An Investigation of the Public Health Informatics Research and Practice in the Past Fifteen Years from 2000 to 2014: A Scoping Review in MEDLINE

by

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Author’s Declaration

I hereby declare that this is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Objective: To examine the extent and nature of existing Public Health Informatics (PHI) studies in the past 15 years on MEDLINE.

Methods: This thesis adopted the scientific scoping review methodology recommended by Arksey and O'Malley in 2005. It proceeded with the five main stages, which were: Stage I - identifying the research question; Stage II - identifying relevant studies; Stage III - study selection; Stage IV - charting the data; and Stage V - collating summarizing and reporting the results. Each methodological stage was carried out with the joint collaboration with the academic supervisor and a final result and conclusion were set forth.

Results: The results of this study captured a total number of 486 articles in MEDLINE focused in PHI. Out of them, a majority belonged to the USA followed by the UK, Australia and Canada. Only about one fifth of the articles were from the rest of the world. Further, About 60% of the articles represented infectious disease monitoring, outbreak detection, and bio-terrorism surveillance. Furthermore, about 10% belonged to chronic disease monitoring; whereas public health policy system and research represented 40% of the total articles. The most frequently used information technology were electronic registry, website, and GIS. In contrast, mass media and mobile phones were among the least used technologies.

Conclusion: Despite multiple research and discussions conducted in the past 15 years (starting from 2000), the PHI system requires further improvements in the application of modern PHT such as wireless devices, wearable devices, remote sensors, remote/ cloud computing etc. on various domains of PH, which were scarcely discussed or used in the available literature.

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List of abbreviations

ARI	:	Acute respiratory illness/infection
AEGIS	:	Automated epidemiological geotemporal integrated system
A and E	:	Accident and emergency
ARTSSN	:	Alberta real time syndromic surveillance network
BARD	:	Bayesian aerosol release detector
CDC	:	Center for Disease Control
COACH	:	Canada's Health Informatics Association
DP algorithm	:	Detection prediction algorithm
ED	:	Emergency department
CEN	:	European Committee for Standardization (CEN)
EHR	:	Electronic health record
EMR	:	Electronic medical record
EMS	:	Emergency medical services
ENPs	:	Engineered Nano-particles
EPHT	:	Environmental public health tracking
EUPHIS	:	European Public Health Information System
GIS	:	Geographic Information System
GI syndrome	:	Gastro enteritis syndrome
GPHIN	:	Global Public Health Intelligence Network
HAN	:	Health Alert Network
HDF	:	Health level-7 development framework

HI	:	Health Informatics
HIE	:	Health Information Exchange
HIPPA	:	Health insurance portability and accountability act
HIS	:	Health Information System
HL7	:	Health level 7
HE	:	Humanitarian emergencies
ICD-9-CM	:	International classification of diseases, ninth revision, Clinical modification
ILI	:	Influenza like illness
IHR	:	International health regulation
IT/ITs	:	Information technology/ Information technologies
LRN	:	Laboratory and Response Network
LMIC	:	Low and middle income countries
NEDSS	:	National Electronic Disease Surveillance System
NHIS	:	National Health Information System
NLP	:	Natural Language Processing
NRDM	:	National Retail Data Monitor
MeSH	:	Medical subject headings
OTC	:	Over the counter
PH	:	Public Health
PHI	:	Public Health Informatics
RCTs	:	Randomized Control Trials
RODS	:	Real time outbreak detection algorithms

SOA	:	Service oriented architecture
SS	:	Syndromic surveillance
Tiab	:	Title/abstract
WHO	:	World health organization
WSARE	:	What’ strange about recent events

Chapter 1: Introduction and Overview

Public health informatics (PHI) is an important discipline of health informatics that integrates information technology and public health (Yasnoff et al., 2001). In 1995, PHI was first introduced by Friede and colleagues as an important and distinct discipline (Friede, Blum, & McDonald, 1995). Friede and colleagues stated that, to improve the efficiency and effectiveness of public health practice, as well as to make information-driven decisions, public health practitioners and researchers must be able to gather information in a timely and reliable manner. Also, public health practitioners and researchers require better tools to analyze and disseminate new knowledge. They provided a definition of PHI as "the science of applying information-age technology to serve the specialized needs of public health" (Friede, Blum, & McDonald, 1995). In 2000, Yasnoff and colleagues defined PHI as an approach that systematically applies information, computer science and technological devices to enhance the research and practice of public health (Yasnoff, O'Carroll, Koo, Linkins, & Kilbourne, 2000)

After the recognition by Friede et al. in 1995, one of the very first attempts to shape and advance the field of PHI was made by American Medical Informatics Association (AMIA). The AMIA is an organization that governs the structure and function of Health Informatics (HI) in the United States. The first national AMIA conference was held in 2001. Although the main focus of the conference was on medical informatics, it also put forward a national agenda for future advancements in PHI. The agenda covered the following topics: funding and governance; standards and vocabulary; research, evaluation, and best practices; architecture and infrastructure; privacy, confidentiality, security; and training and workforce. In addition, the conference put forward 74 recommendations with two major themes that stated the need for a multi-sectoral coordination among the stakeholders as well as the need for informatics training for all public health workers (Yasnoff et al., 2001).

Similarly, Canada's Health Informatics Association (COACH) is the leading Canadian organization responsible for advocating and promoting HI practices within the Canadian health care system. Established in 1975, COACH currently has over 1800 members across the nation. These members have diverse backgrounds representing medical, health care, allied health professionals and health administrators. Indeed, COACH is the apex body for HI in Canada. Although the main focus areas of COACH have been observed in telehealth, eHealth and clinical informatics for improving the Canadian health care system, no significant impetus has been initiated for the advancement of the field of PHI (COACH-National Office).

Following the first AMIA conference, advances in PHI have changed health promotion and disease prevention strategies in a meaningful way. Examples of such strategies include application of computers to collection and dissemination of information to the general public (Dixon, Gamache, & Grannis, 2013), application of Internet-based software for disease surveillance (Robertson & Nelson, 2010), and Geographic Information System (GIS) for disease mapping (Ricketts, 2003). As a result of such strategies, progress in several areas of public health practice have been observed, including: outbreak investigation (Mukhi et al., 2011), infectious disease control (Loschen et al., 2010), chronic diseases' risk mapping with GIS (Gwede et al., 2010), coordination between hospitals and public health units (Downs, Anand, Sheley, & Grannis, 2011; Trebatoski, Davies, Revere, & Dobbs, 2010).

Several major public health threats in the early 2000s contributed to rapid development of the practice of PHI. In particular, events like the September 11th terrorist attacks in 2001

(Massoudi et al., 2012), followed by the bioterrorist attack of anthrax virus in the same year (Centers for Disease Control and Prevention, 2001), and the H1N1 pandemic in 2009 (Loschen et al., 2010) have prompted public health administrators and workers to further realize the need for rapid information sharing and timely action.

After the September 11 terrorist attacks, the need for a mechanism that could gather real time information was experienced by public health leaders. Later in 2001, the anthrax attack delivered through mail received by senator Daschle's office contributed to several illnesses and deaths. As a response, in 2003, the Centers for Disease Control and Prevention (CDC), the national public health organization of the USA, prepared a web based rapid reporting mechanism called BioSense (Khabbaz, 2014)**.** BioSense integrates data from hundreds of local community clinics and other major hospitals across the USA. It facilitates a real time information exchange with the CDC for better responses in public health emergencies such as bioterrorism attacks and disease outbreaks (Loonsk, 2004). Similarly, in spring 2009, the World Health Organization (WHO) declared an H1N1 virus pandemic in many countries across the world including in North American countries (Canadian Institute for Health Information, 2010). As a result, in the USA a secure web based application called InfoShare was created for public information sharing. After post-use surveys, this application proved to be popular among the majority of the public health users to rapidly share and receive useful information. This application was also found to be very helpful to individual jurisdictions, in order to promptly receive valuable information. Eventually, InfoShare was adopted by other jurisdictions after the 2009 H1N1 outbreak (Loschen et al., 2010). Similarly, in Canada, a post-pandemic survey recommended establishing a data-sharing protocol that could be instrumental in maintaining timely communication among various levels of governmental and non-governmental health care providers, clinicians and public health workers (Canadian Institute for Health Information, 2010). In summary, the public health consequences of these events have supported and accelerated research and practice of PHI.

This chapter has presented a few recent developments and activities germane to PHI. However, for a better understanding of the field of PHI, there was an immediate need for a rigorous survey of the extent and nature of previous studies conducted in this field. Thus, this thesis work is an endeavor to conduct a scoping review to find out the existing PHI research found in MEDLINE-PubMed in the past fifteen years spanning from 2000 to 2015.

This thesis is comprised of 10 chapters including this first chapter. Chapters 2 and 3 define and explain the terminology used throughout this thesis. Specifically, Chapter 2 sheds light on the scope of public health and that of informatics, leading to the definition of PHI to be followed in the thesis work. The main aim of Chapter 2 is to develop an etymological definition and scope of PHI. Chapter 3 discusses the basic concepts of different types of review studies in order to differentiate a scoping review from the other types. Further, Chapter 4 describes the MEDLINE database and PubMed search tool, as well as the rationale for selecting only this literature database for this thesis work. Chapter 5 presents and discusses existing review studies related to PHI. This literature search confirmed the current absence of scoping reviews of PHI. Chapter 6 provides the rationale and objectives of this thesis, and Chapter 7 describes the research methodology applied throughout this thesis work. The methodological approach applied in this thesis work has been adapted from the scoping study methodology developed by Arksey and O'Malley in 2005 (Arksey & O'Malley, 2005). Chapter 8 and 9 present the results and discussion of this thesis respectively. Finally, the conclusion, policy implications and future recommendations are presented in Chapters 10.

Chapter 2: Public Health Informatics

2.1 The Scope of Public Health

In 1920, Dr. Winslow defined public health as an art and science of disease prevention and health promotion activity of a population through concerted efforts (Winslow, 1920). These efforts entail multidisciplinary approaches that include social science, politics, engineering, environmental science, biostatistics, and many more disciplines that can collectively impact the health and wellbeing of an entire population. Hence, public health deals with populations rather than specific individuals. According to the WHO, the three main activities of public health are: 1) monitoring and assessing the health status of a community to identify health priorities and problems; 2) formulating policies to solve local and national health problems; and 3) giving people access to disease prevention and health promotion services and activities (World Health Organization, 2014). The major themes of PH can be categorized in different categories based on the functions and nature of the field. For example, in this study, all PH themes were categorized under 11 domains which are: infectious/communicable disease monitoring, outbreak detection, bioterrorism surveillance, emergency response, non-communicable/chronic disease monitoring, injury surveillance, natural disaster management, environmental health, occupational health hazard, public health awareness, public health policy/system and research. These domains are defined in the section '7.2.3 Charting the data'. These were categorized based on the nature of the articles found on the available literature.

Further, the word "medicine" was originally derived from the Latin word "medicina" which means 'the art of healing' (Harper, 2014). Medicine refers to the science of disease diagnosis, treatment and prevention by health care practitioners to cure illness. A distinction between public health and medicine is that public health deals with a group of people or a whole community to prevent a disease and promote healthy conditions, whereas medicine deals with ill individuals to cure their health problems after being infected by a disease. Examples of public health activities include chlorination of public drinking water supply, fluoridation of water supply as well as of tooth pastes, iodine fortification of edible salt, running health awareness campaigns through mass media, distribution of condoms to prevent sexually transmitted diseases (STDs), and X-ray screening for early detection of tuberculosis. In contrast, diagnosing and treating patients with tuberculosis, STD, dental caries or other disease conditions as well as alleviating their disease conditions are within the scope of medicine.

2.2 The Scope of Informatics

While the Oxford Medical Dictionary defines informatics as "the science of processing data for storage and retrieval; information science" (Oxford University Press, 2014), there have been many discussions and publications in the literature regarding the definition of informatics (Hersh, 2009). For example, Glaser defined informatics as a cross-training domain between basic sciences (for instance, computer science, cognitive science, etc.) and an application domain of a professional practice (for instance, public health, clinical health, etc.) (Friedman, 2013). As a result, when a basic science is linked with a health domain, HI is created; and the same school of thought extends to medical, public health and nursing informatics. Friedman further described, that cross-training must imply that the people assisted by information technology will have enhanced efficiency than without the technology (Friedman, 2013). In addition, Hersh delineated the definition of informatics more simplistically as a discipline that is dedicated to the collection, storage and application of information in a specific domain or field of study (Hersh, 2009). Hersh further clarified informatics to be more about information than technology, where technology acts only as a tool to extract information and obtain findings (Hersh, 2009). In summary, informatics encompasses both technology and at least one domain of professional practice to collect and collate data as well as to produce useful information for better results in that domain.

Finally, the fundamental scope of informatics is its focus on the process (e.g., human reasoning, digital computation), communication (e.g., computer networking, human computer interface) and representation (e.g., digital records, images) of information involving various organizations, systems and people (Fourman, 2002). Based on this fundamental scope of informatics defined by Fourman, the major themes of the informatics related with public health can be categorized as information technologies (IT) discussed/used and the informatics concept applied. The IT categories are websites, natural language processing (NLP), statistical/analytical software, detection prediction (DP) algorithm, automated speech processing, electronic medical record (EMR)/electronic health record (EHR)/electronic registry, e-mail, geographic information system (GIS), mass media, mobile phones, and telephone-landline. Similarly, the informatics concepts are data retrieval, data collection, data analytics, data security, data storage, data transmission/ communication, interoperability, information sharing, and knowledge management. These domains are defined in section '7.2.3 charting the data'.

2.3 The Definition of Public Health Informatics

With the scopes of public health and informatics established in the previous sections, PHI can be defined as the application of informatics in the field of public health. In other words, PHI can be defined as a system that applies the modern technologies both tangible (hardware) and intangible (software) to collect data, produce meaningful information, and generate knowledge that can be used to prevent diseases, promote healthy practices, and create health awareness among the general population. The advancements in the field of information technologies (ITs) have made it challenging to specify the role of ITs in a certain areas of human life. In fact, there are no aspects (e.g., physical, social, or psychological) of human society that are not affected by ITs that have been augmented to determine a healthy practice among the general population. The ITs such as smart/mobile phones, portable tablets/IPads, wearable sensors, internet, and website etc. are enabling people to access appropriate information at any time or day.

For the purpose of this thesis work, only the studies that involve both public health and informatics have been included in the analysis. Studies that discuss public health issues but do not utilize informatics tools, or ones that apply informatics to non-public health problems will not be included (described in Chapter 7). Moreover, studies that primarily focus on medical issues or clinical practice will not be included in this study.

Chapter 3: Article Types

Various types of review methodologies and research articles are available for analysis of scientific literature. Some of these studies are conducted systematically to cover a wide range of publications. In contrast, others are conducted to assess particular programs or activities. A description of methodologies applied in different review studies can help understand the basic differences among the different types of review studies.

For the purpose of this thesis, articles have been classified into the following categories:

- Narrative literature review /narrative summary
- Empirical literature review
- Meta-analysis
- Systematic reviews
- Scoping reviews
- Other reviews
- Editorials
- Qualitative study
- Quantitative study
- Mixed study

3.1 Narrative literature review / Narrative summary

This traditional type of review approach is conducted to find, order and chronicle the available literature of a specific field to produce a final account with logical interpretation (Dixon-Woods et al., 2006; Kastner et al., 2012). This type of review focuses on presenting and summarizing the quantitative part of the evidence with a narrative description. However, it can also integrate both qualitative and quantitative evidence (Dixon-Woods et al., 2006; Kastner et al., 2012). These narrative reviews develop and advance new methodologies, leading to exploration of important topics that can ultimately inform policy makers about important changes in the field. (Rumrill, Fitzgerald, & Merchant, 2010). Narrative literature reviews are also useful in identifying issues that need to be investigated by further application of empirical reviews (Rumrill et al., 2010).

3.2 Empirical literature review

Unlike the narrative literature review that is conducted to summarize the existing literature with narrative description, the empirical literature reviews are conducted to summarize literature in terms of quantifiable measurements and descriptive statistics (Rumrill et al., 2010). In other words, this type of review selects, codifies and presents a number of articles in terms of the frequency of methodological frameworks, themes, dates, places and author information (Rumrill et al., 2010). An example empirical review is the review by Araujo and colleagues in which the authors retrieved all publications published in the field of PHI (in MEDLINE) from 1980 to 2006. The authors classified the articles into three time periods, (1980–1995), (1996–2000) and (2001–2006) groups, and tallied the number of publications in those specific years. The author tried to explain that the number of publications were proliferating as the years were proceeding ahead (Araujo et al., 2009). This study only accounted for the total number of publications in specific years and was not an attempt to scope the field of PHI.

3.3 Meta-analysis

While empirical reviews are conducted to quantify trends in literature, meta-analysis applies statistical methodologies for quantitative comparisons and amalgamation of results from different studies. In other words, a meta-analysis is conducted to deduce quantitative evidence from various studies by accounting for variations in research methodology, sample size, sampling technique and bias. After taking consideration of such variables of all the studies selected for meta-analysis, a statistical technique is applied for analysis. This type of study is conducted to find out the effectiveness of two or more approaches conducted to solve the same health problem (Rumrill et al., 2010).

3.4 Systematic Review

Systematic reviews represent a scientific review of literature conducted by applying a specific set of research questions and methodological framework to draw empirical evidence in a specific area (Higgins and Green, 2011). A systematic review synthesizes and analyzes available literature within a narrow range of well-defined research questions (Arksey & O'Malley, 2005). These kinds of studies are conducted to assess the depth and quality of evidence and to draw aggregate findings. Although a large number of available studies may be included initially, only a small percentage of them are often included in the final analysis. A known shortcoming of systematic reviews is that the rest of the literature that is excluded in the final analysis may be hidden from publication (Arksey & O'Malley, 2005).

3.5 Scoping Review

Traditionally, the study methodologies described above (narrative, empirical, meta-analysis or systematics reviews) are conducted by applying systematic approaches, whereas scoping reviews are more inclined to be non-systematic in nature (Rumrill et al., 2010).

The study types mentioned above are basically conducted to find out the depth of available literature, whereas scoping reviews are mostly conducted to explore the breadth of literature (Arksey & O'Malley, 2005). Another distinction between traditional review studies and scoping reviews is that a scoping review does not analyze the quality of the studies included in the review (Rumrill et al., 2010). Furthermore, according to Davis and his colleagues scoping reviews are in general the "initial stage of investigative process which identifies the nature and range of the existing evidence and eventually help in identifying research questions and develop research proposal" (Davis, Drey, & Gould, 2009). This suggests that traditional review studies are conducted to answer a specific research question whereas scoping reviews intend to identify research questions to be investigated by full systematic studies (Rumrill et al., 2010). Arksey and O'Malley suggested a set of objectives of scoping reviews (Arksey & O'Malley, 2005). According to them, the objectives of a scoping review is: to identify the breadth and nature of existing literature; to assess whether or not a full systematic study can be conducted; and to find out gaps in the existing literature, as well as to summarize and publish the research findings.

3.6 Editorial

Editorial articles represent a writer's opinion on a specific program, service, and product or functional/non-functional entity. Generally, these are ideas or commentaries published after a creative analysis and discussion, mostly to provide feedback for specific discussion points or issues.

3.7 Qualitative studies

The published articles that followed a specific qualitative research methodology during data collection, for example interviews with open-ended questionnaire, focus group discussion, or the studies that had a formal program evaluation with in-depth analysis of the program are included as the qualitative studies. The qualitative studies presented in this thesis are mostly case studies of the given program and services.

3.8 Quantitative studies

The articles that followed quantitative research methodology, for example descriptive cross-sectional studies, and analytical studies with quantitative analysis of the given program or services are under quantitative studies.

3.9 Mixed studies

The articles that followed both the qualitative and quantitative research methodology are included as the mixed studies.

3.10 Other reviews

Other review articles include all the articles that do not fit in any of the categories stated above. The articles that fall into this category simply assessed/evaluated a given public health program, service, and information technologies without following a specific scientific research methodological framework. Such evaluations were performed to gather information and provide recommendation, if necessary, for the target subject's overall improvement (Oxford University Press, 2014).

Chapter 4: General background on MEDLINE-PubMed

This scoping review of PHI has been conducted in MEDLINE-PubMed, the world's largest biomedical library maintained by the U.S. National Library of Medicine (NLM). MEDLINE-PubMed includes approximately 5600 contemporary biomedical journals from over 80 countries around the world. In MEDLINE-PubMed, either key words or Medical Subject Heading (MeSH) terms can be used to search for articles. Published articles from 1946 to the present, originally converted from the Current List of Medical Literature (CLML), can be searched (NLM: Fact Sheet - MEDLINE®).

