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The usefulness of the electronic Disease Early Warning System (eDEWS) in the humanitarian crisis of Yemen

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I dedicate this work of mine

To

My wife for supporting me during my study in Germany, my parents for their continuous prayers and my kids Ahmed and Laila who are the joy of my life

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Acronyms

AFP	Acute Flaccid Paralysis
AVH	Acute Viral Hepatitis
AWD	Acute Watery Diarrhea
BD	Bloody Diarrhea
eDEWS	electronic Diseases Early Warning System
CDC	Centers for Disease Control and Prevention
DF	Dengue Fever
Y-FETP	Yemen Field Epidemiology Training Program
HFs	Health Facilities
HIS	Health Information System
HIV	Human Immunodeficiency Virus
IT	Information Technology
LRTI	Lower Respiratory Tract Infection
MoPHP	Ministry of Public Health and Population
NGOs	Non-Government Organizations
OAD	Other Acute Diarrhea
SARI	Severe Acute Respiratory Infection
SMS	Short Message Service
URTI	Upper Respiratory Tract Infection
VHF	Viral Hemorrhagic Fever
WASH	Water, sanitation and hygiene
WHO	World Health Organization

1. INTRODUCTION

Note: The doctoral student has published some aspects of this chapter in the following publications:

- Yemen: Cholera outbreak and the ongoing armed conflict. Journal Infect. Dev. Ctries. 2018; 12(5):397-403. https://doi:10.3855/jidc.10129
- Diphtheria outbreak in Yemen: the impact of conflict on a fragile health system. BMC Conflict and Health. 2019. https://doi.org/10.1186/s13031-019-0204-2
- Cholera Outbreak in Yemen: Timeliness of Reporting and Response in the National Electronic Disease Early Warning System. Acta Inform Med. 2019 JUN 27(2): 85-88; https://doi.org/10.5455/aim.2019.27.85-88
- Dureab F, Jahn A, Krisam J, Dureab A, Zain O, Al-Awlaqi S, Müller O. Risk factors associated with the recent cholera outbreak in Yemen: A case-control study. Epidemiology and Health 2019; DOI: https://doi.org/10.4178/epih.e2019015
- Dureab F, Ismail O, Alfalahi E, Al Marhali L, AlJawaldeh A, Nuri N, Safary E, and Jahn A. An overview on the acute malnutrition among children and food insecurity during the conflict in Yemen. Children 2019, 6(6), 77; https://doi.org/10.3390/children6060077

A health information system is one of the most crucial building blocks of a country's health system, since it provides information for decision making across all levels and components of the health system (WHO, 2008b). This study examined the usefulness of an electronic Diseases Early Warning System (eDEWS) and its influence on humanitarian health actions in Yemen. This introduction chapter has five sections and includes the following: first, a general overview of the Yemeni health information system; second, Yemeni background information including the current political situation and health system; third, an overview of communicable diseases in Yemen; fourth, Yemeni public health surveillance and communicable disease surveillance; and fifth, the justification and the research objectives of the thesis.

1.1 Health Information System

A Health Information System (HIS) is a continuous process that translates health-related data into useful information for policies, interventions, research, regulations and allocation of resources to provide good quality health services (AbouZahr and Boerma, 2005; Yazdi-Feyzabadi et al., 2015). Improving the quality of information also helps the international community to limit public health risks that can cross borders and threaten individuals. The main aim of The International Health Regulations is to support countries' integrated efforts to save lives and prevent avoidable interventions in international trade and travel (WHO, 2016). All countries must notify of high-risk events to the World Health Organization (WHO) based on standardized case definitions. Accordingly, verification of risk alerts (alert is a notification based on threshold for specific disease, one alert may include a single or multiple cases) is strictly required from the national surveillance system and an urgent response is required in a timely manner (WHO, 2008a).

Within HIS, disease surveillance includes the continuing systematic collection, analysis, and interpretation of disease information for immediate action, planning and implementation of communicable-disease outbreak control plans. There are two essential functions for any communicable disease surveillance system: monitoring of specific diseases in a surveillance program and early warnings for public health (WHO, 2006b).

Recurrent epidemics and pandemics in many places of the world have generated a critical need for strengthening disease surveillance systems, therefore the electronic disease surveillance systems have largely become established globally. Many disaster-affected countries, and those recovering from disasters during the last decades have installed these electronic systems for early detection and rapid response (Chretien, 2008). Yemen is one country that implemented an electronic diseases early warning system (eDEWS) in 2013.

The eDEWS is a surveillance system that aims to rapidly detect a disease outbreak and to initiate a timely response. Yemen is among many countries affected by conflict, population displacement and basic service distraction. Thus, effective preventive and control measures through the early detection of infectious diseases and response are sorely needed. eDEWS contributes to morbidity and mortality reduction in Yemen through detection of potential outbreaks at their earliest possible stage using a novel modeling approach that eases the quick transformation of data into actionable information (Ahmed, 2013). The electronic system depends on the signal detection theory to identify the occurrence of health-related events, including rumors, from input data to take a decision (Swets, 2004). A detection process produces signals as output followed by a verification of whether an event is present or not. The detection method compares the amplitude of the signal with a threshold. The quality of the detection method can be tested using various measurements such as sensitivity, specificity, and predictive value (Michael M. Wagner, 2001). Rapid detection and prompt responses to diseases and epidemics are fundamental for preventing and reducing excessive mortality during humanitarian disasters, particularly in countries with weak health systems. Public health surveillance systems in conflict settings can become disturbed or overwhelmed and unable to meet needs in a humanitarian emergency, including timeliness and good data quality. Thus, an early warning system is needed to cover this critical gap during crises (WHO, 2012b).

1.2 Yemen Background

1.2.1 Political Background

Yemen was a buffer between the Ottoman and British empires in the early twentieth century. The Mutawakkilite Kingdom of Yemen was created in 1918 in North Yemen before the Yemen Arab Republic was established in 1962 with Sana'a as its capital city. South Yemen continued to exist as a British protectorate until 1967 when it became an independent state and was established as the People's Democratic Republic of Yemen with Aden as its political capital. In 1990, the two Yemeni republics united to form the Yemen Republic with Sana'a as the political and historical capital of the country (CIA, 2016).

Yemen has experienced a long period of civil unrest and passed through several conflicts (Burki, 2012). Recently, Yemen has been in a political crisis since 2011, which was initiated by street demonstrations against poverty, unemployment, corruption, and many chronic political issues. President Saleh stepped down in 2012 and transferred power to his Vice President Abdrabbuh Mansur Hadi. Two years were agreed upon as a transitional period as part of the UN-backed Gulf Cooperation Council Initiative. The political situation entered a new complicated phase when the Houthi group took over Sana'a in September 2014 with the help of the former president, Saleh, and later declared that they were in control of the country after a coup against President Hadi. This led to a new civil war in March 2015 with a Saudi Arabian-led military intervention aimed at restoring Hadi's government (CIA, 2016). Since March 2015, the on-going conflict has escalated into a severe humanitarian crisis for the majority of Yemen's population with a specific impact on the population's health (El Bcheraoui et al., 2018).

The political situation in Yemen is complex and further aggravated by regional interests and competition between the Arab Gulf states and Iran. In fact, the continuation of this fighting has led to country fragmentation and the loss of control by the central government. On the ground, there are two governments in Yemen: the internationally recognized government in the south under president Hadi and another in the north under the Houthi's group (Ansar-allah). Basic services are delivered by local authorities, which further deepens decentralization in the country. Local (governorate and district) authorities are more active and efficient than the ministries of the both current governments (Hill, 2017).

1.2.2 Humanitarian Situation

Yemen is one of the poorest countries in the Arab region and worldwide, with a low gross domestic product (GDP), low literacy rates, poor governance, a high prevalence of poverty, critical food insecurity and prevalent malnutrition. Yemen was ranked 168th on the Human Development Index (HDI) in 2016 (UNDP, 2016). In March 2015, an extensive armed conflict in Yemen aggravated the humanitarian situation that had been present for more than a decade. More than four years into the bloody war, the situation has been further aggravated by many humanitarian factors such as population displacement, food insecurity, lack of basic commodities and poor essential services with an overall breakdown of the economy (ECHO, 2017).

Yemen was suffering from a poor humanitarian situation before the start of the fighting in 2015, with high levels of food insecurity and malnutrition. During the conflict, the commodity supply chain has been severely affected due to restrictions on importation and exportation from/in ports and airports, increasing fuel prices affecting food prices, fighting, and security fees charged by armed groups who control several checkpoints on the main roads of transportation inside the country. On the other hand, the population's purchasing power has been severely affected due to unemployment in private-informal sector and nonpayment of salaries in the public sector. The relocation of the Central Bank from Sana'a to Aden, has further interrupted civil service salary payments because employee payrolls have not been finalized. The depreciation of Yemeni Riyals against US dollars by over 150% was the coup de grace to the purchasing power of average citizens (Hill, 2017).

Continuing conflict in Yemen has left 80% of the Yemeni population (24.1 million out of 30.5 million people) in need of humanitarian support, and about 14.3 million need acute assistance (UNOCHA, 2019). Humanitarian emergencies forced people to settle in temporary settings or place many families in small spaces with high population density, unsafe water, inadequate food, poor sanitation and a lack of basic social and health services. These circumstances can increase morbidity and mortality due to the transmission of communicable diseases and other conditions (WHO, 2012b). Approximately three million people are displaced internally across Yemeni governorates (El Bcheraoui et al., 2018). An estimated 16.4 million people have inadequate or no access to basic healthcare with chronic shortages in medical supplies, and more than 50 percent of health facilities are not functioning. Approximately 16 million people lack access to safe drinking water and sanitation and around 18 million are food insecure (UNOCHA, 2019).

1.2.3 Health System

The Ministry of Public Health and Population (MoPHP) in Yemen runs four types of health care facilities: 1) primary care health units at a village level, 2) district hospitals, 3) secondary care at governorate hospitals, and 4) tertiary care at referral hospitals in main cities (most of these are autonomous tertiary care hospitals that receive direct funding from the Ministry of Finance). The Central Drug Fund in the MoPHP is the main provider of essential drugs and medical supplies for all health facilities (MoPHP, 2006). In addition to the public health care sectors, there is a private medical care sector that has been growing swiftly with the continuous weakening or absence of the free health care services in the public sector. For example, in Sana'a and Aden, the two largest cities in Yemen, 2,174 private health facilities are registered (WHO, 2014).

Service in the public health facilities has deteriorated due to escalating fighting since 2015 and the unpaid salaries of 74,224 employees in the MoPHP particularly in the north (MoPHP, 2014b). No budget has been allocated by the Ministry of Finance to pay these workers. The lack of a governmental operational health budget for running operations, drinking water, food, electricity and medical drugs and consumables has affected the majority of healthcare services (Dureab et al., 2018b).

The health system in Yemen was among the poorest in the world, even before the crisis. More than 5,000 public health facilities (MoPHP, 2014a) were severely short-staffed and most were in urban areas. Approximately 70% of Yemen's population live in rural areas and have to travel long distances to the nearest health care post. For example, the majority of maternal deaths in remote areas happen either at home or on the way to the nearest health facility (Lindsay, 2015). This conflict has worsened the population's living conditions and hence increased the burden of morbidity and mortality, while devastating all building blocks of the national health care delivery system including health services and facilities, health human resources, medical supplies, financing, and overall governance.

According to the WHO survey in 2016 of Health Resources Availability Monitoring System (HeRAMS), only 45% of public health facilities are fully functional. Out of 258 surveyed hospitals, only 37% were fully functional and no single doctor was available in 45 of 267 districts. Communicable disease services were available only in 43% of functional health facilities, and non-communicable diseases and mental health services were the least available (21% of facilities). Maternal and new-born services were available only in 35% of facilities. Reduced

access to these essential services increases mortality, particularly maternal and child mortality (WHO and MoPHP, 2016b).

1.3 Communicable Diseases in Yemen

Communicable diseases are still the leading cause of mortality and morbidity in many countries that face a double burden of disease due to a change in disease patterns (Gupta and Guin, 2010). In Yemen, communicable diseases still represent the largest disease burden in addition to increasing non-communicable diseases (Mokdad, 2016). Pneumonia, diarrhea, malaria, dengue and measles are the most prevalent diseases among children in Yemen (Qirbi and Ismail, 2017). Yemen also has the highest prevalence rate of many neglected tropical diseases in the Middle East Region, such as schistosomiasis, filarial infections, leprosy, and trachoma (Hotez et al., 2012).

1.3.1 Measles

Yemen is an endemic area for measles; several local outbreaks have occurred across the country. For example, a measles outbreak in 2011 affected more than 4,000 children and caused 155 deaths (El Bcheraoui et al., 2018). In 2016, three measles outbreaks were detected by eDEWS in three distinct governorates with a total of 38 cases and one death. The measles vaccination rate was relatively stable at about 75%, but decreased sharply to 54% in 2015 after six months of the recent conflict (Burki, 2016; Qirbi and Ismail, 2016).

1.3.2 Diphtheria

Diphtheria was not a common disease since the Expand Program of Immunization (EPI) was established in Yemen. The first cases were reported in October 2017, and the disease has spread rapidly across the country since then with 3,524 people infected. The overall crude fatality rate (CFR) of 5.8%, and a total of 203 deaths were reported up to week 52 in 2018 (WHO and MoPHP, 2019).

The occurrence of an outbreak of diphtheria in Yemen reflect the current situation of insufficient coverage of the immunization during the conflict period (Dureab et al., 2019a). There is high risk

for further spread of the disease within the country and to neighboring countries due to the population movement (Dureab et al., 2018a).

1.3.3 Cholera

The occurrence of epidemics in Yemen, especially cholera, is known to be an obvious sign of the disruption of basic services (ECHO, 2017). Several cholera outbreaks have occurred during the last 10 years in Yemen; there were 3 smaller outbreaks in 2009, 2010 and 2011, with case fatality rates (CFRs) of 5.5%, 1.3%, and 0.4%, respectively (WHO, 2010, 2011, 2012a). The most recent outbreak started in October 2016, with 1.423.700 suspected cases and 4,510 laboratory-confirmed cases (serotype O1 -Ogawa) reported from 306 of 333 districts through January 2019; these cases have resulted in 2,767 deaths, corresponding to a CFR of 0.2% (WHO and MoPHP, 2019).

The cholera outbreak in Yemen is the largest in the recent history of this disease. The magnitude of this outbreak can probably be explained by the overall breakdown of public services, including hygiene and sanitation, associated with the war in Yemen. However, evidence on specific risk factors is needed to guide an appropriate public health response (Dureab et al., 2019b).

1.3.4 Malaria

Historically known that malaria has been a main public health concern in Yemen with high prevalence in the Middle East region. Approximately 78% of Yemen's population lives in endemic areas and 25% of population are at high-risk (>1 cases in 1000) for a malaria infection (WHO/EMRO, 2016). In 2015, approximately 668,024 suspected cases were reported by eDEWS. *Plasmodium falciparum* is the primary parasitic form in Yemen (99% of all lab confirmed cases), *P. malariae* and *P. vivax* are not very common (IOM, 2017).

1.3.5 Dengue Fever

Several outbreaks of dengue fever (DF) have affected various locations in Yemen in the last two decades (Qassem and Jaawal, 2014). DF has a seasonal pattern and is caused by dengue virus serotype 3 (DENV 3) in Yemen (Ghouth et al., 2012). Shabwah governorate was the first governorate to report confirmed cases of DF, which then became widely distributed in Aden, Al-Hudaydah, Taiz and Hadramout (Al-Garadi, 2015; Alyousefi et al., 2016). There were 8,803

cases in Yemen in the period between 2010–2013 (Daraan, 2013). According to the surveillance annual report in 2016, 3,363 cases and 17 deaths were reported in various districts (WHO and MoPHP, 2016a).

1.4 Public Health Surveillance System

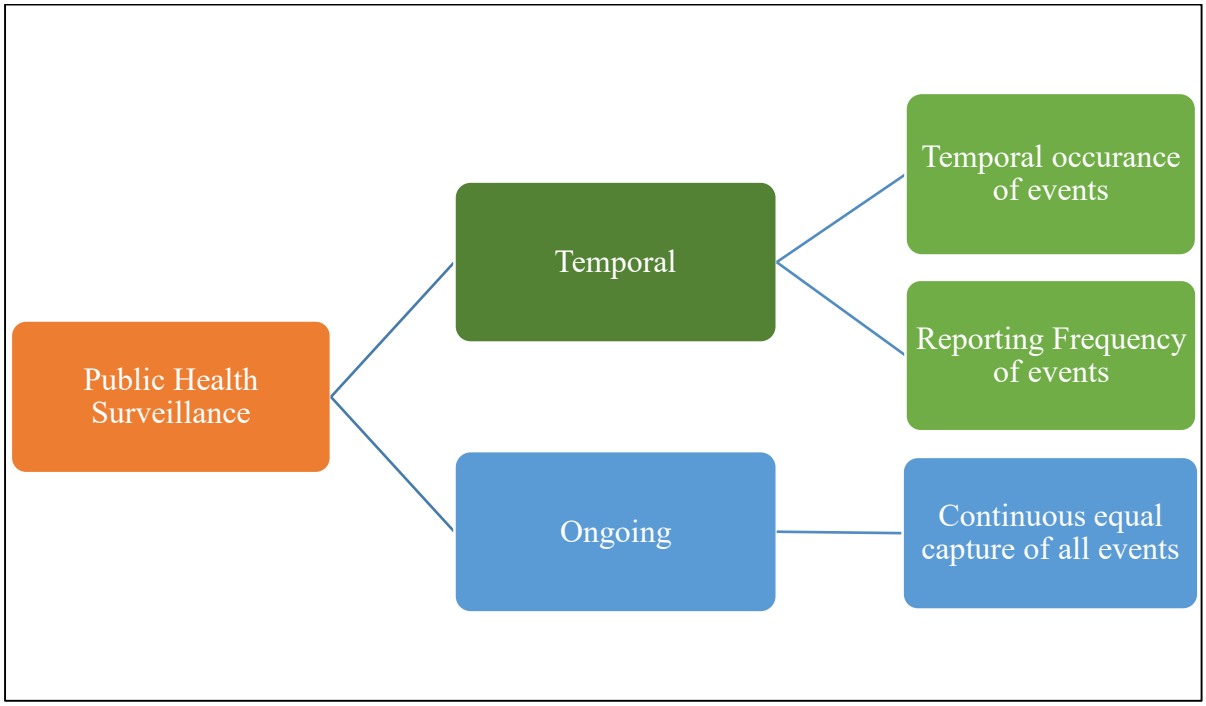
The history of public health surveillance started in the 17th century with the spread of the plague in London where efforts were made to collect, analyze, interpret and disseminate data to stop the disease. These procedures form the basic principles of public health surveillance. Later, in the 18th century, surveillance became part of European and American health policies and played a role in the fight against several epidemics and diseases, such as smallpox and cholera. In the 19th century, surveillance advanced by identifying actions based on collected data by linking disease control with improving living conditions of a population. Many countries established national institutions for registering causes of death. This was followed by the development of surveillance systems in the 20th century across the world. With the expansion of the concept of public health surveillance, the term was associated with communicable diseases and close personal monitoring of patients (personal surveillance). Quarantine was the most important tool to control disease until Dr. Langmuir in the USA promoted the concept of monitoring diseases in the general population (population surveillance) (Declich and Carter, 1994; Kumar and Raut, 2014).

The definition of surveillance has passed through several evolutionary stages. Since the 17th century, epidemiological surveillance has been associated with mortalities due to epidemics and included political aspects. In 1968, WHO defined surveillance as the "systematic collection and use of epidemiologic information for the planning, implementation, and assessment of disease control". Although it is true that surveillance is data collected for action, the 1968 definition missed crucial principles of surveillance reflected in the US Centers for Disease Control's (CDC) definition in 1986: *"Epidemiologic surveillance is the ongoing systematic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know. The final link in the surveillance chain is the application of these data to prevention and control"* (Thacker et al., 2012). The ongoing process and timeliness are very important for any surveillance system. The CDC adopted Langmuir's view in its definition and did not use surveillance for control. Later, this definition was adopted globally by the WHO as the,

"systematic ongoing collection, analysis and interpretation of health-related data essential to the planning, implementation, and evaluation of public health practice" (Choi, 2012).

1.4.1 Concepts of Public Health Surveillance

The definition of public health surveillance has been interpreted and expanded to multiple innovative areas. The CDC has summarized the concepts of the public health surveillance and highlighted two key concepts depending on the temporary and ongoing aspects of data collection in public health surveillance, see figure 1 (CDC, 2012).



Adapted from Lexicon, Definitions, and Conceptual Framework for Public Health Surveillance, CDC, MMWR 61, 44 2012.

Figure 1: The basic concept of a public health surveillance system

1.4.2 Approaches of Surveillance Systems

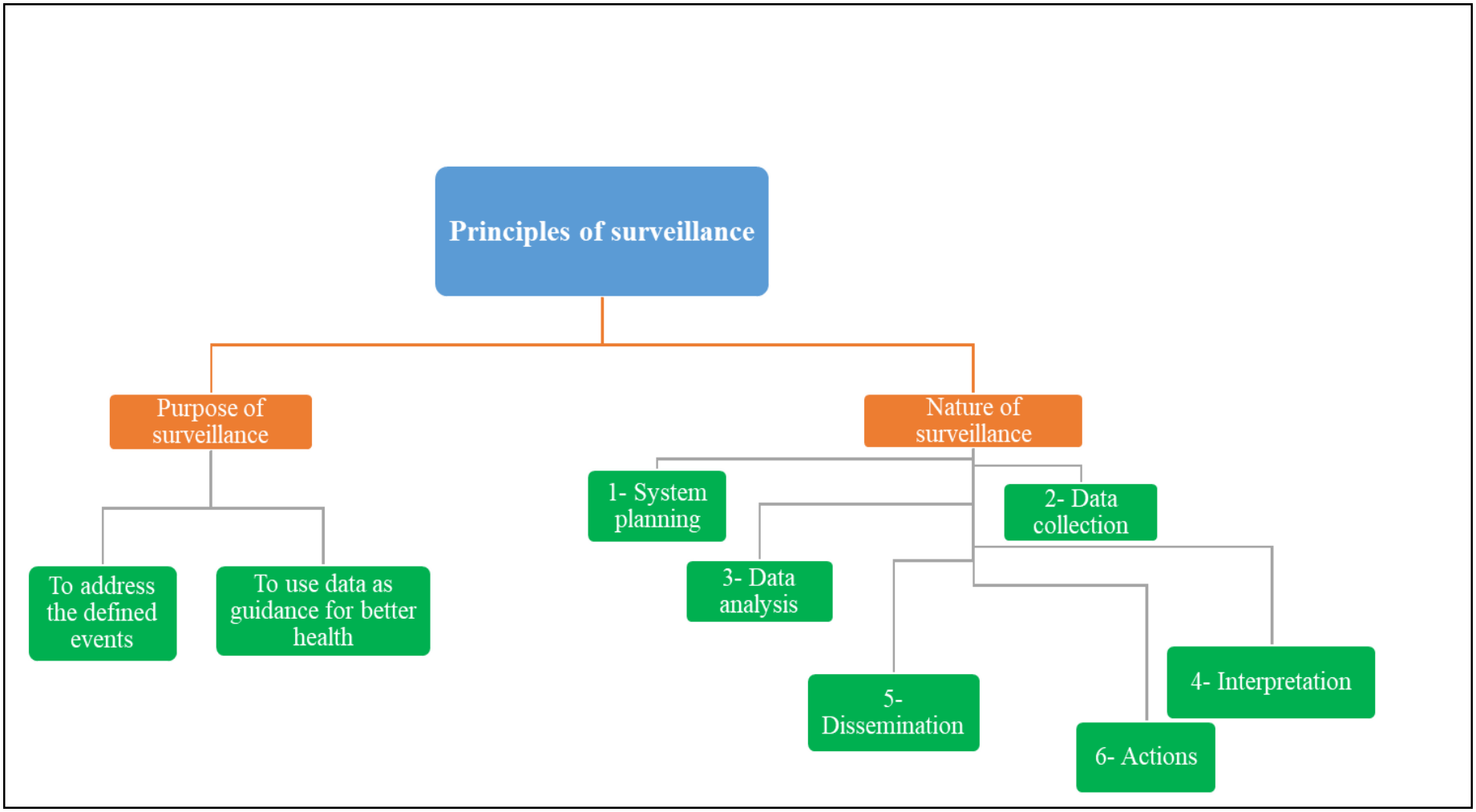
There are two principles for any surveillance system, the first focuses on the main purpose of the surveillance system and the second is related to the nature of the surveillance as seen in figure 2 (CDC, 2012). Surveillance can be active or passive, depending on how information from the field is obtained.

