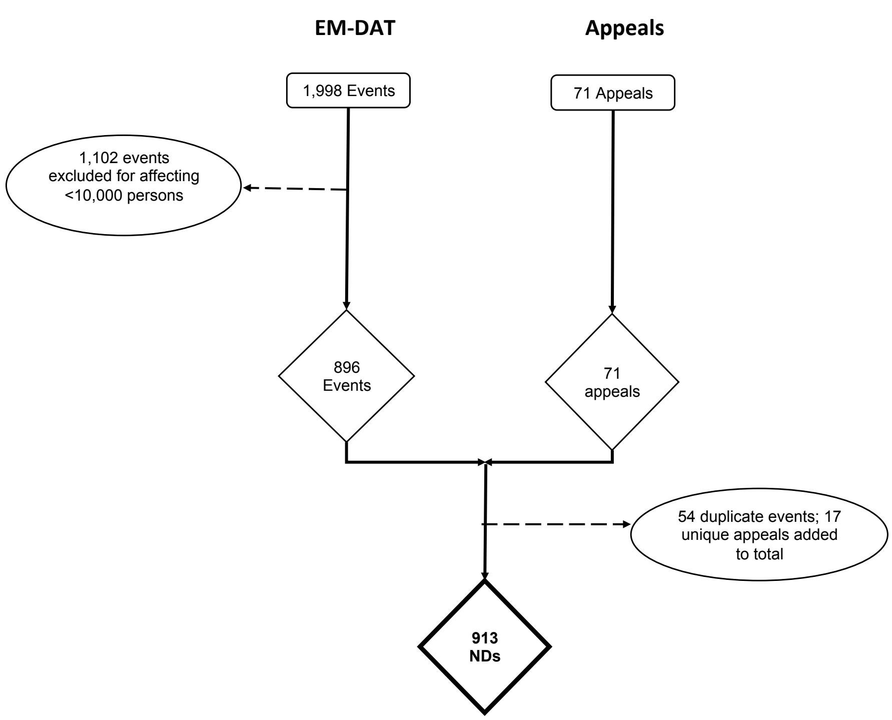


Figure 4. Natural Disasters regional distribution (n=913)