MEDLINE is a subset of PubMed that has a distinct capacity of searching literature using MeSH term (NLM: Fact Sheet - MEDLINE®). Other subsets include publishers-supplied citations, in-process citations, OLDMEDLINE and PUBMEDNOTMEDLINE. Publishers-supplied citations include studies recently supplied by the publishers (Bethesda, 2005) which are proceeded for further scrutiny and may or may not be included in MEDLINE. In-process citations include such literatures that are in the review process to get allocated to the MEDLINE citation list. Further, OLDMEDLINE citations include studies from 1946 to 1965, however these studies can also be accessed through MEDLINE (NLM: OLDMEDLINE Data). Finally, PUBMEDNOTMEDLINE includes those literatures that are reviewed by a review board and concluded that these journals do not meet eligibility criteria to be allocated in MEDLINE citation list, and hence allocated as PUBMEDNOTMEDLINE subset (Bethesda, 2005).

A search methodology in MEDLINE-PubMed is simple and specific. Search can be conducted using a various types of search options by selecting the 'advanced' search and 'search filter'. The advanced search option includes over twenty options, some of which are author, date, ISBN number, publisher, grant number, MeSH terms, title/abstract (Tiab) etc. Out of these various search options, the most commonly used options are MeSH terms and Tiab.

MeSH terms belong to a vocabulary thesaurus controlled by the NLM. For instance, "public health informatics" is a MeSH term. There are a total number of 27,149 MeSH terms for 2014. These MeSH terms are used to index journals from 5400 biomedical journals across the world. Since an article may span more than one topic or discipline, MeSH terms can be used to represent all the aspects to which the article is relevant. This implies that a given article can have more than one MeSH term (NLM: Fact Sheet - Medical Subject Headings). Similarly, the term 'Tiab' integrates two words -- title and abstract. Hence, with the help of the term 'Tiab', one can get access to all publications that include a specific term in title or in abstract (Canese, 2005). For example, by searching with the term "Public Health[tiab]", the result will retrieve all the publications which have the term 'public health' either in the title or in the abstract.

MEDLINE-PubMed also includes search filters. There are a total of five search filters, these are: 'article types', 'text availability', 'PubMed commons', 'publication dates' and 'species'. 'Article type' can be selected to specify the search in PubMed. The filter 'article type' includes over twenty different options to find an appropriate article type. For example, review, systematic reviews, clinical trials, randomize control trials, books, webcasts, news etc. One can select either one or a combination of those options to find the required articles.

Chapter 5: Existing Review Studies in Public Health Informatics

It is important to confirm that no scoping review similar to the one proposed for this thesis has been conducted. A literature search in MEDLINE-PubMed with the MeSH term “public health informatics” resulted in 1014 journal articles (searched on May 15, 2014). After further manual review of their titles and abstracts, many of the articles turned out to be primarily related to clinical, medical, or nursing informatics. Out of the 1014 articles, 83 were found in the review and systematic review section (‘search filter’ section described in Chapter 4) of PubMed. Among these 83 review articles, there were 19 systematic reviews, 19 other literature reviews, 4 editorials and 41 other reviews (these types of review studies were defined in Chapter 3). Furthermore, 75 of the 83 articles were written in English. This literature search concluded that there is currently no scoping review of PHI in MEDLINE.

Additionally, while searching for scoping review articles in MEDLINE-PubMed with more broad terms, (specifically: (Public health[MeSH] OR Health[MeSH]) AND scoping*[tiab]), it resulted in 235 scoping review articles. However, only one of those 235 scoping reviews by (Piette et al., 2012) was partially related to PHI (searched on May 15, 2014). Moreover, when searched with the crude phrase ‘review of public health informatics’ without using [MeSH] or [tiab], it resulted in 505 articles and only one of them (Archambault et al., 2012) resembled a scoping review of PHI (searched on May 15, 2014). Another search with more broad terms (specifically: informatics[tiab] AND public health[MeSH]) in MEDLINE-PubMed resulted in 349 journal articles in the review and systematic reviews section but no scoping review articles (Searched on May 15, 2014).

It is appropriate to present the two scoping reviews by Piette et al. and Archambault et al. in detail. Piette and colleagues focused on the impacts of eHealth on the health care outcomes in low- and middle-income countries (Piette et al., 2012). The main objective of the review was to "highlight the gaps in knowledge of the benefits of eHealth and identify the areas of potentially useful future research on eHealth." The review focused mainly on three domains: systems that facilitate clinical care (e.g., EMR), institutional systems (e.g., public health information and management systems, early outbreak warning and management systems), and systems that facilitate care from a distance (e.g., applications of cell phones for disease prevention and care). For these domains, their specific impacts were assessed in relation to patient outcomes, cost-effectiveness and impact in different low and middle-income countries. The authors conducted the scoping review by scanning scientific databases, reviewing reference lists and consulting with other experts. A total of 91 studies were visited for the scoping review.

At the end of the review, the author recommended future priority areas of study. The results showed that, 92% of the reviewed articles reached a positive conclusion. The most effective interventions in public health were found to be Short Message Service (SMS) and interactive voice calling. The authors also explored the direction of further research in eHealth. Furthermore, they discussed that the findings may not have represented vulnerable communities and hence questioned their generalization, which calls for more Randomized Controlled Trials (RCTs) involving diverse environments.

The second scoping review by Archambault and colleagues investigated Collaborative Writing Applications (CWAs) in health care (Archambault et al., 2012). CWAs are web based engines used as a platform to describe various topics including public health. Wikipedia is a well-known example of CWA. The overall aim of the study was "to explore the depth and breadth of evidence about the effective, safe, and ethical use of CWAs in health care.” The purposes were: to map the literature; to compare the features of different CWAs; to describe the evidence of positive and negative effects of different CWAs in health care as a knowledge translation (KT) tool; to describe the barriers and promoter factors of CWA use; and to prepare a research agenda and action plan. The conceptual framework of the study used the knowledge to action (KTA) framework described by Graham et al. (Graham et al., 2006). The main purpose of using the KTA framework was to map and compare various applications and collaborative projects. The scoping review methodology followed the procedure described by Arksey and O’Malley (Arksey & O'Malley 2005), which will be discussed in detail in Chapter 7. The conclusions of the scoping review were that there was a strong need for proper guidelines for development and implementation of new social media applications for health care. The results showed that the reviewed CWAs were mostly beneficial for health. However, there were also negative effects in certain applications such as those that deal with information on HIV. Since this was the first scoping review of CWAs for health care, a need for further systematic reviews was identified.

The broad searches in MEDLINE identified the two articles discussed above as possible scoping reviews of PHI. However, neither of them provided a general overview of research activities specific to PHI.

Chapter 6: Study Rationale and Objectives

The rationale and objectives of the scoping review are presented in this chapter. First of all, the preliminary literature search described in Chapter 5 confirmed that there is currently no scoping review in MEDLINE that provides a comprehensive picture of the PHI research and practice. Secondly, the rapid advent and innovation of modern information technologies for e.g. smart mobile devices, social networking sites, parallel/cloud computing, remote sensing, wearable sensors, Internet bandwidth, etc. are fuelling many exciting research ideas in PHI and HI in general. These new information technologies are drastically changing the PHI landscape. However, for a better understanding of the field of PHI, there was an immediate need for a rigorous survey of the extent and nature of previous studies conducted in this field. These are the clear gaps in the PHI literature, and they provide a rationale for this thesis. Also, although there was no time restriction while searching the literature, the literature search identified articles in MEDLINE starting only from 2000. Therefore this research confined the scoping review starting from 2000 to 2014.

The main objectives of the thesis are:

- To conduct a scoping review of PHI in MEDLINE-PubMed
- To examine the extent and nature of existing PHI studies
- To identify opportunities for systematic reviews in the field of PHI
- To assess, summarize and disseminate the results of the scoping review of PHI

This study will help broaden our understanding of PHI. It will also identify specific areas within PHI where a full systematic review is warranted and help public health policy makers understand the current state of PHI.

Chapter 7: Methods

7.1 Standard procedure for conducting a scoping review

In 2005, Arksey and O'Malley first postulated and put forward a standard procedure for conducting scoping reviews (Arksey & O'Malley, 2005). Prior to their recommendation, there had been no standard procedures or methodologies to follow for conducting a scoping review. Scoping reviews conducted prior to 2005 include studies by Jepson et al. and Hagell and Bourke (Jepson, Blasi, Wright, and Riet, 2001; Hagell and Bourke 1999).

The standard procedure suggested by Arksey and O'Malley consists of the following stages:

- Stage 1: Identifying the research question. To start a scoping review, the researcher must clearly delineate the research question under study. In a scoping review study, research questions should be broad and provide a sufficient direction for a clear purpose. In addition, to establish an unambiguous research question, a clear understanding of different aspects of the topic or entity under scrutiny is required. It is equally important to clearly state and clarify the research question to avoid further ambiguity. For example, in a scoping review conducted by Arksey and colleagues the proposed research question was: "What is known from the existing literature about the effectiveness and cost-effectiveness of services to support carers of people with mental health problems?" (Arksey, O'Malley, Baldwin and Harris, 2002). In this case, support services could mean any kind of care centers (e.g., home, day care or hospital). Similarly, mental health could mean any kind of mental disease. Hence, the authors clarified those terms in the article. Most importantly, the research question should be sufficiently broad to include as many studies as possible, while being careful to avoid search terms that may result in an unmanageable amount of studies and/or ambiguity in the scope of the review.

- Stage 2: Identifying relevant studies. This stage proceeds with searching relevant studies in web based databases and/or hard-copy publication repositories. Pertinent studies should be selected for further screening. Time-frame and language restrictions must be specified.
- Stage 3: Study selection. In this stage, the relevant literature is screened and articles are selected for further analysis. For this purpose, the inclusion and exclusion criteria must be clearly stated and followed to extract relevant articles from a large number of potential publications. This stage may be time-consuming as meticulous article reviews are necessary. The reviewers can decide to read only the title and abstract. However, at the final step of screening, articles often have to be reviewed thoroughly, since the title and abstract only contain limited information about the article (Badger, Nursten, Williams, and Woodward. 2000).
- Stage 4: Charting the data. Charting is a technique of collecting, sorting and presenting key themes/information of qualitative data. Eventually, the information from the scoping review is synthesized in terms of specific variables. For example, some of the variables that can be used in synthesizing and presenting information include: the aim of the study, author names, the year of publication, study methodologies, major results, the duration of the intervention, and the characteristics of the study population.
- Stage 5: Collating, summarizing and reporting the results. This stage produces a descriptive and comprehensive summary of the charted data. The charted data from the previous stage is collated, synthesized, discussed and reported. In some cases, this stage can be the most challenging part of the scoping review if the volume of reviewed studies is large.

7.2 Methodological approach applied in this thesis

The research methodology for this thesis followed the procedure recommended by Arksey and O'Maley as well as the one suggested by Levac and colleagues (Levac, Colquhoun, & O'Brien, 2010). Levac and colleagues attempted to critically analyze the methodology recommended by Arksey and O'Malley and provided some suggestions clarifying each methodological stages. Colquhoun and his colleagues also suggested the same methodology in 2014 (Colquhoun et al. 2014). These methodological stages have been followed by almost all scoping reviews after the publication of the methodological framework by Arksey and O'Maley in 2005 (Arksey and O'Maley, 2005). This scoping review has followed their recommendations as described in the ensuing sections.

7.2.1 Identifying the research question and determining relevant studies

The main research question of this study is:
"What is the status of PHI research and practice in MEDLINE in the past fifteen years from 2000 to 2015?"

To answer this research question and achieve the study objectives listed in Chapter 6, relevant studies were identified in MEDLINE-PubMed. The MeSH term "public health informatics" was utilized for the initial search; the assumption here was that any article that is truly related to PHI would be assigned with this MeSH term. This MeSH term search resulted in 1014 publications on Dec 5, 2014, which increased to 1020 by the end of Dec. 30, 2014.

7.2.2 Selecting the relevant studies

The relevant article selection procedure was followed in two stages: initial screening, and final selection.

i. Initial screening: The 1020 articles identified by the MeSH term search described in the previous section were manually reviewed for inclusion in the scoping review. Two reviewers participated in this process. The reviewers independently reviewed all 1020 articles. The independent review ensued screening and categorization of the articles in terms of 'Include', 'Exclude', and 'May be'. During the first screening, only the title and abstract were reviewed. However, when the title and abstract alone did not provide sufficient information, the full-text of the article was skimmed. After the initial screening, both reviewers had a meeting together to compare the results of their screening and determine the included and excluded articles. The table no. 1 in chapter 8.1 presents the result of the initial screening.

ii. Final selection of the article: The selected articles from the first screening procedure were reviewed in detail for final inclusion. The articles where there was no decision, that is, the 'May be' articles and the articles where there was disagreement between both the reviewers in the initial screening, were reviewed by both reviewers together in a series of meetings.

The studies selection procedure had the following inclusion and exclusion criteria:

The inclusion criteria:

- Any article that applies, investigates, analyzes, describes, or assesses information technologies within the field of public health.
- An article originally published in English

The exclusion criteria are:

- Any article that mainly deals with branches of health informatics other than PHI such as biomedical, clinical, nursing, or consumer health informatics
- Any article published in a non-English language

The review team met before the start of the selection process, in the middle of the process, and at the end of the process to discuss progress and problems.

7.2.3 Charting the data

The required information from the excerpted PHI literature was initially charted in a table. As recommended by Levac and colleagues (Levac et al., 2010), the initial process of charting began with a pilot charting involving 10 articles. The both reviewers had consensus for any inconsistency and subsequently formulated a common understanding and system for further charting.

The final chart contains the following information as recommended by Arksey and O'Malley (Arksey & O'Malley, 2005) which was further clarified by Daudt and colleagues (Daudt, van Mossel, & Scott, 2013): a. Study number; b. Citation data; c. Year of publication; d. Study country/location; e. Types of the paper/Methodology; f. PH domain; g. Information Technology discussed/ used; h. and Informatics concepts applied.

The data charting technique has followed an approach of a scoping review that was conducted by Arksey and colleagues in 2002 to find out the gaps in research of mental health carers' services (Arksey, 2002). After charting the available literature, Arksey and colleagues identified the total number of major themes of the research areas, explored the overall quality of those studies, and discussed the research gaps accordingly. In this study, after completing the initial piloting for charting, the available studies have been classified into the major 11 PH domains. These domains are listed in Chapter 2 and described in detail below in the 'Meaning of the various public health (PH) domains.

The narrative description of the PH domains were then presented in section 8.2 with respect to the number of articles, study setting, methodology applied, domains of IT discussed/used, domains of informatics concepts applied, and in-depth analysis on research and practice presented at the end of each PH domain. The domains of IT discussed/used, and domains of informatics concepts applied are also listed in Chapter 2 and described in detail below in 'Meaning of information technology (IT) discussed/used, and 'Meaning of informatics concepts applied'.

Meaning of the various public health (PH) domains:

Public health has been divided into the following domains according to the functions and nature of the PH field. It was also based on the available literature in the MEDLINE-PubMed that was focused on PHI.

i. Infectious/Communicable disease monitoring: The articles that used/discussed any infectious and communicable diseases monitoring were categorized under this category. The infectious/communicable diseases are caused by many types of microorganisms such as bacteria, virus, fungus, arthropods etc. Essentially, the terms infectious diseases and communicable diseases have the same meaning and are often used interchangeably; however, the difference is rooted with the etymological meaning of these terms. Etymologically, an infectious disease means it can produce a pathological condition in an infected person, whereas a communicable disease means it can transfer from one person to another person. In practice, diseases which have high virulence are often termed as infectious diseases (e.g., influenza, anthrax, viral conjunctivitis, cholera etc.); whereas, diseases with low virulence are termed as communicable diseases (e.g., giardiasis, malaria etc.).

ii. Outbreak detection: The articles focussed on outbreak detection activities were categorized under this subheading. Such activities involve the program planning and prevention activities implemented at health care facilities, PH departments, and targeted communities. The main difference between the articles allocated in the infectious/communicable disease monitoring and outbreak detection is that the former represents a regular PH program focussed on infectious/communicable disease prevention; whereas the latter is focused on outbreak detection caused by specific pathogens e.g., seasonal influenza. There are many articles which are allocated in both of them (especially if an article includes a broad national PH system and health care program), however when there were specific discussions on outbreak detection and prevention, then the articles were allocated only in outbreak detection.

iii. Bioterrorism surveillance: Any article that discussed bioterrorism surveillance activities as one of the main purpose of the given program was categorized under bioterrorism surveillance. There are many articles which had both outbreak detection and bioterrorism surveillance as one of the most important functions, therefore they were categorized under both of these categories.

iv. Non-communicable/chronic disease monitoring: This PH domain includes the articles that are focused on all kinds of non-communicable or chronic diseases. The non-communicable diseases are caused by the physiological, hormonal, or neurological causes and are not transmissible from one person to another. Some example of non-communicable diseases are heart diseases, diabetes, Alzheimer's disease, cancer, and mental/psychological diseases etc. Most of the non-communicable diseases are chronic in nature i.e. they last months or years. However, there are infectious diseases which are also considered chronic diseases, such as HIV/AIDS and tuberculosis. For the purpose of this thesis all the infectious diseases (either acute or chronic) are included in the infectious/communicable disease monitoring PH domain. Only the non-infectious diseases are included in the non-communicable/chronic disease monitoring.

v. Emergency response: There are articles which focussed on improving the emergency medical services (EMS) by diverting ambulances from the place of accident to the hospitals, these articles are included under the emergency response PH domain. Especially, during chaotic situations, for example, seasonal infectious disease outbreaks, large mass gathering events (such as Olympic game or presidential elections etc.) the ambulances need to be diverted in time to appropriate hospitals, because many of the hospitals' beds are pre-occupied. There are articles that discuss about the application of the IT for better management of such situations. The emergency response is crucial to protect people's health and prevent possible mortality during such a critical time for patients.

vi. Injury surveillance: This category includes the articles that are focused on preventing and monitoring the injuries that occur at home or public places by applying the IT. The example of such injuries are, fall, burn, electric injury, and others.

vii. Natural disaster management: The natural disasters; for example, hurricanes, cyclones, flooding, earth quakes etc. are under this category. It is different from the emergency response; the natural disaster management applies the IT to prevent the possible casualties caused by any kinds of natural disasters; therefore, the application of IT is planned for before, during, and after any natural disaster occur. It entails a broad preparedness and response activities. In contrast, the emergency response is focussed for example, on ambulance diversion and better medical response before a patients reaches to the hospital.

viii. Environmental Health: This PH domain includes all the articles that are focused on the application of IT to monitor environment related PH problems, e.g., air pollution, water pollution/ contamination, and soil pollution/ contamination etc. There are some articles which discussed PH programs and activities that are focussed on promoting the environmental health and these are also included in this PH domain.

ix. Occupational health hazard: The articles that discussed the application of IT to monitor the health hazards that occurred in the work place (e.g., industries, factories), especially due to chemical leaking/poisoning, work place safety, and other work place hazards are categorized under this PH domain.

x. Public health awareness: The articles focussed on creating awareness of PH issues by disseminating information through mass media, electronic media, or any other IT are under this category.

xi. Public health policy/system and research: If an article talks about PH programs without specifying a single PH domain it was put under this category. These articles discuss in a broad manner about PH problems and issues, and their possible solutions. It also includes those articles which are related to applications of IT with regard to a National PH system, National immunization system, National health information system (NHIS) or conducting research on PH policy and research related activities.