1.4.2.1 Passive surveillance

Passive surveillance is a method by which health facilities regularly submit disease reports to a health authority. It is an easy approach and provides information for monitoring disease trends over time. However, data quality and timeliness are difficult to control since passive surveillance depends on health care provider reporting, and the reports are usually not representative for the population as this type of surveillance largely depends on access to health services (Nsubuga et al., 2006). Most surveillance systems use this approach (Moffatt, 2006).

1.4.2.2 Active Surveillance

Active surveillances conducted by surveillance officers who regularly contact health care providers or the population to obtain data on health conditions. It is expensive, but provides accurate and timely information (Nsubuga et al., 2006). Active surveillance is vigorous and sensitive and usually used in serious conditions to investigate certain diseases or confirm outbreaks (Moffatt, 2006).



Adapted from Lexicon, Definitions, and Conceptual Framework for Public Health Surveillance, CDC, MMWR 61, 44 2012.

Figure 2: The principles of public health surveillance

1.4.3 Types of Surveillance Systems

1.4.3.1 Routine Health Information System

A routine health information system is a passive system in which health facilities regularly report diseases and programs including financial, logistic and administrative data of the public health and clinical systems (Nsubuga et al., 2006).

1.4.3.2 Integrated Surveillance System

An integrated surveillance system is a single system with multiple functions and components to collect data about multiple diseases, risk factors or programs. It is a combination of active and passive systems. Some vertical surveillance programs continually gather additional disease-specific data and data from both systems can be used for quality control and evaluation (Nsubuga et al., 2006). This system offers possible synergy among surveillance systems and use of common resources (WHO, 2018a).

1.4.3.3 Sentinel Surveillance Systems

A sentinel surveillance system is one by which diseases of public health concern are detected early using sentinel populations, e.g. drug users and sexually transmitted infection patients in HIV surveillance (Moffatt, 2006). This requires a prearranged representative sample from reporting sites to document all cases of a defined event. Sentinel surveillance systems are very sensitive for large disease outbreaks indicating trends in the targeted communities, and also allow for rapid and flexible responses to suspected outbreaks using limited resources (Nsubuga et al., 2006).

1.4.3.4 Syndromic Surveillance Systems

Syndromic surveillance systems are based on clinical features without a diagnosis, such as diarrhea, which may include all types of diarrhea from relatively minor diarrhea to shigellosis or severe cholera. It can be an active or passive system using standard case definitions. Syndromic surveillance systems are simple and inexpensive, but this information needs additional verification and investigation from higher levels such as governorate and national levels (Nsubuga et al., 2006).

1.4.3.5 Periodic Surveillance System

A periodic surveillance system is an active periodic survey focused on certain indicators such as anthropometric measurements in nutritional surveys or behavior measurements that cause disease or injury such as smoking, alcohol use, or lack of physical exercise, for example a stepwise survey. This type of surveillance provides a direct measure of the effect of the behavioral risk factors in the population, and these surveys are useful to measure the effectiveness of any intervention for communicable or non-communicable diseases (Nsubuga et al., 2006; WHO, 2018b).

1.4.4 Functions of Public Health Surveillance System

Public health surveillance systems have core and supportive functions to operate properly at a country level. The core functions have a technical focus on case information and early warnings, and include eight functions. Support functions have administrative focus; it has six functions. Both core and supportive functions are used as main components to evaluate any public health surveillance system, see the functions in table 1 (Phalkey et al., 2013; WHO, 2006a).

Table 1: Functions of a surveillance system

Core functions	Supportive functions
1. Case detection; 2. Case registration; 3. Case confirmation; 4. Case reporting; 5. Data management and analysis; 6. Feedback. **Public Health Action:** 7. Outbreak preparedness; 8. Outbreak response.	1. Guidelines and manuals; 2. Training; 3. Resources (financial, human, material and equipment); 4. Supervision; 5. Coordination and communication; 6. Laboratory capacity.

Case detection is the first step of public health surveillance and starts with case detection by the health care provider based on a case definition, who then registers the case into a public health record. These two functions usually occur at the health-facility level and are strongly affected by the health-care provider. Disease confirmation is an epidemiologic process that can occur at all

levels of a health system from a health facility to a national laboratory and sometimes requires international confirmation. Reporting and notification steps (data collection from lower levels of a health system [health facility or laboratory] to a higher level in the system) can occur before or after a case confirmation. Reporting can be done by paper or electronic databases. Data management and analyses should be done at the closest point to the primary reporting point to avoid a delay in response to any new event. Usually, data analysis occurs at a regional or national level, particularly in low-income countries. Data analyses produce results that are the end points of public health surveillance followed by action. Feedback is the return of information and messages from high levels to lower levels of health care infrastructure. In an electronic system, an automatic message is send back to all levels of health care infrastructure as a notification or alert if there is a health-threatening event (McNabb et al., 2002).

Transformation of data results in action, which is the ultimate goal of public health surveillance. Action begins from the returning feedback to the primary reporting level for a timely response. There are two key actions in public health surveillance; one at the management level is to plan and prepare for a timely response to new events at any level, and the second is a direct response to an epidemic with immediate action to prevent the spread of the disease (Perry et al., 2007).
Training and supervision are supportive operations that contribute to a scale up of health care provider capacity and enhance public health action in a timely manner. The availability of resources such as funds, trained personnel, and working systems and materiel (i.e., communication, computers, electricity, gasoline, or vaccine) improves all core functions. These three supportive functions are applicable for all health system levels, while communication and coordination are functions of a higher level within a health system (McNabb et al., 2002; Perry et al., 2007).

1.4.5 Monitoring and Evaluation of Public Health Surveillance

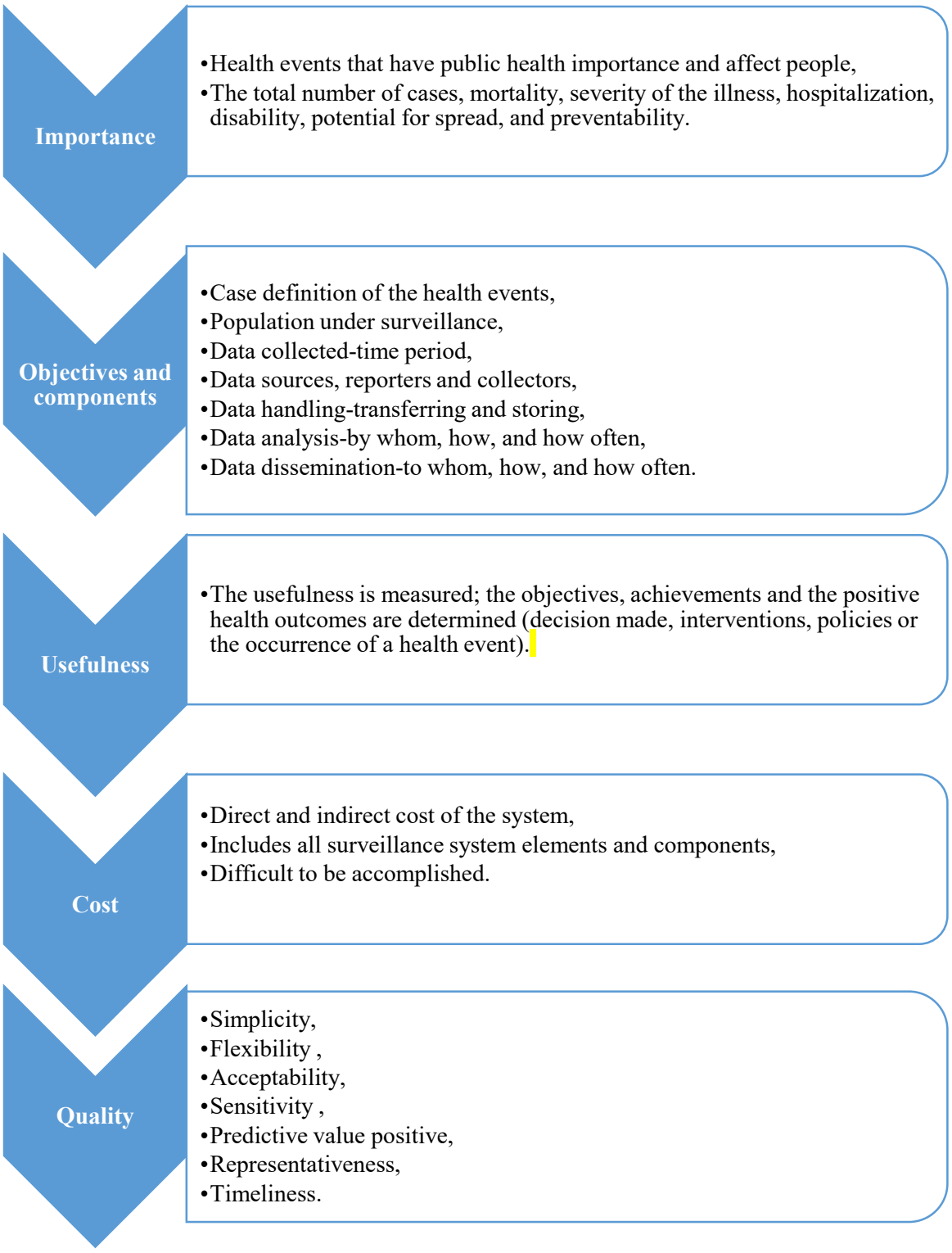
Monitoring and evaluation processes in public health surveillance are critical for system strengthening and should be an integral part of surveillance. Tracking planned activities in a health system should be continuous to identify and solve system problems and improve system performance. Evaluation ensures accountability within surveillance to meet the goal of public health surveillance and objectives. Indicators for surveillance success exist, and can be used to measure achievement and performance of surveillance systems. These indicators assess input, process, output, outcome and impact, see table 2 (WHO, 2004).

Table 2: Classification of public health surveillance measurement indicators

Classification	Definition	Indicator
Input indicators	What are the resources needed to establish and implement surveillance and response activities?	• Trained personnel • Finances • Standards and guidelines • Communication facilities & forms
Process indicators	What are the activities and functions to run the program?	• Training • Supervision • Guideline development • Core and supportive functions
Output indicators	What are the results of the activities conducted?	• Reports • Feedback • Determine if training and supervision conducted according to plan.
Outcome indicators	To what extent are the surveillance objectives being achieved?	• Usefulness of the surveillance in producing actions and policies including data quality, timeliness, simplicity, sensitivity, acceptability, representativeness, flexibility, and predictive value positive.
Impact indicators	To what extent does the surveillance achieve the overall goal of the system?	• Decrease in the case-fatality rate of epidemic-prone diseases • Changes in the morbidity pattern of targeted communicable diseases • Changes in behaviors of health staff and the population

Adapted from Overview of the WHO framework for monitoring and evaluating surveillance and response systems for communicable diseases (WHO, 2004).

Using these indictors in the evaluation process addresses various aspects of public health surveillance including the importance of health events in the system, the objectives achieved, cost, usefulness and quality of the surveillance system as seen in figure 3 (Declich and Carter, 1994).



Adapted from Declich, S., and Carter, A.O. (1994). Public health surveillance: historical origins, methods and evaluation. Bull World Health Organ 72, 285-304.

Figure 3: Evaluation aspects of public health surveillance

1.5 Disease Surveillance System in Yemen

The disease surveillance system in the Yemen Republic was established in August 1998 in conjunction with the beginning of the investigation of cases of acute flaccid paralysis (Polio surveillance). It was then included in the national diseases control program within the organogram of the Primary Health Care Sector of the MoPHP. It functions on three levels:

1. **Central level** represented by the national disease surveillance program at the MoPHP.
2. **Governorate level** represented by the disease surveillance department at the governorate health offices (GHO).
3. **District level** represented by all health institutions that collect disease data from surveillance focal points in each health facility.

The national surveillance system's reporting mechanism focuses on communicable diseases and passes through four phases. The first phase starts at the health facility level where focal-point personnel collect the data, prepare a paper-based report and send it to the next level. The second phase starts at district level where the surveillance coordinator collects reports from all health facilities in the district for review before sending them on to the governorate level. In the third phase, the reports are sent from the district to the surveillance department at the governorate health office where the verification process begins prior to forwarding the reports to the central level. The fourth and final phase takes place at the National Surveillance Program in the MoPHP where the data are analyzed to complete a final report (MoPHP, 2002).

The MoPHP has established the Yemen Field Epidemiology Training Programme (Y-FETP) in 2011 to strengthen the national health system through building the capacity of national staff in field epidemiology to enhance the early detection of outbreaks and rapid response (Al Serouri et al., 2018). Y-FETP aimed to train 10 – 12 new epidemiologist every two year to support MoPHP in meeting the Global Health Security Agenda target to have one epidemiologist per 200 000 inhabitants by 2025 (Al Serouri et al., 2018; Y-FETP, 2015). Furthermore, MoPHP and WHO has developed the eDEWS in 2013 to enhance the national capacity to achieve the Global Health Security (Ahmed, 2013).

1.5.1 The electronic Disease Early Warning System

The eDEWS is a health facility-based system using an electronic dashboard; it is a mobile-based interface system (MBI) that assembles data on a weekly basis. The eDEWS was established to strengthen the routine disease surveillance system, mainly in early detection of epidemic-prone diseases, and thus to enhance rapid responses particularly in conflict situations. eDEWS was initiated in Yemen in March 2013, by the MoPHP and WHO country office. eDEWS passed through many stages of expansion. It started as a pilot project in 4/23 governorates (provinces) with 98 health facilities (sentinel sites). The first expansion phase took place at the end of 2013 and included 247 health facilities in 10 governorates. In 2015, six more governorates were added to cover 408 health facilities in 16 governorates. The last six governorates were included in 2016 to increase the total number of health facilities to 1,982. Currently eDEWS covers all 333 districts in Yemen. The system began by reporting on 16 and later increased to include 31 communicable diseases (WHO and MoPHP, 2016a).

Since health facilities are the first points to collect data, an eDEWS focal person is nominated in each eDEWS health facility, who is responsible for data collection from the registration book of the health facility's clinics. All data of the week is entered into the eDEWS system using a mobile android application on Saturday afternoons (an epidemiological week is from Sunday to Saturday), and there are six diseases that must be reported immediately if diagnosed by a health worker: acute flaccid paralysis (AFP), measles, diphtheria, pertussis, acute watery diarrhea (AWD), and acute hemorrhagic fever (AHF) (Ahmed, 2013).

A unique account is created for each focal person at the health facility level to facilitate the tracing mechanism during an alert's validation by program coordinators at the governorate and central levels. All diseases monitored by eDEWS are diagnosed primarily by health workers using case definitions. The system generates automatic alerts (notifications); an alert may include one or more cases based on alert thresholds for each disease in eDEWS (see annex 1) (Ahmed, 2013).

All weekly reports pass through the validation process starting at the governorate level and then the central level. Initially, a surveillance coordinator at the governorate level verifies and confirms the reported events, and then it goes to the central level. Field visits, phone calls or short messages are the usual means of verification during the first response in eDEWS. For immediate alerts, verification should not exceed 24 hours from the initial report in the system as the standard time for immediately notifiable diseases. The publication of the final weekly bulletin should not

exceed more than 48 hours from the reference week, and ideally it should be released on the Monday of the next week (Ahmed, 2013).

The eDEWS platform was developed to capture data electronically on prioritized epidemic-prone diseases on a real time basis (information is delivered immediately after collection to the district or governorate hubs for validation) using mobile and web-based (internet) interfaces, secure automatic electronic transmission and analysis of data, alert generation and dissemination of information to main stakeholders as shown in figure 4 (Ahmed, 2013).

The eDEWS project was initiated by WHO with close collaboration with MoPHP. The pilot phase supported by the UNOCHA funded by Emergency Response Fund in 2013 (Ahmed, 2013). The total grant amount was 250,000 US Dollar to cover 100 health facilities for six months (approximately 2500 USD per health facility for six months). In addition to the contribution of MoPHP that covering the staff salaries at health facility level, other donors such as the USA, EU and World Bank has continuously supported the system. Currently, eDEWS is full funded by donor fund and without this support this system will be collapsed (Mayad et al., 2019; World Bank, 2017).

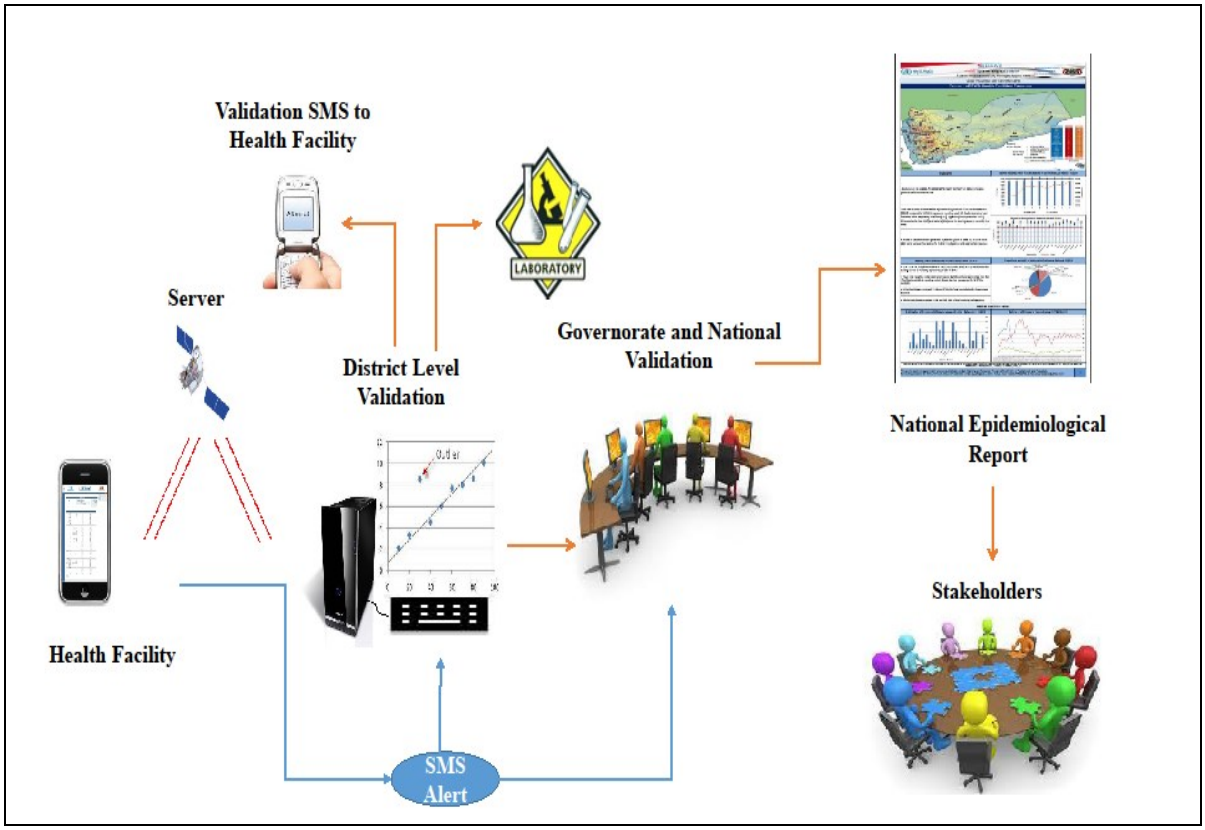
1.5.1.1 Weekly epidemiological bulletin

Reported weekly data in eDEWS includes demographic data (age and sex) and geographic data (e.g., location of the reporting point to identify the place of reported events) of the affected person, laboratory results for malarial species, generated alerts and verified alerts and actions taken.

Two types of eDEWS interfaces were developed as follows:

1) Mobile-based eDEWS interface (MBI), which is used to capture data directly from health facilities (referred to as reporting unit [RU]) using GPRS-based (General Packet Radio Service) mobile phone connections.

2) Web-based eDEWS interface (WBI), which is used to submit paper/SMS (Short Message Service) - based reports online using computers from a governorate health office, whereas RU personnel in charge submit paper-based reports in person to governorate health offices or by sharing an SMS report with eDEWS focal persons on a weekly basis (Ahmed, 2013).



Adopted by the author from MoPHP

Figure 4: Conceptual framework of eDEWS in Yemen

1.6 Problem Statement

The Yemeni National Routine Surveillance System is very weak for collecting data in terms of timely, accurate and comprehensible information. There is a lack of proper and adequate data on various diseases in Yemen, which makes it difficult to quantify disease burden and respond effectively to the population's real needs.

In a country like Yemen with a long history of conflict, regular data collection is very difficult due to interruptions in sending paper to the central levels. The security situation and the disturbed health system hinder the control of any emerging epidemic in early phases. Therefore, the electronic system using mobile networks available everywhere, in both rural and urban areas, offered the opportunity to adopt the innovative eDEWS. In Yemen, eDEWS strengthens the health information system and detects early alerts of epidemics using representative health facilities (sentinel sites) as sources of data.

In 2013, eDEWS was designed to include 98 sites in four governorates as a pilot for early disease detection and rapid response. In 2016, the project expanded to cover all districts in all governorates. The expansion has been a great success for the eDEWS program; however, the quality of the program has decreased in terms of alert verification and delays in reporting and responses. The evaluation of eDEWS and appropriate recommendations for its improvement are sorely needed based on the results of the program and discussions with stakeholders and decision makers.

1.7 Rationale

Health care authorities in countries entering into complex emergencies tend to continue relying on their "peacetime" health information systems, including disease reporting, despite the escalating needs for timely and specific information on priority issues for immediate response. To install a system like eDEWS in parallel to existing disease-reporting systems was difficult to justify because of political governance issues (ownership of the system in a divided MoPHP, costs, and human resource implications). Routine surveillance systems report monthly on a long list of diseases, while eDEWS promptly (immediately by phone and daily) reports on a much shorter list of priority communicable diseases, provides the opportunity for fast verification and accurate responses and issues weekly reports for action, planning and policy. Later in 2016, eDEWS was expanded to cover all function health facilities and all list of infectious diseases of the routine surveillance system. It became the main source of data in the country and its name was changed to the electronic Integrated Disease Early Warning and Response System.

Data on various aspects of the eDEWS and its relation to routine surveillance systems in Yemen are not sufficiently available to have a clear conclusion. eDEWS's sustainability is also an issue of concern in the country, despite its expansion and the advantage of data availability on a daily and weekly basis. Thus, this study reports on the collection and analysis of eDEWS data, highlights this system and its performance, and demonstrates eDEWS's usefulness in protecting Yemen's population by early alerts and responses to communicable disease outbreaks. The findings are intended for policy makers to improve the performance of the health system in Yemen and other similar countries.

1.8 Research Question and Objectives

1.8.1 Research Question

To what extent is eDEWS useful in protecting Yemen's population by early alerts and responses to communicable disease outbreaks?

1.8.2 Research Objectives

The main objective was to evaluate the eDEWS in Yemen through the assessment of the performance indicators and its functions in detecting early alerts of epidemics and response. The specific objectives included:

1) To identify the public health importance of health-related events and tracer conditions included in the eDEWS,
2) To assess eDEWS system performance and indicate the level of usefulness,
3) To evaluate eDEWS response level,
4) To determine the usefulness of eDEWS in provoking public health actions in the current situation in Yemen.