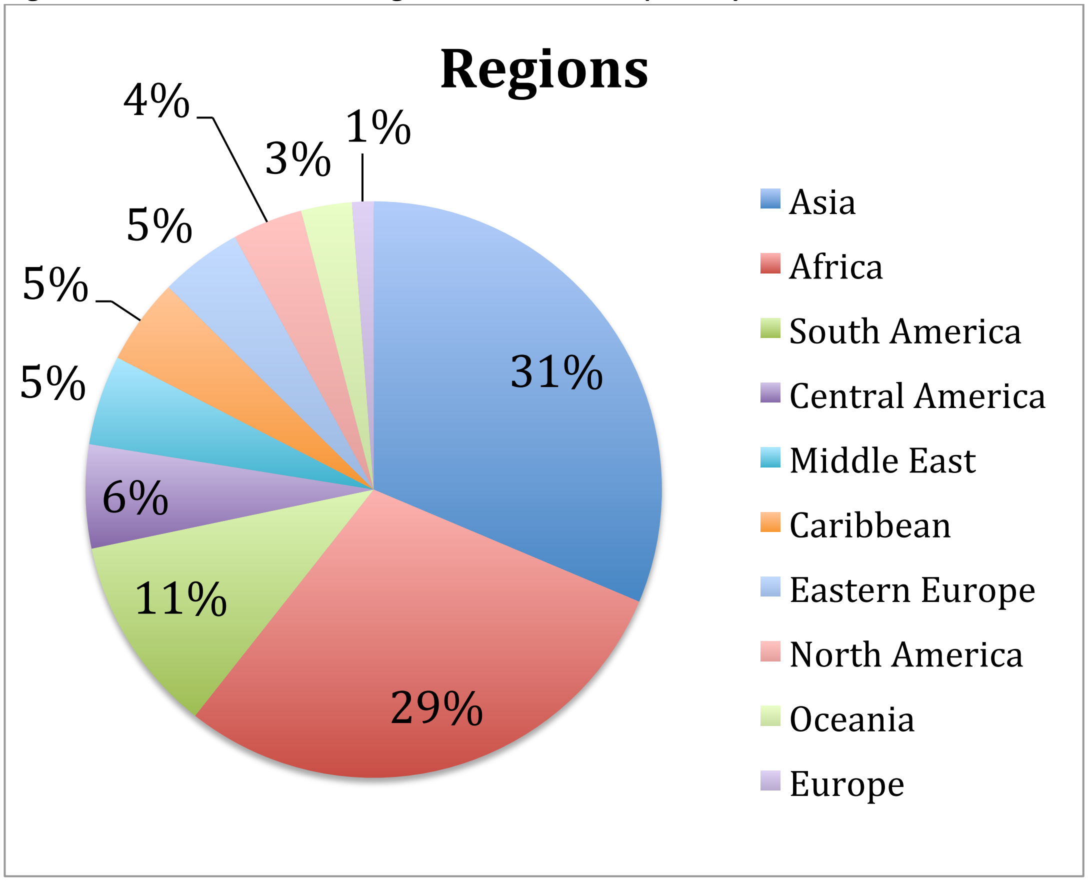
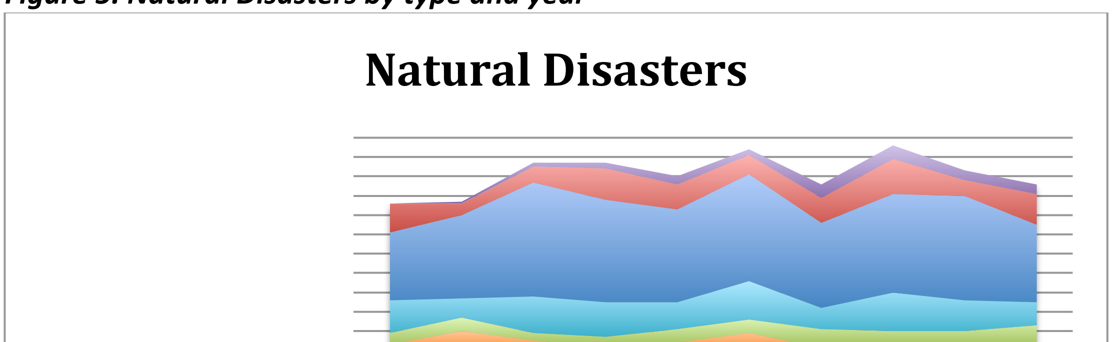


Figure 5. Natural Disasters by type and year



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Extreme Temperature	0	1	2	3	4	3	7	7	5	5
Drought	15	6	8	16	13	10	13	18	8	16
Flood	35	43	59	53	48	55	44	51	54	40
Storm	17	10	19	18	14	20	11	20	16	12
Earthquake	6	7	4	5	7	7	10	9	7	9
Other	3	10	5	2	4	9	1	1	3	4