Meaning of Information technologies (IT):

The IT discussed/used in the PHI related articles are categorized under 11 different types which are as follows:

i. Website: Website is a room or a location found on the World Wide Web (WWW). It is accessed through the Internet. Each website has its own address and are accessed by people using that specific website address. Websites can be both publicly accessible and private, e.g., Yahoo news, Google, YouTube are open websites; whereas public and private companies may have their private websites which require permission to access them, e.g., many governmental office websites, financial institution websites, university library websites etc. The articles that included application of online medias for example, Wikis, LinkedIn, Twitter, Yahoo pipes (is a Web 2.0 mashup tools), Google, YouTube and all other information sources that are in the form of webpages are included under website in this thesis.

ii. Natural language processing (NLP): The Natural language processing refers to the human and computer linguistic interaction to derive meaningful language. The information technologies that are categorized under NLP are automated character recognition, text-tagger engine, and log analysis software etc. There are many tasks of the NLP some of which include: determine the semantics and syntactic structure of a sentence, parsing the text, mining databases or websites for specific search terms, and artificial intelligence etc. In the PH system, the NLP has been mostly applied to mine the websites to capture frequency (number), trend (time), location, and demographic characteristics of people visiting the website, mining certain disease trends, and text parsing from clinical data reporting system.

iii. Statistical/analytical software: The statistical/analytical software include those IT that are used to analyze data and draw meaningful information by applying statistical programming and software. The statistical/analytical software includes the Early Aberration Reporting System (ABER) (which includes 5 methods: cumulative sums methods (CUSUM), C1, C2, C3, and the historical limit method), SAS, SPSS, OWL (Web Ontology Language), and what' strange about recent events (WSARE) etc.

iv. Detection prediction (DP) algorithm: An algorithm refers to a set of processes involving input, process, and output functions that exist in a space and time, and provide a meaningful result. Essentially all the computational processing are examples of computational algorithms where once there is a data input, the computer network of process derives an output as a result. However, for the purpose of this thesis, information technologies that are under the DP algorithm are: Machine learning classifiers (Naïve Bayes, and Support Vector Machine (SVM) classifiers), Mathematical modelling, and spatial surveillance algorithm etc. which are used to detect and predict the PH problems.

v. Automated speech processing: The automated speech processing is also within the umbrella of NLP, where there are automated processing of human languages with speech-to-text and text-to-speech. A new concept in the field of NLP is to construct a machine that can completely understand all the human languages and provide a meaningful response. However it is considered AI-complete. For the purpose of this thesis, the automated speech processing is separated from NLP to distinguish articles which are focused on the human speech processing in machines for PH programs.

vi. EMR/EHR/electronic registry: This refers to any electronic database or registry that can be Internet based or only electronic; these are categorized under this category.

vii. E-mail: The electronic message sent from one person to other person or organization via Internet is referred as e-mail.

viii. Geographic Information System (GIS): The Geographic Information System is a subdomain of Geoinformatics that is used to show the geographic location or space as a main variable with respect to other PH related information such as prevalence of disease in a geographic location. The features of GIS systems include visual representation of a geographic area. The technologies that are used for GIS are the geographic positioning system (GPS), and remote sensing or satellite based pictures of the earth. There are many computer based GIS-software that are applied to analyze temporal and spatial information relevant to the PH programs. One of them is SaTScan (space-time scan statistics) which has been widely used in the available literature of PHI.

ix. Mass media: The mass media include all the electronic or paper based publicly available information dissemination tools that are used for the information sharing and creating PH awareness among the general public. The conventional mass media (e.g., television, radio, FM stations, and newspapers) are under mass media category. However, for the purpose of this thesis website based information sharing systems are also included under the website category, not under the mass media category.

x. Mobile phones: The portable mobile phones and their applications for example, smart phones, and text messages are under mobile phones.

xi. Telephone-landline: The traditional landline phones which are not portable, are under telephone-landline category. However, if a paper does not specify if it is a mobile phone or a land-line phone, and there is no other way to differentiate if the call was conducted from a mobile phone or landline phone, then these phones were categorized under the telephone-landline category.

Meaning of the Informatics concepts:

The Informatics concepts applied are under the following 9 domains.

i. Data collection: Data collection means to gather data from a targeted population or program using data collection tools such as observations, interviews, surveys etc. If any PHI related article included in this thesis used these data collection tools to collect data they are categorized under the data collection informatics concept domain. The IT applied to collect data are telephone, website, e-mail, and electronic registry etc.

ii. Data retrieval: This is a method for obtaining data from a single or multiple data source. Any article that applied information technologies to retrieve data from the existing electronic data sources, for example, computer based electronic database, web based electronic database, or electronic registry is categorized under data retrieval.

iii. Data analytics: The articles that discussed/used IT to analyze data, to draw meaningful information are categorized under data analytics. These IT applied are mostly statistical/analytical software, for example, SPSS, SAS, MS excel, and EpiInfo etc.

iv. Data security: Due to the advent of the Internet, the electronic data collection, reporting, and warehousing system are increasing. However, at the same time the data security is a major concern to protect personal identification and confidentiality. Any article that discusses data security concepts, methods, and processes is included in the data security domain. These may include a general discussion about the data security or the actual application of some anti-virus or any other kinds of software to secure the data/informatics system to be considered this informatics concept.

v. Data storage: If there is a general discussion or application about the data storage or warehousing in the given article then it is categorized under the data storage. Storage is in the electronic form and mostly in computer and/or Internet.

vi. Data transmission/ communication: If there is data transmission from one source to another source, with two or more parties engaged together to communicate or to transmit the electronic data then these kinds of articles are categorized under data transmission/ communication category.

vii. Interoperability: The interoperability refers to a feature of a computer, software, or a technological system that enables the exchange of data or communication to each other in a semantic or syntactic manner. In syntactic interoperability, there is a free exchange of the data or information among two or more systems; whereas in the semantic interoperability, the data exchanged are in a meaningful manner among the systems. For the sake of this thesis, any article that discusses the semantic or syntactic data or information exchange between two or more machines or technological systems is included in this informatics concept domain.

viii. Information sharing: When the PH data/information is shared with the public or any group under the population to increase awareness or raise knowledge on a specific PH topic, then these kinds of articles are categorized under the information sharing category.

ix. Knowledge management: If the given article applies the application of web ontology or ontology web language (OWL) then the article is also categorized under knowledge management. The ontology is a discipline of science in which the specific ontology language is applied so that a computer can understand the language. To elaborate this concept, the ontology language is applied to categorize the various kinds of heterogeneous data coming from a diverse sources.

7.2.4 Collating, summarizing, and reporting the results

This is the final stage of this thesis work which analyzes the charted data in a narrative version. This stage answers the research question and attains the objectives of this thesis. In particular, a descriptive summary of the included studies is provided as suggested by Arksey and O'Maley (Arksey & O'Malley, 2005). The overall finding of each PH domain is presented as a gist in a table form at the end of each domain to provide a crux of the finding in each domain.

Chapter 8: Results

8.1 Result of the article selection procedure

The following table and figure presents the result of the first screening and final selection procedure.

Table 1. Initial screening

1st Reviewer

2nd Reviewer

	Include	Exclude	Maybe
Include	485	100	10
Exclude	37	328	3
Maybe	1	10	46
Total =1020			

The table 1 above shows that both the reviewers had reached to the same conclusion with 485 articles for ‘include’, 328 articles for ‘exclude’, and 46 articles for ‘may be’. In total, the reviewers reached the same conclusion with 859 articles (84.21%) and they had disagreement with rest 161 articles. The internet based inter coder reliability calculation was used during this calculation found from (www. http://dfreelon.org/recal/recal2.php). The scientific validation of the calculation is described is this article (Freelon, 2010) in detail.

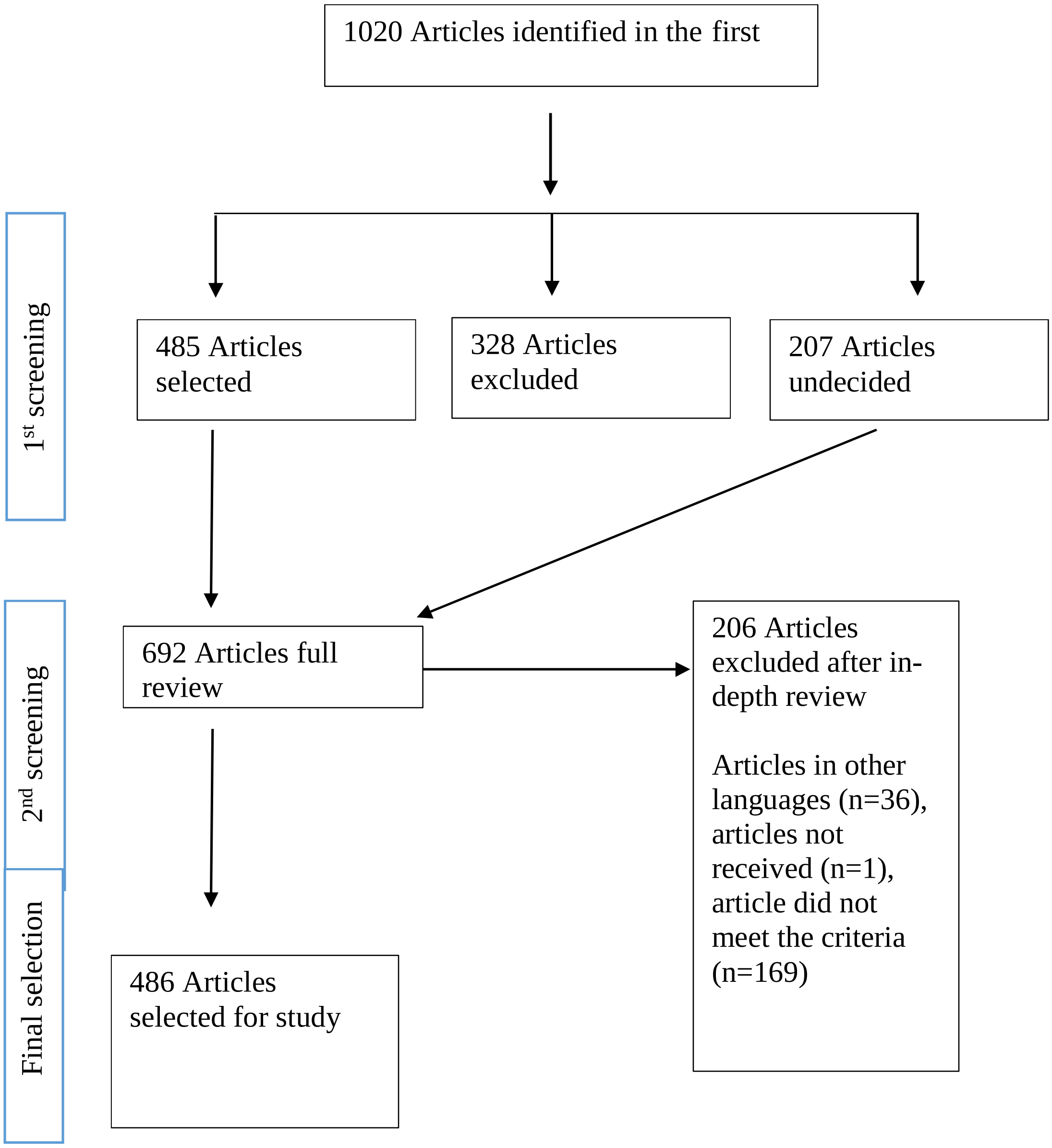

Figure 1. Diagrammatic flow of the screening process

The figure above demonstrates that there were a total number of 692 articles for the full review of the articles. At this stage, a total number of 206 articles were excluded because these articles did not meet the inclusion criteria. Among these excluded articles, 36 articles were in a language other than English, 169 articles did not meet the inclusion criteria, and for 1 article a full manuscript was not received despite the help from the University of Waterloo library. The library had helped to locate 142 articles whose full manuscript was missing in the initial screening. Finally, at the end of the final selection 486 articles were included for this study.

8.2 Demonstrating the current status of PHI in literature

8.2.1 Settings of PHI research/articles

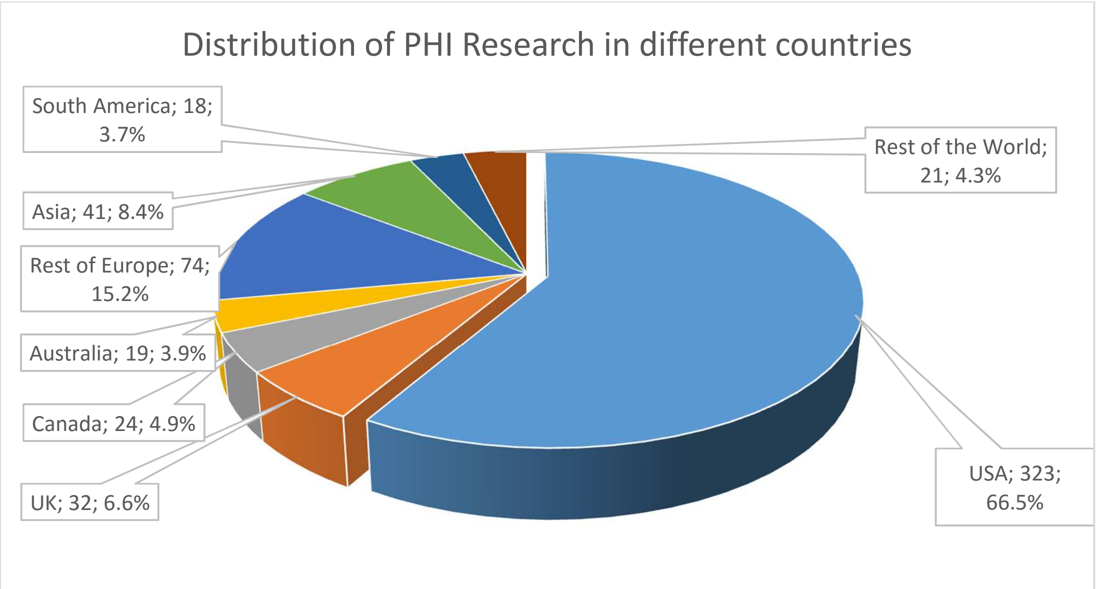

Figure 2. Distribution of PHI research in different countries

The figure above shows that two third of the total articles are from USA. Among the remaining one third of the articles, the rest of the Europe has the highest number followed by Asia, UK, Canada, and Australia. The remaining few articles are from South America and the rest of the world. (The rest of the Europe does not include UK, hence called as the rest of the Europe).

8.2.2 Years of publication

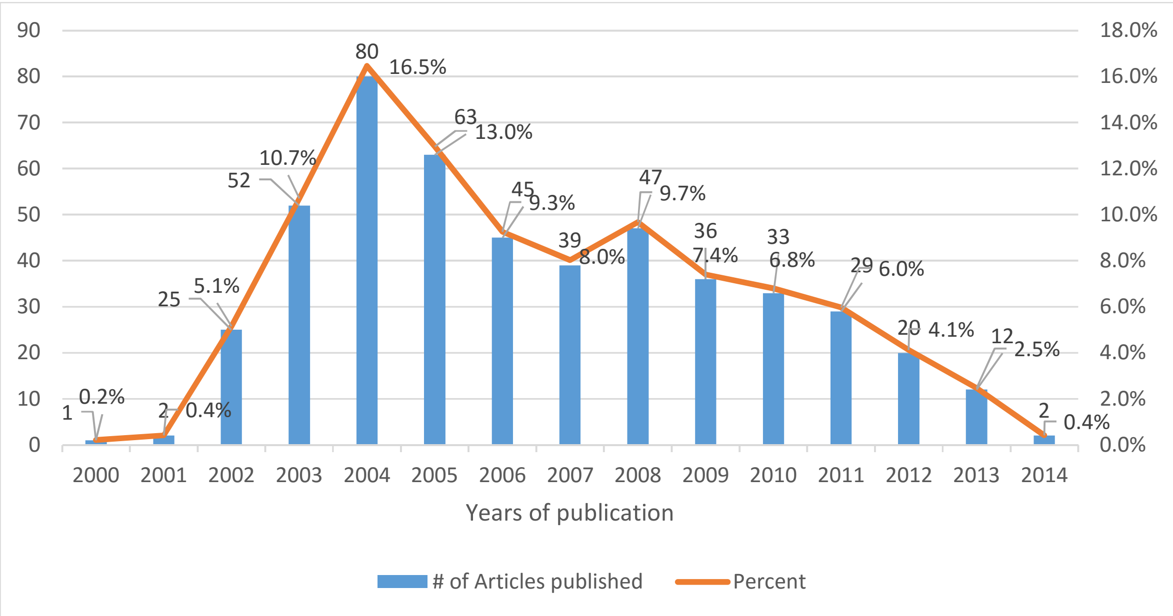

Figure 3. Years of publication

The figure above shows that the PHI literature is only available since 2000, although the search did not have time restrictions. The figure also shows that the highest number of articles were in the time period from 2003 to 2006, this could be because of the September 11, 2001 terrorist attack followed by a bioterrorism (anthrax) attack in 2001 in the USA that motivated global PH experts to apply modern IT to improve the PH prevention strategies in the subsequent years. Another reason could be that after the bioterrorism attack in 2001, the US government invested a huge amount of its budget on research and development in electronic healthcare systems that may have motivated the entire PH research community to conduct more research on PHI.

8.2.3 Types of articles

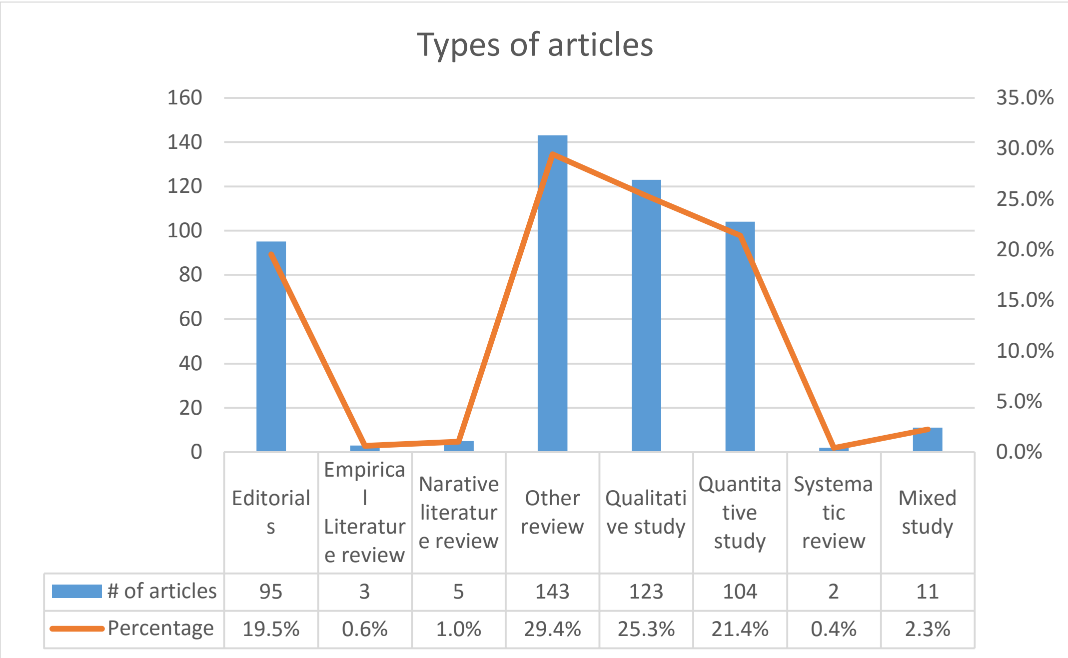

Figure 4. Types of articles

The figure above shows the types of existing PHI literature found in MEDLINE-PubMed. It shows that the majority of the articles are related to other reviews, quantitative study, qualitative study, and editorials. These articles collectively constitute more than 90% of the overall articles. Remaining articles are empirical literature reviews, narrative literature review, mixed studies and systematic studies.

8.2.4 PH domains

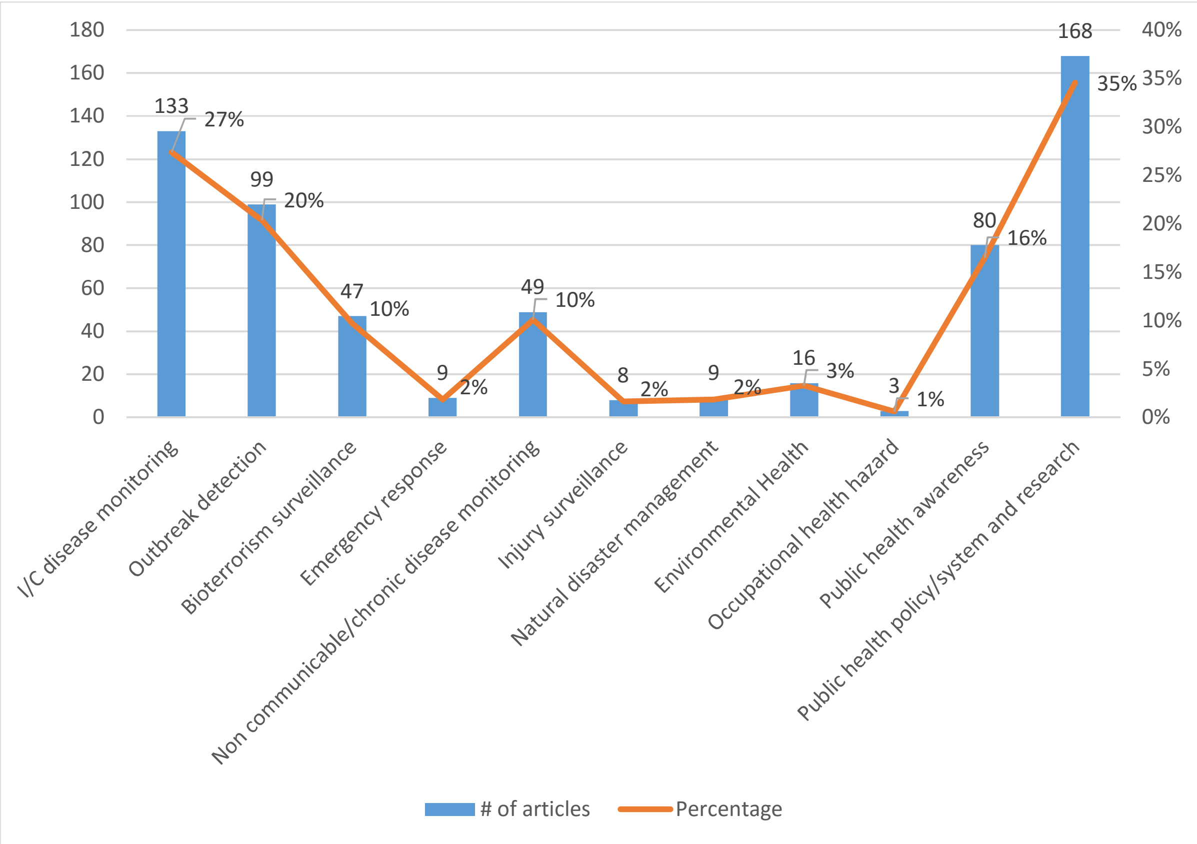

Figure 5. Distribution of articles with public health domains.