2. MATERIALS AND METHODS

Note: The doctoral student has published some aspects of this chapter in the following publications:

- Yemen: Cholera outbreak and the ongoing armed conflict. Journal Infect. Dev. Ctries. 2018; 12(5):397-403. https://doi:10.3855/jidc.10129
- Diphtheria outbreak in Yemen: the impact of conflict on a fragile health system. BMC Conflict and Health. 2019. https://doi.org/10.1186/s13031-019-0204-2
- Cholera Outbreak in Yemen: Timeliness of Reporting and Response in the National Electronic Disease Early Warning System. Acta Inform Med. 2019 JUN 27(2): 85-88; https://doi.org/10.5455/aim.2019.27.85-88

The major purpose of this study was to evaluate the eDEWS in Yemen initiated in 2013, and to quantitatively evaluate the system's performance indicators using online data collected from the eDEWS electronic portal, eDEWS weekly bulletins, and annual reports. In addition to the in-depth interviews were conducted as a qualitative method to assess the scope and perception of eDEWS among health workers in the health centers and key informants in the MoPHP and non-governmental organizations (NGOs).

2.1 Study Area

2.1.1 Yemen Administrative Background

Yemen is one of the oldest civilizations in the world and was once known as Arabia Felix. Currently, the official name is the Republic of Yemen. It is an Arab autonomous state in southwest Asia at the end of the Arabian Peninsula. Yemen is bounded by the Kingdom of Saudi Arabia to the north, Oman to the east, the Arabic Sea to the south and the Red Sea to the west. It is the second-largest country on the peninsula after the Kingdom of Saudi Arabia, with an area of approximately 527,970 square kilometers and a long seaboard of about 2,000 kilometers. The country is divided into 22 governorates and has 333 districts including 36,986 villages (Presidential Office-Yemen, 2018). Yemen has a population of more than 30 million according to the population projections in 2019 based on the last national census in 2004 (CSO, 2014; Nations, 2016; UNOCHA, 2019). Approximately 73.5% of the population lives in rural areas (EMRO/WHO, 2009).

2.1.2 Topography:

Geographically and epidemiologically, the country has three distinct zones: the coastal areas including Tehama planes and southwest, mountains and desert.

Costal Lowlands: Coast lowlands run sporadically along the Yemeni coasts where the mountains and plateaus reach the sea in more than one place. These areas are characterized by a hot climate throughout the year. They are considered to be an important agricultural region, especially the Tehama region in the west of the country.

Mountainous Region: The mountainous region extends from the north to the far south. The mountains here are the highest on the Arabian Peninsula, and the area is rich in surface valleys and mountain basins. The average temperature year-round is 18°C and the region benefits most during the rainy season. In the east and north of the mountainous areas, there are highland regions that widen towards the Empty Quarter Desert (Rub'a Al-Khali). Most of this region consists of a desert rocky surface and valleys, especially the Wadi Hadramout.

Desert region: The desert region is a sandy area with almost no vegetation and a height between 500-1000 meters above sea level that descends without significant disturbance to the northeast to finally reach the Empty Quarter (Rub'a Al-Khali). The climate here is harsh, and characterized by high temperatures, rare rain and low humidity (CIA, 2016; Presidential Office-Yemen, 2018).

2.2 Study Design

This study employed a mixed methods design (explanatory sequential) to have complementary strengths of both quantitative and qualitative methods. Mixed method approaches to research are widely used in evaluating programs for triangulation of different perspectives in particular issue, and useful for better explanation of findings (Odendaal et al., 2016). The purpose for using the mixed method in this study was to describe the outcomes of quantitative results and to have detail information on the electronic Disease Early Warning System. There are several designs of mixed methods. This chapter explains the most common used designs.

First, convergent parallel mixed methods provide comprehensive interpretation of the results, in which both the quantitative and qualitative are converged and takes place simultaneously (Creswell, 2014). The second design is the exploratory sequential design, the researcher first starts with qualitative data to explores the views of people and uses the findings to build the next step of quantitative data collection (Fetters et al., 2013). Finally, the explanatory sequential design which is the reverse sequence from the exploratory sequential design. The researcher begins first with the quantitative data then move to the next phase of qualitative study (Creswell, 2014; Fetters et al., 2013).

The first phase of this study presents quantitative data analysis using the data available in the Yemeni health care system including weekly bulletins and annual reports to explore the system's performance and usefulness. It included analyses of the following;

- Notifications of 2016 obtained from the eDEWS website,
- The eDEWS weekly bulletins sent to all partners by email,
- Investigation reports, and
- The national reports, statistics and related surveys.

The second phase is the qualitative data. It was collected from the service providers involved in the eDEWS project and stakeholders, as well as health partners in the field, to identify their perceptions and eDEWS response level.

2.2.1 Sampling Framework:

The methodological tools used this study are summarized in a framework see table 3:

Table 3: General framework of the study sample

	Type of study	Methodology	Sample size	Pre-defined criteria	Site of the study	Theme
1	Quantitative	Primary data analysis	37,947 alerts	Raw data of the generated alerts in 2016	eDEWS dashboard	To assess the timeliness of eDEWS timelines and early responses
2	Quantitative	Secondary data analysis	251	eDEWS weekly bulletins 2013-2017	MoPHP and WHO in Yemen	To identify and assess the public health importance of health-related events and tracer conditions included in eDEWS, by indices of frequency (total cases, death, incidence rates, prevalence and mortality rates). To identify eDEWS usefulness indicators according the Center of Disease Control's guideline.
3	Qualitative	In-depth interviews	11	Health workers in eDEWS health facilities, surveillance officers, and NGO staff	Interviews	To assess the extent to which eDEWS is useful and results in public health action (response) in the current situation. To identify eDEWS usefulness indicators according CDC guideline.
4	Review	Literature and document review		Diseases surveillance system. Monitoring and evaluation of disease surveillance.	Google search, PubMed, Web of Science, Endnote, a web search and the Heidelberg library	To describe the structure and function of diseases surveillance system.

2.2.2 Methods Aligned to the Specific Objectives

This study evaluated the eDEWS by assessing its performance in identifying early alerts for epidemics and actions taken; therefore, four specific objectives were structured to facilitate the research methodology and develop the research results.

1- **To identify the public health importance of health-related events and trace conditions included in the eDEWS**

A total of 251 eDEWS weekly bulletins from 2013 to 2017 were reviewed and quantitatively analyzed to identify health events in the system by disease frequency and leading causes of morbidity. Recent outbreaks, such as cholera and diphtheria, were described as examples of early disease detection.

2- **To assess the system performance and indicate the level of eDEWS usefulness**

To assess eDEWS usefulness according to CDC standard indicators (CDC model) (CDC, 2001), raw data of 2016 alerts from the eDEWS website and data from the published bulletins were analyzed. Qualitative data from in-depth interviews were added to reflect the opinions of health workers on eDEWS usefulness.

- **Data quality:** depends on the completeness and validity of eDEWS data, and the accuracy of its reports.
- **Timeliness:** refers to the speed or interval between steps in the eDEWS. The time interval between any two sequential steps can be assessed.
- **Simplicity:** refers to the simple structure and ease in applying the procedure to improve the timeliness of the eDEWS.
- **Positive predictive value (PPV):** reflects the proportion of confirmed cases or alerts from the condition under surveillance. eDEWS allows for the calculation of a PPV at the level of case detection depending on the number of alerts generated and the proportion of confirmed alerts as truly under surveillance.
- **Sensitivity:** is the proportion of disease cases detected by eDEWS or by its ability to detect epidemics.
- **Acceptability:** is the willingness of health workers and partners to participate in the surveillance system.

- **Flexibility:** means the ease with which a) information or conditions can be changed as needed, b) eDEWS can accommodate a new disease, c) changes can be made in case definitions, and d) variations can be made in reporting sources.
- **Representativeness:** defines disease occurrence over time and the characteristics of a covered population.

3- **To evaluate the response level of the electronic system (eDEWS)**

Analyze the investigation reports of the true alerts and follow the disease trend using the online data by analyzing disease trends (including age, sex, season and geographical area) with examples of epidemic events and investigations cholera, dengue, etc. In addition, qualitative data from in-depth interviews were included to assess the response levels of eDEWS and the health system.

4- **To determine the extent of eDEWS's usefulness and results in public health action (responses) in the current situation**.

Qualitative methods using in-depth interviews of health workers and stakeholders from health-cluster partners determined if people use the generated information when designing their health projects and pursue targets on the ground.

2.3 Study Population

Data of diseases collected by the eDEWS system from 2013-2017 targeting the Yemeni population of 1,982 representative sentential sites (Health Facilities) distributed throughout the country. An online disease surveillance and response system was launched in four governorates (Aden, Abyan, Lahj and Taiz) in March 2013 and later in November of the same year, six additional governorates were included in the first expansion phase after the pilot (Sana'a City, Hodeida, Hajjah, Ibb, Hadramout Al-Sahel and Sadah). The system started with 98 sentinel sites. The next expansion of sentinel sites in April 2015 involved six additional governorates (Amran, Shabwah, Al-Mahrah, Sana'a, Hadramout Al-wady and Dhamar). Finally, in June 2016, eDEWS expanded to 1,982 sentinel sites and included the remaining governorates (Al-Baidha, Mareb, Al-Jawf, Al-Mahweet, Rayma, Al-Dhale and Socotra) (WHO and MOPHP, 2016c). Health workers and program focal points at a health facility level and a governorate level, MoPHP stakeholders and NGO personnel were involved in the study.

2.4 Selection Procedure for In-depth Interviews

For the individual in-depth interviews, a total of 11 participants from eDEWS focal-point personnel in health facilities, surveillance officers and health officers from health-cluster partners were interviewed. The participants were selected randomly. Health workers were selected from the list of the health facilities in eDEWS. The staff of eDEWS and NGOs were selected randomly from the emailing list of the health-cluster partners who receive the bulletin on a weekly basis. The interviews were stopped till saturation were achieved.

2.4.1 Inclusion Criteria

1. Health workers who diagnose disease and provide treatment
2. Focal-point personnel who collect data and send reports to a health facility or governorate health office level
3. NGO staff who receive the weekly bulletin and work on health projects in the field (health-cluster partners).
4. Participants who gave a consent.

2.5 Research Tools

The methodological tools used in this study were designed to be compatible with the objectives of the study and consistent with the context of the study area and security situation. Feedback was solicited from the supervisors; therefore, a modification on some questions was performed.

1. Weekly bulletins of eDEWS from 2013 to 2017 were reviewed in a secondary data analysis. A structured spreadsheet was developed to collect data on diseases and leading cause of morbidity in Yemen and included three main parts. The first part identified the general characteristics of the performance in the reference week, such number of the total health facilities and governorates involved in eDEWS, number of reported health facilities and date of publication. The second part addressed the frequency of diseases per week. The third part explored total alerts generated per week for each event and number of true alerts in the reference week.

2. Three eDEWS annual reports (2013, 2014 and 2016) were reviewed to assess the quality of data in comparison with the published data in the weekly bulletins and describe the actions taken as a response to the reported events.
3. Data on 2016 eDEWS alerts were extracted from the system and analyzed by the author to strengthen the results of the study. The analysis focused on the eDEWS's timeliness and responses based on the following variables: week number, suspected diagnosis, location, number of cases and deaths, action taken, means of verification, outcome of investigation, time/date of reporting and date of investigation. Moreover, all disseminated emails by the eDEWS program from 2014-2017 were reviewed to compare the actual date of dissemination of the bulletins against the standard date.
4. In-depth interviews were conducted with 11 health care providers in selected health facilities as well as the key informants from the MoPHP and organizations working in health. Two guidelines were prepared; the first was used for the health providers and the eDEWS focal person at a health facility level and surveillance officers at the governorate level. The second guideline was used for partners who were working in health programs in the MoPHP and NGOs. The interviews were conducted by the author using skype and another recruited interviewer (trained using Skype) to reach people who had no internet access. Interviews were recorded and short notes were taken during the interviews. Detailed notes and transcriptions were prepared after the interviews. The guidelines are in annex 2.
5. Previous literatures and documents were discussed and reviewed for more evidence. Published documents were accessed using Google search, PubMed, Web of Science, Endnote, a web search and the Heidelberg library. Other non-published documents were obtained from MoPHP and WHO in Yemen.

2.6 Pilot Testing

The pilot testing was intended to check the guidelines for content clarity and test the feasibility of the qualitative tool. Two interviews were conducted, one with a surveillance officer and second with a health officer from an NGO. As a result of this pilot procedure, several changes were made to the content of the guideline. First, some questions were added, and others were modified or deleted in order to fit the social context of the people. Second, the pilot test confirmed that average of 40 minutes was sufficient to complete one interview.

2.7 Data Entry and Analysis

Quantitative: A data file was created using a spreadsheet for analysis by the Statistical Package for Social Sciences (SPSS version 25). The data entry was completed by the author using Excel. Data entry double checking was done to detect errors. Data entry errors were cleaned by entering the correct data. There was no missing data.

Qualitative: The interviews were transcribed and analyzed using NVivo 12. Coding of the transcriptions was performed, and coded data was initially classified according to overall themes and then subthemes were identified.

2.8 Ethical Clearance and Consideration

The study protocol complied with the Declaration of Hensinki (2008) guidelines for ethical clearance and informed consent to ensure the privacy and confidentiality of the research participants, and to cover the risks and benefits of the research for the participants.
The ethical clearance was obtained from the Ruprecht Karls Universität Heidelberg to conduct this study. Moreover, formal permission was granted by the authority of the MoPHP in Yemen to use the eDEWS data. Individual informed consent was also sought from the participants. If they agreed to participate in this research study, then their verbal approval was accepted.

The consent form addressed the purpose of the study, details of what would happen if someone participated or did not participate in the study. It explained that acceptance or refusal to participate in the study would have no consequence on the participant's rights and benefits and that they were free not to participate. It was made clear that participation was voluntary, and participants were free not to answer any questions if they felt uncomfortable or traumatized. Participants were guaranteed that they had the right to withdraw at any time and ask for their data to be withdrawn as well from the study. Participants were guaranteed of confidentiality, and the interviews were coded by numbers to ensure no participant's name was linked to the data. This assured that the information provided was confidential. The benefits and risks of participation were stated in the consent form. Participants were informed that there was no financial gain from participating in this study.

3. RESULTS

Note: The doctoral student has published some aspects of this chapter in the following publications:

- Yemen: Cholera outbreak and the ongoing armed conflict. Journal Infect. Dev. Ctries. 2018; 12(5):397-403. https://doi:10.3855/jidc.10129
- Dureab F, Müller O, Jahn A. Resurgence of diphtheria in Yemen due to population movement, Journal of Travel Medicine, 2018, tay094, https://doi.org/10.1093/jtm/tay094
- Diphtheria outbreak in Yemen: the impact of conflict on a fragile health system. BMC Conflict and Health. 2019. https://doi.org/10.1186/s13031-019-0204-2
- Cholera Outbreak in Yemen: Timeliness of Reporting and Response in the National Electronic Disease Early Warning System. Acta Inform Med. 2019 JUN 27(2): 85-88; https://doi.org/10.5455/aim.2019.27.85-88

The results are summarized in tables and figures with some clarifications as an overview. Data are presented according to the main study themes. This chapter includes five sections: 1) identification of the system characteristic and main features, 2) exploration of health-related events and tracing conditions included in the eDEWS, 3) assessment of eDEWS performance and level of usefulness, 4) assessment of the eDEWS response level, and 5) usefulness of eDEWS in provoking public health actions in a situation of conflict.

3.1 System Characteristics

Table 4 shows the general features of the eDEWS since it was established in 2013 and summarizes the expansion phases of the system to cover the country by the end of 2017. eDEWS started by reporting on 18 communicable diseases and later expanded to include all communicable diseases in the national surveillance system list (31 diseases). The number of consultancies in targeted health facilities increased over time. In 2013, the total consultancies were 1,028,686, while in 2017, the targeted health facilities conducted approximately 12,908,255 consultancies.

Table 4: General features of the electronic Disease Early Warning System 2013-2017

Indicators	Dec 2013	Dec 2014	Dec 2015	Dec 2016	Dec 2017
Number of governorates	10	10	16	23	23
Number of districts	31	124	209	306	333
Number of health facilities	247	249	402	1406	1982
Number of weekly bulletins	41*	51	51	49	49
Number of reported events	18	18	18	28	31
Number of consultancies	1,028,686	3,324,105	3,178,795	6,327,905	12,908,255

*in 2013 system report started from week 11

3.2. Health-Related Events and Conditions Included in the eDEWS

3.2.1 Health-Related Events

Table 5 presents the list of diseases reported in eDEWS from 2013 to 2017. All cases in this system were clinically diagnosed suspected or probable cases. Reported diseases in the system were classified into five groups. The first group was respiratory system diseases or air borne diseases including upper respiratory tract infection (URTI), lower respiratory tract infection (LRTI), severe acute respiratory infection (SARI) and influenza-like illness (ILI). URTI and LRTI were the most prevalent diseases in this group, with the largest number of cases over five years of the system; in 2016, the rate of these diseases (22.3%) was the highest compared to all other diseases.

The second group included digestive system diseases or water/food borne diseases: acute watery diarrhea (AWD), bloody diarrhea (BD), other acute diarrhea (OAD) and typhoid fever. This group was the second most prevalent group after air borne diseases with a prevalence rate that varied from 8% in 2013 to 19% in 2017 and with a high rate in OAD 10% and AWD 7%. The third group was vector borne diseases including: malaria, dengue fever (DF), viral hemorrhagic fever (VHF) and cutaneous leishmaniosis (CL) with about 3% representation across disease groups.

The fourth group included vaccine-preventable diseases: measles, acute flaccid paralysis (AFP), acute viral hepatitis (AVH), neonatal tetanus (NNT), pertussis, diphtheria, meningitis and mumps. The last and fifth group included all other infectious diseases, such as chicken pox, brucellosis, schistosomiasis, rabies, HIV/AIDS, tuberculosis (TB), scabies and Guinea worm. The last two groups are the least prevalent groups with rates less than 1% over the five-year study period.

Table 5: Event distribution reported in eDEWS from 2013 to 2017

Diseases	2013		2014		2015		2016		2017	
	frequency	%	frequency	%	frequency	%	frequency	%	frequency	%
A) Air Borne Diseases										
Upper Respiratory Tract Infection (URTI)	171,116	17%	437,062	13%	426,839	13%	969,229	15%	1,716,065	14%
Lower Respiratory Tract Infection (LRTI)	41,076	4%	125,863	4%	153,304	5%	386,602	6%	736,877	6%
Influenza (ILI)*							51,059	1%	94,377	1%
Severe Acute Respiratory Infection (SARI)*							5,586	0.09%	7,132	0.06%
Total A	212,192	20.6%	562,925	16.9%	580,143	18.3%	1,412,476	22.3%	2,554,451	20.4%
B) Water /food Borne Diseases										
Other Acute Diarrhea (OAD)	78,322	8%	270,337	8%	295,739	9%	522,373	8%	1,202,177	10%
Bloody Diarrhea (BD)	4,064	0.4%	9,029	0.3%	9,473	0.3%	26,966	0.4%	73,527	1%
Acute Watery Diarrhea (AWD/Cholera)	33	0.00%	5	0.00%	5	0.00%	14,235	0.23%	844,952	7%
Typhoid Fever*							108,516	2%	250,595	2%
Total B	82,419	8.0%	279,371	8.4%	305217	9.6%	672,090	10.6%	2,371,251	20%
C) Victor Borne Disease										
Malaria	16,129	2%	80,227	2%	108,297	3%	204,715	3%	363,725	3%
Dengue Fever (DF)	1,021	0.1%	1,939	0.06%	10,620	0.33%	27,272	0.43%	19,839	0.12%
Viral Hemorrhagic Fever (VHF)	12	0.00%	7	0.00%	147	0.01%	251	0.00%	75	0.00%
Cutaneous Leishmaniosis (CL)	198	0.02%	1,189	0.04%	1,145	0.04%	2,563	0.04%	4,380	0.04%
Total C	17,360	1.7%	83,362	2.5%	120,209	3.4%	234,801	3.5%	388,019	3.2%

* Diseases included in the system since 2016

Diseases	2013	2014	2015	2016	2017					
	frequency	%	frequency	%	frequency	%	frequency	%	frequency	%
D) Vaccine Preventable Diseases										
Measles	1,694	0.17%	3,680	0.11%	1,944	0.06%	3,089	0.05%	4,873	0.04%
Acute Viral Hepatitis (AVH)	2,326	0.23%	3,216	0.09%	5,658	0.18%	10,585	0.17%	14,085	0.11%
Neonatal Tetanus (NNT)	36	0.00%	94	0.00%	67	0.00%	127	0.00%	269	0.00%
Acute Flaccid Paralysis (AFP)	87	0.01%	244	0.01%	289	0.01%	535	0.01%	538	0.00%
Mumps*							4,801	0%	27,591	0%
Diphtheria	6	0.00%	3	0.00%	6	0.00%	26	0.00%	388	0.003%
Pertussis	660	0.06%	907	0.03%	1050	0.03%	9,992	0.16%	9,932	0.08%
Meningitis	1314	0.13%	2422	0.07%	2249	0.07%	2,501	0.04%	3,536	0.03%
Total D	6,123	0.6%	10,566	0.3%	11,263	0.4%	32,889	0.5%	65,132	0.26%
E) Other diseases										
Tuberculosis*							1,233	0.02%	3,920	0.03%
Rabies (RB)	1,036	0.1%	4,282	0.13%	3,865	0.12%	5,194	0.08%	5,850	0.05%
Schistosomiasis (Sch)	815	0.08%	2,512	0.08%	2,819	0.09%	8,057	0.13%	20,952	0.17%
HIV/ AIDS*							105	0.002%	617	0.005%
Brucellosis*							7,998	0.13%	43,331	0.35%
Chicken Pox*							2,640	0.04%	22,014	0.18%
Guinea Worm*							0	0.00%	2	0.00%
Total E	1,851	0.2%	6,794	0.2%	6,684	0.2%	23,994	0.4%	92,766	0.7%
Other diseases (not reported in eDEWS)	708,741	69%	2,381,087	72%	2,155,279	68%	3,951,655	62%	7,436,636	58%
Total consultancies	1,028,686	100%	3,324,105	100%	3,178,795	100%	6,327,905	100%	12,908,255	100%

* Diseases included in the system since 2016

Table 6 provides data limited to the five leading causes of morbidity in each year from 2013 to 2017 the percentage was calculated out of the total consultancies in the previous table. The five leading causes of morbidity from the first two years (2013 to 2015) start with URTI, followed by OAD, LRTI, malaria and bloody diarrhea. When the system was expanded in 2016, URTI (13%), OAD (9%), LRTI (5%) and malaria (3%) remained the most frequent, but typhoid fever (2%) appeared in the top five morbidities. In 2017, URTI remained as the first cause of morbidity (14%) followed by OAD (10%), but cholera appeared as the third most frequent morbidity (7 %), followed by LRTI (6%) and malaria (3%).

Table 6: Leading causes of morbidity reported in eDEWS from 2013-2017

Year	First cause	Second cause	Third cause	Forth cause	Fifth cause
2013	URTI* 17%	OAD** 8%	LRTI*** 4%	Malaria 2%	BD**** 0.4%
2014	URTI 13%	OAD 8%	LRTI 4%	Malaria 2%	BD 0.3%
2015	URTI 13%	OAD 9%	LRTI 5%	Malaria 3%	BD 0.3%
2016	URTI 15%	OAD 8%	LRTI 6%	Malaria 3%	Typhoid 2%
2017	URTI 14%	OAD 10%	Cholera 7%	LRTI 6%	Malaria 3%

* Upper respiratory tract infection; ** other acute diarrhea; *** lower respiratory infection; **** bloody diarrhea

Table 7 shows the total number of alerts (notification) generated from 2013 to 2017 with the number of alerts verified as true alerts (checked by surveillance officer clinically or confirmed by laboratory investigation) and the total number of the detected outbreaks. In 2017, the total number of eDEWS generated alerts was 126,555 and five outbreaks were detected; cholera was the major outbreak in both 2016 and 2017. A pertussis outbreak was detected three times in 2013 and 2014 and once in 2017.