Figure 6. Concurrent CE and ND – regional distribution

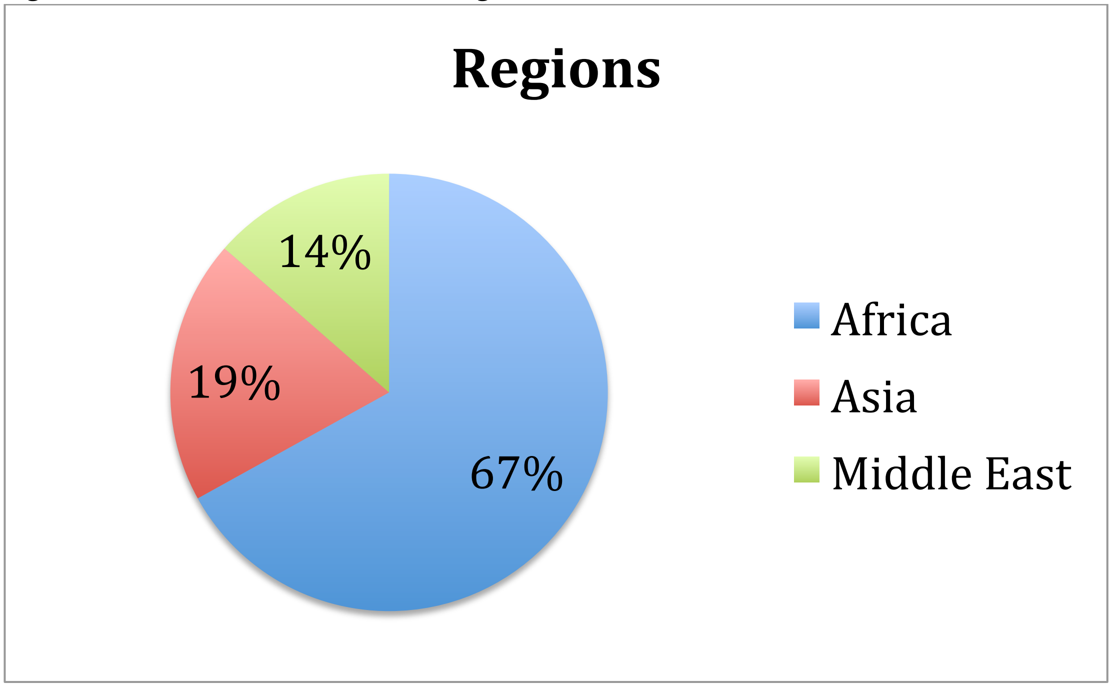


Figure 7. Outbreak process diagram

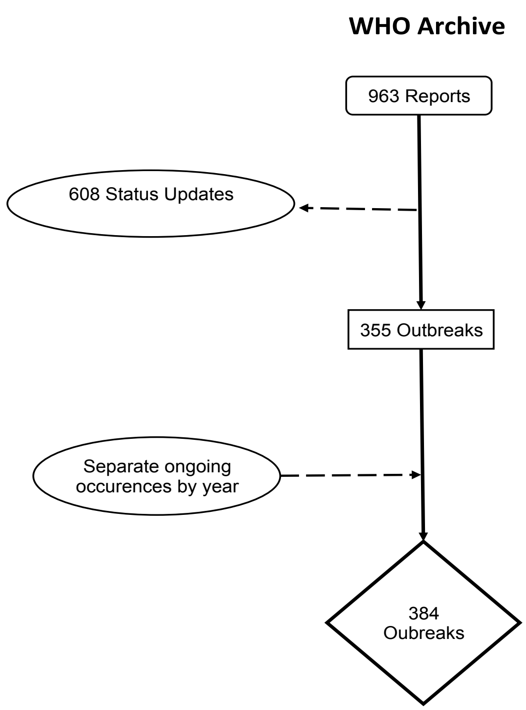