The figure shows the total number of PH domains discussed in the MEDLINE. It shows that public health policy/system and research constitutes more than one third of the total articles which is the highest number of articles among all the PH domains. This was followed by infectious/communicable disease monitoring[1], outbreak detection, public health awareness and non-communicable/chronic disease monitoring. In fact, the PH domains: infectious/communicable disease monitoring, outbreak detection, and bioterrorism surveillance

[1] I/C disease monitoring refers to the infectious/communicable disease monitoring.

are similar in nature and represent 57.5% of the total articles. The remaining articles of all the PH domains constitute less than 2 percent of the total articles.

8.2.5 Information technology domains used

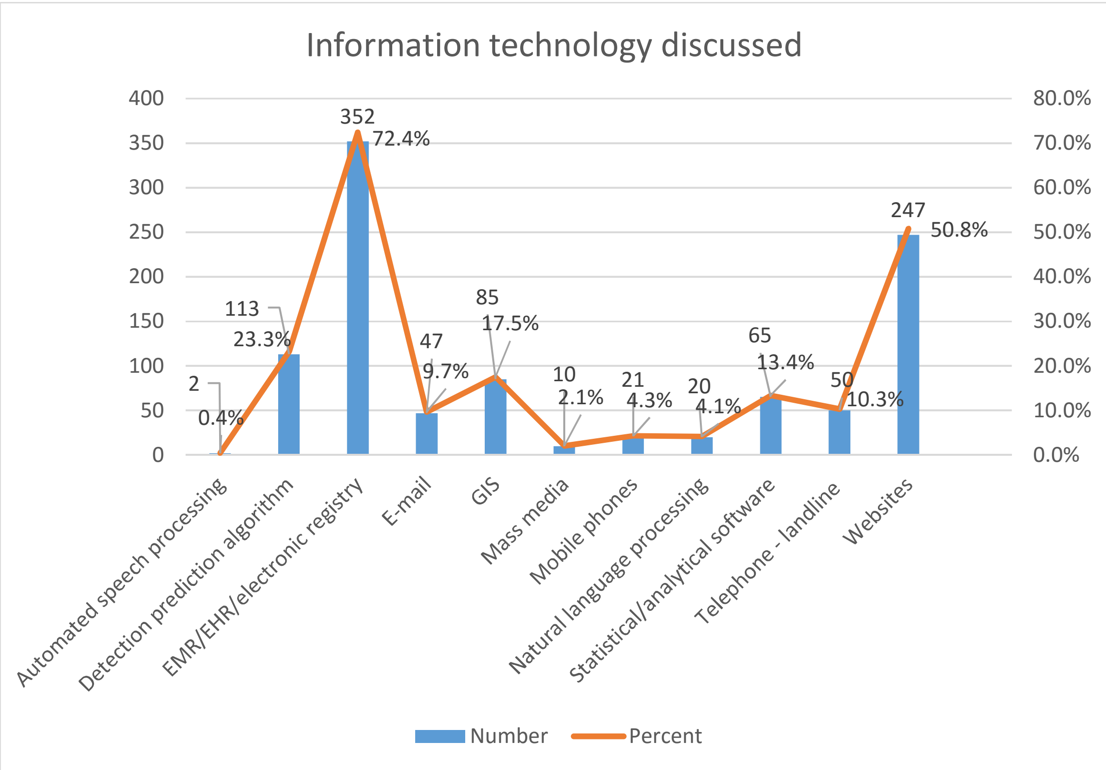

Figure 6. Distribution of the articles with the information technologies discussed/used

The figure shows that over all there were 11 different types of the technological informatics tools used in the literature. The most frequently used informatics device was EMR/EHR/electronic registry which was used by more than two thirds of the total articles. Another frequently used informatics tool was the website which was used by just above half of the articles. The remaining informatics devices that often used were DP algorithm (23.6%), GIS (17.7%) and statistical/analytical software (13.4%). The least used informatics technologies were NLP 3.5%, mobile phones 3.9%, mass media 2.0% and automated speech processing 0.4%.

8.2.6 Informatics concept applied

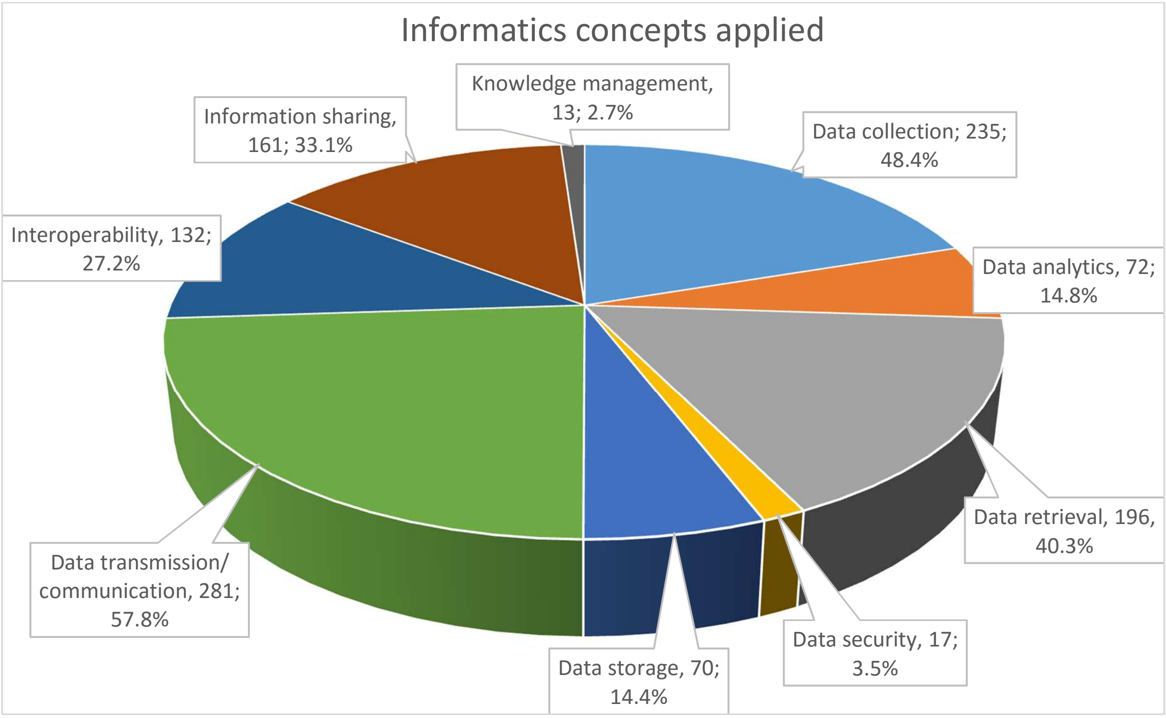

Figure 7. Distribution of the articles with informatics concepts discussed/used

The figure above shows that data transmission/ communication represent the highest number of the total articles followed by data collection and data retrieval, these are the leading informatics concepts discussed/used in the articles. The least used informatics concepts are data security and knowledge management.

8.3 The current practice and research in specific domains.

The PH domains are listed in Chapter 2.1. The Information technology discussed/used in the articles are categorized under 11 different domains, and Informatics concepts applied are categorized under 9 different domains as described in Chapter 2.2. A gap in research and practice is provided to each PH domain to make the analysis more specific and meaningful.

All articles under each PH domains are analyzed under the following headings: Number of articles; study settings with number of studies; types of articles/methodology; and evidence relating to use of information technology and informatics concepts

8.3.1 Infectious/Communicable disease monitoring

8.3.1.1 Number of articles

There are 133 articles related with this PH domain.

8.3.1.2 Study settings

Among them, the majority of the articles were from the USA 86 (64.7%), followed by the rest of Europe 24 (18.0%), Canada 9 (6.8%). UK 9 (6.8%), Australia 5 (3.8%), and Asia 11 (8.3%). The remaining articles are from the rest of the world.

8.3.1.3 Types of articles/methodology

Of the total number of 133 articles, most of the articles are other reviews which represent 41 (30.8%) of the articles. The rest are 31 (23.3%) qualitative studies and 36 (27.1%) quantitative studies; both of them collectively represent more than half of the total articles. The mixed studies, narrative literature reviews, and systematic reviews represented the lowest amount of articles that collectively represent only 9 (6.5%) of the total articles.

8.3.1.4 Evidence relating to the use of Information technology

A large number of the articles discussed/used EMR/EHR/electronic registry which is 109 (82%) of the total number of 133 articles. This was followed by website 44 (33.1%), DP algorithm 42 (31.6%), GIS 27 (20.3%), and statistical/analytical software 23 (17.3%). There were also some articles that discussed/used e-mail 14 (10.5%) and telephone-landline 11(8.3%). The least number of articles discussed/used were NLP 8 (6.0%), mobile phones 3 (2.3%), and mass media 2 (1.5%). Automated speech processing was not discussed at all in any of the article of this category.

8.3.1.5 Evidence relating to the use of Informatics concepts

Data transmission/ communication, data collection, and data retrieval are most frequently used informatics concepts in this PH domain, they were used in 83 (62.4%), 82 (61.7%) and 71 (53.4%) of the total articles respectively. Further, interoperability and data analytics were used in 38 (28.6%) and 32 (24.1%) of the total articles. The least used/discussed informatics concepts were knowledge management 3 (2.3%) and data security 7 (5.3%).

8.3.1.6 In-depth analysis on research and practice

Quantitative studies:

An in-depth analysis of the total 36 quantitative articles included in the infectious/communicable disease monitoring PH domain showed that the main settings where the studies were conducted included the hospital, pharmacy, and population. There were a total of 19 hospital based studies (Asatryan et al., 2011; Bottle & Aylin, 2008; Cecelia et al., 2006; Cojocaru, van Hest, Mihaescu, & Davies, 2009; Fan, van Dijk et al., 2010; Hadler, Siniscalchi, & Dembek, 2005; Harcourt, Edwards, Fleming, Smith, & Smith, 2004; Rivest, Richer, & Bédard, 2004; Marsden-Haug et al., 2007; San Gabriel et al., 2003; Sartorius, Jacobsen, Törner, & Giesecke, 2006; Staes, Gesteland et al., 2009; Takahashi, Koehler, Swenson, & Duchin, 2004; Thomas, Carter, Torrone, & Levandowski, 2008; Tokars et al., 2009; Truyers et al., 2010; Hest et al., 2008; Yiannakoulias & Svenson, 2009; Yih et al., 2010. These articles are the descriptive studies mostly conducted to monitor the diseases and find out the disease morbidity and/or mortality. The electronic registry and website are most often used ITs. As an example, one study conducted by Truyers and his colleagues (Truyers et al., 2010) in Belgium used the general clinical practice based computerized networks: Intego database and the European influenza surveillance scheme (EISS). These two electronic databases were analyzed and compared for the morbidity trend of acute respiratory illness (ARI) and influenza like illness (ILI). The result showed that these databases are good predictors for monitoring the respiratory illnesses.

Further, 4 articles (Sokolow et al., 2005; Najmi & Magruder, 2005; Ohkusa, Shigematsu, Taniguchi, & Okabe, 2005; Pelat, Boëlle, Turbelin, Lambert, & Valleron, 2010) were conducted on pharmacy to measure the over the counter (OTC) drugs sales and prediction of infectious diseases in the near future. For example, a study (Ohkusa et al., 2005) was conducted on assessing the OTC drug sale from 1,100 pharmacies throughout Japan. The data collected during November 2003 to April 2004 and analyzed to find out the possible correlation between the OTC drug sale and influenza incidence rate in a weekly and bieekly data sets. Data on the influenza was obtained from the national influenza epidemic database. The result showed no significance with the OTC drug sale and influenza incidence in Japan.

Also, there are a total 12 articles which were population-based studies (Murty, Srinivasa Rao, & Misra, 2008; Scholer et al., 2007; Cooper et al., 2007; Dausey et al., 2008; Oliva, Rienks, & Chavez, 2007; Olson, Grannis, & Mandl, 2006; Kanlayanaphotporn et al., 2004; Kerani, Handcock, Handsfield, & Holmes, 2005; Lazarus, Kleinman, Dashevsky, DeMaria, & Platt, 2001; Niccolai et al., 2005; Weitzman, Kelemen, Kaci, & Mandl, 2012; Dunn et al., 2007). These articles are cross-sectional studies to find out the disease burden of specific disease or measure the public health related information in a given population. For instance, a study (Cooper et al., 2007) was conducted to find out the number of telephone-landline calls and its association to the respiratory illness burden in the UK. The main IT applied in those studies were EMR/EHR/electronic registry, website, and telephone-lines. Among the remaining 2 articles, one article (Cecelia et al., 2006) was studied in a research institute and one article (Chan, Sahai, Conrad, & Brownstein, 2011) was web based data query system.

In conclusion, almost all the quantitative articles had the use of electronic registry; it could be because the infectious diseases are acute and outbreak prone which require an immediate action. Another possible reason for higher level of application of electronic registry could be that it is widely accessible and used in almost all the hospital and PH offices in the developed world, where the majority of the studies have come from. The wide application of EMR/EHR systems in hospitals also may have encouraged the PH community to conduct more research on its application to prevent infectious diseases. After assessing the thirty-six quantitative studies, it is discernible that the majority of the studies are conducted to monitor the diseases trends, and detect the outbreaks in time. However, a small number of the studies look at the application of DP algorithms, statistical/analytical software raises a concern that there are not enough quantitative articles on them. It shows an opportunity to conduct more studies to test these software in the future. There was only one article (Tokars et al., 2009) which actually studied how to improve the existing DP algorithm in infectious disease monitoring, and there were few other quantitative articles which discussed applying DP algorithm while monitoring the infectious diseases.

Qualitative studies:

The qualitative studies (n=31) were mostly the case studies, and program evaluations of PH programs. There were 11 studies in total that represented the hospital based data reporting system (Buck et al., 2012; Espino, Wagner, Tsui, et al., 2004; Flamand et al., 2011; Hurt-Mullen & Coberly, 2005; Jones and Marshall, 2004; Lober, Baer, Karras, & Duchin, 2004; Ma et al., 2005; Pina, Turner, Kwan-Gett, & Duchin, 2009; Smith et al., 2007; Terry, Ostrowsky, & Huang, 2004; Troppy, Haney, Cocoros, Cranston, & DeMaria, 2014). The main objectives of these studies were to integrate the data between the clinical/ ED units to the PH units or central database monitored by epidemiologists. The surveillance system is electronic and real time. An epidemiologist monitors the disease trend by calculating trends applying the statistical/analytical software. The DP algorithm is applied in automatic detection of outbreaks. One article (Espino, Wagner, Tsui, et al., 2004) published in 2004 raised the issue on integrating the statistical/analytical software with the real time outbreak detection algorithms (RODS). The articles published in later years showed applying both of these techniques; however it was unclear whether there was integrated system or not, because most of the articles had their statistical analysis done by epidemiologists on a daily basis. One prominent article on this topic is (Troppy et al., 2014) published in a 2014 article.

There were a total 8 articles (Bédard et al., 2003; Robertson & Nelson, 2010; Ruiz & Remmert, 2004; Savory, Cox, Emch, Alemi, & Pattie, 2010; Scotch et al., 2008; Srivastava et al., 2003; Marechal, Ribeiro, Lafaye, & Güell, 2008; Brownstein, Freifeld, Reis, & Mandl, 2008) that were focused on the application of GIS in PH programs, in different parts of the world. In general, these studies applied the GIS for disease monitoring by mapping the diseases, vectors, environmental factors, temperature, and also in terms of temporal and spatial information. For example, a study in 2008 (Scotch et al., 2008) was conducted for the spatial and temperature representation of the WNV in two different states of the USA: Delaware and New Jersey. The program presented the map of diseases with temperature in a specific day. However, the study could not present the better map than the conventional maps, and concluded that the online mashup tools were not yet mature to prepare such maps. It shows that more needs to be done on these mashup tools to make it more attractive. One other study (Robertson & Nelson, 2010) in 2010, examines the types of software available for space-time disease surveillance and reports that "the space-time disease surveillance are not included in most of the conventional GIS or statistical software". These methods are available only in the softwares: SaTScan 8.0, ClusterSeer 2.3, GeoSurveillance 1.1, and Surveillance package 1.1-2 for R. The main problems with these software are that they need to be installed on the computer and are not available online. The article (Robertson & Nelson, 2010) suggests that there is a need for an internet-based open software that can be accessed through multiple users at a single time. Also, it is very difficult to merge the data run through these various software, a need to standardize the data coding and formatting system is sought in this area. This thesis research could not find more articles after 2010 in this field, and hence concluded that internet-based open software is required on application of GIS in PHI. Furthermore, a study (Brownstein et al., 2008) published in 2008 included the HealthMap monitoring system that monitors and presents global disease trends in country specific maps on a daily basis. The country specific information is captured from the international news, websites, and blogs of different languages in many countries across the world. However, there are a lot of things to be improved on; first, the news from the developing countries are often not captured due to a poor reporting system at the local level of these countries. Also, the future work on "clearly stating the NLP (machine learning techniques) on clearly identifying the pathogen" is highly recommended (Brownstein et al., 2008). Although the study was conducted in 2008, and there might have been improvements since then, this thesis research could not find any articles on the recent developments.

Among the remaining qualitative articles, 5 articles (World Health Organization, 2003; Advani et al., 2010; Persson & Bartlett, 2004; Wuhib, Chorba, Davidiants, Mac Kenzie, & McNabb, 2002; Lee, McKenna, & Janssen, 2003) are related with the NHIS of a specific country or state in general. These studies discussed about the information system applied in national programs and the IT applied were: electronic reporting system and website.

Remaining 3 articles (Wells & Bullen, 2008; Turner, Ramey, & Lee, 2008; Høstgaard & Pape-Haugaard, 2012) were the reports of the ethnographic studies on culture and practices that were contributing for the data error. These studies were mainly investigating the health workers' attitudes and practices while applying ITs during data reporting.

There were only two studies (Surjan et al, 2006; Vuurden, Hartvigsen, & Bellika, 2008) that were focused on specifically testing and developing statistical/analytical software in PH programs. The first study (Surjan et al., 2006) tested ontological algorithm and second study (Vuurden et al., 2008) studied the application of statistical algorithm for outbreak detection. The first study (Surjan et al., 2006) showed that the ontology of the abstract concepts applied in PH are not well advanced and difficult to present. The main disadvantage was that the indicators excerpted from the other domains e.g., economics, environmental health science were not well applied in PH. Based on the article, it can be concluded that ontology development in PH was first initiated in 2006. However, this thesis research could not find any other studies that take efforts to test ontologies after 2006, it could be because it was exclusively technological in nature and related with computer science and may be not be published in MEDLINE.

Mixed studies:

There were 4 mixed study design articles (Moore, Reddy, Kapell, & Balter, 2008; Muscatello et al., 2005; Schindeler et al., 2009; Travers et al., 2007). These studies were about the application of the electronic reporting system from the ED/clinical departments to the PH units, and applying DP algorithms and statistical methods for disease monitoring. One study (Travers et al., 2007) was also about improving the NLP system in PH database in USA where the researcher evaluated the emergency medicine text-processor (EMT-P). The researchers were able to revise the existing text processor and make a better text processor system.