Table 7: Distribution of all disease alerts and outbreaks in eDEWS 2013-2017

Indicators	Dec 2013	Dec 2014	Dec 2015	Dec 2016	Dec 2017
Total alerts	2,075	4,281	5,321	39,624	126,555
True alerts	1,561	3,583	5,046	28,476	120,637
Outbreaks	6	4	5	5	5
list of outbreaks	(n) Outbreak	(n) Outbreak	(n) Outbreak	(n) Outbreak	(n) Outbreak
	(3) Pertussis (2) AVH* (1) CL**	(3) Pertussis (1) CL	(1) Measles (1) AVH (3) Dengue	(1) Cholera (4) Dengue	(1) Measles (1) Pertussis (1) Dengue (1) Cholera (1) Diphtheria

*AVH: acute viral hepatitis, ** CL: cutaneous leishmaniosis

Figure 5 shows the distribution of reported infectious diseases in comparison to other diseases (not in the disease' list of eDEWS) according the eDEWS weekly bulletins. Approximately one third of the total consultancies in the targeted health facilities in 2013, 2014, and 2015 were infectious diseases: 31%, 28% and 32% respectively. The proportion of reported infectious diseases increased to 38% in 2016 and 42% in 2017.

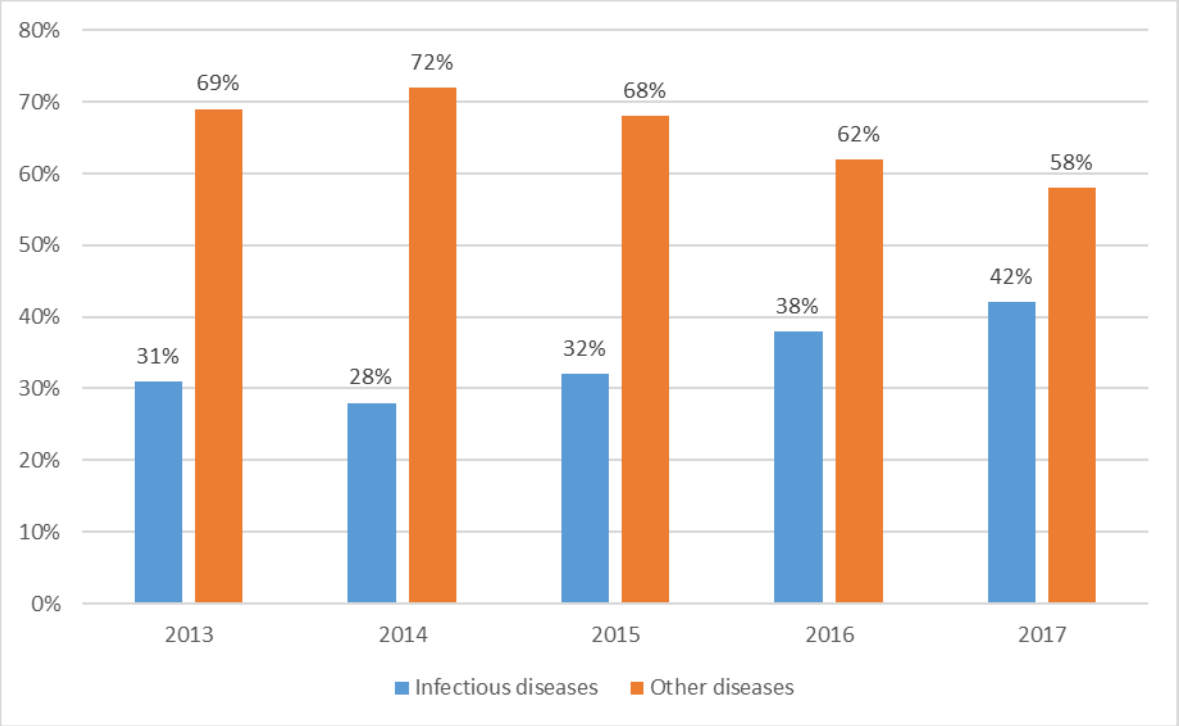


Figure 5: Distribution of infectious diseases in comparison to other diseases 2013-2017.

2.2.2 Early Detection of Outbreaks

3.2.2.1. Cholera

Figure 6 presents the 43 suspected cholera cases reported in the system from 2013 to 2015. All cases were verified as false reports except two cases in week 25 and 26, which were verified as true alerts. That said, both alerts did not exceed the threshold of the outbreak alerts and there was no lab investigation to confirm.

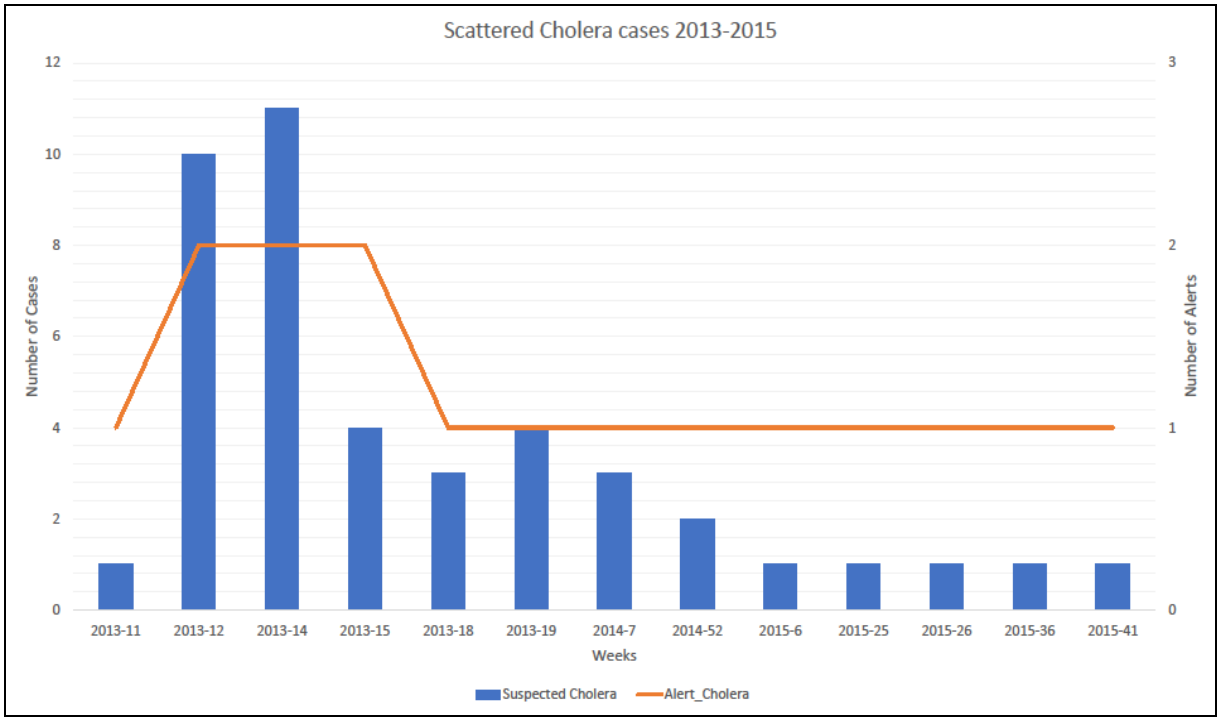


Figure 6: Distribution of suspected cholera cases and alerts in eDEWS 2013 - 2015.

Figure 7 shows the number of suspected cholera cases during the first wave of the outbreak from week 39/2016 until week 15/2017 with a total of 25,152 cases and 1,034 alerts. A few scattered cases had already been identified in week 25 (2 cases), week 28 (19 cases) and week 37 (3 cases). Most of these early suspected cases were reported from one governorate (Albaidha), however, they were verified as false alerts. In the following weeks, a large proportion of positive cases were from Albaidha governorate. Cholera cases increased gradually to reach the peak in week 49 of 2016 (1,698 suspected cases), and then declined gradually till week 15 in 2017.

Figure 8 presents the second wave of a cholera outbreak and generated alerts from epidemiological weeks 16 to 52 in 2017, with 892,257 cases and 15,936 alerts. The second wave started in week 16 as a continuation of the first wave. The number of cases increased sharply from 220 cases in week 16 to 2,426 in week 18 and 8,812 in week 19. The first peak was observed during week 26 (46,667 cases), followed by the second peak in week 38 (35,500 suspected cases). Then the number of suspected cases declined gradually to reach to 9,613 in week 52 of 2017. The number of cases were continued to decrease during 2018.

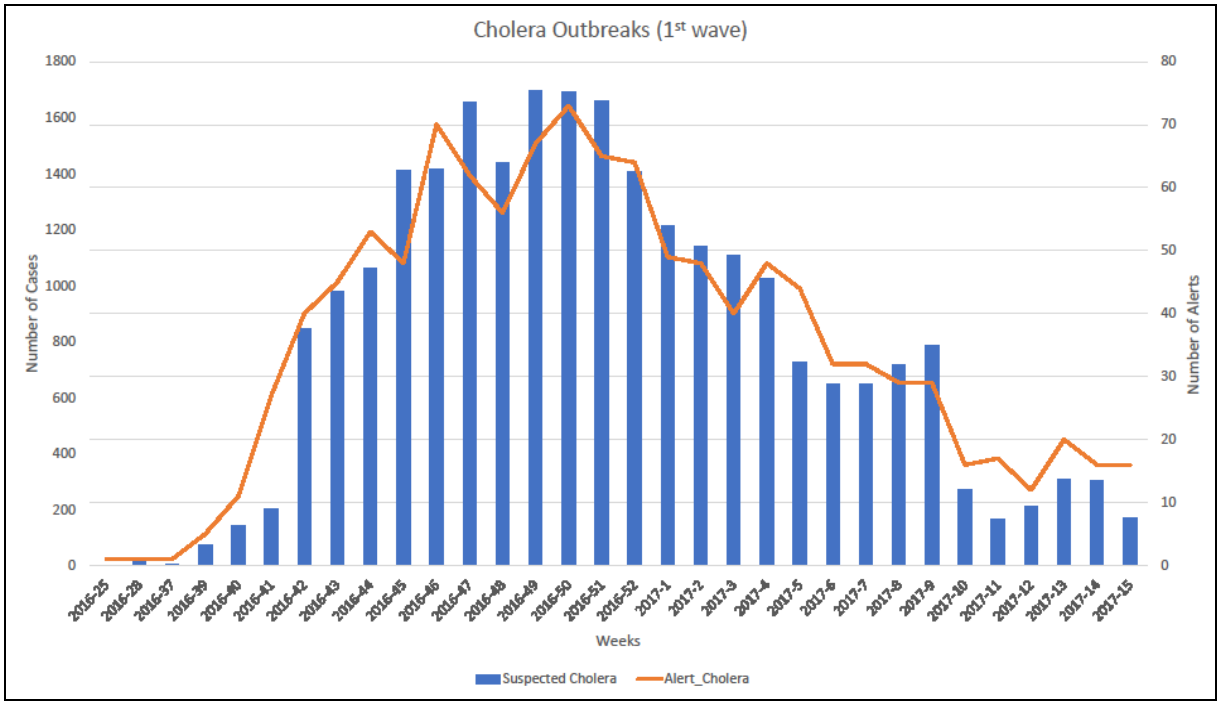


Figure 7: Trends of the first wave of a cholera outbreak and alerts (week 25 in 2016 to week 15 in 2017).

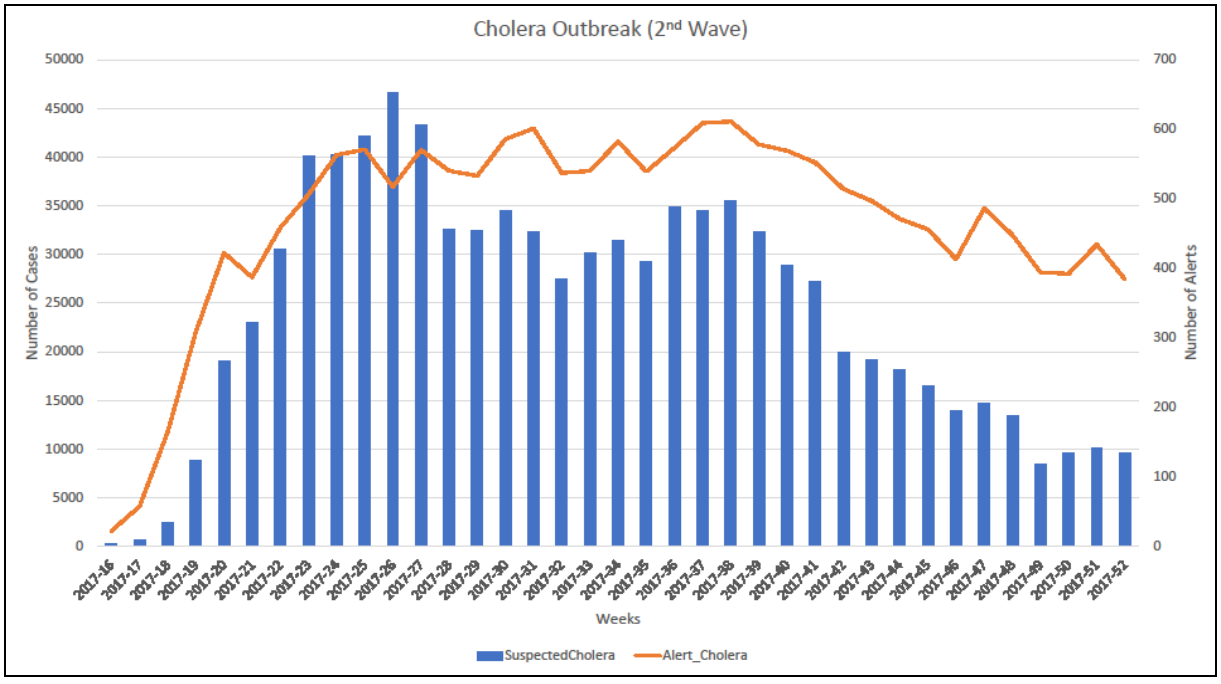


Figure 8: Trends of the second wave of cholera outbreak and generated alerts from week 16 to week 52 in 2017.

Table 8 shows the overall attack rate (AR) during the first wave in the 17 governorates was 62.1/100,000 population. The attack rate ranged between (0.88/100000 in Dhamar and

198/100000 in Al-Baidha). A total of 76 deaths were reported with an overall case fatality rate (CFR) of 0.5%, where Al-Mahweet had the highest fatality rate of 33%, although the attack rate was 1.52/100000.

Table 8: Distribution of cholera attack and fatality rates stratified by governorates.

Governorates	Estimated population 2016	Cases	Attack rate /100,000	Deaths (%)	Case fatality
Abyan	571,569	46	8.05	0 (0%)	0.0%
Aden	888,203	1561	175.75	16 (21%)	1.0%
Al-Baidha	749,575	1490	198.78	6 (8%)	0.4%
Al-Dhale'e	713,778	1258	176.25	1 (1%)	0.1%
Al-Hodeida	3,065,921	3324	108.42	13 (17%)	0.4%
Al-Jawf	542,582	40	7.37	0 (0%)	0.0%
Al-Mahweet	789,145	12	1.52	4 (5%)	33.3%
Sana'a city	2,890,950	244	8.44	0 (0%)	0.0%
Amran	1,100,880	31	2.82	1 (1%)	3.2%
Dhamar	1,939,352	17	0.88	1 (1%)	5.9%
Hajjah	2,099,064	1081	51.50	2 (3%)	0.2%
Ibb	2,884,823	1465	50.78	12 (16%)	0.8%
Lahj	994,516	757	76.12	0 (0%)	0.0%
Rayma	581,021	575	98.96	2 (3%)	0.3%
Sana'a	1,086,942	994	91.45	7 (9%)	0.7%
Shabwah	629,569	85	13.50	2 (3%)	2.4%
Taiz	2,764,727	2094	75.74	9 (12%)	0.4%
Total	24,292,617	15074	62.05	76 (100%)	0.5%

3.2.2.2. Diphtheria

Figure 9 shows the number of probable diphtheria cases and early alerts generated by eDEWS in 2017, including 438 cases and 226 alerts. The early alerts were generated in weeks 5, 6 and 7 (one case each week). Other diphtheria alerts were generated in weeks 30, 31, and 32. Then, the outbreak alerts started from week 39 with one case and increased sharply to 88 cases in week 51. Diphtheria outbreaks also continued in 2018 with high case fatality rates.

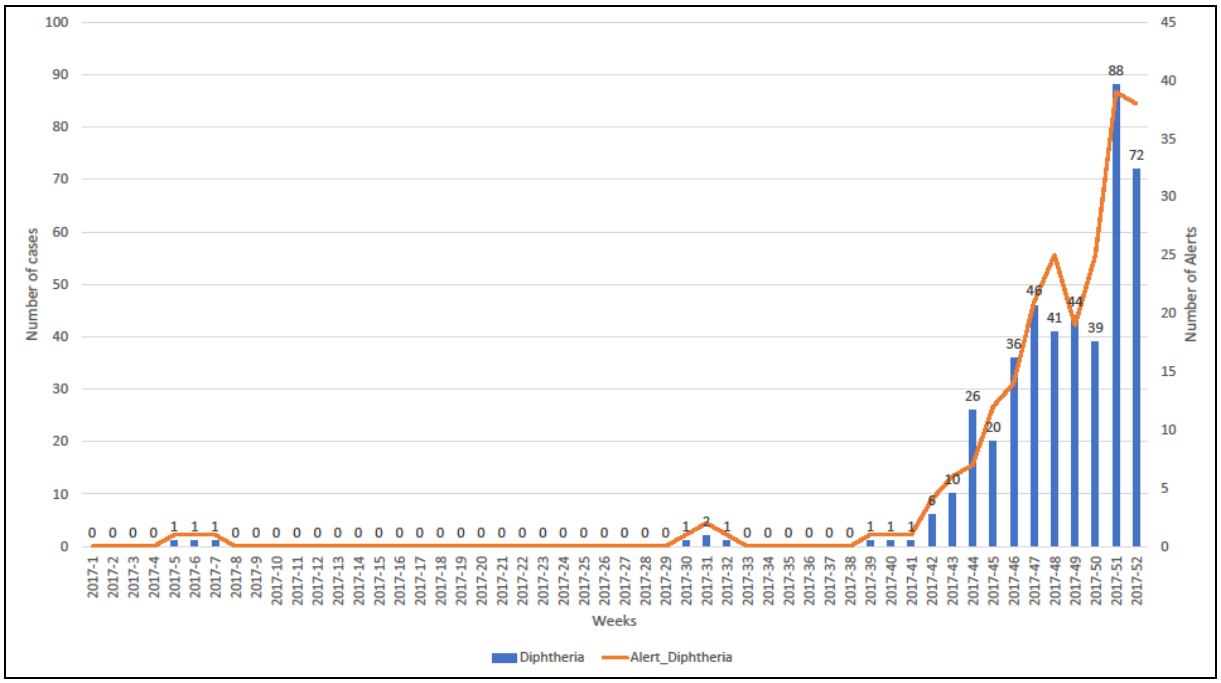


Figure 9: Distribution of diphtheria cases and generated eDEWS alerts from Epi week 1-52 in 2017

A diphtheria outbreak was announced on 29 October 2017 by the Ministry of public Health and population and WHO in Yemen. From that date to March 10, 2018, a total of 1,294 probable cases were recorded in 177/333 (53%) districts in 20/23 (87%) governorates. Table 9 presents the distribution of reported cases, deaths and corresponding case fatality rate (CFR) by governorates. Most cases occurred in three governorates, Ibb governorate (441cases, 34%), Hodeida governorate (151 cases, 12%) and Sana'a governorate (133 cases, 10%). A total of 73 deaths were reported in all governorates, which resulted in an overall CFR of 5.6 percent.

Table 9: Distribution of diphtheria cases, deaths and corresponding case fatality rates by governorates in Yemen (October 2017 – March 2018)

Governorates	Total No. of districts	No of affected districts	No of probable cases	Deaths	CFR (%)
Ibb	20	19	441	16	3.6
Abyan	11	1	4	2	50.0
Sana'a city	10	9	60	1	1.7
Al Baidha	20	11	19	3	15.8
Al Jawf	12	3	6	3	50.0
Al Hodeida	26	20	151	12	7.9
Ad Dhale'a	9	8	107	2	1.9
Al Mahweet	9	8	52	1	1.9
Al Mahrah	9	0	0	0	

Governorates	Total No. of districts	No of affected districts	No of probable cases	Deaths	CFR (%)
Taiz	23	15	45	6	13.3
Hajjah	31	15	48	4	8.3
Al Mukalla	12	0	0	0	
Say'on	16	2	2	0	0.0
Damar	12	9	39	4	10.3
Raymah	6	3	6	2	33.3
Socotra	2	0	0	0	
Shabwah	17	1	1	0	0.0
Sadah	15	4	11	3	27.3
Sana'a	16	15	133	5	3.8
Aden	8	7	63	2	3.2
Amran	20	19	86	4	4.7
Lahj	15	5	10	2	20.0
Mareb	14	3	10	1	10.0
Total	**333**	**177**	**1294**	**73**	**5.6%**

3.3 Performance Indicators and Usefulness of the eDEWS

3.3.1 Data Quality

3.3.1.1 Completeness

Completeness is reported as the percentage of reports received by eDEWS on Sunday of the following epi-week (i.e. a report was considered incomplete if it was delayed by more than 7 days). Figure 10 shows the health facilities reporting rate in eDEWS by weeks from 2014 to 2017, the average reporting rate was more than 90% in all years except in 2015 the average reporting rate was around 80%, the low reporting rate continued from week 12 till week 40, then it showed gradual improvement till the end of 2015. The high reporting rate was also obvious in 2016 and 2017.

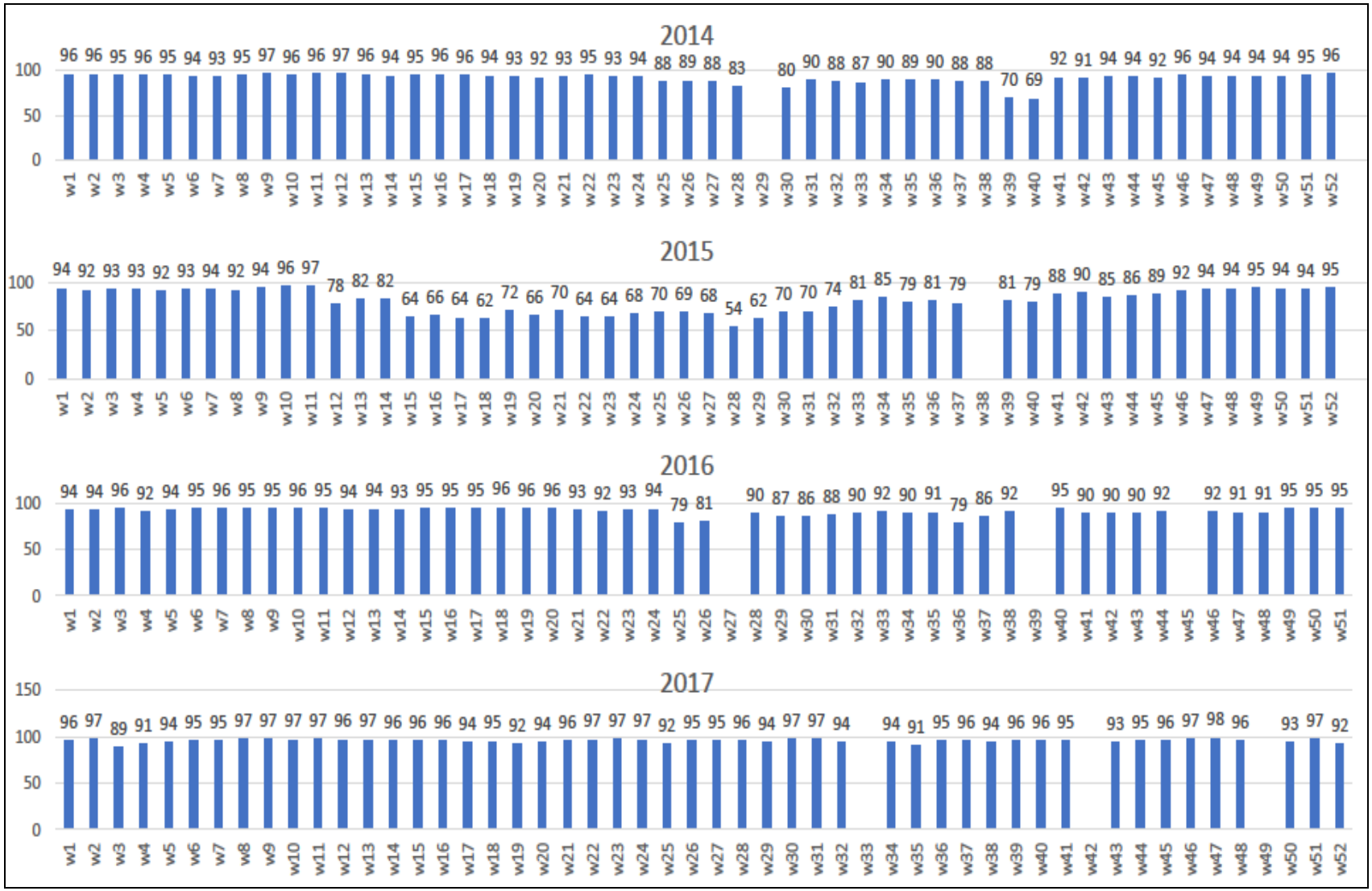


Figure 10: eDEWS total reporting rate by week from 2014-2017.