Figure 8. Outbreaks by Year

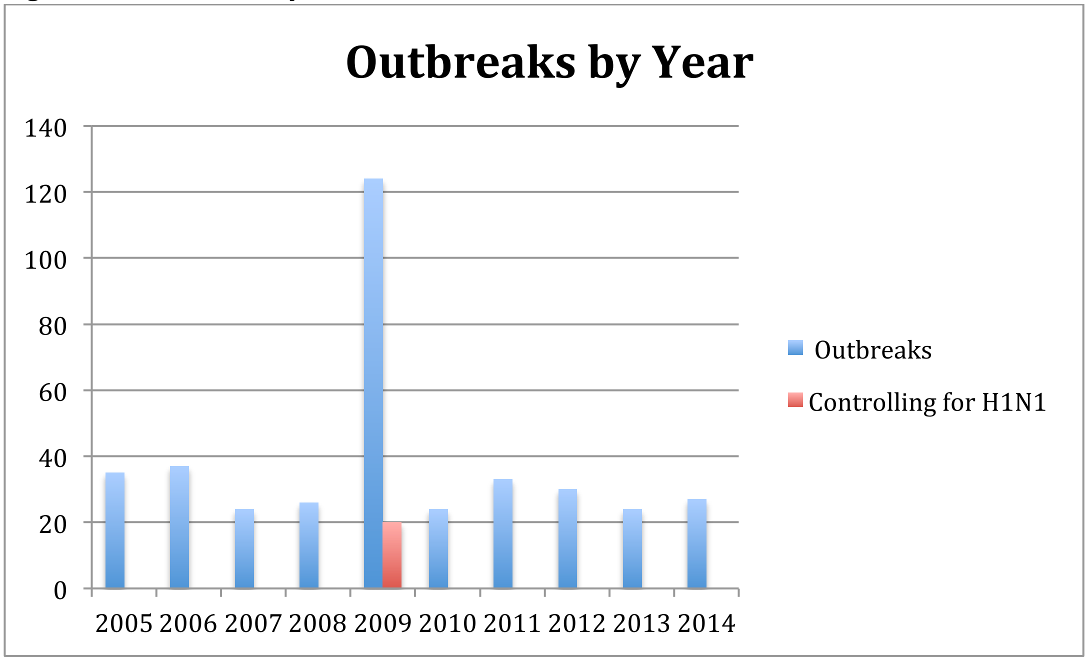


Figure 9. Outbreaks regional distribution

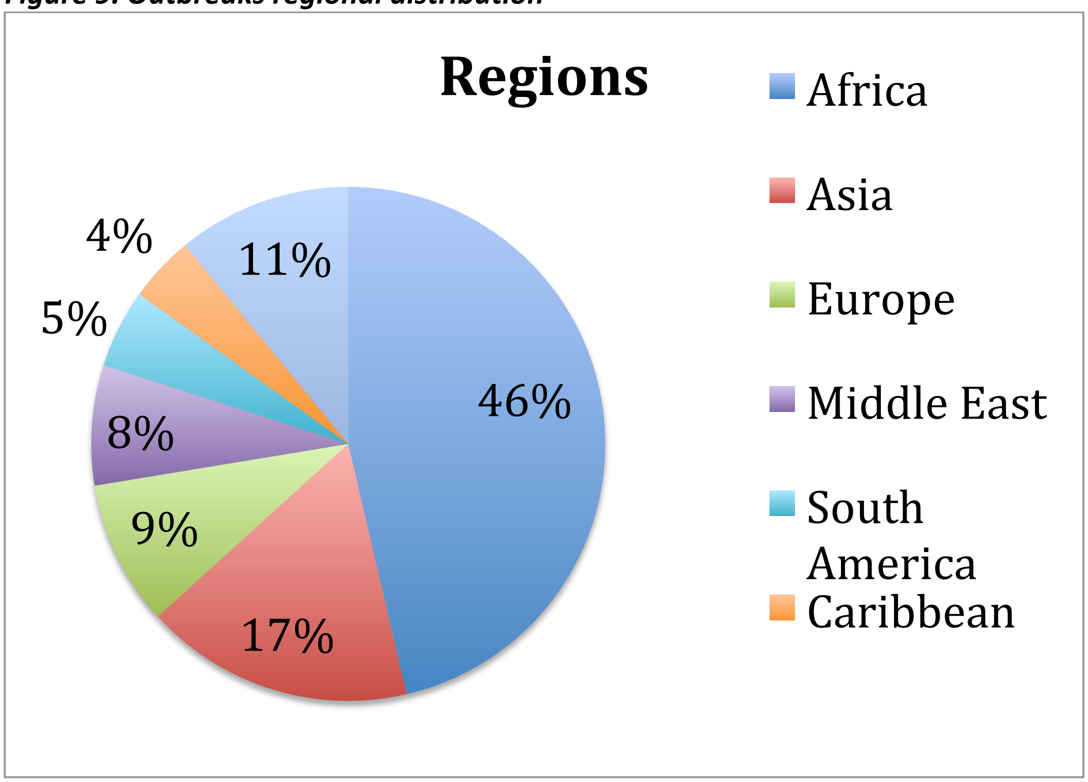
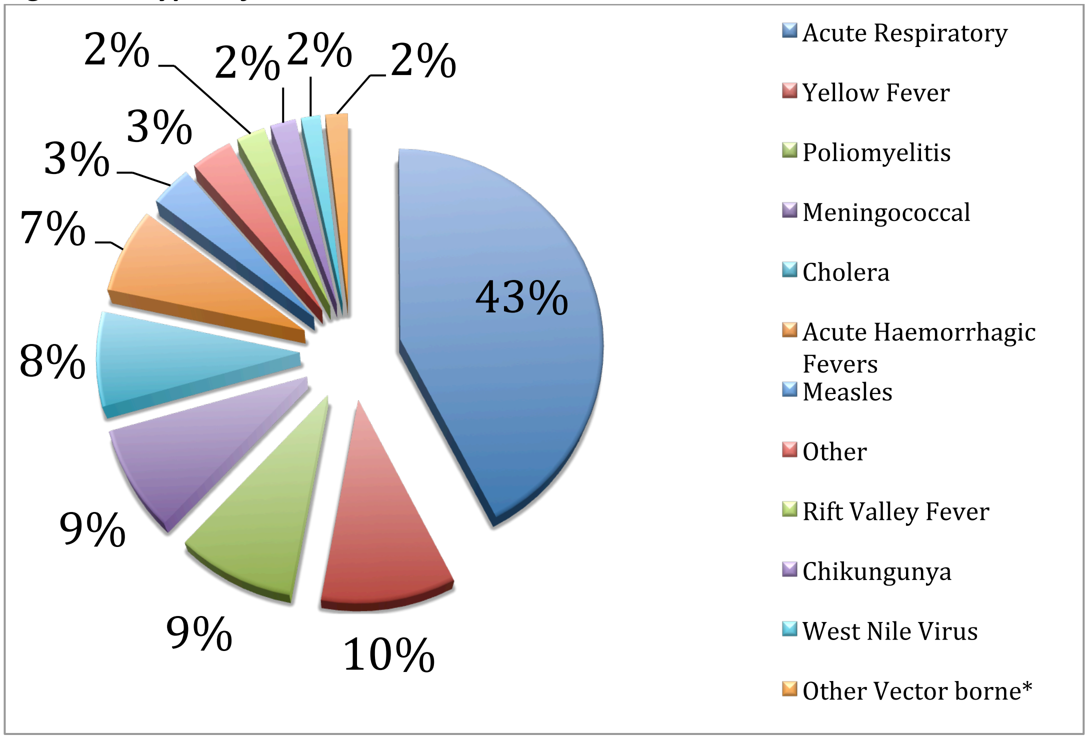