Narrative literature reviews:

There were 2 narrative literature review articles (Jajosky & Groseclose, 2004; Silk & Berkelman, 2005). The article (Jajosky & Groseclose, 2004) is about the evaluation of the articles published in MEDLINE about timeliness of reporting from the clinical departments to PH units in US from 1970 to 2003. This paper presented the baseline report of the timeliness for the future studies. This study found out that there was a reporting lag across the States (except for Hepatitis B). The article (Silk & Berkelman, 2005) is also focused on strategies for enhancing the completeness of notifiable disease reporting in the USA and suggests implementing automated, electronic laboratory-based reporting system, strengthening the reporting mechanism among clinicians and other key partners; and increase the use of laboratory diagnostic tests for detecting new cases.

Systematic reviews:

There are two systematic review articles (Hiller, Stoneking, Min, & Rhodes, 2013; Dixon et al., 2013) focused in this PH domain. The article (Hiller et al., 2013) published in 2013 is focussed on the systematic review of the ED based syndromic surveillance system for Influenza and ILI across the world. The study was conducted in PubMed on April 2012 and on April 2013. This paper showed that the countries that applied electronic syndromic surveillance in ED were: The United States, Canada, Australia, Italy, China, Guam, Taiwan, Israel, France, and the United Kingdom. The SS included a single clinic to the multinational large health care centres. The main finding of the study is that the SS is becoming popular to measure the yearly influenza outbreaks. Similarly, another article (Dixon et al., 2013) also published in 2013, conducted the systematic review on MEDLINE and Google Scholar. The study was focussed on summarizing the computer based bidirectional communication approaches between clinical and PH units. The literature search was conducted on April 2010 and Dec 2011. The study identified four main areas: Architecture, Governance, Interoperability, and Usability. The main finding was that, the architecture for the two way communication between clinicians and PH units needs to be improved and should be from local level to the central (CDC) level. It also stressed the need to develop and test the data security system. The article showed that the electronic data reporting system from the clinical units to PH units is mostly unidirectional and lacked an electronic feedback mechanism. The study highlighted a need for further research and development for improving the bi-directional system. It also showed that the feedback the clinicians obtain from phone, fax or mail, is mostly not followed due to the other work load of the clinicians. It suggested further research to improve this situation.

Other reviews:

There were a total of 41 other review articles. Among them, there are 23 articles (Hopkins, 2005; Popovich & Watkins, 2006; Tsui et al., 2005; Lewis et al., 2011; Fan, Blair et al., 2010; Li et al., 2012; Shapiro, 2007; Orlova et al., 2005; Heisey-Grove, Church, Haney, & Demaria, 2011, Lazarus et al., 2001; Aller, 2009; Dunbar et al., 2011; Hripcsak et al., 2009; Platt et al., 2003; Reis, Kirby et al., 2007; Wood, Hopkins, Peppert, & Jourden, 2002; Flahault et al., 2006; Lober, Trigg, & Karras, 2004; Loonsk, 2004; Magnuson et al., 2004; Ansaldi et al., 2008; Broome & Loonsk, 2004; Tamang, Kopec, McCofie, & Levy, 2006) which are related to reporting from the ED, lab, OTC drug sale, school, and poison center for disease monitoring. More specifically among these 23 articles, 3 articles (Hopkins, 2005; Popovich & Watkins, 2006; Tsui et al., 2005) also extend the reporting from OTC drug sale, 1 article (Lewis et al., 2011) from OTC drug sale, school, and poison center based reporting, and 1 article (Fan, Blair et al., 2010) from the school based reporting system. The IT applied among all of these articles was mainly the electronic registry, GIS, and DP algorithms, and a few also applied NLP. Some important insights were derived from these articles. For example, an article (Popovich & Watkins, 2006) presented the 3 layers of disease monitoring system: data layer, business layer and presentation layer. The data layer can be early warning data, case specific data, and supporting data. The business layer represents that segment of disease monitoring architecture where the data is gathered and meaningful information is derived by the application of probabilistic or deterministic solutions/algorithms. Finally, the presentation layer helps to present the result in the form of the graphs, tables and meaningful reports. This paper helps to understand the overall, architecture of electronic disease monitoring system, however this paper suggests that creating a standard vocabulary and communication for interoperability is more important than just establishing such infrastructure. Another study (Fan, Blair et al., 2010) published in 2010 on Alberta real time syndromic surveillance network (ARTSSN) from Alberta, Canada showed the reporting system based on the city of Edmonton and nearby Parkland County. The system collects data from the ED, laboratory, schools for absenteeism, and laboratory about the disease occurrences both syndromic data and or confirmed cases data. The information is transmitted electronically to the PH units and disease pattern is 24 hours a day, 7 days a week and 365 days in a year (24/7/365). However, as per this paper, the main challenge this system faced were that the ARTSSN was lacking the statistical modeling capability. Also, the integration of the multiple data sources for deciphering the aberration signals was challenging as the ARTSSN was expanding from regional to the provincial system. Therefore, it was working with the university researchers for NLP and statistical analysis. In another study (Li et al., 2012) from China conducted in 2012 showed that molecular-typing-of-bacterial diseases-on-lab based disease monitoring and outbreak detection system. The author shows that this type of system is acting independently without collaborating with a PH reporting mechanism, however it has a huge potential of disease outbreak detection in real time if these systems are collaborated with the national PH surveillance system. They also highlight the need of collaborating this system by each country and at the global level. Also, an article (Reis, Kirby et al., 2007) was published in 2007 about the real time automated epidemiological geotemporal integrated system (AEGIS), the online software implemented in the state of Massachusetts department of PH. This paper raised the issue of scalability, robustness and security as an important component to be considered while integrating local, state and NHIS. The scalability and robustness cab be enhanced by developing the modular and fault tolerant designs whereas the data security can be maintained by giving full authority and autonomy of the data to the local owners/institutions. This paper also highlighted that for the future they are working on making AEGIS an open source software that can be used from anywhere and any country in the world through the Internet.

Further, there are 2 articles (Pelat et al., 2007; Doyle, Ma, Groseclose, & Hopkins, 2005) related with the statistical/analytical software and 3 articles (Hutwagner, Thompson, Seeman, & Treadwell, 2003; Izadi et al., 2009; Zhu, Wang, Atrubin, & Wu, 2005) related with DP algorithms. The article (Pelat et al., 2007) published in 2007 presents an online statistical software that was developed by a French team. This online tool helps to detect the disease outbreak by calculating the disease threshold and the upper percentiles of 90% or 95%. There is a need of at least one-year of data for calculating the disease outbreak and threshold, however two to three years of data would be the best for better prediction. It was developed in such a way that a field level epidemiologist with little knowledge about the use of computer applications can also apply it. It has been made more user friendly through these means. It can be used for both prospective and retrospective time series data sets. This software is promising when looking at its application in resource limited areas of the world. However, more training for the field level health workers in usability is definitely an issue.

There are 5 articles (Abrams & Kleinman, 2007; Kaiser, Spiegel, Henderson, & Gerber, 2003; Khan et al., 2010; Martin, Curtis, Fraser, & Sharp, 2002; Rushton, 2003) related with the application of GIS in PH programs. An article published in 2003 discussed the application of GIS system and its application in humanitarian emergencies (HE), disease survey, monitoring, and research. The main areas of further research the paper identified were: developing more user friendly and cheaper GIS technologies, providing training to the field workers about the application of the GIS, and making more use of GIS for decision making system. Again, in 2010, an article (Khan et al., 2010) suggested that the potential areas of GIS application yet to be developed are in policy making and in underdeveloped setting. Most of the under-developed settings have to be supported by the international organizations, and the GIS is not applied much in policy making.

There are 4 articles (EUPHIN, 2003; Johnson et al., 2004; Denecke et al., 2011; Trewin, Strand, & Grøholt, 2008) that are related with the web based disease monitoring system. For example, the article (EUPHIN, 2003) is about the European union public health information network (EUPHIN), which is established for the internet based information exchange and disease monitoring across the European union (EU) in a secure way. Similarly, the article (Trewin et al., 2008) is about Norhealth which is a web-based system that monitors both infectious and non/communicable diseases and is used to create awareness among the population, media, politicians and policy makers. This system requires further development in incorporating more diseases in the fact sheet, translating the language to English, and making it more visually appealing and interactive. One article (Denecke et al., 2011) was a discussion about the event-driven architecture that was implemented to capture the real time disease events from multiple sources e.g., TV, radio, websites, blogs, and Twitter. The system's attributes include actuality (real time monitoring), efficiency (capacity to monitor a huge data), robustness (an easy adding or replacing of the components), flexibility and adaptability (new events can be integrated easily). The diseases are monitored both in a real time and retrospectively. The information retrieved from TV and radio is collected via satellite and transcribed by SAIL media mining system. The data from the web sources are mined using DP algorithm (machine learning classifier). The data is then calculated by using the statistical/analytical software (CUSUM), the result is sent as a feedback to the user.

There are two articles (Kirk, 2004; Sobel, Griffin, Slutsker, Swerdlow, & Tauxe, 2002) about the application of the food sources monitoring system published in 2004 and 2002 respectively. These articles highlighted need for establishing monthly monitoring system for food based disease monitoring system. A lack of studies after 2004 in this area suggests that there may not be enough application of IT in food sources monitoring system.

Among the two remaining articles, one (Scotch, Mei, Brandt, Sarkar, & Cheung, 2010) is related with the application of the web 2.0 and web 3.0 semantics for the geographic distribution tracing of pathogenic agents. These tools can help to understand the geographic distribution of the pathogens and also find out the disease burden and affected population. Another article (Morse, 2007) is a viewpoint of the author, where they recommended some important facts to improve the global and country specific reporting and surveillance system. Some of which are: (a) ensuring a global compatible standards for data reporting and sharing and coordinating reporting systems worldwide (as a prototype the European MedVetNet (http://www.medvetnet.org/cms) can be used.); (b) encouraging the improvement of the national reporting system by training local health personnel, strengthening the local infrastructure, and increasing the laboratory capacity; (c) encourage clinicians to report any new diseases in time with appropriate feedback; and (d) educate the policy makers to consider disease surveillance as a priority.

Based on the other review articles, some important findings can be highlighted, which are: the application of GIS has to be improved both in developed and developing countries; the food based disease monitoring system is not well advanced; and there is a web based disease monitoring system named AEGIS being developed that can be adapted across the world by any country.

Editorials:

There are a total of 17 editorials found on this topic. The editorials are the representations of discussions that were made in the scientific community. Among these 17 editorials, the eight articles (Internet syphilis testing, 2003; Brownstein & Freifeld, 2007; Coleman & Delea, 2013; Rubertone & Brundage, 2002; Madoff, Fisman, & Kass-Hout, 2011; World Health Organization, 2005; Rehle, Lazzari, Dallabetta, & Asamoah-Odei, 2004; Mykhalovskiy & Weir, 2006) discussed the application of a website for the disease monitoring or data reporting system. Among them, the first editorial (Internet syphilis testing, 2003) published in this PH domain was in 2003, which was focused in maintaining patients confidentiality by disseminating web based HIV reporting to the patients. One editorial (Brownstein & Freifeld, 2007) was on the application of HealthMap; a web based global disease monitoring system. The information retrieved from the governmental organizations reports, RSS feeds, WHO reports, CDC reports, Euro surveillance reports, online news, and expert-curated accounts (ProMED-Mail). The editorial suggested that a collaboration with similar kinds of system would be beneficial for the global disease monitoring. Another editorial (Coleman & Delea, 2013) talked about the PHI approaches to environmental health initiatives in USA. In 2001, the CDC first initiated the PHI approach by developing the environmental health specialist network information system (EHSNIS). This system is a web-based application which can be accessed from anywhere through the Internet. The system provides useful tools in food borne diseases outbreak environment assessment, risk assessment of *Listeria* in a retail environment, and information on private wells. The editorial further suggests that the large amount of data with scarce useful information is a problem with the current environmental health system. Although, the web based system is accessible by all, and anyone can report in it without exposing their identity, improving the data quality and developing the data collection, analysis, and dissemination protocols are still a challenge to the system. The report also suggests that regular updating of the data collection tools and developing the new analytical techniques could be very beneficial to improve the environmental health and outbreak detection functions. Some other articles discussed web based archived in defense medical surveillance system (DMSS) (Rubertone & Brundage, 2002), web based data query system (Madoff et al., 2011), web-based global rabies monitoring by the WHO (World Health Organization, 2005), HIV surveillance (Rehle et al., 2004), and web based global public health intelligence network (GPHIN) based in Canada which has a global disease monitoring system (Mykhalovskiy & Weir, 2006).

Among the remaining articles, some important concepts discussed were: importance of electronic data security (Fairchild et al., 2007; Mostashari & Hartman, 2003); need of interoperable systems in the USA for the bioterrorism surveillance (Jossi, 2006); need for a health information exchange (HIE) among the PH and clinical units of NHIS in the USA (Nangle, Xu, & Sundwall, 2009); and description about the syndromic surveillance in EU (Soler Sala et al., 2011). The paper (Mostashari & Hartman, 2003) published in 2003 also presented that developing statistical software is important for analyzing the timeliness of the data; whereas, deployment of electronic registry is important for the advancement of the SS in the future. Similarly, the editorials (Fenton & Lowndes, 2004; Goedert, 2008) are related with the clinical and laboratory based electronic reporting to PH units in England and USA respectively. The final two articles are related to the application of mobile phones (Freifeld et al., 2010) and use of electronic systems for the ambulance diversion in hospital environments (Page, 2004). The article (Freifeld et al., 2010) presents some of the developments in the application of mobile phones in the PH activities until 2010. The use of the Internet and mobile phones are very innovative ways of detecting outbreak and disseminating information to a large number of the population at a single time. It reduces the reporting time from the source/affected population, and helps real time information sharing. Some of the developments are: FrontlineSMS developed in 2005- this is mobile based SMS (two-way communication system); the health worker from a remote area sends an SMS to PH units, and the PH units send a SMS to a large number of people at a single time. These systems are applied in Malawi, Honduras and in other developing countries. Another system is Ushahidi (developed in 2007) which is applied in tracking medical supply stock-outs, tracking wildlife, and helpful in disaster response. It is in use on Haiti after the 2010 earth quake, and in Kenya for wild life tracking. This software requires the Internet to use. Similarly, the GeoChat (2008) is also open source software that can be downloaded for free. The users/crisis control team can communicate among each other through SMS. This is applied for natural disaster management and has been applied in Thailand and Cambodia. Another innovation is an iPhone application named Asthmapolis (developed in 2010) that is a GPS-enabled inhaler that tracks the location and time of inhaler use. Individuals, clinicians, or PH scientists for population surveillance can access the information from this application. Finally, the ‘Outbreaks Near Me’ (developed in 2009) is an online map that can be accessed from the internet based application and can be downloaded for free. Anyone can contribute for disease reporting on a real time reporting. Although, crowd sourcing has emerged as an important source of disease monitoring, there is a potential misuse of such a system by increasing the rate of fraud, which poses a potential challenge for system users. However, these kinds of reports are useful for real time early notification that has to be verified with other sources. In conclusion, the main findings from the editorials are that the editorials have mostly discussed the application of websites for the disease monitoring, application of mobile phones for disease monitoring, the importance of data security data, the importance of electronic reporting system among the clinical and PH units for HIE and interoperability, and the importance of syndromic surveillance system.

Summary of the findings:

Table 2. Tabular presentation of the overall finding of the infectious/communicable disease monitoring.

Focus of the research/discussion	Qualitative studies	Quantitative studies	Other reviews	Editorials	Mixed studies	Narrative literature reviews	Systematic reviews
Reporting from clinical/laboratory to PH units based studies	11	19	23	3	4	2	2
Pharmacy (OTC drug sell) based studies	1	4					
Population-based studies		12					
Testing and Improving the DP algorithm			3				
Application of GIS in PH programs	8		5				
NHIS	5		1	2			
Ethnographic studies	3						

Testing and developing statistical/analytical software in PH programs	2		2	1			
Web based disease monitoring system		1	4	8			
Insurance claim based studies	1						
Food sources based diseases monitoring system			2				
Genetic research			1				
Electronic data security				2			
Application of mobile phones				1			
Total	31	36	41	17	4	2	2

Table no. 2 presents the tabular presentation of the total number of articles with respect to the area of research and/or discussion that were discussed in the in-depth analysis above.

8.3.2 Outbreak detection

8.3.2.1 Number of articles

There are a total of 95 articles included in outbreak detection PH domain.

8.3.2.2 Study settings with number of studies

About two thirds 68 (71.7%) of the total articles are from the USA, followed by 12 (12.6%) from Asia and 11 (11.6%) from the rest of Europe. In Asia, most are from China, which could be because of the SARS outbreak in China in 2003 that encouraged Chinese PH professionals and scholars to conduct research and raise issues regarding this PH domain.

8.3.2.3 Types of articles/methodology

There were 38 (40.0%) qualitative studies, which was followed by 24 (25.3%) other reviews of the total 95 articles. There were only 19 (20.0%) quantitative studies. The remaining 10 (10.5%) are editorials; whereas 4 (4.2%) of the articles represent empirical literature review, narrative literature review, and mixed studies.

8.3.2.4 Evidence relating to the use of Information Technology

Among the total number of 95 articles, the majority 76 (80%) of the articles have discussed/used EMR/EHR/electronic registry, followed by DP algorithm 61 (64.2%) and website 37 (38.9%). Further, statistical/analytical software and GIS were used by 28 (29.5%) and 21 (22.1%) of the total articles respectively. Very few of them discussed/used NLP 5 (5.1%), mobile phone 1 (1.0%) and mass media 1 (1.0%); non-of them discussed/used automated speech processing.

8.3.2.5 Evidence relating to the use of Informatics concepts

Among the total 95 articles, 70 (73.7%) applied data collection, 56 (58.9%) applied data retrieval, and equal number of 53 (55.8%) of the articles applied data transmission/ communication and interoperability. Further, a significant number 37 (38.9%) articles also applied data analytics. Less than 10% of the articles used/discussed data storage, information sharing, data security, and knowledge management informatics concepts.

8.3.2.6 In-depth analysis for the current status of research and practice:

An assessment to the individual articles shows interesting facts about the application of IT in this PH domain. First of all, the articles in this PH domain started to be published since 2003.

Qualitative studies:

There are a total number of 38 qualitative studies included in this PH domain. Among them, 8 articles (Bradley, Rolka, Walker, & Loonsk, 2005; Cakici, Hebing, Grunewald, Saretok, & Hulth, 2010; Daniel et al., 2005; Espino, Wagner, Tsui, et al., 2004; Shen, Adamou, Dowling, & Cooper, 2008; Wijngaard, Pelt, Nagelkerke, Kretzschmar, & Koopmans, 2011; Wu et al., 2008; Yan et al., 2012) are about the hospitals/ED to the PH units based disease reporting and 5 articles (Burkom, 2003; Lombardo, Burkom, & Pavlin, 2004; Yan et al., 2013; Yan et al., 2012; Chen et al., 2005) also extend the reporting from pharmacy, and school absenteeism in addition to the hospitals/ED based reporting to PH departments. The literature shows that the first endeavor on establishing electronic disease monitoring system was the RODS which was established during the 2002 winter Olympic in Utah, USA (Espino, Wagner, Tsui, et al., 2004). The system successfully implemented and is continuously functional after 2002 in that State. The IT applied are mainly DP algorithms and electronic registry. Following the 2003 SARS outbreak, the RODS system was embraced in other parts of the world. For example, in China (Yan et al., 2012), after the SARS outbreak in 2003, the government established the China information system for disease control and prevention (CISDCP) which is real time internet based daily reporting system. By the end of 2007, "the system covered 79.04% of township hospitals, 95.99% of hospitals at or above county level and 100% of center for diseases control (CDC) units in China" (Yan et al., 2012). However, there was a challenge for reporting from the villages due to lack of computer and internet system. The China-CDC tested the applicability of the mobile phone for disease reporting from the rural level during an earth quack in the Sichuan province in 2008 and proved to be a successful tool for disease reporting. Similar to the Chinese project, a disease monitoring program was also implemented in Taiwan in 2004 (Wu et al., 2008) which was found to be successful for syndromic surveillance and outbreak detection. Some other exemplary programs are the electronic surveillance system for the early notification of community-based epidemics (ESSENCE) (Lombardo et al., 2004) and BioSense (Bradley et al., 2005) disease surveillance programs implemented in USA and national computer supported outbreak detection system CASE (Cakici et al., 2010) implemented in Sweden. The IT applied during the reporting were: the EMR/EHR system for reporting, the DP algorithm for detecting possible outbreak based on disease syndromes, statistical/analytical software for analyzing the data, and NLP for text parsing and text classification. The GIS system SaTScan statistics was applied to find out the temporal-spatial occurrences of the diseases.