3.3.1.2 Data accuracy

1. Discrepancies in eDEWS Weekly Bulletins

Table 10 shows discrepancies in the number of diphtheria cases between the data collected from the table of weekly cases and the data presented in published figures in weeks 40-52. For example, in week 40, the number of probable cases of diphtheria was one, but the published figure in week 44 was four, and in week 46, it was five. The cumulative total number of cases shows a significant discrepancy in bulletins published from week 40-52 in 2017.

Table 10: Discrepancies between diphtheria data collected from weekly bulletin and published figures in the eDEWS bulletin in 2017.

Week number in 2017	Data from weekly bulletin	Data from reported figure in bulletin 44	Data from reported figure in bulletin 46	Data from reported figure in bulletin 51	Data from reported figure in bulletin 52
33	No bulletin	1	1	No numbers written in the graph	No numbers written in the graph
34	0	1	1		
35	0				
36	0				
37	0	14	14		
38	0	26	26		
39	1	12	13		
40	1	4	5		
41	1	4	5		
42	No bulletin	7	9		
43	10	6	8		
44	26	26	26		
45	20		20		
46	36		36		
47	46				
48	41				
49	No bulletin				
50	39				
51	88				
52	72				
Cumulative total cases	381	101	170	433	583

2. Discrepancies between eDEWS Weekly Bulletins and Annual Report

Five outbreaks were reported in the eDEWS published bulletins in 2016 (one cholera and four dengue outbreaks); however, the eDEWS annual report in 2016 reported 23 outbreaks. Additional outbreaks mentioned in the annual report included three measles, four pertussis, three malaria, three cutaneous leishmaniosis, two chickenpox, one scabies and one tinea capitis outbreaks, see table 11.

Table 11: Discrepancies between outbreak data collected from eDEWS bulletins and annual reports in 2016.

Diseases	**Outbreaks reported in all weekly bulletins 2016**	**Outbreaks reported in annual report 2016**
B) Water /food-borne diseases		
Other Acute Diarrhea (OAD)	0	0
Bloody Diarrhea (BD)	0	0
Acute Watery Diarrhea AWD /Cholera	1	1
C) Vector-borne disease		
Malaria	0	3
Dengue Fever (DF)	4	5
Viral Hemorrhagic Fever (VHF)	0	0
Cutaneous Leishmaniosis (CL	0	3
D) Vaccine preventable diseases		
Measles	0	3
Acute Viral Hepatitis (AVH)	0	0
Acute Flaccid Paralysis (AFP)	0	0
Diphtheria	0	0
Pertussis	0	4
E) Other diseases		
Tinea Capitis	0	0
Chickenpox	0	2
Scabies	0	1

3. Discrepancies between eDEWS Weekly Bulletins and Online Data

The accumulated alerts from all eDEWS bulletins in 2016 was 39,624, however the total number from the data extracted online from the system platform shows the total number as 37,947. The

total number of reporting health facilities in the eDEWS bulletin 52 was 1,406, but in the online data it was 1,593.

The key informants agreed that quality of data is a crucial aspect of any health information system, and some of the interviewees believed that the eDEWS information was not totally accurate. The main problems included false case diagnoses, poor recording of cases, and the weak health system and security situation in Yemen, which may have hindered the verification process to ensure data quality.

> *"I can say to a certain point, eDEWS is a reliable program, but not 100%, but at least it guides us to a certain way of investigation. It is helpful, but not fully accurate for me."* **Informant # 5**

> *"It is difficult to say eDEWS is precise because of the current conflict situation and the weak health system in Yemen, it gives approximate data about the situation, and it is good to reflect the situation."* **Informant # 4**

> *"Compared to other alternatives, eDEWS data are of good quality. It is not perfect but good enough and can be improved, most of the problems come from the health facility level. I am not sure if the mistakes [are] from writing the diagnosis or from filling of eDEWS form, but I am sure that [the] eDEWS team tries to verify and clean the data."* **Informant # 1**

3.3.1.3. Completeness and Discrepancy

According to the respondents, weekly data submitted by health facilities using a mobile application were completed by default since the eDEWS system could not accept incomplete forms at the reporting point in the health facility, or at other levels. Completeness of eDEWS data was obviously noted by another vertical surveillance system such as polio or measles program in the country. However, there were some discrepancies between eDEWS data and other vertical programs because eDEWS provides information about disease in total numbers and not

by cases. The second issue was related to eDEWS's limited capacity to verify all reported cases and process the data. This may have had to do with the rapid expansion of the network "under fire" without also expanding the capacity for processing verification.

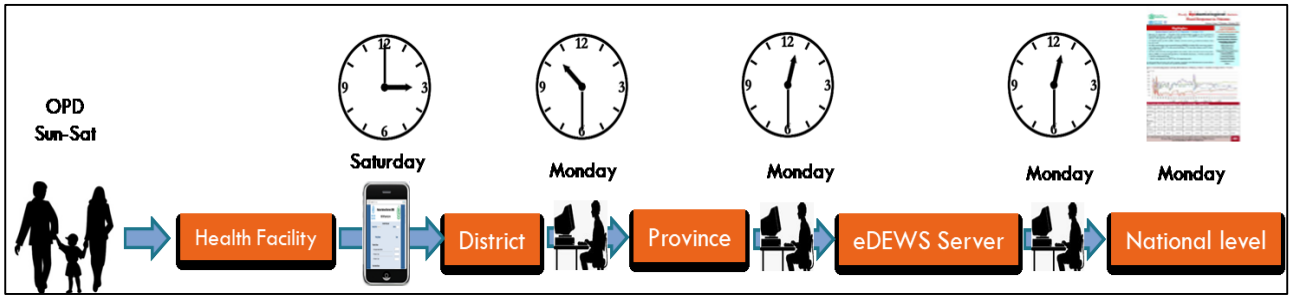
> *"In 2017, the completeness was 92% for eDEWS, which is extremely acceptable and for us in the Polio Program; the completeness should be more than 80% as a good indicator, so 92% is really good. However, the problem in eDEWS is providing us with only a number. When we receive the weekly bulletin from eDEWS, we compare it with our own data to see if there is a discrepancy; so, for example, in the polio there was a sort of discrepancy between our data and eDEWS data. It is not to a high extent. A high number of AFP [acute flaccid paralysis] in eDEWS, could be that one case has visited many health facilities and every health facility report one case, which is the same case, so there is sometimes duplication."* **Informant # 7**

> *"I know from the number of the alerts and the number of verifications there is discrepancy, it means that some alerts did not receive verifications at all. I don't have the data now, but I know that we do not have the capacity for immediate* ***verification*** *[of] all alerts."* **Informant # 3**

3.3.2 Timeliness

eDEWS was designed as an early warning system to identify alerts immediately after data entry at a peripheral level and simultaneously send SMS alerts to all responsible people in the district, governorate and central levels to verify and take rapid action before generating the weekly bulletin. Figure 11 summarizes the flow of data in eDEWS. Collection of data at health facility level should start after 15:00 each day and be reported on each Sunday. On Monday, data should be validated by the district and governorate level to reach the central level not beyond 12:30 to

start analysis and issue the bulletin. The bulletin should be circulated to all health partners in the country on Monday evening.



Source: eDEWS program in Ministry of Public Health and Population -Yemen

Figure 11: **Data flow on all levels of the eDEWS**

Table 12 shows the time interval between the date of reporting in eDEWS and the first rapid action taken by eDEWS staff to verify alerts as the first response. Data shows 14% of alerts were verified within 24 hours of the reporting time, and 19% were verified on the day after the reporting date, while the majority (29%) were verified within one week of reporting.

Table 12: Time interval between reporting and investigation days in 2016.

Time interval after report	Frequency	Percentage
Response first day	5,315	14%
Response second day	7,294	19%
Response 3-7 days	11,027	29%
Response 8-30 days	743	2.0%
Response more than a month	80	0.2%
No data written on responses	13,488	35.5%
Total alerts in 2016	37,947	100%

Table 13 shows that the mean delay time of weekly bulletin dissemination increased in the last two years, from 2.8 days in 2014 To 9 days in 2016 and 2017.

Table 13: Mean time delay in data dissemination in eDEWS

Year	Number of published Bulletins	Delay in days			Standard Deviation
		Minimum	Maximum	Mean	
2014	50	0	10	2.80	1.654
2015	46	0	5	0.15	0.788
2016	49	5	30	9.55	4.912
2017	48	3	22	9.00	4.048

The majority of respondents indicated that there had been a delay in eDEWS timeliness, although all respondents recognized the eDEWS's function of early detection of disease. Eight participants revealed that the investigation process is very slow compared to the required action for immediate alerts and all participants confirmed a delay in weekly bulletin dissemination. Several reasons were cited for the delay in eDEWS timeliness, e.g., security situation, political issues, limited technical capacities, lack of financial resources, and the massive information received from 1,982 health facilities, which need more time and staff to process and prepare the weekly reports. According to the informant's reports, two forms of delay were identified;

1- Delay in Verification

> *"It is impossible to verify reported alerts rapidly, maybe because the current situation security wise, or health workers without salaries who cannot visit or investigate, so it is difficult to verify health-related events within the first 24 hours of alerts".* **Informant # 4**

> *"From my experience, usually the response team does not respond in the first 24 hours, maybe it is not everywhere, but due to the difficulties and the available infrastructure, it may take more than 24 hours to respond".* **Informant # 5**

> *"In some diseases which are supported by a vertical surveillance program, I can agree that investigation can be done within 24 hours. For example, in acute flaccid paralysis cases, one suspected case urges the team to do the investigation as soon as reported because one case is considering as an outbreak".* **Informant # 9**

2- Delay in Dissemination

> *"Lately, some delays [have] lasted one or two weeks due to the huge amount of data and the length of the verification process; it may take a lot of time. The tool of*

the software itself is a good way of getting the information, but now we have a lot of information that needs to be processed. We need more resources, more people who work on this to make it faster; we start with 200 HFs [health facilities] now about 2000 HFs with less staff; WHO needs really to add more people and [the] MoPHP needs to add more people to improve processing of data." **Informant # 1**

"Honestly speaking, there are many issues that challenge the eDEWS from publishing the Bulletin [in a] timely [fashion]. But, I will not talk about them since there are very sensitive and political issues" **Informant # 2**

"There is a delay one week, for example when I finish week 1, I expect to receive the bulletin for week 1, but when week 2 finishes, I receive bulletin for week 1. But, eDEWS receives data on time. I think the problem occurs after receiving data during validation, (analysis and prepare the bulletin) that's why I told you we took a long time in validation and we sit with eDEWS more than once to take their data and validate it to our data in [the] AFP [acute flaccid paralysis] program; we spoke with eDEWS, they have some problems, but I do not want to go into details"

Informant # 7

3.3.3 Stability

The informants who have information technology (IT) background revealed that the system is reliable, it can collect and manage data without disturbance. It is available 24 hours and seven days a week, so focal points have access any time they need it**.** More information (obtained from the IT department at WHO and MoPHP) was summarized in table 14.

"*the percentage of time the system is operating fully is about 99%, only once or twice per year the system goes down and each time it does not take more than an hour to fix it*".

Informant 11

Table 14: Responses of IT Unit on the stability and simplicity of eDEWS in Yemen

#	Question	Answer	Comments
1	The number of unscheduled outages and down times for the system's computers or server.	*"1-2 per year"*	*"Not for more than an hour each"*
2	The cost involved with any repair of the system's computer, including parts, service and amount of time required for the repair	*"Service cost, and yearly rent for cloud service of about 1500 to 2000 USD per year"*	*"We don't have physical servers because of [the] electricity problem in Yemen. We have [a] dedicated server in the cloud, meaning that we have full control"*
3	The percentage of time the system is operating fully	*"99%"*	
4	Time required for the system to manage the data including transfer, entry, editing, storage and data backup	*"The data arrives immediately to the server when it is sent, and requires about 48 hours for validation and correction"*	
5	Time required for the system to release data	*"About 48 hours after validation to release the bulletin"*	

3.3.4 Simplicity

Figure 11 shows the simplicity of data flow from health facilities using the mobile application till reaching the central level for analysis. In cases of an internet disturbance, a focal person at the district or governorate level receives the data by phone and enters it using a computer. All focal persons at health facilities received training on data collection and data entry using an electronic form that can be accessed by a mobile phone or computer.

Only four respondents who directly work in eDEWS said that eDEWS is a simple program because it has a basic form and can be sent quickly from a health facility to the eDEWS server.

"eDEWS is simple and has a basic form to enter the data; it is easy to use the form, if you something happens, it gives you an immediate alert and [the] staff has to confirm it in the system directly, so it is easy to use. The only problem is the internet connectivity and lately, [WHO] has found a solution to make the form fillable offline, so that the form is filled and saved to be automatically sent when internet is available." **Informant # 1**

Other informants thought eDEWS was not simple because the information passes through several difficult steps to be ready for dissemination.

"Of course, not simple, we can say it is quick and dirty. This means something, we do very quickly that is important, but not simple. It needs many things and pass[es] through many difficult steps; from the structure it is very nice because it gives us where, when and what, these three things that we need in disease control. But I don['t] know detail[s] about the software itself. I am only a user of the eDEWS data". **Informant # 3**

3.3.5 Positive Predictive Value

Table 15 shows that the eDEWS central database generated 2,075 SMS alerts in 2013, of which 1,561 were verified as true alerts. Of these true alerts (Positive Predictive Value (PPV) of 75%), six were confirmed as outbreaks. In 2016, eDEWS had the lowest PPV (72%) (28,476 true alerts verified of 39,624 generated alerts), while in 2015 and 2017, the system had the same high PPV (95%) and five outbreaks were detected in each year (outbreaks are presented in table 7).

Table 15: Positive predictive values by year for eDEWS data 2013-2017.

#	Indicators	2013	2014	2015	2016	2017
1	# alerts	2,075	4,281	5,321	39,624	126,555
2	# true alerts	1,561	3,583	5,046	28,476	120,637
3	Positive Predictive Value (PPV)	75%	84%	95%	72%	95%

3.3.6 Sensitivity

All listed events in table 5 are reported on a weekly basis using a case definition to diagnose cases. Disease trends can be monitored and a change in the number of cases is easily detected, so the eDEWS can generate SMS alerts if the number exceeds the threshold. For example, in 2016, the trend for dengue fever was monitored on a weekly basis in eDEWS (see figure 12) and five dengue outbreaks were confirmed (table 16).

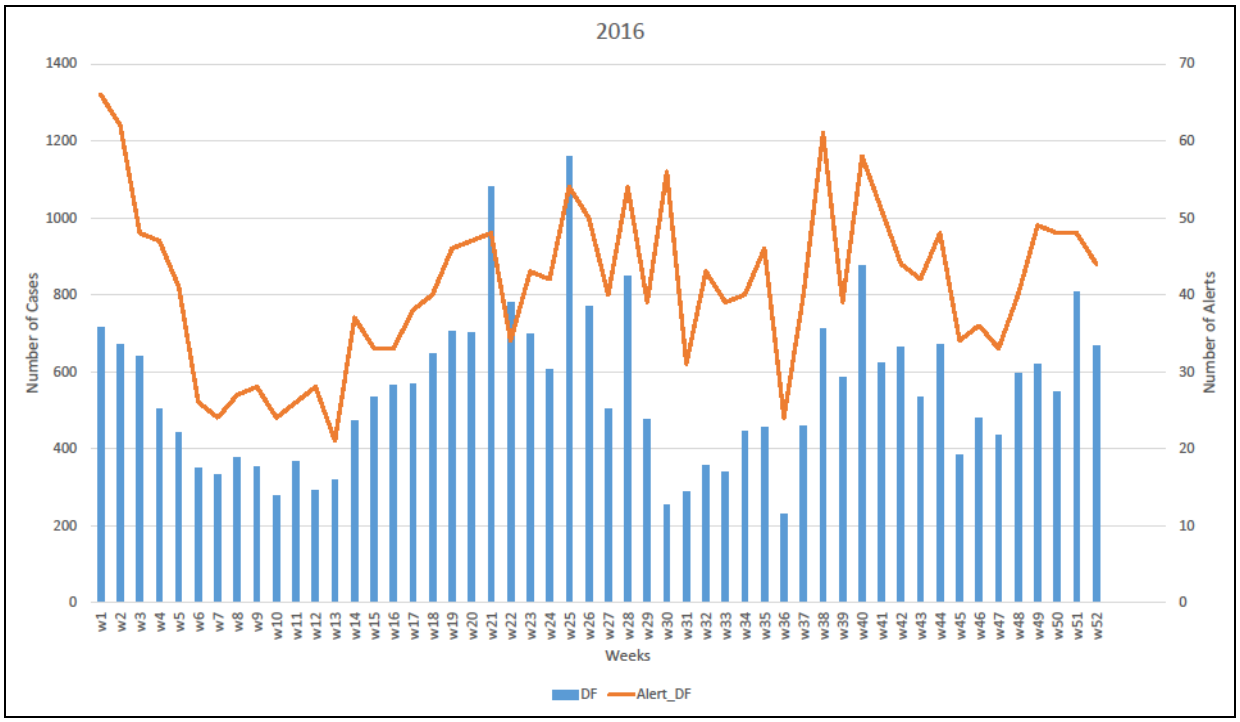


Figure 12: Distribution of dengue fever (DF) cases by week in 2016

Table 16: Dengue fever outbreaks in 2016 by governorate.

Governorate	Total Cases	Total deaths	Samples collected	Confirmed cases
Aden	1,307	11	61	24
Lahj	914	4	89	20
Marib	69	1	10	5
Hajjah	37	0	37	16
Hodeidah	848	2	0	0

Undoubtedly, eDEWS play a strong role in the early detection and control of health-related diseases and several epidemics such as cholera and diphtheria. All people who were interviewed accepted the fact that eDEWS is able to detect outbreaks early because of its new innovative and easy method of using a mobile phone for reporting as reflected below;

> "*If the report[s] from HFs [health facilities] are sent regularly, then it is detected early. It is not only about weekly reports, but we have an immediate report, so they [do not] have to wait for the end of the week to send the report, but can send it immediately if they [have] found [a] case of cholera for example or something serious."* **Informant # 1**

> *"eDEWS can detect outbreaks, but could be better, for example cholera was detected by eDEWS.*" **Informant # 3**

> *"The cholera outbreak in Yemen was a good example, and lately we have the diphtheria outbreak; I think so the alarm of the eDEWS was the guide not only to detect cases, but even to report death cases and everything becomes clear now."* **Informant # 5**

> *"The weekly diseases surveillance reveals the spread of any new case for any outbreak earlier and reports it."* **Informant # 9**

3.3.7 Acceptability

The informants believed that eDEWS is widely accepted by health professionals working with eDEWS. This is obvious from the high rate of reporting and willingness of eDEWS staff to continue working with the system despite all the challenges facing them in the field. Professionals in other surveillance systems and partners from other organizations have shown a willingness to support eDEWS.

> *"Our work in eDEWS is very exhausting, but we are going forward not backward; despite the challenges and obstacles, our work is continuous every day and night, no interruption in work".* **Informant # 6**

> *"You know eDEWS is a Ministry of Health structure system and partners every time express their willingness to support and help [the] MoPHP [Ministry of Public Health and Population] in the surveillance system for eDEWS. If [the] MoPHP requests support, I think partners will be happy to support that. By the way, the WHO is the main partner that is supporting eDEWS now."* **Informant # 2**

3.3.8 Flexibility

Most of the participants (8/11) agreed that eDEWS is a flexible surveillance system. The reasons were that eDEWS is a national program owned by the MoPHP and WHO in Yemen, easy to maintain, and can adjust to changes or modifications. However, a few participants thought that eDEWS took a very long time to adjust to a new change compared to other vertical programs, because it needed to provide the new health facilities with new mobile phones, and the staff had to have many training courses before starting to report using the application.

> *"WHO and MOPHP owned the code and can maintain the system and improve the system anytime. It is flexible enough for new changes and modification."* **Informant # 1**

"In the integration, we took the good and practical features from both systems [routine surveillance and eDEWS] and we reduced the challenges that experienced during the implementation of eDEWS; the paper-based still there, every health facility writes the number of cases weekly on a new form which modified from the eDEWS form with some changes and such as increasing the number of the reported events." **Informant # 8**

"It takes very long time to be able to extend for example to add the 40 health facilities of acute flaccid paralysis [AFP] that I requested to be included. It is very hard for them; some points we made in our reporting [are that] we have a problem in expansion because when you add health facilities, you need to provide a mobile phone and train them on software and reporting. To do this is not easy. In AFP from this month to the next I can change in the health facilities according to importance, but in eDEWS [I] cannot do this." **Informant # 7**

3.3.9 Representativeness

Table 17 shows that eDEWS is present in all 23 governorates in Yemen and covering 333 districts. The total number of health facilities involved in eDEWS was 1,984 by the end of 2017, which represented 37% of the total number of health facilities in the country (5,316). The capital city of Sanaa had the highest eDEWS coverage by health facilities (88%), followed by the Aden governorate with 79%. Amran, Albaidha and Taiz had the lowest eDEWS coverage rate with 21%, 22% and 26% respectively.

Males and females from all age categories were represented in the eDEWS data obtained from the health facilities. Approximately 35% of patients were between ages 15-44 years in each year from 2013-2017 and female patients were 53% of the total population in this study (table 18).

The majority of informants (8/11) agreed that eDEWS describes the occurrence and distribution of diseases on a weekly basis per governorate. A total of 1,982 health facilities are now included by the eDEWS reporting system in all 333 districts of Yemen.

> *"We are working in all governorates of Yemen. We cover around 1,982 health facilities in all districts; at least there is one health facility in each district. The selection of health facilities was done by the governorate health offices. They selected the main health facilities in the districts to reflect the morbidity situation in the catchment and be representative as possible."* **Informant # 8**

> *"Actually, eDEWS is the most effective and dominant right now. It is the only system which reports because it has bases in all areas in each district. There are Sentinel health facilities in each district covered under the eDEWS."* **Informant # 6**

> *"We expand it in the entire country. It has reporting sites in all 333 districts of all 23 governorates. Now we have in some governorates around 70 health facilities and in [an]other only two. This is nothing to do with eDEWS, it has to do with the health system of the country."* **Informant # 3**

Table 17: The percentage of eDEWS coverage by district and health facility in 2017.