Figure 10. Types of Outbreaks



* Dengue, Japanese encephalitis, malaria

Figure 11. Outbreaks VPD vs. NVPD by region

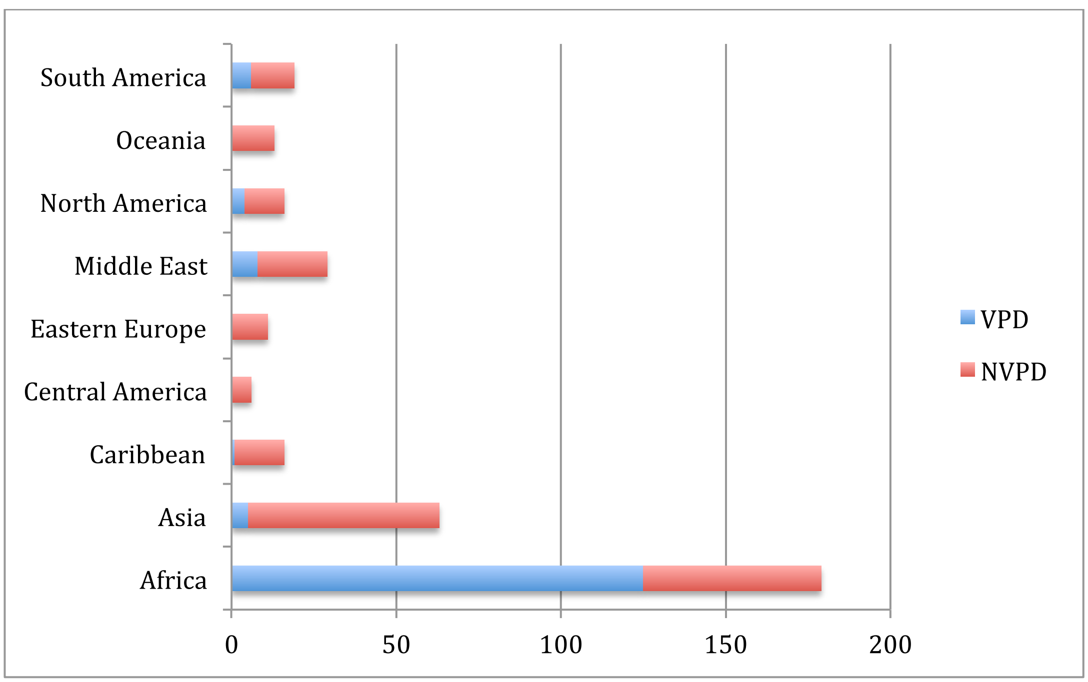


Figure 12. Outbreaks VPD vs NVPD by region, excluding H1N1