Further, there are 10 articles (Buckeridge et al., 2004; Buckeridge et al., 2005; Mohtashemi, Kleinman, & Yih, 2007; Mohtashemi, Szolovits, Dunyak, & Mandl, 2006; Mandl, Reis, & Cassa, 2004; Murphy & Burkom, 2008; Naumova, O'Neil, & MacNeill, 2005; Silcocks

& Robinson, 2004; Torii et al., 2011; Wong et al., 2005) focused on testing DP algorithms in simulated data and tried to find out the effectiveness of the models. The DP algorithms were: population-wide anomaly detection and assessment (PANDA) (Wong et al., 2005), temporal model (Buckeridge et al., 2005), and simulation and dispersion model (Buckeridge et al., 2004) for detecting the outbreaks based on the syndromic data. These models were applied on syndromic data at a population level to model the individuals based on Bayesian techniques. For example, the PANDA tool (Wong et al., 2005) was applied to detect the outbreak by combining the data from two sources: OTC sale and ED syndromic data. Each person in the population is included in the model and subsequent result is generated. In another study (Buckeridge et al., 2005), a temporal algorithm was tested in a simulated data for anthrax outbreak. The result showed that the temporal algorithm was successful to detect the outbreak effectively in time when there were 50,000 cases and 40% of them visited the health care at the prodromal state. However, the sensitivity decreased when the number of infected people decrease. The study had modelled the disease factor and health care seeking behavior factor. It had considered the health care seeking at 4th day of the prodromal stage, because in real life scenario, people may seek health care before 4th day. This study proposes to conduct future study on it. Similarly, DP algorithms, for example, Naive Bayes and Support Vector Machine (SVM) classifiers also applied in a paper published in 2011(Torii et al., 2011) in a South Asian journal. The study was conducted over a month to find out the effectiveness of these classifiers for internet-based bio surveillance of a disease. A total of 40,000 articles were identified, which were manually reviewed by an analyst finding 169 articles. The main finding of the study was that, "a large number of training corpus (available articles) could be captured with these framework (Torii et al., 2011)." Also, the authors concluded that "these types of classifiers may be useful for the common diseases, however it may lose the rare diseases" (Torii et al., 2011) the authors recommend further study on this direction.

There are 11 articles (Burkom, Murphy, Coberly, & Hurt-Mullen, 2005; Eriksson et al., 2007; Fricker et al., 2008; Guo et al., 2011; Timpka, Morin, Jenvald, Eriksson, & Gursky, 2005; Vuurden et al., 2008; Wagner et al., 2013; Wallstrom, Wagner, & Hogan, 2005; Wang et al., 2010; Wong, Moore, Cooper, & Wagner, 2003; Wu et al., 2011) focused on statistical techniques. The articles focused on testing the statistical/analytical algorithms that were tested in simulated and real test data. For example, a study (Eriksson et al., 2007) talks about applying the ontological simulation modelling for the outbreak identification. The simulation entails both community model and disease model. It uses the simulation modelling for identification of outbreak. The community model may consist of school, household, work place, and child care, whereas the disease model is based on SIR (susceptible-infectious-recovered) model. This type of modelling is useful for infectious diseases. The paper explains the main problem with this type of simulation is that it requires a simulation expert and programmers for this type of modelling task. Hence, it cannot be used by general health workers. Similarly, the study (Burkom et al., 2005) was focused on the evaluation of statistical methods for outbreak monitoring: these statistical methods are either applied or being applied in the ESSENCE II program. It applies consensus monitoring methods, multiple univariate methods, and multiple multivariate methods. Another study (Fricker et al., 2008) compared two statistical algorithms: CUSUM method and EARS (Early aberration reporting system) system, which include C1, C2, and C3 method. It found that CUSUM is better than the EARS method and recommended to replace EARS with CUSUM. Further, one study (Wang et al., 2010) compared five different outbreak detection algorithms: space-time permutation scan statistics, exponential weighted moving average

(EWMA), C1, C2, and C3 on Bacillary dysentery data from 2005 to 2007 in Beijing, China. The result showed that the former two algorithms outperformed the later three algorithms. However, the result lacked generalizability because the study was conducted in a simulated environment with baseline data and was not a true outbreak. The research suggests further study in it. Similarly, WSARE (Wong, et al., 2003) is applied in ED daily data. This algorithm detects the daily data aberration at any time in a day.

There are two articles (Chanlekha, Kawazoe, & Collier, 2010; Travers et al., 2013) focused in testing NLP. The article (Travers et al., 2013) published in 2013 specifically discussed about the NLP. The article applied ED text classifier for the outbreak detection in the North Carolina (NC). The purpose of the study was “to implement emergency medical text classifier (EMT-C) system into daily production for syndromic surveillance and evaluate system performance and user satisfaction” (Travers et al., 2013). In this study, the EMT-C was developed and applied to find out the gastro intestinal (GI) syndromes in NC DETECT from Jan. 10 to 30, 2013 and compared its effectiveness with the existing system called 'GI syndrome'. The study showed that the classifier is effective to detect the GI syndromes with high sensitivity and specificity than the usual system. However, the main problem associated with this system was that it contains only the limited number of CC (e.g., nausea, vomiting, diarrhea, and fever) and there was no option for previous medical history, for example, history of chronic diseases resulting in a false positive to some records. The study recommended to incorporate these problems by adding the new features of medical history in the future version of EMT-C. This study also called for applying this system to other diseases’ syndromes, for example, fever-rash-illness, and ARI syndromes to test the syndromic surveillance system. However, the study lacks the generalizability due to small sample size and small number of epidemiologists' involvement during analysis, the authors admit.

Finally, between the remaining 2 articles, the article (Brownstein et al., 2008) was about the global disease monitoring system analyzing internet based news, blogs and presenting them in spatial-temporal format in the website. Another study (Sintchenko, Gallego, Chung, & Coiera, 2009) proposed a novel idea about applying IT for detecting the genetic and geographic profiling of the pathogens and comparing it with the spatial permutation scan statistics data from other parts of the world and thereby finding the original sources of the disease pathogens.

In conclusion, the qualitative studies included in this PH domain, were almost all the studies from the hospital to PH units reporting. The DP algorithms or statistical/analytical software capability were tested in the simulated data. Since, the outbreak detection has been mostly from the developed countries and hospital-based, most of the IT applied was electronic registry, followed by DP algorithms, and statistical/analytical software.

Quantitative studies:

There are a total of 19 quantitative studies in this PH domain. Out of them, 10 articles (Das et al., 2003; Dembek, Carley, & Hadler, 2005; Foldy et al., 2004; Krause et al., 2007; Ritzwoller et al., 2005; Mostashari, Fine, Das, Adams, & Layton, 2003; Shimoni, Gershon, Kama, Dusseldorp, & Froom, 2006; Steiner-Sichel, Greenko, Heffernan, Layton, & Weiss, 2004; Reis & Mandl, 2003; Yih et al., 2005) were related with ED based syndromic surveillance, two articles (Reis, Kohane, & Mandl, 2007; Enki et al., 2013) are related with testing DP algorithms, and the remaining articles are each on testing statistical/analytical software (Kulldorff et al., 2004), OTC drug sale monitoring (Das et al., 2005), poison control center based phone call monitoring system (Derby et al., 2005), survey on PH workers' perspective (Drociuk, Gibson, & Hodge, 2004), school based surveillance (Mann et al., 2011), the application of GIS (Olson et al., 2006), and the final quantitative study (Chan et al., 2011) was about the web based data query system.

Among the 10 articles related with the ED based syndromic surveillance system; the articles were focused on the system which were implemented by reporting the data from the ED to the PH units where diseases were monitored for any disease aberration. For example, one study conducted in Israel from 2003 to 2004 for over 2 years. An admission secretary asked the patients or their family member the reasons to visit the ED. The cause/symptoms of disease were entered into the electronic database and data were analyzed periodically. The study found that monitoring the patients' reason of visit can detect ILI in time and can be helpful for outbreak and bioterrorism surveillance. The writer also suggests to conduct the same kind of the surveillance in other parts of the world. Some emerging concepts in SS were studied in some articles. For example, in one study (Das et al., 2003), it was found that ED based SS could be inefficient to detect anthrax attack because only 25% of the patients visit ED after being attacked and the rest would visit to the outpatient department. Similarly, another comparative study (Yih et al., 2005) was conducted to find out the effectiveness of the SS system to detect the GI illnesses. A total number of 110 GI illnesses outbreaks of the ambulatory clinics data were compared with the GI outbreak data presented by Minnessota department of public health over a 2-year period from 2001 to 2003, retrospectively. The study could not associate the SS effectiveness as compared with the data obtained from the Minnessota department of public health, hence recommended for further investigation with prospective studies in it. A similar finding was also identified in another mixed study design (Steiner-Sichel et al., 2004) where the SS could not identify a norovirus outbreak in New York City in 2002. In another study (Reis & Mandl, 2003), the effectiveness of the syndromic surveillance system from two different large urban hospitals compared the effectiveness when the data were integrated. The data contained from June 1998 to Dec 2002. Three sets of models were created to test the effectiveness of the outbreak detection. The first model contained data from hospital 1, second model contained data from hospital 2 and the third model contained the combined data. The result of the study showed that the combined model is better in detecting outbreak with higher sensitivity than the individual hospitals model. However, the individual hospital model is better to detect the local outbreak with better population group identification. The main problem with the combined model was that it could not differentiate the specific populations, e.g. school exposure of the child patients. In summary, the report suggests to conduct both the individual hospital model to detect the local level outbreak and the combined model at the regional level. It also suggests that combining data from different kinds of hospital with their various types would be a prudent way. For example, integrating data from child hospitals and maternal hospitals separately for disease monitoring. As there is a recent trend to increase the data integration and outbreak detection at the regional and national level, this study suggests to continue to detect the outbreak at all levels. A similar finding was also detected in an identical study (Reis, Kohane, & Mandl, 2007) where the researchers identified that integrating data from various health care centers can be very effective in detecting outbreak especially during a large scale event e.g., high profile events, elections, or multinational games.

Among the studies focused on statistical/analytical software, one study (Kulldorff et al., 2004) evaluates the effectiveness of the space-time scan statistics for the outbreak detection in the NY city. It shows that this method is useful for the citywide outbreak detection however not powerful for the geographically localized outbreak detection. One study focused in application of GIS showed that using patient's exact location while detecting the outbreak has over 50% higher power of detecting outbreak than only with the centroid method, i.e. using zip code, although this method has a high probability of exposing the patient's privacy. In the studies focused on DP algorithms, one retrospective descriptive study (Enki et al., 2013) on the 20 years database of England and Wales, the study finds the important findings about the use of DP algorithms to detect the outbreak. In another study (Reis, Kohane, & Mandl, 2007), a new DP algorithm called epidemiological network modelling is developed. This modeling is compared with the reference time-series model. The five hospitals' ED from the same metropolitan area are used where simulated outbreak is introduced into the real 5 years historical data of respiratory and GI diseases of these hospitals. The study showed that, under normal conditions, the epidemiological network modelling detects outbreak better than reference time-series model. The epidemiological network model monitors the relationship between the EDs data streams, which was found to be better during the large-scale events, e.g., world cup football. However, the main disadvantage with these types of modelling is that these networks only include the temporal modelling and do not have information about the geospatial of the patients.

Similarly, a study (Das et al., 2005) focused on the outbreak detection through OTC drug sale showed that different store hours and consumer behavior were some challenges associated with such outbreak detection systems, because it makes the data modelling and spatial analysis difficult to find out the local cluster.

In summary, the quantitative studies presented above invariably used the electronic registry, e-mail, statistical/analytical software, DP algorithms, GIS, and telephone-landline. The main discernible findings are that most of the studies are in hospital settings whereas some are in OTC drug sale, school absenteeism, and poison center based monitoring.

Mixed study:

There was only one mixed study (Heffernan, Mostashari, Das, Karpati, et al., 2004) found in this PH domain which was conducted to find out the effectiveness of a SS program conducted by NY City Department of Health and Mental Hygiene (DoHMH) in 36 participating hospitals. The EDs send syndromic data daily to the PH units and it is examined daily by an epidemiologist to find out any aberration in the data. The study was conducted from 15 Nov 2001 to 14 Nov 2002, in its first year of implementation of the program. The data is sent daily in an electronic data transfer. The study detected the aberration in terms of both spatial and temporal variation. The study identified an increase of community wide increase of influenza and diarrheal diseases and informed to the clinicians about it, which was a very new activity and improvement for the disease prevention activity. However, no outbreak was detected during this study period. This study further declares that most of the adults with such syndromes do not visit the ED, but instead go to family physicians. This study also suggests developing further analytical designs and determining appropriate threshold level for detection are important for detecting outbreaks.

Other reviews:

There are a total of 24 other review articles under this PH domain. Among them, 15 articles are related with clinical settings to the PH units for syndromic surveillance (Ansaldi et al., 2008; Espino, Wagner, Szczepaniak, et al., 2004; Foldy, 2004; Heffernan, Mostashari, Das, Besculides, et al., 2004; Lober et al., 2003; Lombardo et al., 2003; Mollura et al., 2008; Paladini, 2004; Pavlin, 2003; Pavlin et al., 2003; Sosin, 2003; Wagner, Espino, et al., 2004; Yih et al., 2004;

Cochrane, 2004; Broome, 2005). Among the 15 clinical settings based articles, one article (Heffernan, Mostashari, Das, Besculides, et al., 2004) also included reporting from OTC drug sale and workers absenteeism data reporting, and two articles (Lombardo et al., 2003; Mollura et al., 2008) included OTC drug sale and school absenteeism based data reporting. Further, three articles (Tu et al., 2007; Hogan, Cooper, Wallstrom, Wagner, & Depinay, 2007; Jiang, Cooper, & Neill, 2009) are related with the application of the DP algorithms, and another three articles (Hoen, Keller, Verma, Buckeridge, & Brownstein, 2012; Hutwagner, Browne, Seeman, & Fleischauer, 2005; Pelat et al., 2007) are related with the application of the statistical/analytical software. Among the remaining three articles, each are related with the mobile phone based outbreak detection in developing countries (Campbell et al., 2012), telephone-landline query based disease monitoring (Doroshenko et al., 2005), and application of new health monitoring devices, e.g., fever monitoring devices, asthma monitoring devices, and also smart phones for disease monitoring (Eysenbach, 2003).

It is important to discuss some of the valuable insights captured from these articles. Among the clinical settings based data reporting, e.g., one paper (Broome, 2005) published in 2005 presents the role of CDC in USA for developing and strengthening local, state and federal level disease surveillance systems through the respective clinical and PH units. The Public health information network (PHIN) is the apex system that ensures the national standard on technology, data, vocabulary, and information security at all levels of health units. CDC also has established the national electronic disease surveillance system (NEDSS) which is a software program with PHIN standard tool. Such system is in place in all the states in USA and provides information on individual case. The reporting is internet based, which is interoperable, secure, and can be used by all the health jurisdictions. Another program also implemented by CDC is Biosense, which is a secure, internet based syndromic surveillance approach. The article recommended for incorporating the system for continuous evaluation and modifications. Similarly, one paper (Cochrane, 2004) published in 2004 presents the emergency medical associates (physicians) views on the importance of the syndromic surveillance. They highlight some issues related with SS: the data reporting is costly in SS; it is difficult to maintain the patients' confidentiality in SS; and SS was a novice system and lacked research and validation, which could cost a high expense and human resources for a false alarm.

Similarly, among the articles related with the DP algorithms, an article (Hogan et al., 2007) presented the Bayesian aerosol release detector (BARD) algorithm for detecting the anthrax outbreak by considering both the medical surveillance and meteorological condition preceding the outbreak. The existing anthrax outbreak detection algorithms only consider the medical surveillance data, which need to be updated to make the surveillance more vivid. This study showed that the BARD algorithm could be useful for the future, which needs to be further developed to test in real life detection.

Further, among the articles related with statistical/analytical software, one article (Hoen et al., 2012) applied the receiver operating curve (ROC) to identify the threshold of the dengue virus in South American countries (some states of Mexico, Brazil, Bolivia, Argentina and Paraguay). The study identified an appropriate threshold level by using the data from HealthMap (an online real time global outbreak monitoring system). Eventually, the researchers were able to identify the expansion of the dengue fever to other parts of the participating countries even before the official reports were obtained. Also, in this paper (Hutwagner et al., 2005), the authors present a study that tests the effectiveness of the statistical methods seasonally adjusted CUSUM methods, as compared to C1, C2 and C3 methods. The study demonstrates that to the non-historical data where little baseline data is available, C1, C2, and C3 are also as sensitive and specific as CUSUM methods.

Also, an article based on mobile phone based monitoring (Campbell et al., 2012) published in 2012 showed that to mitigate the electronic syndromic surveillance in resource-limited areas of the world, the Electronic Surveillance System for the Early Notification of Community-based Epidemics (ESSENCE) Desktop Edition (EDE) and OpenESSENCE (OE) were developed by Johns Hopkins University Applied Physics Laboratory. These two systems are freely accessed systems, which were implemented in Philippines over two years in 2009. These systems have the same capacity of ESSENCE, a proprietary commercial product in use by CDC USA since 2004. These two systems can be applied without internet access and with the data gathered by mobile phones. Several local clinics implemented these two systems and are effectively monitoring the syndromic surveillance from desktop computers. The EDE is installed in personnel computers, although it does not have the capability of data collection, the messages entered into the computers can be obtained from mobile SMS and used for analysis. The article indicates that "other countries are considering using smart phone data forms to collect health data and transmit it via SMS." OE is more advanced than EDE because data can be collected/entered by multiple users through internet. However, it can be used both at internet based and without internet. The sole purpose of these systems is to provide enough capability to the resource prone areas of the world enough capability to analyze their data. The OE included the DP algorithms, which are Exponentially-Weighted Moving Average (EWMA), linear regression, Poisson regression, and the US Centers for Disease Control and Prevention (CDC) Early Aberration Reporting System (EARS versions 1, 2, and 3). It also has the GIS system SaTScan, which can present the data in terms of spatial-temporal distribution. The result shows that the system is capable of obtaining the report two to three weeks earlier than the usual system by using the SMS system. The paper recommends producing future versions of these systems for resource-constraint scenarios as simple as possible so that any users can apply such system in their jurisdictions.

Editorials:

There are total 10 editorials (Gabel & Leon, 2004; Burns, 2006; Butler, 2008; Duchin, 2003; Jossi, 2006; Kaiser & Coulombier, 2006; Nardone, 2004; Mostashari & Hartman, 2003; Piotrowski, 2003; Weiner, 2006) found in MEDLINE-PubMed. These were published from 2003 to 2008. The result did not find any editorials published after 2008. The majority of these articles (Gabel & Leon, 2004; Duchin, 2003; Jossi, 2006; Nardone, 2004; Piotrowski, 2003; Weiner, 2006) were discussing the application of the electronic reporting system from hospital ED to the PH departments. The syndromic surveillance was the main strategy of these systems. For example, in a paper (Nardone, 2004) the author talks about the first start of the Healthcare Collaborative Network (HCN) in USA in 2004. This network was initially established in three hospitals: New York-Presbyterian, New York, and Vanderbilt University Medical Center, Tennesse, and Wishard Memorial, Indianapolis. This system included the real time electronic reporting from the hospitals to the Federal departments: CDC; U.S. Food and Drug Administration; and the Centers for Medicare and Medicaid Services (CMS). This initial step was initiated after 10 weeks, when secretary of the department of health and human services, USA announced the first set of uniform standards for the exchange of clinical health information across the federal government. The network established in 2004 applied the patients' demographic information (zip code, age and gender, hiding the personnel information to maintain the privacy) and other communicable and non-communicable diseases (diabetes, cardio vascular disease, anthrax, meningitis). The information from laboratory and ED were directly entered to the electronic information reporting system, which could be accessed by the federal units in a real time fashion. It was expected that such system could cost 8 billion over the next 5 year to establish across USA, however could save 8 trillion during the same time period.