Governorates	Total district	Total health facility	Total Functioning health facilities	Total health facility covered in eDEWS	Total
Abyan	11	173	134	68	39%
Aden	8	78	78	62	79%
Albaidha	20	192	127	42	22%
Al-Dhale	9	187	133	52	28%
AlHodaidah	27	457	271	155	34%
Al-Jawf	12	97	97	35	36%
Al-Mahra	9	70	42	42	60%
Al-Mahweet	9	206	173	60	29%
Amana	10	172	71	151	88%
Amran	20	362	255	75	21%
Dhamar	12	359	306	142	40%
Hadramout	28	435	323	163	37%
Hajjah	31	385	282	135	35%
Ibb	20	450	309	149	33%
Lahj	15	242	206	121	50%
Mareb	14	124	81	s 40	32%
Rayma	6	140	132	71	51%
Sada	15	173	105	49	28%
Sanaa Governorate	16	308	236	150	49%
Shabwah	17	197	154	75	38%
Socotra	2	29	23	21	72%
Taiz	23	480	362	126	26%
Grand Total	333	5,316	3,900	1,984	37%

Table 18: Distribution of consultations in eDEWS by age groups 2013-2017.

Year		< 1 years		1-4 years		5-14years		15-44years		45 years		Total
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	
2013	Frequency	58,920	48,455	88,840	83,508	103,344	100,985	150,942	214,898	82,267	89,350	1,021,509
	Percentage	6%	5%	9%	8%	10%	10%	15%	21%	8%	9%	100%
2014	Frequency	207,282	200,524	276,239	274,541	330,925	330,395	472,279	689,245	255,213	298,123	3,334,766
	Percentage	6%	6%	8%	8%	10%	10%	14%	21%	8%	9%	100%
2015	Frequency	200,984	192,702	262,882	261,470	311,793	308,538	479,559	657,627	261,208	300,680	3,237,443
	Percentage	6%	6%	8%	8%	10%	10%	15%	20%	8%	9%	100%
2016	Frequency	380,233	365,365	531,977	526,511	632,020	631,391	949,848	1,278,976	486,039	562,857	6,345,217
	Percentage	6%	6%	8%	8%	10%	10%	15%	20%	8%	9%	100%
2017	Frequency	767,159	754,270	1,084,805	1,080,345	1,240,416	1,280,300	1,770,128	2,421,790	966,251	1,069,844	12,435,308
	Percentage	6%	6%	9%	9%	10%	10%	14%	19%	8%	9%	100%

3.4 Response in eDEWS

The early response to any alert is an important component of the eDEWS. Approximately 62% of all disease alerts were verified in the first week of the reporting date. Table 19 shows that some diseases received high attention in the system and were verified earlier in the week than others, for example, AFP 88%, measles 86%, cholera 85%, pertussis 85%, VHF 81% and dengue fever 85%. On the other hand, mumps, influenza, respiratory tract infections including SARI, OAD and malaria received low attention when the non-response rate by the system was high.

Table 19: Distribution of disease alerts according to the eDEWS response time 2016.

Diseases		24 Hrs	48 Hrs	3-7 days	8-31 days	More than 1 month	No response	Total alerts
Acute Flaccid Paralysis	Frequency	93	106	121	10	1	33	364
	Percentage	25.5%	29.1%	33.2%	2.7%	0.3%	9.1%	100%
Acute Viral Hepatitis	Frequency	56	70	113	3	2	71	315
	Percentage	17.8%	22.2%	35.9%	1%	0.6%	22.5%	100%
Bloody Diarrhea	Frequency	293	534	897	86	9	972	2,791
	Percentage	10.5%	19%	32%	3%	0.3%	34.8%	100%
Cholera	Frequency	208	168	176	28	10	61	651
	Percentage	32%	25.8%	27%	4.3%	1.5%	9.4%	100%
Cutaneous Leishmaniosis	Frequency	20	25	62	6	0	62	175
	Percentage	11.4%	14.3%	35.%	3.4%	0%	35.4%	100%
Dengue Fever	Frequency	529	548	639	17	0	285	2,018
	Percentage	26.2%	27.2%	31.7%	0.8%	0%	14%	100%
Diphtheria	Frequency	2	3	6	0	0	4	15
	Percentage	13.3%	20%	40%	0%	0%	26.7%	100%
Influenza-like Illnesses	Frequency	156	239	380	24	1	717	1,517
	Percentage	10.3%	15.8%	25%	1.6%	0.1%	47.3%	100%

Diseases		24 Hrs	48 Hrs	3-7 days	8-31 days	More than 1 month	No response	Total alerts
L. Respiratory Infection	Frequency	614	885	1326	74	3	2,285	5,187
	Percentage	11.8%	17.1%	25.6%	1.4%	0.1%	44%	100%
Malaria	Frequency	354	499	949	50	4	1,249	3,105
	Percentage	11.4%	16.1%	30.6%	1.%	0.1%	40.2%	100%
Measles	Frequency	378	505	766	33	11	239	1,932
	Percentage	19.6%	26%	39.6%	1.7%	0.6%	12.4%	100%
Meningitis	Frequency	39	52	78	6	0	69	244
	Percentage	16%	21.3%	32%	2.5%	0%	28.3%	100%
Mumps	Frequency	34	78	96	10	0	264	482
	Percentage	7%	16.2%	19.9%	2.1%	0%	54.8%	100%
Neonatal Tetanus	Frequency	5	15	28	2	0	25	75
	Percentage	6.7%	20%	37.3%	2.7%	0%	33.3%	100%
Other Acute Diarrhea	Frequency	618	904	1393	67	5	2461	5,448
	Percentage	11.3%	16.6%	25.6%	1.2%	0.1%	45.2%	100%
Pertussis	Frequency	665	863	1,030	81	15	354	3008
	Percentage	22.1%	28.7%	34.2%	2.7%	0.5%	11.8%	100%
Sever Acute Respiratory Inf.	Frequency	26	56	110	12	0	173	377
	Percentage	6.9%	14.9%	29.2%	3.2%	0%	45.9%	100%
Schistosomiasis	Frequency	31	65	99	0	0	118	313
	Percentage	9.9%	20.8%	31.6%	0%	0%	37.7%	100%
Typhoid Fever	Frequency	556	805	1331	142	16	1,358	4,208
	Percentage	13.2%	19%	31.6%	3.4%	0.4%	32.3%	100%
Up. Respiratory Tract Infection	Frequency	554	768	1,205	66	2	2,378	4,973
	Percentage	11%	15.4%	24.2%	1.3%	0%	47.8%	100%
V. Hemorrhagic Fever	Frequency	43	33	35	3	0	23	137
	Percentage	31.4%	24.1%	25.5%	2.2%	0%	16.8%	100%

3.4.1 Means of Verification of eDEWS Disease Alerts

Approximately 25,641 eDEWS alerts (68%) were verified in 2016 by one of three means: phone call, SMS or visit. Figure 13 illustrates that more than half (54%) of the alerts were verified by phone calls and 10% (3,632) by field visits and investigations. Only 4% of verifications were conducted by SMS by contacting the focal-point personnel at the health facility level.

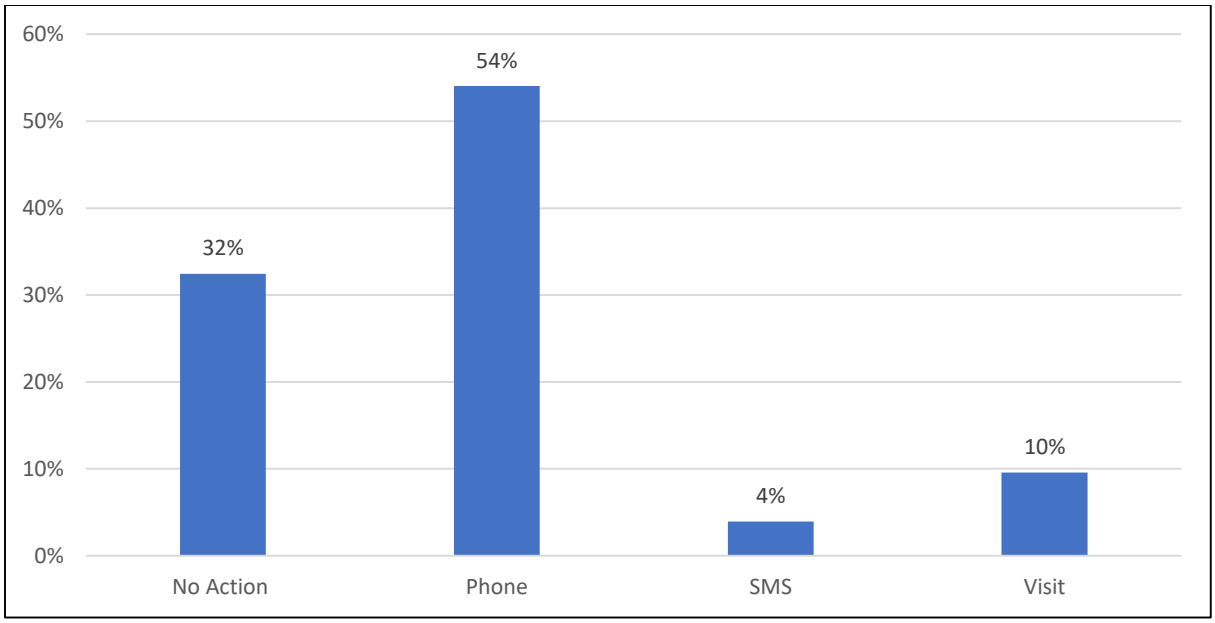


Figure 13: Means of eDEWS disease alert verification in 2016

3.4.2. Response to Cholera Outbreaks

Cholera was a serious health event that occurred in 2016 during the conflict in Yemen, and required a rapid eDEWS response. Table 20 demonstrates that only one-third of the eDEWS-generated alerts in 2016 were verified in the first 24 hours, and 53% of the alerts were verified within 2-7 days of the reporting date.

Table 20: Time interval between reporting and response during the cholera outbreak in 2016.

Time interval	Frequency	Percentage
Response within 24 hours	208	32%
Response 25-48 hours	168	26%
Response 3-7 days	176	27%
Response 8-31 days	28	4.3%
More than one month	10	1.5%
No response noted	61	9.4%

The majority of the 1,034 cholera alerts in the first wave of the outbreak were verified by SMS (4.4%), phone call (45%) or field visits (40.6%). There were major differences in the timeliness of reporting within the first 24 hours between the governorates, ranging from 8% in Abyan to 62% in Aden, and major differences in the proportion of the means of verification between the governorates. For example, a field visit was the main mean of verification in Sana'a city and Sana'a governorate (92%) while neither Shabwah nor Al-Dhale'a reported a field investigation as a means of verification during the first wave of cholera outbreak (Figure 14)

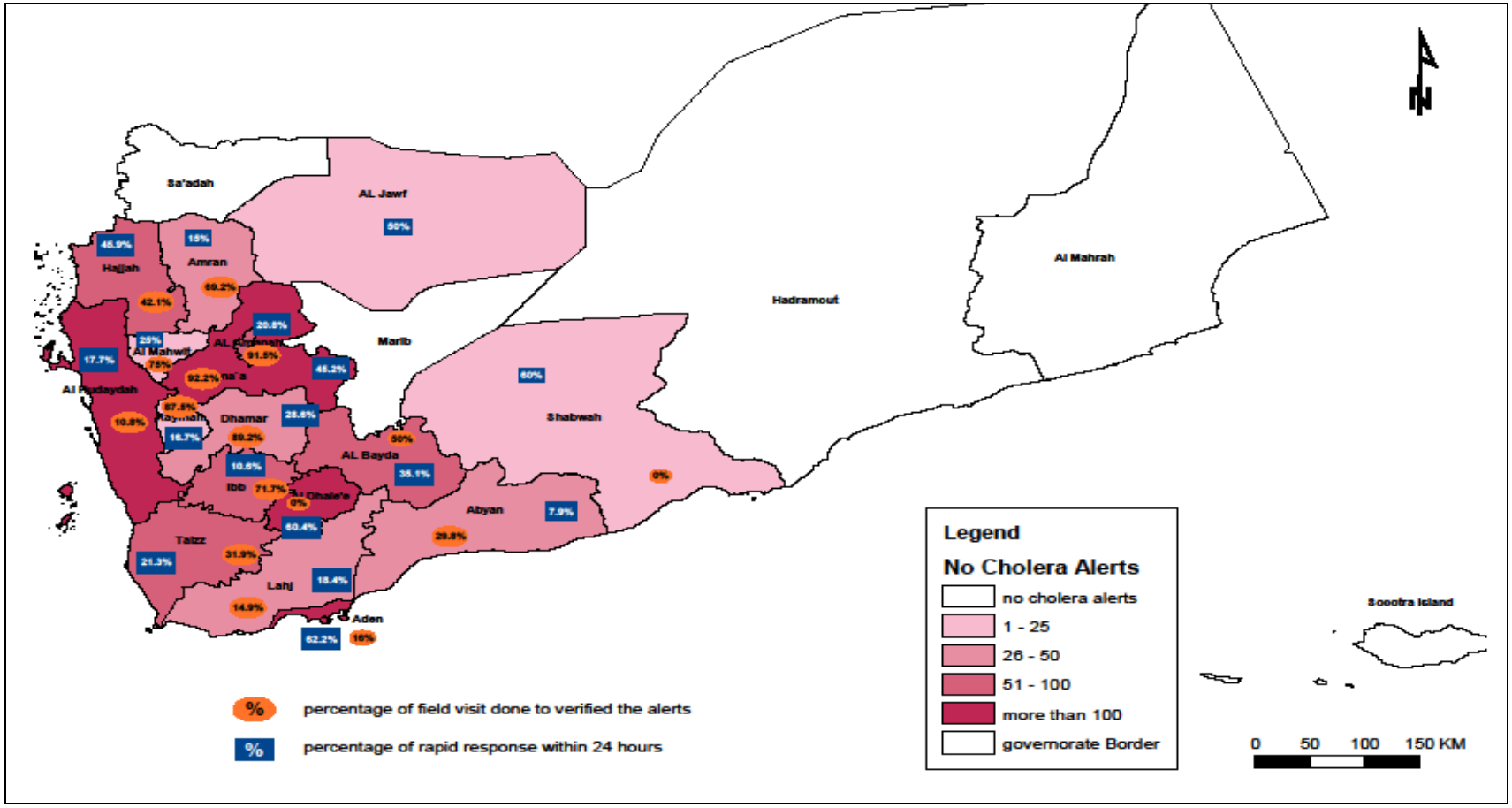


Figure 14: The distribution of alerts, response time and field visits during the first wave of the cholera outbreak in Yemen per governorates.

Most of the interviewed participants (8/11) agreed that the first response in eDEWS is slow. The reason may be due to the armed conflict and its impact on the security situation of the country, the system's lack of human and financial resources and the huge number of alerts received on a daily and weekly base. Some key informants reported that eDEWS was used in the verification process at the district level to reduce the workload at governorate and central levels.

> *"In terms of responding to [an] alert there is a kind of delay, but it can be due to the resources, the distance and all security reasons. Similarly, there is always a problem maybe within the system of the response and the long term we have the curative response or prevention. Sometimes it takes time for the partner to allocate their response. I think it is a problem in coordination. Maybe at [the] beginning it was not that slow, but later, it took time."* **Informant # 5**

> *"When [the] focal person confirms the outbreak; it goes to the high-level decision makers to do action. There are some rapid actions we do, but there are many further actions or interventions that should be taken from the other programs at [the] governmental level. So, the primary action [is] based on the eDEWS information."* **Informant # 8**

> *"Our task is detecting cases and report[ing] immediately or by line list and find in which area [the] number of cases is increasing for intervention and do the necessary steps. The interventions sometimes might be very slow, but disease is discovered as early as possible."* **Informant # 6**

> *"We have added a new feature called a district level response, so [the] eDEWS team trained all district health officers to respond as far as*

possible to [an] outbreak and there is a new form for this investigation separate from the original form of eDEWS." **Informant # 1**

3.5 Usefulness of eDEWS in Provoking Public Health Action

3.5.1 Overall Usefulness of eDEWS

All informants had consensus on the usefulness of eDEWS in disease control. All also agreed on the contribution of eDEWS in improving the health information system because eDEWS is the only program that provides baseline data on the health situation on regular weekly basis, which has an obvious impact on policies and decision making in the current Yemen situation.

"eDEWS is very useful, because in many contexts we need eDEWS. We have many inaccessible areas, especially in our current situation. It is good to have a program that can gather information about 31 diseases, which we didn't use to receive before eDEWS. This is very crucial and very essential not only for now, but for the future. In order to have a good planning for health, we need to know the real issues on the ground; eDEWS is providing baseline data." **Informant # 7**

"eDEWS is a very critical and very informative instrument, which informs policies and decisions that made for the humanitarian interventions. eDEWS is one of the important data sources for the humanitarian needs overview assessment." **Informant # 2**

"eDEWS brings data based on health facilities. For example, in cholera, eDEWS gave me the number of cases in each district and I prioritized my response based on the most affected areas according the eDEWS data". **Informant # 8**

3.5.2 Partners' Contribution in the eDEWS Process

Health partners can positively contribute to the eDEWS process by reporting, supporting the investigation process, training, initiating responses, conducting advocacy activities and funding the operations of the surveillance system as reported by the key informants below.

> *"We contribute in eDEWS through reporting of cases. We report as early as possible to the surveillance system and we monitor the alert and the report to see the number of cases before or after the interventions. We report daily to see if these control measures are effective or not. eDEWS is used as an indicator to evaluate our work."*
>
> **Informant # 10**

> *"I am now seven months in this position and it came to my knowledge many examples of this. We always encourage the partners who are working in mobile or fix[ed] posts to have connections with eDEWS staff at the nearest health facility or rapid response team at district level, and I think it happened many times when partners informed eDEWS focal person about certain disease or specific alerts of outbreak or epidemics or diseases. It is not limited to reporting, but they have to be sure that the rapid response team did the necessary action and investigation."*
>
> **Informant # 2**

> *"They can contribute very much, particularly in the response part because the information part [of] this is a facility base. But, in the areas where these entities present they can close [an] important gap in surveillance and can play a vital role in responses because they are*

mobile, they are independent logistically and much more motivated and capable of doing the work than the local demotivated authorities. The NGOs, not the UN agencies, can play [a] role in extra short training. We provide partners with much information, first for them to read, and second for their health work because this is indirect advocacy; they are our arms for advocacy as well for more responses, although we do not see that or use that." **Informant # 3**

"I think there is strong support for eDEWS from WHO and the donors such as [the] World Bank, part of [the] fund is going to support eDEWS and part [is] going to surveillance, which also going to support eDEWS at the end through [the] rapid response team. There is interest and focus on eDEWS from all partners and donors." **Informant #7**

3.5.3 Partners' Contributions in Responses

The respondents reported that health cluster partners play important roles in generating useful actions as a response to the disease and outbreak information published in eDEWS. During the cholera outbreak, many partners used the eDEWS data to prioritize the areas with high cholera prevalence, and establish rehydration centers and vaccination campaigns.

"Once the MOPHP [Ministry of Public Health and Population] and leading agencies announce or declare an outbreak in the country or a certain area, partners start working in their available capacities responding to the needs." **Informant # 2**

"The response is very rapid for any reported suspected case, the field investigation on suspected cases is a good example to prove that. Another example for the next response level is the vaccination campaign, which

leads to a decrease in the reported cases after the campaigns." **Informant # 9**

"As a response to the cholera outbreak, we established Diarrheal Treatment Centers (DTC). We contacted the surveillance department in the governorate health offices asking them about the most affected areas [hot spots], and according the weekly data of the eDEWS; we screened which health facilities are near to those hot spots." **Informant # 10**

"As action to use eDEWS data for response[s], WHO opened re-hydration centers in [the] cholera outbreak and supported the rapid response teams at [the] district level. We did also train[ing] on case management and we did TOT [training of trainers] on case management." **Informant # 8**

4. DISCUSSION

Note: The doctoral student has published some aspects of this chapter in the following publications:

- Yemen: Cholera outbreak and the ongoing armed conflict. Journal Infect. Dev. Ctries. 2018; 12(5):397-403. https://doi:10.3855/jidc.10129
- Dureab F, Müller O, Jahn A. Resurgence of diphtheria in Yemen due to population movement, Journal of Travel Medicine, 2018, tay094, https://doi.org/10.1093/jtm/tay094
- Dureab F, Shibib K, Yé Y, Jahn A, Müller O. Cholera epidemic in Yemen. Lancet Glob Health. 2018; DOI: https://doi.org/10.1016/S2214-109X(18)30393-0
- Dureab F, Jahn A, Krisam J, Dureab A, Zain O, Al-Awlaqi S, Müller O. Risk factors associated with the recent cholera outbreak in Yemen: A case-control study. Epidemiology and Health 2019; DOI: https://doi.org/10.4178/epih.e2019015
- Diphtheria outbreak in Yemen: the impact of conflict on a fragile health system. BMC Conflict and Health. 2019. https://doi.org/10.1186/s13031-019-0204-2
- Dureab F, Ismail O, Alfalahi E, Al Marhali L, AlJawaldeh A, Nuri N, Safary E, and Jahn A. An overview on the acute malnutrition among children and food insecurity during the conflict in Yemen. Children 2019, 6(6), 77; https://doi.org/10.3390/children6060077
- Cholera Outbreak in Yemen: Timeliness of Reporting and Response in the National Electronic Disease Early Warning System. Acta Inform Med. 2019 JUN 27(2): 85-88; https://doi.org/10.5455/aim.2019.27.85-88

This dissertation addresses the eDEWS in the framework of a national disease surveillance system from 2013-2017 during an on-going conflict in Yemen. Disease surveillance is an important component of public health action to track potential epidemics, monitor interventions, and inform health policy (WHO, 2019). This study is one of the few performed in Yemen and the Middle East Region to assess an electronic early warning system (eDEWS, based on CDC standard indicators) and identify the system's usefulness during Yemen's ongoing complex emergency situation. Key findings include the following:

1- The eDEWS is the only regular functioning information system run successfully under the supervision of the two governments in Yemen. It currently reports weekly on 31 infectious diseases in the country. Results indicate that respiratory tract infections (upper and lower), diarrheal diseases, and malaria were the most prevalent diseases from 2013-2017.
2- The eDEWS is a resilient and reliable system, and despite the conflict, the system is still functioning and expanding. Data quality and response timeliness remain somewhat problematic, since only 14% of all eDEWS alerts were verified in the first 24 hours of detection in 2016. However, these gaps did not affect the system's ability to identify outbreaks in the current fragile situation. This study's findings show that eDEWS data is representative, since it covers the entire country. Although, eDEWS covers only 37% of all health facilities, this represents 83% of all functional health facilities in all 23 governorates and all 333 districts.

3- eDEWS, functions to alert authorities to emerging outbreaks, e.g., cholera and diphtheria. However, despite the system's strength in early disease detection, only 25.5% of suspected polio cases and 19.6% of suspected measles were verified in the first 24 hours following reports being generated.
4- Health cluster partners are using eDEWS data in their program management. The early warning function of eDEWS timely alerts national authorities to the emerged cholera and diphtheria outbreaks. While this did not lead to a full control of cholera outbreak, it was crucial for all health partners to achieve low mortality rate, CFR has been declined to 0.2% in this recent outbreak compared to the CFRs of 5.5% and 1.3% in the outbreaks occurred in 2009 and 2010 respectively.

This chapter presents a discussion of the above key findings using scientific evidence from previous studies on surveillance output and overall morbidity, surveillance system quality and performance indicators, an early warning system, and responses. The issue of eDEWS expansion and implications of the system's overall purpose is addressed. The discussion concludes with study limitations and implications using an eDEWS model to improve health information systems in other countries.

4.1 Overall View on Morbidity Reported in eDEWS

The eDEWS is a regular information system that currently reports on 31 communicable diseases in Yemen. The analysed data is published weekly, thus providing an overview of morbidity, mortality, and actions taken on the ground (WHO/EMRO, 2017). The findings revealed that approximately one-third of all consultancies in Yemen were related to three causes of morbidity: respiratory tract infections (upper and lower), diarrheal diseases, and malaria. This morbidity pattern is similar to results of studies from Nigeria and Brazil (Ezeonwu et al., 2014; Rasella et al., 2018). According to published eDEWS weekly bulletins, measles, dengue, cholera and diphtheria outbreaks were detected for the first time during the conflict period in Yemen. However, other sources of external data reported measles and dengue outbreaks prior to the current conflict (OCHA, 2012). Infectious diseases reported in the eDEWS system increased from 31% in 2013 to 38% in 2016 and 44% in 2017 of the total consultancies. This can be attributed to improved reporting through eDEWS, the increase in of the number (from 18 to 31) of reported

diseases in the system since 2016, and the program's expansion to include almost 2000 health facilities; or it may be due to the deterioration of socioeconomic and hygienic conditions that have led to an increase in morbidity such as cholera outbreaks, which dramatically increased in 2017 (Camacho et al., 2018). The continuation of the war, which has led to the devastation of the country's infrastructure and deterioration of the health system, has had a role in increasing morbidity and mortality across the community. For example, a decline in immunization coverage during the conflict has led to an increase of the prevalence of vaccine-preventable diseases among children in Yemen, such as measles and diphtheria (El Bcheraoui et al., 2018; Qirbi and Ismail, 2016).

4.2 Quality and Performance of eDEWS

Data completeness remains a significant challenge for many national surveillance programs (Makombe et al., 2008), however, the high level of completeness in eDEWS is ensured due to a mobile software electronic data collection process, and the system's automatic refusal of incomplete health facility reports. Evidence shows that the use of electronic reporting systems contributes to good data quality in terms of availability, timeliness, reliability, and completeness (Kiberu et al., 2014). The high reporting rate in eDEWS reflects the data completeness and system acceptability for all partners involved in the system.

Despite the high rate of report completeness in eDEWS, data accuracy is still questionable, which may affect data usage in decision making (Adokiya et al., 2015a). eDEWS needs further investigation to ensure good quality and accurate reports starting from the health facility level and including the use of case definitions in diagnosis, case recording and further data processing. This study found that discrepancies between the eDEWS weekly reports, annual reports, online data, and paper-based vertical surveillance program for the same diseases are a serious issue that needs to be addressed. These discrepancies may occur because of the absence of a timely communication mechanism between surveillance focal points of various vertical programs at the health facility, district and central levels. In addition, Yemen's security situation may have hindered the verification process and affected data quality.

Immediate public health action is always required in public health surveillance following the effective delivery of health facility information. This study shows that alert action

followed within 24 hours (one day) only for 14% of all eDEWS alerts in 2016, thus highlighting a gap in the system's timeliness. A response delay during outbreaks increases the burden of morbidity and mortality (Ahmed et al., 2015b). For example, in 2016, only 31% of the cholera cases received a response within the first 24 hours of the eDEWS warning notification (Dureab et al., 2019b). Response timeliness remains a problem in many countries, e.g., in the USA, a study found a significant difference in response delay times compared to the standard immediate response time for Category II vaccine-preventable diseases in West Virginia (Fahey, 2015).

In Yemen, delays in dissemination of weekly information may be one reason for delayed partner intervention (especially in WASH interventions), thus reducing surveillance usefulness due to a missing link between data collection and public health action (CDC, 2012). This study revealed that dissemination delays increased over time from 2.8 days in 2014 to 9.0 days in 2016 and 2017. All key informants interviewed in this study confirmed the delay in the dissemination of the weekly eDEWS bulletin. In Syria, the average delay for publishing information was 24 days for the Early Warning and Response System (EWARS) based in Damascus, while in Turkey, the average delay was 11 days for Early Warning and Response Network (EWARN) (Sparrow et al., 2016).

It is important to understand the barriers and challenges facing a surveillance system to improve performance, since problems with timeliness are a significant challenge (Adokiya et al., 2016). The current security and political situations in Yemen have hindered the smooth dissemination of information related to disease outbreaks, as exacerbated by limited technical capacities, issues of internet connectivity and a lack of financial resources. Health actors tend to first invest in establishing the information arm of a surveillance system (data collection), and postpone needed capacity for verification and response at both a governorate and district level.

Measuring eDEWS's usefulness and acceptability is the main attribute of an evaluation to prove quality and ensure the system's sustainability (Sosin, 2003). A Positive Predictive Value (PPV) reflects the specificity of system. Having low false positive alerts, especially in 2015 and 2017 in Yemen, reflected the program's effectiveness in detecting outbreaks. Therefore, detected outbreaks were generally true with a high PPV of more than 95%. Most of the prominent outbreaks detected in 2017 were cholera and diphtheria. The eDEWS has excellent PPV ranges from 95%-100%. This in line with a systematic

review study comparing an electronic surveillance system with a paper surveillance method that showed that electronic surveillance has moderate to excellent utility compared with conventional surveillance methods (Leal and Laupland, 2008). A low PPV for a surveillance system leads to wasted resources and time due to an unnecessary investigation of every reported case (German, 2000).

Data obtained from the system shows that eDEWS is highly sensitive, and able to detect changes over time since data is frequently supported by field investigation and laboratory testing. eDEWS sensitivity is constant over time and very useful in monitoring disease trends in Yemen's current situation. This study shows that Yemen's eDEWS is a reliable surveillance system with a high sensitivity for timely detection of disease cases and high specificity in verification and confirmation of alerts. For example, in 2016, eDEWS monitored the trend of dengue fever on a weekly basis in the system, and there were a total of five confirmed dengue outbreaks (Aden, Lahj, Mareb, Hajjah and Al-Hodeida). The eDEWS was useful in locating outbreaks in unusual geographic locations, for example, cholera and dengue fever were reported for first time in Sanaa in 2016. Although a public health surveillance system may have low sensitivity, it can still be useful in trend monitoring as long as the sensitivity remains reasonably constant and change is notable (German, 2000).

Population representation in any surveillance system is influenced by access to the health facilities as well as sex and age groups (Merrill and Dearden, 2004). In Yemen, eDEWS data are regularly used to provide national estimates of the incidence and prevalence of infectious diseases and guidance for required interventions. The eDEWS is used by only 37% of all health facilities in the country, however, this represents 83% of all functional health facilities (WHO and MoPHP, 2016b). Despite the current armed conflict, eDEWS now covers all 23 Yemeni governorates (provinces) and all 333 districts. This study shows that although only 7/23 governorates were covered by eDEWS, this reflected more than 50% of all functioning local health facilities. All age groups are represented in eDEWS data; however, one-third of the patients were between 15-44 years. Approximately 53% of the registered patients in the health facilities were women. In a similar study on the representativeness of an Online Nationwide Surveillance System for influenza in France, the authors found that more than half of registered patient were females (Debin et al., 2013).

Acceptability is a cross-cutting measure of surveillance usefulness. It can be measured by several indicators such as the percentage of reporting, completeness and responses by surveillance staff and relevant stakeholders. Results show that various partners are supporting eDEWS in the field, and many donors trust the system to identify new emerging infections at a country level and have continued to finance the program since 2013. Increasing the health staff and field health partners' transparency and knowledge of the system's processes will increase the surveillance system's accessibility (Schulz et al., 2016). By reviewing the stages of eDEWS development, we found that the system has gone through multiple changes. The literature reviewed in this study indicated that eDEWS surveillance began with 16 diseases and increased to 31 diseases. Many key informants did not agree that eDEWS was a flexible system since they believed that eDEWS needs more time to achieve change. However, flexibility is not a matter of time, but rather the ability to adapt to changes in risks and information input (Sosin, 2003).

4.3 Early Detection and Response to Specific Diseases

Verification and responses to contain outbreaks are the main components following the reporting function of any surveillance system. Delays in verification may affect control interventions and subsequently result in uncontrolled outbreaks (Hitchcock et al., 2007). Despite the strengths of eDEWS in early disease detection, only 25.5% of suspected polio cases and 19.6% of suspected measles were verified in the first 24 hours following reporting. This study shows the gaps between the notification and verification process that need to be improved. Findings showed that the security situation and the limitation of resources were the system's main weaknesses.

Although eDEWS detected 97% of all cholera cases reported in the first wave 2016-2017 and 87% of cases in the second wave 2017-2019, there were missed opportunities to identify the cholera outbreak in an early stage. For instance, several cholera alerts were generated in the first three years (2013-2015) of the eDEWS system, but all were verified as false alerts except for two cases reported in 2015 after the conflict began. The first case in 2015 (week 25), occurred in Dhamar Governorate, and the second case in Amran Governorate in 2015 (week 26), but there were no laboratory confirmations (WHO and MoPHP, 2015a, b).

Generally, data delivery in surveillance systems should be followed by direct public health action, which is particularly important for epidemic-prone diseases. This study recognized the eDEWS timely warning during the cholera outbreak that prompted an investigation and confirmation of cholera cases in 2016. Unfortunately, these prompt responses were limited to 32% of the suspected cases of cholera, which reveals a major problem with the system's timeliness. Furthermore, there were major differences in response timeliness among provinces. The timeliness of responses to inform the regional and national health authorities are serious issues in many countries. For example, in Ghana, a study presented that timeliness remains a problem even though there has been an improvement in completeness (Adokiya et al., 2015b; Ohene et al., 2016). Another study, in the USA, showed a significant difference in response delay times compared to the standard 24-hour mean time (Fahey, 2015).

The diphtheria outbreak in Yemen was another example of a delay in response to an early eDEWS alert. Study results showed that several diphtheria alerts were detected early in week 5, in 2017. However, the official MoPHP statement of the diphtheria outbreak was launched in week 39, in 2017. The increasing number of diphtheria cases in Yemen revealed the gap in the immunization coverage among population, in addition to other factors that contributed to the rapid increase such as the population movement and low immunity due to the high prevalence of malnutrition (Dureab et al., 2018a; Franca et al., 2009).

4.4 Effectiveness of eDEWS

This study described the level of eDEWS effectiveness on the ground in Yemen. Findings demonstrate three main aspects of eDEWS effectiveness as an electronic surveillance system: 1) positive opinions of overall usefulness from users, 2) partner contribution in surveillance processes and 3) partner action in response to newly emerging events. The results showed that the eDEWS system has supported public health control throughout the emerging outbreaks in Yemen over the last four years of the on-going war. Despite all existing gaps in the eDEWS and national health system, eDEWS information helped the health partners on the ground to keep the cholera case fatality rate to 0.22% (Camacho et al., 2018).

A surveillance system is effective and useful if it can produce applicable action to control and prevent emerging health-threatening events or clarify the process leading to an adverse outcome as a response to collected data (Thacker and Berkelman, 1988). This study revealed that eDEWS is an informative program, and many health partners have used eDEWS information while implementing interventions during disease outbreaks. The system showed high acceptability from partners who are contributing in the processes of data collection, investigation, and health staff training. The system's sustainability depends on the contributions of MoPHP health staff, UN and NGO partners' commitment and donor engagement. (Reddy et al., 2006). This continuous support will contribute to eDEWS functionality and sustainability.

4.5 The Implication of eDEWS for Health Information System in Fragile Countries

The eDEWS is a crucial component of the health system in Yemen and has proven to be useful in organizing the humanitarian health response in general and infectious disease control in particular. Beyond that, the pioneering experience from Yemen, including the relative resilience and robustness of eDEWS, may also inform health agencies and authorities in similarly fragile, conflict-prone and deprived setting, on how to cope with the threat of infectious diseases and epidemics through outbreak detection and an enhanced rapid response during a conflict. Key factors of the success of eDEWS are its resilience and basic mobile technology that does not need a high-speed connection and the simple structure of codes and routines. However, eDEWS may become a victim of its own success if ever more programs want to use it for monitoring their projects and if it is expanded to replace the overall HIS by adding many more indictors and variables. So far, eDEWS has been replicated and adapted in the region as low cost intervention for poor resources countries beyond Yemen in other crisis-hit countries such as Somalia (Ahmed et al., 2015a; Muhjazi et al., 2013).

The eDEWS is functioning well within its limited human resources capacities, scarce financial resources, and restricted access due to security situation, low internet access, inadequate electricity coverage and partial function of health facilities. There is still a need to improve on the observed deficiencies in data quality and timeliness, however,

one has to acknowledge that many well established surveillance systems in developed and developing countries are struggling with similar problems, that are affecting the overall quality of surveillance systems (Sahal et al., 2009).

4.6 Study Strengths and Limitations

4.6.1 Strengths

The main strength of this study is that it included eDEWS information over five years from 2013 to 2017. Second, the study followed the multiple expansion phases of the program and recorded major changes over five years of eDEWS use. The third strength was the use of a triangulation method. The research problem was addressed from multiple angles using both qualitative and quantitative research methodologies including in-depth interviews and reviews of published eDEWS reports and scientific publications to approach the research problem.

4.6.2 Limitations

1. **Security**: the escalating conflict in Yemen hindered the author from physically conducting the in-depth interviews in the field (qualitative), so an alternative option was used (skype interviews). Therefore, the fifth objective to obtain information on knowledge, practice and attitudes of health staff using eDEWS was cancelled because of missing contact addresses for staff working at a health facility level and it was not possible to send local interviewer to unsafe places.
2. **Access to internet**: Since not all participants had access to the internet, some in-depth interviews were conducted by trained local interviewers (trained remotely using skype).
3. **Lack of available and/or reliable data from other sources**: This study used only eDEWS data. Due to the lack of other data on routine surveillance, it was impossible to compare eDEWS data with other Yemeni routine surveillance data sources to better assess the quality of the information from eDEWS.
4. **Personal Bias:** There may be personal bias in the interpretation of the qualitative data by the investigator.

4.7 Conclusions

The eDEWS is the only regular information system on infectious diseases in Yemen. The data is published weekly providing an overview of morbidity and mortality; it strongly influences decision making and health policies during responses to disease outbreaks. eDEWS contributes to most building blocks of the health system (governance, information, health services, human resources, medical supplies) and through its cost effectiveness, it contributes to spare financial resources for Yemen's under-resourced system.

Although the eDEWS covers 83% of all functional health facilities and is critical for early detection of disease outbreaks, there remain major challenges to eDEWS functioning, quality and responses. In particular, eDEWS data accuracy and report timeliness need urgent attention. Currently, the eDEWS bulletin is generated manually at the central level, which leads to a delay in the dissemination of the national weekly reports and affects the quality of information.

Despite, the system is specifically designed for the purpose of early detection of epidemic-prone diseases during emergencies, the role of eDEWS extended beyond this purpose to include all infectious diseases on the list of the national surveillance system and covered most of the functioning health facilities during the Yemeni crisis. eDEWS is flexible and in continuous development, thus it might cover additional disease events such as non-communicable diseases in the future.

The national routine surveillance system (paper-based system) collapsed down during the current situation in Yemen, therefore, the eDEWS was developed and expanded rapidly to fulfil this role. It is good to have an integrated surveillance system to provide timely information, however, the main purpose of eDEWS, to provide early detection of epidemics, was affected by the overwhelming amount of data received each week from 1,982 health facilities.

4.8 Recommendations

The study presented here focused on health system strengthening for diseases control in Yemen during the recent conflict. Therefore, this section highlights areas for system improvement;

1- Enhance the capacity of health staff at the district level to establish ~~a~~ rapid response team thus ensuring early disease detection and timely responses. Expanding the eDEWS team at the central and governorate levels will improve the eDEWS's data quality and performance.
2- Increase the number of health facilities included in eDEWS in other provinces to reach at least 50% all health facilities and thus improve the representativeness of the system.
3- Generate bulletins automatically at the national and regional levels to reduce discrepancies and improve the quality of reporting and responses.
4- Keep the purpose of the eDEWS's early warning function intact and make a weekly random selection of health facilities (representative number) to analyse data rapidly and identify early alerts of disease outbreaks for swift responses.
5- Establish a permanent maintenance or control unit in the surveillance program to ensure eDEWS functionality since its stability can be affected at any time due to the lack of a sustainable control unit at the MoPHP or WHO.
6- Increase attention and coordination among stakeholders and consistent support, particularly with the event of the dramatic and ongoing cholera epidemic, thus making close attention and continuous support for eDEWS even more relevant going forward.
7- End this war and strengthen public health actions to save lives and improve the overall health system.

5. Summary

Yemen is a poor country suffering from the civil war since 2015 which aggravated the poor humanitarian and health situation of the population. This study examines the usefulness of an electronic Diseases Early Warning System (eDEWS) and its influence on humanitarian health actions in Yemen. Disease surveillance is the continuing systematic collection, analysis, and interpretation of disease data for action. The Yemeni National Disease Surveillance systems (paper-based system) became increasingly dysfunctional and was thereafter unable to meet the surveillance needs during the humanitarian emergency. New and recurrent epidemics and pandemics have generated a critical need for strengthening disease surveillance through early warning systems. Yemen implemented the eDEWS in 2013 for the rapid detection of disease outbreaks and prompt response. The eDEWS is a health facility-based system which uses an electronic dashboard and a mobile-based interface system (MBI). The system registers notification of 31 different infectious diseases. The system generates automatic alerts (notifications); based on alert thresholds for each disease in eDEWS.

Aims:

This study examines the performance and usefulness of eDEWS, in term of several dimensions including timeliness, sensitivity, representativeness, and response intended to determine the goal of protecting the population in order to maintain and improve health care in Yemen.

Methods:

This study used a mixed-methods design to evaluate the eDEWS by assessing its performance in detecting early alerts of epidemics. The first part of the study reports on a quantitative data analysis using alert data from 2016 obtained from the eDEWS database, weekly bulletins and annual reports. The second part (qualitative data) was collected using in-depth interviews with health care providers in selected health facilities and key informants from Ministry of Public Health and Population and health cluster partners, comprising international agencies, such as WHO.

Results:

- *Infectious disease reporting:* Approximately one-third of all patient contacts in the targeted health facilities in 2013, 2014, and 2015 were due to infectious diseases (31%, 28% and 31%, respectively). The percentage of reported infectious diseases increased in 2016 (38%) and 2017 (44%). Respiratory tract infection, other acute diarrhea, malaria and bloody diarrhea were the most prevalent diseases. In 2017, cholera appeared as the third cause of morbidity with a prevalence rate of 7% of all consultations.
- *Performance and usefulness of the eDEWS:* The eDEWS is a resilient and reliable system, and despite the conflict situation, the system is still functioning and continuously expanding. However, there are problems with data quality and timeliness of the response actions in eDEWS. For example, only 14% of the total alerts were verified in the first 24 hours of detection in 2016. The mean delay time of the eDEWS weekly bulletin dissemination has increased over time: 2.8 days in 2014 but 9 days in 2016 and 2017. Despite these gaps eDEWS's was able to identify relevant outbreaks (e.g. cholera, diphtheria) in the current fragile situation. The findings show that eDEWS is representative since it uniformly covers the whole country, although it covers only 37% of all health facilities. However, this percentage represents 83% of all functioning health facilities in all 23 governorates and all 333 districts.
- *Early detection and response:* The early warning function of eDEWS correctly and timely alerts national authorities to the emerged cholera and diphtheria outbreaks. While this did not lead to a full control of cholera outbreak, it was crucial for all health partners to achieve low mortality rate, CFR has been declined to 0.2% in this recent outbreak compared to the CFRs of 5.5% and 1.3% in the outbreaks occurred in 2009 and 2010 respectively.

Conclusions:

The eDEWS is a crucial component of the fragile health system in Yemen and has proven generally useful to all those involved in infectious disease control. It could also be a useful system for outbreak detection and enhanced rapid responses during a conflict situation and serve as a model for others in similar settings. However, a substantial improvement in the health situation will only be achieved by ending the war.

Zusammenfassung

Seit 2015 herrscht im Jemen ein Bürgerkrieg, der zu einer humanitären und gesundheitlichen Katastrophe geführt hat. Um drohende Epidemien rechtzeitig zu erkennen, wurde daher mit Unterstützung der Weltgesundheitsorganisation das elektronisches Frühwarnsystem *eDEWS (electronic Disease Early Warning System*) aufgebaut. Die vorliegende Studie untersucht die Qualität und Wirksamkeit dieses Systems. Weltweit wiederkehrende Epidemien und Pandemien haben deutlich gezeigt, wie wichtig effektive Frühwarnsysteme sind. Jemen früheres nationales Krankheitsüberwachungssystem - ursprünglich auf Papierbasis – war zunehmend damit überfordert, den Anforderungen in humanitärer Notsituationen gerecht zu werden. Um Daten schneller erfassen zu können und ein zügiges Handeln zu gewährleisten, hat Jemen daher ab dem Jahr 2013 mit Unterstützung der Weltgesundheitsorganisation das elektronisches Frühwarnsystem *eDEWS* aufgebaut. Das eDEWS setzt sich aus einem elektronischen Kontrollzentrum und einer mobilen Benutzeroberfläche (*MBI – Mobile-Based Interface*) zusammen. Es registriert Meldung über 31 verschiedene Infektionskrankheiten; Fallmeldungen werden dann systematisch überprüft. Beim Erreichen eines Schwellenwerts wird ein Warnhinweis (alert) ausgelöst.

Ziel: Diese Studie untersucht die Leistungsfähigkeit von eDEWS hinsichtlich der Aspekte Rechtzeitigkeit, Durchführbarkeit, Akzeptanz, Vorhersagewert und Zielerreichung hinsichtlich des Schutzes der Bevölkerung durch rechtzeitige Warnungen und Gegenmaßnahmen. Die Forschungsergebnisse sollen die lokalen Entscheidungsträger und internationalen Hilfsorganisationen dabei unterstützen, die Gesundheitsversorgung im Jemen aufrecht zu erhalten und zu verbessern.

Methodik: Die Studie folgt einem Mixed-Method Design. Der erste Teil basiert auf einer quantitativen Datenanalyse der Frühwarndaten aus der eDEWS Datenbank und den wöchentlichen Bulletins und dem Jahresbericht von 2016. Qualitative Daten sind durch ausführliche Interviews mit Schlüsselinformanten (Gesundheitsarbeitern in Gesundheitszentren, Mitarbeitern im Gesundheitsministerium und Partnern aus dem Gesundheitscluster (internationale Hilfsorganisationen) erhoben worden.

Ergebnisse:

- *Gesundheitsberichterstattung:* Ungefähr ein Drittel der Konsultationen in den untersuchten Gesundheitseinrichtungen von 2013, 2014 und 2015 betrafen Infektionskrankheiten (31%, 28% und 31%). Die Zahl der gemeldeten Infektionskrankheiten stieg in den Jahren 2016 und 2017 um jeweils 38% und 44%. Darunter waren Atemwegserkrankungen, andere akute Durchfallerkrankungen, Malaria und blutiger Durchfall am häufigsten. Mit einer Prävalenzrate von 7% war Cholera im Jahr 2017 die dritthäufigste Diagnose. Das eDEWS stellte sich als ein resilientes und verlässliches System heraus, welches trotz andauernder Konfliktsituationen aufrechterhalten und kontinuierlich weiterentwickelt wurde.
- *Leistungsindikatoren und Nutzen von eDEWS:* Probleme mit der Datenqualität und zeitnahen Reaktionsmaßnahmen bleiben jedoch weiterhin bestehen. So sind in 2016 nur 14% aller Frühwarnungen in den ersten 24 Stunden seit der Entdeckung verifiziert worden. Die durchschnittliche Verzögerung der wöchentlichen eDEWS Bulletin Veröffentlichung hat sich über die Zeit erhöht: Waren es 2014 und 2015 nur 2,8 und 0,5 Tage so stiegt die Zahl für 2016 und 2017 auf jeweils 9 Tage an. Dennoch beeinflussen diese Lücken die Rolle des eDEWS, Ausbrüche in der momentanen, fragilen Situation rechtzeitig zu detektieren, nicht. Die Ergebnisse zeigen, dass der eDEWS ein repräsentatives System ist, da es die gesamte Region des Landes abdeckt. Auch wenn es nur 37% aller Gesundheitseinrichtungen umfasst, so erfasst es dennoch 83% aller funktionalen Einrichtungen in allen 23 Regierungsbezirken und allen 333 Distrikten.
- *Früherkennung und rechtzeitiges Handeln:* Die frühzeitige Warnung ist der Hauptzweck des eDEWS, damit sich die zuständigen Behörden vor Ort rechtzeitig auf einen möglichen Ausbruch vorbereiten können. So wurden Cholera und Diphterie-Ausbrüche vorzeitig vom eDEWS erkannt. Damit konnten zwar die Ausbrüche nicht verhindert werden, aber es war für die Gesundheitspartner wichtig, zumindest die Letalität deutlich zu senken, was auch gelang. Diese liegt nun bei 0,2% und damit deutlich niedriger als 5,5% und 1,3% bei den Cholera-Ausbrüchen 2009 und 2010.