Also, there were some editorials which focused on global disease monitoring system by news feeds mining (Burns, 2006), web based data query system for disease surveillance (Butler, 2008), and disease monitoring during large mass gathering events e.g., FIFA world cup, and presidential elections (Kaiser & Coulombier, 2006). The article (Burns, 2006) talks about the WHO response to contain the disease outbreak at a global level. After the Plague outbreak in Gujarat, India, in 1994, the international news from TV and newspapers were the only means of information captured by the WHO, which was overwhelming due to maze of thousands of newspapers from across the world. To solve this problem, Dr. Ron St John and Dr. Rudy Nowak from Health Canada, the Canadian health ministry, innovated a new idea of mining the global news feeds published in English and French. The system called Global Public Health Information Network (GPHIN) was established in 1999. This system provided information to WHO about the Global outbreak information on a daily basis. The e-mail was the only means of information sharing. Before sending it to the WHO, it was verified by 8 PH specialists in Health Canada. The GPHIN-II was functional since 2002, which also started to include 4 other languages (Arabic, Chinese, Russian, and Spanish). Similarly, the WHO had International Health Regulations (IHR) by which all the member countries across the world voluntarily reported plague, cholera, and yellow fever outbreak. However, after the SARS outbreak in 2003, the IHR was updated. Effective from 2007, all the member countries had to legally report all the disease outbreaks; natural disasters; chemical, nuclear and laboratory accidents; and bioterrorism attacks. In gist, this report shows that there was not much development in PHI application for containment of the disease outbreak before 1999 when the GPHIN was first introduced to find the disease outbreak on a daily basis by mining the news feeds. The only applied ITs were the mass media (TV, Radio) and e-mails.

Similarly, another study (Butler, 2008) presents about using Google and Yahoo data mining system to predict the disease outbreak, especially the flu outbreak. This paper shows that the flu surge can be determined before a few weeks by monitoring the 'search terms' in Google and Yahoo. However, this paper suggests that it should not replace the existing disease surveillance system, rather it should be supplementing the system. These types of studies are only in the English language, however, it suggests applying such a system in other languages and in other countries as well.

Another study (Kaiser & Coulombier, 2006) presented the establishment of the outbreak detection mechanism in large scale mass gathering in special events like world cup games or high profile meetings e.g., G20 meetings. The paper states that there should be surveillance mechanisms in place in advance before such events. These mechanism could be enabling the existing surveillance system, setting-up venue/event-specific surveillance systems, strengthening the disease reporting and information dissemination mechanism and applying the DP algorithms for early detection of outbreaks. In setting-up event-specific surveillance systems, it suggests to establish a surveillance system e.g., OTC drug sale monitoring, monitoring the health related web data queries, and clinical investigations (e.g., number of blood tests, stool tests, and chest x-ray). This paper suggests that establishing such a system could be very effective in finding diseases in time and control disease outbreaks.

Finally, according to the editorials included, there were a lot of works done in between 2003 to 2006 on establishing the local, state and federal level real time electronic outbreak monitoring system in USA governed under CDC which were: National Electronic Disease Surveillance System (NEDSS), the Health Alert Network (HAN), the Laboratory and Response Network (LRN), and the Division of Public Health Surveillance and Informatics (Weiner, 2006). Almost all the editorials stress that the September 11, 2001 terrorist attack and 2001 anthrax attack were the main catalysts for initiating new electronic disease monitoring systems mainly in USA and also throughout the world. The main application of IT was electronic registry, and they also mentioned about the data security in few occasions, however there was not much discussion about the DP algorithm or Statistical algorithms. It could be because the whole scientific community was more concerned about establishing the electronic reporting system then refining and improving it. Also, the literature from MEDLINE-PubMed could not find editorials from other parts of the world except USA in this thesis research.

Narrative literature review:

There are two narrative literature review articles (Sintchenko & Gallego, 2009; Watkins, Eagleson, Hall, Dailey, & Plant, 2006) published in this PH domain. This review article (Sintchenko & Gallego, 2009) was conducted in PubMed, which included the papers from 1995 to 2007. The main objective of the study was to detect the emerging practice of laboratory-based disease monitoring systems and research on biosurveillance. The main finding of the paper was that there were three main disease surveillance systems in place: syndromic surveillance based on health indicators, genotyping-based surveillance, and laboratory-based infectious disease monitoring system. The paper highlights a need for a better coordination between the SS and laboratory-based surveillance system. The main barriers highlighted were: inefficient integration of surveillance signals into action plan, and delayed decision support system which needs to be addressed as soon as possible. Similarly, another article (Watkins et al., 2006) was focused on reviewing the articles that applied the approaches to the evaluation of outbreak detection methods.

Empirical Literature review:

There was one article (Dato, Wagner, & Fapohunda, 2004) which was an empirical literature review article. This article reviews the methods applied in USA to detect the infectious disease outbreaks. A literature review was conducted and found that the major 5 organizations that are involved for this process which are: the clinical health care system; local/state health agencies; federal agencies; academic/ professional organizations; and collaborating governmental organizations. These entities share data to detect outbreaks in the USA, however the local and state level health care organizations detect the outbreaks before any others in the first place.

Summary of the findings:

Table 3. Tabular presentation of the overall finding of the outbreak detection.

Focus of the research/discussion	Qualitative studies	Quantitative studies	Other reviews	Editorials	Mixed studies	Narrative literature reviews	Empirical literature review
Reporting from clinical/laboratory to PH units based studies	8	10	15	5	1	2	1
Pharmacy based studies	5	1					
Testing and Improving the DP algorithm	10	2	3				
Application of GIS in PH programs		1					
NHIS				1			
Ethnographic studies		1					

Testing and developing statistical/analytical software in PH programs	11	1	3				
Web based disease monitoring system	2	1		2			
Application of mobile phones		1	1				
Testing NLP	2						
School based reporting		1					
Others*			2	2			
	38	19	24	10	1	2	1

*Others include all other areas which are not represented in the list presented in the table, some of them are application of new devices: wearable sensors, fever devices, monitoring of the large mass gathering etc.

The table no. 3 presents the tabular presentation of the total number of articles with respect to the areas of research and/or discussion that were presented in the in-depth analysis of this PH domain.

8.3.3 Bioterrorism surveillance

8.3.3.1 Number of articles

There are 47 articles included in this PH domain.

8.3.3.2 Study settings with number of studies

Among the 47 articles, 43 (91.5%) of articles belong to USA, 3 (6.4%) to Canada and a single article (2.1%) to Australia.

8.3.3.3 Types of articles/methodology

About half 22 (46.8%) of the 47 articles in this PH domain belong to other review, followed by qualitative study 14 (29.8%) and quantitative study 4 (8.5%). Only 6 (12.5%) of the total 47 articles are editorials.

8.3.3.4 Evidence relating to use of Information Technology discussed used

The articles found in the bioterrorism surveillance discussed/used EMR/EHR/electronic registry, DP algorithm, and website in 38 (80.9%), 32 (68.1%), and 20 (42.6%) of the total 47 articles respectively; whereas, statistical/analytical software, telephone-landline, and e-mail were used in about 20% of the total articles. Further, GIS was used only in 5 (10.6%), and mass media and mobile phones are used in a single article. Notably, automated speech processing was not used in any of the articles.

8.3.3.5 Evidence relating to use of Informatics concepts discussed/used

Based on the finding, data collection, data transmission/ communication, and interoperability are the most often used informatics concepts which are used in 33 (68.8%), 32 (66.7%) and 32 (66.7%) of the articles, respectively. Data retrieval and data analytics are also discussed/used quite often, that is, in 21 (43.8%) and 17 (35.4%) of the total articles, respectively. In contrast, data security, information sharing and knowledge management were applied in less than 10% of the total articles.

8.3.3.6 An in-depth analysis to the articles

Qualitative studies:

There are a total of 14 qualitative studies in this PH domain. Among them, 4 articles (Bradley et al., 2005; Lombardo et al., 2004; Ma et al., 2005; Shen et al., 2008) are about the electronic data reporting from hospitals, laboratories, and schools to PH departments. For example, two articles (Bradley et al., 2005; Ma et al., 2005) are about the BioSense program implemented by the CDC in USA since 2004. The study (Bradley et al., 2005) published in 2005 shows that the main objectives of the BioSense program are: to conduct the near real time bio-surveillance, provide assistance to the state and local PH units for establishing surveillance system, and promote the national standards among all the clinical and PH departments for data reporting and analysis. BioSense collects and analyzes data from approximately 1,100 department of veterans' affairs (VA) treatment facilities, 700 departments of defense (DoD) military treatment facilities, and laboratory corporation (LabCorp) of American test orders. LabCorp includes data from a nationwide network of 31 primary testing centres and more than 1,100 patient service centers.

The data are collected in the form of international classification of diseases, ninth revision, clinical modification (ICD-9-CM). The system also analyzes, and presents the report of analytical results by temporal and spatial information e.g., source, day, ZIP codes, state, and metropolitan area of the patients. The visual representation of the data was also presented through graphs, maps, and tables. A number of DP algorithms and statistical/analytical software are applied with the system for the rapid disease detection, some of which are CUSUM and small area regression and testing (SMART). Similarly, another article (Lombardo et al., 2004) is about the ESSENCE II test-bed developed by Johns Hopkins University Applied Physics Laboratory (JHU/APL) and implemented by the Maryland Department of Health and Mental Hygiene (DoHMH), the District of Columbia Department of Health, and the Virginia Department of Health. The main objectives of the program are: to integrate electronic data from the clinical department of military hospitals with the data from civilian and health care systems especially hospitals, pharmacy (prescription plus OTC drug sale) data, school absenteeism data; and to develop the test-bed for analyzing the outbreak detection algorithms. The reporting is all electronic and automatic**.** The data security is maintained by keeping the patients personnel information only at the local level. The ESSENCE II applied the statistical methods (such as early aberration reporting system algorithms) to identify the outbreaks. The outbreak detection test is conducted by an epidemiologist on a daily basis at midnight. The above described three qualitative studies (Bradley et al., 2005; Lombardo et al., 2004; Ma et al., 2005) were all from the USA. There are some areas to be improved. First of all, these articles were published in 2004 and 2005 which means there must be a lot of advancements in their system and hence require more studies. Second, based on these articles, we can envision an automated system be incorporated with the automated bioterrorism event detection algorithms that can detect any aberration of a disease in a real time without being manually tested by the epidemiologist on a regular basis.

There are 7 articles (Kleinman, Abrams, Mandl, & Platt, 2005; Mohtashemi et. al.; 2006; Mandl et al., 2004; Mohtashemi et al., 2007; Wong et al., 2005; Buckeridge et al., 2004; Buckeridge et al., 2005) focussed on testing DP algorithms for early detection of bioterrorism attacks. For example, the article (Wong et al., 2005) tested to integrate the data from two streams: OTC drug sale and ED data. The population-wide anomaly detection and assessment (PANDA), a spatial-temporal multivariate Bayesian approach for disease surveillance was applied. The Bayesian network algorithm models the individual patients as a subset of the Bayesian network. This report presented that real time disease surveillance is possible for disease outbreaks applying the PANDA while incorporating the multiple data sources. Similarly, the remaining articles (Buckeridge et al., 2004; Buckeridge et al., 2005) also tested the DP algorithms in a simulated data to detect the bioterrorism attack by Anthrax spores. The DP algorithms applied were (simulation models based on dispersion model, infection model, disease and behavior model, data-source model) (Buckeridge et al., 2004), and temporal algorithm (Buckeridge et al., 2005).

Among the remaining articles, one article (Ruiz & Remmert, 2004) is a case study of a GIS program in local health departments, and 2 articles (Burkom et al., 2005; Das et al., 2003) are about testing statistical/analytical software. For example, the study (Wagner et al., 2013) is about the statistical/analytical software for knowledge management. The article talks about Apollo-SV (structured vocabulary), an ontology for epidemic simulation. This provides set of definitions and acceptable standard vocabulary, which can be supplanted with standard syntaxes for representing epidemic simulation results.

The main observation to the qualitative articles is that these articles except (Wagner et al., 2013) were published in between 2004 to 2008, which shows that there are not many qualitative studies focussed on bioterrorism surveillance after 2008. The main focus of the studies were on testing the DP algorithms on simulated data mainly for anthrax and ILI syndromes. The majority of the articles applied the DP algorithms, which could be because this domain requires immediate response for detecting the outbreak and hence high preference was put on testing the effectiveness of the DP algorithms.

Quantitative studies:

There are a total of 4 quantitative studies focussed on this PH domain. Among them 2 studies (Das et al., 2003; Dembek et al., 2005) are about the descriptive study of the electronic data reporting system from clinical health care to the PH units for syndromic surveillance and the remaining 2 articles are about the descriptive study to test DP algorithm (Tokars et al., 2009), and a cross-sectional survey (Drociuk et al., 2004) on syndromic surveillance system.

In this article (Das et al., 2003), an ED based syndromic surveillance was established in the NYC, just after the September 11, 2001 terrorist attack, from Sep.14 to Oct. 12, 2001. The main objective of the study was to detect any bioterrorism attack and find unusual aberration of any diseases. Epidemic intelligence officers (EISOs) were assigned. The syndromic data on bioterrorism prone diseases were collected e.g., upper/lower respiratory infection with fever, diarrhea/gastroenteritis, fever of unknown origin, botulism like syndrome, meningitis/ encephalitis, sepsis/non-traumatic shock, and rash with fever. The data were sent to the NYC DH on a daily basis. The main IT applied were electronic registry, and statistical/analytical software. The study identifies the main problems associated with the ED based SS were that, the 25% of the patients, especially affected with anthrax, would visit the ED only after diagnosis and the rest would visit outpatient providers or family physicians. Another challenge with this type of surveillance was that the ED health workers were very busy with filling the data and the web-based reporting was very limited at that time, which made it difficult for them to fill all the information of the one page form. The information was entered into the computer daily and transmitted to the PH department for data analysis. SAS, CUSUM method, and SaTScan software were applied for further analyses. Following the NYC experience in 2003 about the ED based SS, the Connecticut department of public health (CDPH) determined to establish the hospital ED-based syndromic surveillance (Dembek et al., 2005). It included 50% of the acute care hospitals and 65% of the state hospitals.

Similarly, between the remaining 2 articles, one article (Tokars et al., 2009) is a descriptive study to test on DP algorithm, and the study (Drociuk et al., 2004) is a cross-sectional survey about the importance of the information privacy and security during the syndromic surveillance system. The survey (Drociuk et al., 2004) was conducted on October 15, 2003 by sending electronic questionnaires by e-mail to the participants. It was implemented throughout all the 50 states, 8 territories and District of Columbia epidemiologists and health coordinators, and with the staff of CDC, division of public health surveillance and informatics. The main objectives of the study were to collect the perspectives of state level epidemiologists on SS data reporting due to the privacy concern; and perceived effects of HIPPA on SS data sharing and outbreak investigation. The study found that over 84% of the participants had no objection on reporting the SS data because of the establishment of the secure data transmission system, for example, virtual private networks and secure state file transfer protocol (FTP).

Other reviews:

There are a total of 22 other review articles included in this PH domain. Among them 17 articles are concentrated on the electronic data reporting from the clinical, laboratory, OTC drug sale to the PH departments (Broome & Loonsk, 2004; Broome, 2005; Cochrane, 2004; Foldy, 2004; Heffernan, Mostashari, Das, Besculides, et al., 2004; Lazarus, Yih, & Platt, 2006; Lober et al., 2004; Lober et al., 2003; Loonsk, 2004; Mollura et al., 2008; Pavlin et al., 2003; Platt et al., 2003; Sosin, 2003; Reis, Kirby et al., 2007; Tsui et al., 2005; Wagner et al., 2004; Yih et al., 2004). Among them the article (Heffernan, Mostashari, Das, Besculides, et al., 2004) also included workers absenteeism and the article (Mollura et al., 2008) included school absenteeism surveillance. Also, these articles have discussed mostly on applying the electronic registry, telephone-landline, statistical soft wares, and DP algorithms. Among the remaining 5 articles, 3 articles (Tu et al., 2007; Hutwagner et al., 2003; Izadi et al., 2009) discussed about the DP algorithms, one article (Eysenbach, 2003) about the population health technologies, and one article (Woodhall, 2005) is about the interoperable communication infrastructure for detecting injuries and bioterrorism attacks.

Among the article related with the clinical and PH units based reporting, the article (Lazarus et al., 2006) talks about the National Bioterrorism Syndromic Surveillance Demonstration Program (NDP) implemented in 5 states and 7 data providers in the USA in 2006. This surveillance system has an electronic data reporting system in place from the hospitals and to the PH units which is transferred to the central data repository. The data is analyzed daily to detect aberration applying DP algorithms. The diseases included are Lower gastro-intestinal (GI), respiratory, neurological, botulism-like, upper GI, fever, hemorrhagic, shock-death, skin lesions, lymphatic, rash, influenza-like illness and SARS-like illness. The NDP program had an automated alert system, to PH authorities to take necessary action. The alerting was via automatic e-mail, text-messaging, or telephone-landline. To make the personnel health information secure, the distributed data process system was implemented. In this system, the personal health information is pre-processed at the data sources/provider level, only the aggregate data required for the statistical analysis and signal detection transferred to the central level. Although, the risk is not completely free, but the aggregate level data reduced the Personnel identification to a minimum level.

In another study (Lober et al., 2003) a similar system implemented by the University of Washington and PH-Seattle and King county (PHSKC) in ED and discharge data of three emergency departments and urgent care (ED/UC) departments, and nine primary care clinics in 1999 shows that one of the main challenges were related with the data coding, as the same diseases were coded differently by different health care organizations or different health personnel of the same health care organization. This article also emphasized on applying the Health Insurance Portability and Accountability Act's Standards for Security.

In this article (Tsui et al., 2005), the National Retail Data Monitor (NRDM) system that monitors the OTC drug sale since 2002 has been discussed. The NRDM monitors the data from over 18,600 retail pharmacy stores across the USA. The paper presents that the architecture of the monitoring system entails event-driven architecture. In this architecture, the vendors can either push data into the NRDM data server or the NRDM server pull data in every 2 hours. The NRDM manager checks the new data in every hour and conducts near-real time data analysis, and the data is analyzed using DP algorithm on a daily basis.

This paper (Broome, 2005) presents the role of CDC in USA for developing and strengthening the local, state and federal level disease surveillance system through the respective clinical and PH units. The article (Loonsk, 2004) discusses about the Biosense program implemented in the USA. This is the federal program implemented to integrate the local, state and federal/national level PH data to conduct the real time automated outbreak detection of the diseases prone to the bioterrorism across the USA. The system includes the electronic reporting from all levels, and automated detection and visualization algorithms to find out the temporal and spatial features of the outbreak events.

In this paper (Lober et al., 2004), the authors presents the three types of SS system architectures. The first generation integration architecture is the simplest form which, entails reporting from the local, field level medical departments, and the central PH units enter the data in a computer spread sheet. The second-generation integration architecture includes the consolidation of data using enterprise information architecture. In this system, reports from the local medical clinics to the centre PH units are sent, and the central units act as a data warehousing. The data are usually formatted using HL7 standard. The surveillance is made only at the central PH units. The surveillance is based on retrospective data. The central units should ask from the sources to report the data and then the central PH units conduct the surveillance based on the previous data. The third generation integration architecture is real time, automated reporting system proposed for the future in 2004. The queries are run in situ data, and SS can be conducted both at the central database as well as at the source level/clinical units.

Similarly, in these articles (Foldy, 2004; Pavlin et al., 2003; Sosin, 2003) the authors emphasized on the SS system strengthening. For example, this article (Pavlin et al., 2003), the requirement of SS system was discussed for the local, state and the federal level. Some important insights put forward are: SS should be able to expedite the process of data transmission and analysis, integrate data at all levels, display detailed information for facilitating outbreak detection, provide geographic information for disease location, assist in delivering the medical adds e.g., vaccine and antibiotics, evaluate the success and provide historical data for calculating the threshold level and long term monitoring. Additionally this article (Sosin, 2003) focussed on putting forward some concepts about the evaluation framework of SS system. This paper suggests that a SS must be flexible, sensitive and predictive value positive, and timeliness. The SS must be flexible according to the needs of new data collection tools and able to change the threshold according to the new outbreak situation.

Among the remaining articles, one article (Woodhall, 2005) (published in 2005) discusses the National Emergency Alerting and Response Systems (NEARS) Initiative, an interoperable emergency messaging framework that integrates the information from various jurisdictions e.g., fire, 9-1-1 call, emergency medical services (EMS), PH, emergency medicine, emergency management, private infrastructure, and media. The framework already includes over 50,000 agencies and 400,000 individuals from emergency response profession across USA. This system includes an integrated web service that can be accessed and communicated across all the jurisdictions via a secure network. This has acted a big enterprise network of the various networks.