Schlussfolgerungen: Das eDEWS ist eine essentielle Komponente des fragilen Gesundheitssystems im Jemen, welches sich trotz der schwierigen Sicherheits- und Versorgungslage als generell sehr hilfreich für Kontrolle von Infektionskrankheiten erwiesen hat. Es kann somit auch als Modell für die Erkennung und das Management drohenden Epidemien für weitere Ländern in Konfliktsituationen dienen, die von einer ähnlichen Situation betroffen sind. Eine substantielle Verbesserung der Gesundheitssituation wird aber erst durch eine Beendigung des Krieges im Jemen zu erreichen sein und so sollte auch eDEWS als Teil einer Friedensinitiative gesehen werden.

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7. Own publications

This study is based on an individual research project focused on assessing the surveillance system in my country (Yemen) during the conflict situation. My contribution to the following publication as first author comprised the development of the study design, data collection, data analysis and writing the drafts.

7.1 Publications in peer review journals Related to the Doctoral Research

1- Dureab F, Shibib K, Al Yousufi R, Jahn A. Yemen: Cholera outbreak and the ongoing armed conflict. Journal Infect. Dev. Ctries. 2018; 12(5):397-403. https://doi:10.3855/jidc.10129

This publication is part of the findings of objective 1 of my dissertation. It is based on the results of dissertation in chapters 3 focusing on the early detection of cholera outbreak in 2016/2017 as well part of the paper presented in chapter 1, 2 and chapter 4.

2- Dureab F, Müller O, Jahn A. Resurgence of diphtheria in Yemen due to population movement, *Journal of Travel Medicine*, 2018, tay094, https://doi.org/10.1093/jtm/tay094

This publication is part of the findings that cover objective one of my dissertation. It is focusing on the early detection of diphtheria outbreak that increases with the population movement in Yemen; it is presented in chapter 3 and 4.

3- Dureab F, Shibib K, Yé Y, Jahn A, Müller O. Cholera epidemic in Yemen. Lancet Glob Health. 2018; DOI: https://doi.org/10.1016/S2214-109X(18)30393-0

This publication presents a discussion and gives an overview on the cholera risk factors, reflecting the debate on the different hypothesis that explain the accelerating factors of this worst epidemic in the history. It is included in the discussion of this work in chapter 4.

4- Dureab F, Jahn A, Krisam J, Dureab A, Zain O, Al-Awlaqi S, Müller O. Risk factors associated with the recent cholera outbreak in Yemen: A case-control study. Epidemiology and Health 2019; DOI: https://doi.org/10.4178/epih.e2019015

This publication aimed to identify the risk factors for the recent large cholera outbreak in Yemen, the methodology is not part of my thesis. The findings are included in chapter 1 and chapter 4 of this dissertation.

5- Dureab F, Al Sakkaf M, Ismail O, Kuunibe N, Krisam J, Müller O, Jahn A. Diphtheria outbreak in Yemen: the impact of conflict on a fragile health system. BMC Conflict and Health. 2019. https://doi.org/10.1186/s13031-019-0204-2

This publication is part of my results (chapter 3), it comes under the objective 1 in my dissertation, which explains in detail the diphtheria outbreak in Yemen and reflects the impact of war on the health system. It is also reflected in chapters 1 and 4 of this work.

6- Dureab F, Müller O, Ismail O, Jahn A. Cholera Outbreak in Yemen: Timeliness of Reporting and Response in the National Electronic Disease Early Warning System. Acta Inform Med. 2019 JUN 27(2): 85-88; https://doi.org/10.5455/aim.2019.27.85-88

This publication is covered under objective 2 and 3 of my dissertation; it is based on the quantitative findings that presented in chapter 3. The methodology of this paper explains part of my general methodology of this dissertation. It is also reflected in chapters 1 and 4 of my dissertation.

7- Dureab F, Ismail O, Alfalahi E, Al Marhali L, AlJawaldeh A, Nuri N, Safary E, and Jahn A. An overview on the acute malnutrition among children and food insecurity during the conflict in Yemen. Children 2019, 6(6), 77; https://doi.org/10.3390/children6060077

This publication is presented in chapter 1 of my dissertation, it reflects the current situation of malnutrition in Yemen which is one of the underlining cause of increasing morbidity in Yemen. It is mentioned as well in chapter 4.

7.2 Published Peer Reviewed Conference Abstracts

8- Dureab F, Shabib K, Jahn A. The association of cholera outbreak with conflict-related factors in Yemen. Trop Med Int. Health. 2017;22 (Supplement 1):53. Conference paper (ECTMIH 10, Antwerp).

9- Dureab F, Beiersmann C, Jahn A. Assessment of Data Quality of the electronic Disease Early Warning System for infectious diseases in Yemen. ECTMIH 11, Liverpool 16-20 September 2019 (Accepted).

7.3 Additional Publications During the Doctoral Study Period

10- Nuri N, Sarker M, Ahmed H, Hossain M, Dureab F, Jahn A. Quality of the Mental Health Information System in a Specialized Mental Hospital in Bangladesh. ACTA INFORM MED. 2018 SEPT 26(3):168-172. doi:10.5455/aim.2018.26.168-172

11- Nuri N, Sarker M, Ahmed H, Hossain M, Dureab F, Agbozo F, Jahn A. Overall Care-Seeking Pattern and Gender Disparity at a Specialized Mental Hospital in Bangladesh. Mater Sociomed. 2019 Mar; 31(1): 35-39. doi:10.5455/msm.2019.31.35-39

7.4 Published Non-Peer Reviewed Papers

12- Fekri Dureab. Ayoub Aljawaldeh, Latifah Ali. Building capacity in inpatient treatment of severe acute malnutrition in Yemen, Field Exchange 55, July 2017

7.5 Publications under Review

13- Assessment of the performance of the electronic Disease Early Warning System in Yemen.

This paper is still under review, it is listed under objective 2 in this work, mixed methods presented in chapter 2 and the findings of this paper mainly reflected in chapters 3 and 4.

8. Annexes

8.1 Annex I: Case Definitions

The list of some communicable diseases in eDEWS program with the cases definitions used and relevant thresholds of alerts and outbreaks.

Disease/ Condition	Case Definition	Alert Threshold	Outbreak Threshold
Acute Upper Respiratory Infection	Any person with acute onset of cough with mild fever, runny nose, pharyngitis, laryngitis, otitis, tonsillitis, or bronchitis, with normal breathing and without any danger signs.	2 times the mean number of cases of the previous 3 weeks for a given location	Not specified until infectious agent is identified
Acute Lower Respiratory Infection (pneumonia, bronchiolitis, epiglottitis, croup & severe pneumonia)	**Children < 5 years:** Any child presenting with cough or difficulty breathing and any one of the following: fast breathing (Less than 2 months: > 60 breaths/min; 2 months to 12 months: >50 breaths/min; 12 months to 5 years: > 40 breaths/min), or unable to drink or breastfeed, difficulty to awaken, fits / convulsions, cyanosis, lower chest wall in-drawing or stridor in calm child. **5 years or over:** Any person presenting with acute onset of cough, fever, and difficulty in breathing or chest pain which increases with breathing.	2 times the mean number of cases of the previous 3 weeks for a given location	Cluster of cases in a single location above the alert threshold
Acute Diarrhea (non-cholera)	Any person with acute diarrhea (passage of 3 or more loose stools in the past 24 hours) with or without dehydration, and which is not due to bloody diarrhea or suspected cholera.	2 times the mean number of cases of the previous 3	Cluster of cases in a single location above the alert threshold

		weeks for a given location	
AWD / suspected Cholera	Any person aged five years or more with severe dehydration or death from acute watery diarrhea.	1 AWD case	One lab confirmed cholera case, or a cluster of 6 or more AWD in a single locality
Bloody Diarrhea	Any person having acute diarrhea with visible blood in the stool.	3 or more cases in one location	Cluster of 6 or more cases in one location
Suspected Dengue Fever (DF)	Any person having acute onset of fever (> 38^0C) for 2-10 days with at least two of the following manifestations: severe headache, retro-orbital pain, myalgia/ arthralgia, positive tourniquet test.	3 or more cases in one location	Cluster of 6 or more cases in one location + one lab confirmed DF case
Viral Hemorrhagic Fever (VHF: either DHF or CCHF / Chicken Guinea)	Any person having acute onset of fever (> 38^0C) for 2-10 days and platelets <100,000 cells/mm3, with at least one of the following: hemorrhagic or purpuric rash, epistaxis, hematemesis, hemoptysis, blood in stools, other hemorrhagic symptoms and no known predisposing host factors for hemorrhagic manifestations.	1 VHF case	One lab confirmed case, if CCHF. 6 or more cases in one location + one lab confirmed case, if DHF.
Acute viral hepatitis (A & E) / acute jaundice syndrome	Any person having acute onset of jaundice (yellow coloration of skin and sclera, dark urine) and severe illness (fatigue, nausea, vomiting, and abdominal pain) and absence of any known precipitating factors.	3 or more cases in one location	Cluster of 6 or more cases in one location.

Suspected Malaria	Any person having had recent fever (>38°C in the last 48 hours) with or without other symptoms (chills, headache, body aches, nausea, vomiting, diarrhea), in whom other causes of fever have been excluded. NB severe malaria may also include signs and symptoms related to organ failure.	2 times the mean number of cases of the previous 3 weeks for a given location	In endemic area, slide positivity rate above 50% or falciparum rate above 40%; In non-endemic area, evidence of indigenous transmission of falciparum.
Suspected Measles	Any person with fever and maculopapular rash and one of the following: cough, coryza or conjunctivitis or Any person in whom a clinician suspects measles infection.	1 suspected case	Cluster of 3 or more clinical cases in a single location over a 30-day time period with at least one lab confirmed case
Suspected Meningococcal Meningitis/ Neisseria Meningitis	Any person having sudden onset of fever (>38°C axillary) and one or more of the following: -Neck stiffness -Altered consciousness -Other meningeal sign or petechial or purpura rash -In infants under one year of age, suspect meningitis when fever is accompanied by bulging fontanelle.	3 or more suspected cases in one location or one confirmed cases of N. meningitides	2 or more lab confirmed meningococcal meningitis cases from a single location
Cutaneous Leishmaniosis	Any person having skin lesions on the face, neck, arms, and legs (exposed body parts), which began as nodules	1 case outside endemic area,	Cluster of 6 or more cases in one location

	and turned into skin ulcers, eventually healing but leaving a depressed scar.	3 cases in endemic area.	
Suspected Pertussis	Any person with a cough lasting at least 2 weeks with one of the following: Paroxysms of coughing; or inspiratory "whoop"; or post-tussive vomiting AND without other apparent cause	1 suspected case	5 cases in one locality
Probable Diphtheria	A probable case is any person with illness characterized by an adherent membrane on the tonsils, pharynx and/or nose and any one of the following: laryngitis, pharyngitis or tonsillitis.	One probable case	One confirmed case who has been lab confirmed (culture or linked to a laboratory confirmed case
Neonatal tetanus (NNT)	**Suspected case:** Any neonatal death between 3 and 28 days of age in which the cause of death is unknown or any neonate reported as having suffered from neonatal tetanus between 3 and 28 days of age and not investigated. **Confirmed case:** Any neonate with normal ability to suck and cry during the first 2 days of life, and who between 3 and 28 days of age cannot suck normally and becomes stiff or has convulsions or both. Hospital-reported cases are considered confirmed.	One case requires investigation for safe birth practices and immunization	NA

Suspected Schistosomiasis	Urinary schistosomiasis: in endemic areas, Visible hematuria or positive reagent strip for hematuria, or with eggs of S. haematobium in urine (confirmed case) Intestinal schistosomiasis: in endemic areas, non-specific abdominal symptoms, blood in stool, hepatosplenomegaly (suspected case), or presence of eggs in stools (confirmed case).	Five cases	Not applicable

Source: eDEWS program in MOPHP Yemen

8.2 Annex II: In-depth Interview Guideline

8.2.1: In-depth Interview Guideline for Health Workers

A-Knowledge

1-Could you tell by which different means you can detect outbreaks in your area?

PROBE:

-What do you think staff at this clinic can do to find out whether an outbreak has started?

2-What do you know about eDEWS? Probe its purpose, components and function events in the system, using case definition in diagnosis

3-What do you think the similarity and difference between eDEWS and other national surveillance system? Probe integrated surveillance and vertical surveillance

B-Practice:

1-How do you contribute in eDEWS in your position? Probe diagnoses and write in the record correctly, collecting data, data entry, and time spend in these tasks of eDEWS

2-If there is a new outbreak or new cases of infectious disease, are these diagnosed by you? What are the steps that should be taken by you as health worker?

3-What problems do you face during your daily work in eDEWS?

4-How can you describe the link or relationship between health facilities and surveillance departments in the district, governorate, MOH and WHO? Probe support, feedback, supportive field visit, training.

C-Attitudes

1-What is your opinion on eDEWS and its administrative staff? Probe: Pro and cons, Satisfied or not and why? You will continue working in eDEWS or not, and why?

2-Lessons learned from working with eDEWS and what do you suggest improving the program?

8.2.2: In-depth Interview Guideline for Workers in NGOs

To assess the extent to which emergency alerts of the eDEWS result in a public health action in the current situation. (target people who work in NGOs in Yemen)

1-Do you receive data from eDEWS? Do you use data in your projects? How, Why and Where? How often do you receive eDEWS data?

2-To what extent the data is useful in your work?

3-What is your opinion about eDEWS? Method of collecting data, analysis and dissemination

4-Do you receive any alerts by SMS, is it useful? What is your opinion about timeliness in case detection and response?

5-How do you react to any new outbreak in the region? How do you know, what the first action from your side and the coordination between all partners?

6-How can NGOs contribute to eDEWS? Is there any suggestion to improve the eDEWS?

8.3 Annex III: Information Sheet

My name is Fekri Ali Dureab, I would like to invite you to take part in our research study titled "The Usefulness of the Electronic Disease Early Warning System (eDEWS) in The Humanitarian Crisis of Yemen".

The study is conducted by a doctoral student from the Ruprecht Karl University of Heidelberg in Germany. The information will be useful to improve the performance of the surveillance system to reduce the morbidity and mortality in the community.

Procedures

If you agree to participate in this research, I will conduct the research at the time of your choice. The questions will involve the eDEWS including your knowledge and experience with the system. The interview should last no more than one hour. We would appreciate if you could tell us the best time to visit or call you.

Benefits

There is no direct benefit for you from taking part in this study. It is hoped that the research study will be beneficial to improving the national health system

Risks/discomforts

You are free to decline any questions you do not wish to answer or stop the interview at any time. As with all research there is a chance that confidentiality could be compromised; however, we are taking precautions to minimize this risk.

Confidentiality

Your study data will be handled as confidential as possible according to the §4 Federal Data Protection Act (Bundesdatenschutzgesetz = BDSG). If results of this study are published or presented, individual names and other personally identifiable information will not be used. Your phone number or other details will not be shared by anyone else outside the research project.

To minimize the risks to confidentiality, you will be given a code so that nothing you share in the study will be linked to identifying information. All study records will be stored on a password protected, encrypted computer.

When the research is completed, I will retain these records for up to 5 years after the study is over. The same measures above will be taken to protect confidentiality of this study data.

Compensation

You will not be paid for taking part in this study. In case you will be invited to individual meeting or any other activity (such as Focus Group Discussion) away of your duty station, refreshments and transportation fee will be provided during the interview.

Rights

Participation in research is completely voluntary. You are free to decline to take part in the project. You can decline to answer any questions and you can stop taking part in the project at any time. Whether or not you choose to participate in the research and whether or not you choose to answer question or continue participating in the project, there will be no penalty to you or loss of benefits to which you are otherwise entitled. You are free also to ask your data to be withdrawn from the study when you withdraw from the study.

If you have any questions about this research, please feel free to contact me.

German number: 004915730660293, or fekridureab@yahoo.com, fekri.dureab@uni-heidelberg.de

If you have any questions about your rights or treatment as a research participant in this study, please contact the information and research department at the ministry of health.

8.4 Annex IV: Consent Form

I have been invited to participate in the study titled "The Usefulness of the Electronic Disease Early Warning System (eDEWS) in The Humanitarian Crisis of Yemen". I understand during this interview I will be interviewed on my opinion, knowledge, and experiences of working with eDEWS.

I understand that the information will be recorded, I acknowledge they might be chances of participating in individual meeting or any activity such as focus group discussion if needed. I am aware of the procedure of the study, the risks, my rights and my right to confidentiality. I am also aware there is no direct benefit for me to participate in this study as well there will not be any compensation for my time except for the refreshments and transportation fee that will be provided, if I am invited to a meeting that requires me to move from my place of work. I have been given a chance to ask questions and ask for clarifications in places if I did not understand. I have also been given contacts on where I can report in case, I feel my rights have been violated.

The information I agree to share with the interviewer is to be used solely for educational and academic purposes. In terms of privacy issues, this is to be highlighted according to the §4 Federal Data Protection Act (Bundesdatenschutzgesetz = BDSG). I was informed about it and I give consent and I give my consent to the fact that my data which will be collected in the course of the study, can be recorded, evaluated and, if needed, passed on in an anonymous form/under a pseudonym. Third parties do not get access to my personal files, though. In case the study is published, my name will not appear in this publication. I therefore consent to voluntarily participate in this study and I understand that I have the right to withdraw from the interview at any time.

Name of the interviewee

Date

Signature

Name of the interviewer

Date

Signature

9. Curriculum Vitae

Fekri Ali Salem Dureab, MD, MSc.IH

Place of Birth	Aden, Yemen
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EDUCATION

Oct.2016- Now	Doctorate-Student, Public Health, Heidelberg University
2010 - 2011	Master of Science in International Health, Heidelberg University
Jan 2008	Part one in Community Medicine from Arabic Board for Medical Specialization.
2006 – 2007	Diploma of Community Medicine from Yemeni Board for Medical Specialization.
1998 – 2004	Bachelor of General Medicine & Surgery (M.B.Ch.B.) from University of Aden, Faculty of Medicine & Health Sciences.

LANGUAGES

Arabic	Mother Tongue
English	Very Good in Written and Spoken
German	Fair

EXPERIENCE

Job Title	**Coordinator** of Yemen case study under The Lancet Commission on Synergies between universal health coverage, global health security and health promotion.
Work Place	Heidelberg, Germany
Work Period	March 2019 – present
Job Title	**Nutrition Consultant**
Work Place	WHO Somalia
Work Period	3-Aug – 12-Dec 2017

Job Title	**Nutrition & NCD Officer**
Work Place	World Health Organization (WHO), Yemen
Work Period	Jun 2014 – Jun 2016

Job Title	**Nutrition Coordinator in Emergency / EHA Officer / eDEWS Project manager**
Work Place	World Health Organization (WHO), Yemen
Work Period	April 2012 – May 2014

Job Title	**Intern (Maternal, Newborn, Child and Adolescent Health)**
Work Place	World Health Organization (WHO), Geneva, Switzerland
Work Period	11 Nov 2011 – 3 Feb 2012

Job Title	**Technical Officer of Community Based Reproductive Health Promotion.**
Work Place	YG-RHP, GTZ.
Work Period	July 2008 up to May 2010.

Job Title	**IMCI Technical Officer**
Work Place	Child health department (MoPHP).
Work Period	April 2007 up to June 2008.

Job Title	**Medical General Practitioner.**
Work Place	Sheba primary health care polyclinic Sana'a city.
Work Period	Jul. 2005 – Jan 2007.

WORKSHOPS, MEETINGs and CONFERENCES

1. Expert meeting on Using climate and weather information for predicting and preparing for cholera and VBD June 2019, WHO, Geneva

2. 4th Congress on Hidden Hunger, March 2019, Stuttgart, Germany

3. 9th World Health Summit, October 2018, Berlin, Germany

4. Expert Strategic Planning Meeting: Research and Action on Health and War/ Armed Conflict, The Lancet commission on Syria. June 2018 Beirut.

5. 10th European Congress on Tropical Medicine and International Health, October. 2017 Antwerp, Belgium.

6. GTP Annual Conference, The German Society for Tropical Pediatrics and International Child Health January 2017, Heidelberg, Germany.

ACADEMIC EXPERIENCE

Thesis Supervision

1. Association of Cholera and Malnutrition among Children under Five Years Old in Yemen, Hussein Zaid Ahmed, Master of Science in International Health, 2018. Heidelberg Institute of Global Health. Thesis supervisor: Prof. Dr. Albrecht Jahn, thesis co- supervisor: Fekri Dureab.
2. The Impact of Health System Fragmentation on The Implementation of National Health Policies in Yemen, Taha Hussein Ben Hendad, Master of Science in International Health, 2019 (ongoing). Heidelberg Institute of Global Health. Thesis supervisor: Prof. Dr. Albrecht Jahn, thesis co-supervisor: Fekri Dureab.
3. Implementation of International health regulation during the recent cholera outbreak in Yemen, Hanan Noman, Master of Science in International Health, 2019 (ongoing). Heidelberg Institute of Global Health. Thesis supervisor: Prof. Dr. Albrecht Jahn, thesis co- supervisor: Fekri Dureab.

The Lancet Commissions

1. Member of the Lancet commission on Syria (Health in Conflict 2017).
2. Member of the Lancet commission on Synergies between universal health coverage, global health security and health promotion, 2018

Awards Received

1- Awarded German Academic Change Scholarship (DAAD) for Master in International Health from Heidelberg University 2010.

2- Award an internship position at WHO Geneva to work as part of the MNCH department to update IMCI computerized version and prepare the data for the countdown report 2012.

3- Awarded German Academic Change Scholarship (DAAD) for PhD in Public Health from Heidelberg University 2016-2019.

Acknowledgement Received

1. Acknowledgement in the countdown report 2012 From UNCEF/Statistics and Monitoring Section for preparation of country profiles and inputs to the health systems and health policies analysis, as part of WHO, Geneva.

2. Acknowledgement certificate from WHO country office 2016 for my successful contribution in humanitarian aid action during the war in Yemen.

COMPUTER SKILLS

- Microsoft Word, Excel, Power point, etc.
- Work on SPSS, STATA, NVivo and I have knowledge about EPi.INFO.

10. Acknowledgements

First of all, I am very appreciative and thankful to Allah, most beneficial and the sincerest entity to me, which is the one and only the Almighty 'Allah'. The favors of Allah are limitless and countless. I would like to acknowledge with gratefulness my scholarship sponsor DAAD for supporting me to participate in this course.

My deep wishes and thanks go to my tutor Prof. Dr. Albrecht Jahn for all his support, critical review and friendly dealing. I attribute the level of my dissertation to his support and effort; without his support this study will not present in this form. I would like to give my special thanks to Prof Dr. Olaf Müller for his guidance, support and respect. He has provided much advice and insight throughout my publications. I want also to extend my thanks to all colleagues (Bergheimer group) and other colleagues in the Institute for their support and cooperation.

I would give my thanks to the interviewers and those people in the MoPHP and WHO who helped and supported me to collect data. I also want to thank all interviewees who participated in this study and responded to my questions. I also thank Dr. Reema Al-Yousufy for her encouragement and support. I expressed my gratitude to Miklos Kedves for his time for proof read and valuable feedback.

My indebted expression goes to all my friends, colleagues who encouraged me during my work in Heidelberg. I have been blessed with a friendly and cheerful group. I expressed my gratitude and love to my family especially my parents who supported and kept me motivated to do this work. Finally, I would like to extend my sincere love and thank to my wife Lina, my daughter Laila and my son Ahmed for their patience and constant encouragement that motivated me to complete this work.

11. Affidavit

I hereby confirm that my thesis entitled “The usefulness of the electronic Disease Early Warning System (eDEWS) in the humanitarian crisis of Yemenis” the result of my own work. I did not receive any help or support from commercial consultants. All sources and / or materials applied are listed and specified in the thesis.

Furthermore, I confirm that this thesis has not yet been submitted as part of another examination process neither in identical nor in similar form.

Heidelberg

25.06.2019

Fekri Dureab