Finally, there are 3 articles (Tu et al., 2007; Hutwagner et al., 2003; Izadi et al., 2009) which are focussed on the DP algorithms, and one article (Wagner et al., 2013) on the statistical/analytical software. The article (Tu et al., 2007) talks about configuring and testing a computational test bed called BioStorm that can be applied for evaluating the alternative biosurveillance methods. Similarly, this article (Hutwagner et al., 2003) presents the early aberration reporting system (EARS) for infectious diseases and bioterrorism surveillance. There are mainly two types of EARS, which are the case definition method and pattern recognition method. The case definition method is further classified into infectious and chronic disease case definition, whereas pattern recognition method is for detecting sets of symptoms (syndromic approach). This paper focusses on only on the infectious diseases method for monitoring the infectious diseases and bioterrorism attacks. It presents the various statistical methods that are useful for detecting short-term and long-term diseases base-line data sets.

Editorials:

There are a total of 6 editorials in this PH domain (Baker & Porter, 2005; Duchin, 2003; Krohn, 2003; Nardone, 2004; Rode, 2002; Weiner, 2006). The main concepts derived from these articles are the importance of establishing the electronic disease reporting system at the national, regional, state and local level. These articles discussed mainly the need of data standardization, data security, and need of more financial support to establish a PHI system at all levels. For example, in this article (Baker & Porter, 2005) the author discusses about the HAN established in 1999 in USA by the national association of county and city health officials (NACCHO), a federal body of PH professionals. This network is used to notify all the PH workers (working at local, state and national level) to notify the recent infectious disease outbreak and natural disasters such as hurricanes. This article discusses that the main augmenting factors that helped to develop the HAN are: strong partnership initiated by the federal level agency; an advocacy to gain political support; and an effective use of the HAN during 2001 terrorist attack and anthrax attack in USA.

In another article (Duchin, 2003), the main concepts derived were the approaches of epidemiological responses for SS signals derived from the hospitals. The main approaches of epidemiological investigation are phone calls, onsite observation, contact tracing, interview to the patients, and notification to the internal and external partners.

This article (Krohn, 2003) talks about the importance of establishing the information infrastructure to contain the bioterrorism attack in USA and the challenges the US health care is facing. The challenges related with the system are: conceptualizing the multidimensional threats by biological, chemical, and radiation hazards; establishing a secure communication infrastructure; and having the best use of limited resources. The challenges related with the functions are: coordinating the multiple stakeholders and players e.g., PH units, hospitals, private sectors, health care organizations, fire departments, police, ambulance, social services etc. The article presents that there is a need of establishing 3 levels of preparedness for the bioterrorism defence which include before, during and after a bioterrorism event. According to the editorial, before any bioterrorism attack, a system should be already established on data collection, data mining, data modelling, analysis system (e.g., surveillance system, simulation of terrorist attack), and communication infrastructure system (e.g., HAN, NEDSS). Securing the data system should also be a prime priority. For this purpose, data sharing should be done through a secure web based systems architecture, and also protected by encryption technology. Other technologies such as secure socket layer (SSL) and public key infrastructure (PKI) protect the e-mail and digital information.

Also, to improve the data integration of the multiple jurisdiction, a solution proposed are standardizing the architecture, codes, devices, and applications. Additionally, during an event there should be an establishment of a command and control mechanism, crisis communication with multiple stakeholders, and a medical management system. The system e.g., GIS and patients' identification and management are important during this stage. At last, after a bioterrorism attack, analysing the response plan and remediation activities are needed. If there was any problem identified during the prevention activities, it should be corrected for the future. The monitoring activities has to be continued with more dedication and astute vision.

These articles (Rode, 2002; Nardone, 2004) also emphasize on the establishment of standardizing the data with ICD-9-CM and ICD-10, and need of extra budget to establish the system and to conduct the bioterrorism surveillance applying the electronic SS. Since, these articles were published before 2006, the concept may not represent the present scenario. The last article (Weiner, 2006) highlights the role of the nursing staff for the information management system at the local, state and federal level.

Narrative literature review:

In this review article (Watkins et al., 2006), a literature search was conducted in PubMed in Sep. 2004 and in Web of science on Oct. 2004, to obtain the relevant literatures. A total of 1,630 articles were identified; among them, only 67 were included for the study. The main objective of the study was to review the outbreak detection methods applied in infectious diseases and provide a conceptual framework to identify a standard methodology. This article identified that by 2004 there were mainly 4 types of outbreak detection methods which were: descriptive, derived, epidemiological, and simulated methods. The study concludes that a mixed methodology is better than a single methodology, since no single method is enough to fulfill all the evaluation requirements. The article recommended to develop more evaluation methods. .

Summary of the findings:

Table 4. Tabular presentation of the overall finding of the bioterrorism surveillance.

Focus of the research/discussion	Qualitative studies	Quantitative studies	Other reviews	Editorials	Narrative literature reviews
Reporting from clinical/laboratory to PH units based studies	4	3	17	3	
Testing and Improving the DP algorithm	7	1	3		
Application of GIS in PH programs	1				
NHIS			1	2	
Testing and developing statistical/analytical software in PH programs	2				
Others*			1	1	1
Total	14	4	22	6	1

*Others include all other areas which are not represented in the list presented in the table, some of them are application of new devices: wearable sensors, fever devices, monitoring of the large mass gathering etc.

The table no. 4 provides a snap shot of all the included articles and the area of their research and discussion that were discussed in the in-depth analysis above.

8.3.4 Emergency response

8.3.4.1 Number of articles

There are total 9 articles included in emergency response.

8.3.4.2 Study settings with number of studies

There were very few articles focused on the emergency response. Out of these 9 articles, 7 (77.8%) articles were from USA, and two from Australia and Canada each.

8.3.4.3 Types of articles/methodology

Among the 9 articles, 3 (33.3%) articles were qualitative and quantitative studies, five articles were other reviews, and there was one editorial.

8.3.4.4 Evidence relating to the use of Information Technology discussed/used

The study showed that 8 (88.9%) out of 9 articles discussed/used EMR/EHR/electronic registry, 8 (88.9%) articles used telephone-landline, and 6 (66.7%) used website. Only one of them used/discussed DP algorithm, e-mail, GIS, mobile phones and statistical/analytical software in the articles. Non-of these articles discussed/used mass media and NLP.

8.3.4.5 Evidence relating to the use of Informatics concepts discussed/used

The study showed that data transmission/communication and data collection are the most used informatics concept in emergency response which are discussed/used in 7 (77.8%) and 5 (62.5%) of the total articles respectively. The interoperability was used in 4 (44.4%) of the articles; whereas, data retrieval, interoperability and information sharing are discussed/used in 3 (37.5%)

articles. Also, data analytics and data security are discussed/used in a single paper. Knowledge management was not used in any of the papers.

8.3.4.6 An in-depth analysis to the literature available

The emergency service PH domain contains the articles which are focused in the information system applied for the pre-hospital settings e.g., for ambulance diversion, or applying the immediate medical care while patients are on the way to hospitals.

Qualitative studies:

There is only 1 qualitative study in this PH domain (Krafft et al., 2003). In this article, program implemented by a project called European Emergency Data (EED) project is presented. The EED project formulates the indicators for the EMS system and evaluates their applicability in broader PH domain. In this article the objectives and methodology applied for identifying the indicators for EMS is discussed. The main objective of the project was to identify a framework that can be applied throughout the EU member states as a common integrated health monitoring system. A series of 6 international workshops were conducted among the12 member states and a common result was deducted. The project resulted in a new framework of EMS system starting from the initial contact with an emergency patient to until he/she arrives in a hospital. The IT applied was the telephone-landline at the beginning of the contact with the emergency patient. The article also proposed to apply the GIS system to detect the patient's location and enhance the prevention strategy.

Quantitative study:

There are two quantitative studies (Coory, Kelly, & Tippett, 2009; Mostashari et al, 2003) included in this PH domain. In this article (Coory et al, 2009), a study is conducted in Melbourn, Australia to find out if the ambulance dispatch call data can be used as tool to early identification of ILI outbreak. The data from locum services and GP sentinel surveillance data were captured from 1997 to 2005. The study concludes that the ambulance dispatch call data shows a similar seasonal trend to that of the clinical data trend, however it was not statistically significant.

Similarly, another article (Mostashari et al., 2003) also tested the possibility of using the ambulance dispatch calls to detect any ILI outbreaks in New York City. The New York City Fire Department EMS had computerized electronic ambulance dispatch system where all the medical related calls made to 911 are electronically entered. Any call types which are related with the respiratory diseases symptoms are included as ILI. Data from 1993 to 2003 were serially projected for every two weeks data. The laboratory confirmed data from the same time period were collected from the New York State Department of Health. Finally, the linear data analysis was conducted using SAS. The study showed that the electronic database of the outbreak dispatch calls are effective in detecting the community wide respiratory outbreak. This article also proposes that this kind of surveillance could be useful in detecting bioterrorism related outbreaks. Because, any kind of disease outbreaks are mostly originated from the community, a capacity to detect it at its initial stage could be an effective way to contain the possible outbreak. However, the timely diagnosis and immediate reporting should be followed with this type of monitoring, since it is only as a supportive tool for laboratory confirmed outbreaks.

Other reviews:

There are 5 other reviews included in this PH domain (Barthell et al., 2003; Foldy, 2004; Heffernan, Mostashari, Das, Besculides, et al., 2004; O'Connor et al., 2004; Woodhall, 2005). These articles present the web based emergency medical services implemented in various jurisdictions. The IT applied during the emergency response are mainly the website, electronic registry, and telephone-landline. As for example, this article (Barthell et al., 2003) presents some historical background and developments of EMS in Milwaukee metropolitan area. The first application of technology in ambulance diversion was applied in 1991, where the Computerized Hospital On-Line Resources Allocation Link (CHORAL) system applied the Dos-based computerized system and dial up protocols using modem for information sharing. The use of internet made it possible to apply the application service provider (ASP) model in this system. In 1999, Milwaukee metropolitan area also applied the ASP system to ambulance diversion and emergency management. All the 14 hospitals and 8 ambulance providers were participated in the system. In this system, the users securely access to the web portal through internet. This system provided the Milwaukee a capacity to real time communication to all affected parties for effective use of hospital resources during emergencies and ambulance diversion. In 2000 to 2001, the increase of ambulance diversions were found to be associated with the seasonal influenza trend. The web based EMS had been used to share the daily count of different kinds of syndromes and diseases. The article also proposes that the web based EMS can be a very effective avenue to share among the medical and PH professionals the daily trend of certain bioterrorism related syndromes which could help to be alert early to detect the potential threat in time. This article (Foldy, 2004) also sheds some light of the EMS of the Milwaukee metropolitan area; whereas (Heffernan et al., 2004) discusses about the EMS ambulance dispatch calls implemented in New York City as discussed in the previous quantitative study (Mostashari et al., 2003). Finally, this article (O’Connor et al., 2004) provides insights on importance of the EMS in disease surveillance and reporting. It also sheds light on adding video communication in EMS. The main problem associated with this system is lack of interoperability among the various jurisdictions involved in the system. To solve the problem, the article suggests to provide training to the health care workers, to collaborate with interdisciplinary organizations, and to enhance the communication with the community people.

Editorials:

There is only one editorial (Page, 2004). It discussed during emergency events such as disease outbreak or disasters, the hospital beds are over occupied and patients may be diverted to other hospitals. To avoid this situation, John Hopkins University hospital, Baltimore designed an electronic system called MedBed which could monitor the number of occupied and vacant beds for new patients.

Summary of the findings:

Table 5. Tabular presentation of the overall finding of the emergency response.

Focus of the research/discussion	Qualitative studies	Quantitative studies	Other reviews	Editorials
Reporting from clinical/laboratory to PH units based studies	1	2	5	
Web based disease monitoring system			4	1
Application of mobile phones			2	
Total	1	2	11	1

The table no. 5 provides a snapshot of all the included articles and the area of their research and discussion that were discussed in the in-depth analysis above. There are only 5 other review articles; however they span more than one areas, therefore the total count was 11.

8.3.5 Environmental health

8.3.5.1 Numbers of articles

There are a total of 16 articles included in environmental health.

8.3.5.2 Study settings with number of studies

Among the 16 articles, 8 (50%) articles are from USA and the rest are from Canada 5 (31.3%), France 2 (12.5%), and UK 1 (6.3%).

8.3.5.3 Types of articles/methodology

There were 5 (31.25%) editorials, followed by equal 4 (25%) other reviews and qualitative studies, and 3 (18.75%) quantitative articles.

8.3.5.4 Evidence relating to use of Information Technology discussed/used

The study revealed that EMR/EHR/electronic registry and websites were used in equal 10 (62.5%) of the articles, followed by GIS with 9 (56.3%) articles. Further, 4 articles (25%) applied DP algorithm, whereas, e-mail and telephone-landline was discussed/used in equal 3 (18.8%) articles. Only 2 articles discussed/used statistical/analytical software, and a single article discussed/used mobile phones. None of the papers contained automated speech processing and NLP.

8.3.5.5 Evidence relating to the use of Informatics concepts discussed/used

The study found that out of the 16 articles, majority 13 (81.3%) of them discussed/used data transmission/communication followed by data collection in 11 (68.8%) articles and data retrieval in 8 (50.0%) of the total articles respectively. Also, data analytics was discussed/used in 5 (31.3%) articles. Additionally, equal 3 (18.8%) articles also discussed/used data storage and information sharing. No article discussed/used knowledge management.

8.3.5.6 In-depth analysis to the existing literature

Qualitative studies:

There are a total number of 4 qualitative studies included in this PH domain. Among them, 3 studies are focused on the application of GIS (Bédard et al., 2003; Maciejewski et al., 2008; Marechal et al., 2008) and one study (Toutant, Gosselin, Bélanger, Bustinza, & Rivest, 2011) is focused on the application of the websites and GIS for monitoring the meteorological events tested in the heat waves.

This article (Marechal et al., 2008) presents a French program called re-emergent diseases global environment monitoring from space (RedGems). The main mission of the RedGems is to study the health-environment relationship to establish an early warning system (EWS). The tele-epidemiology and tele-medicine are the two branches of this system. The tele-epidemiology studies the change in disease pattern with regard to the environmental factors (e.g., vegetation, meteorology, oceanography with hydrology data (distribution and numbers of lakes, rivers and reservoirs). A predictive mathematical modelling can be constructed with these data and with the clinical information of the location. The study presented an example of a study conducted in Ferlo region, Senegal for Rift valley Fever (RVF). In this region, the mosquito burden was associated with the rainfall, number of ponds, and vegetation present or absent in the ponds. The satellite images of all the ponds and vegetation of the areas were taken. These images were verified by the in situ observations. The result showed that the risk of the RVF increased as the proximity of the ponds increased. The researcher presented that this technique might be further developed by “adding digitized ecological zone layers (Marechal et al., 2008)”. Further, another article (Bédard et al., 2003) integrated the GIS and the online analytical processing (OLAP) technologies for geographic knowledge discovery and the decision support. The final product called Spatial OLAP or SOLAP applies the geomatics technologies that can access the environmental and health related geo-spatial data in a single interface. The indicators include both infectious and chronic diseases as well as environmental related factors. This system also has capability to apply the statistical program to find out the diseases association to detect the causative factors. Also, in this article (Maciejewski et al., 2008), the authors present the application of the internet based GIS (also called web-GIS) in Hamilton, Canada. The study presents that the application of web-GIS can be an effective tool to explore the association of socio economic status, air pollution and asthma. However, the main challenges related with these technologies are confidentiality and data accessibility issues.

Finally, one article (Toutant et al., 2011) applied the web based software called Surveillance and Prevention of the impacts of Extreme Meteorological Events (SUPREME) system to monitor the meteorological events in PH. The system was tested to monitor the heat waves in the province of Quebec during the summer of 2010. This system included the features such as data acquisition, risk analysis, cartographic application, and information dissemination. The heat data is obtained from the Landsat satellite, whereas medical data is obtained from the ED and hospitals. Air quality data and GIS data is obtained from their respective provincial ministry sources. The SUPREME system can be accessed by the specialists through a secure portal which provides information on patients’ admission, real time indicators, emergency response activities, weather forecasts, and cartographic information. The system was found to be effective in monitoring and taking appropriate action in time during the heat events in summer of 2010 in Quebec, Canada. The article further suggests to provide access to more specialists and stakeholders to the portal. Also, such system should be applied and tested with other meteorological events.

In conclusion, the application of GIS in the environmental health has been seen in the field of geographical mapping to detect the causative factors, geographic knowledge discovery system, and application of web GIS system.

Quantitative studies:

There are 3 quantitative studies in this PH domain (Josseran et al., 2009; Litt et al., 2007; Massawe, 2013). These studies are the surveys among the state level PH specialists and environmental health specialists to assess the existing environmental health surveillance program, find out their knowledge and practice on environmental health surveillance activities. The main IT applied were electronic registry and website among these studies. As an example, this study (Massawe, 2013) was conducted from April to June 2011 among the state level PH professionals and environmental experts across all the states of the USA. A total of 606 participants were involved. The main aim of the study was to generate the generic theme and framework required at the state level PH agencies to monitor the engineered nano-particles (ENPs) throughout the process of manufacture, handling, storage and disposal. The study found out that at present the states are dependent upon the federal information, however surprisingly "even at the federal level the very limited nano-specific information, regulations and standards exist (Massawe, 2013)". A further work is required in constructing databases of the nano-materials where PH workers can access information on the properties of the nano-materials, its possible hazards, and handling and disposal techniques. The study also recommends applying a precautionary while dealing with the nano-materials to avoid its exposure, further research is sought to find out the exposure and disease outcome, and develop a monitoring and surveillance databases.

Further, this study (Josseran et al., 2009) is a study based on the real time electronic syndromic surveillance system implemented in 49 EDs across France. The data were collected by the French Institute for Public Health Surveillance which conducted the study to find out the types of diseases people suffered during period of the heat waves during the summer of 2006. This study found that ED based real time surveillance is very useful to find out the number of elderly people or children suffered by the heat waves and take necessary action tailored to specific population in time. This article further recommends to conduct more studies to find out the efficacy of ED based SS on environmental hazards.

Another survey (Litt et al., 2007) was conducted among the state level environmental health officials to find out the status of the environmental PH tracking (EPHT) system implemented across all the states by the CDC since 2002. The study found that by 2005, 90% of the state level environmental programs collect data on air and water pollutants. The other regularly monitoring goes to blood lead level in children, indoor air quality for carbon monoxide and radon, etc. However the main challenges identified are enhanced federal-state partnership; capacity building on data analysis, communication, and surveillance; and support for tracking the affected personnel. The tracking is weak at the community level and more enhanced communication, mapping, data analysis, public access and effective reporting are required to maintain the personnel tracking effective.

Other reviews:

There are 4 other review articles in this PH domain (Bedard & Henriques, 2002; Cromley, 2003; Fan, Blair et al., 2010; Hogan et al., 2007). The articles discussed on applying the GIS for monitoring the environmental factors and diseases associated with such factors, and electronic registry for hospital based SS and environmental hazards monitoring.

In this article (Bedard & Henriques, 2002), the application of web based databases, GIS, real time electronic monitoring devices, and wireless communication and media etc. in environmental health (EH) and EH surveillance activities are discussed. The decision support system for the knowledge discovery from the web portals are also being invented and developed which are data query tools (e.g., Impromptu, Crystal Report), data mining tools, and spatial online analytical processing software developed in Quebec Canada. The article recommends that to enhance the traditional epidemiological studies, the application of GIS and spatial statistics can be applied by modelling the exposure results in terms of topography, land, air, and water quality etc. can produce exposure and affects results. However, the major challenges existed are: to find out the area of the environmental problem, obtaining the data from such places, maintaining the data standard and providing the training to the PH workers on use.

In this study (Cromley, 2003), the application of GIS for the disease mapping by applying the GIS technology e.g., remote sensing to find out the association of disease causative factors and the geographical environmental factors.

In this article (Hogan et al., 2007), the process applied in the environmental surveillance adopted in the world are discussed, The first is hospital and lab based notifiable disease surveillance; second is enhanced medical surveillance conducted by astute physicians and pharmacy drug sale, which brings data earlier than the regular notification surveillance, and third is BioWatch program in which the biologic agent scattered in the atmosphere is sampled in a filter paper and installed in various places of cities. Such systems are installed across 33 cities and 500 locations across USA. This paper also discusses about an application of a DP algorithm (mathematical modeling) called Bayesian aerosol release detector (BARD) which includes both the medical data and the meteorological data for early prediction of the *B. anthracis*. The report shows that such modelling is effective in predicting the *B. anthracis* earlier and recommends further research is required on it.

Editorials:

There are 5 editorials included in this PH domain (Coleman & Delea, 2013; Eng, 2005; Graber, Macdonald, Kass, Smith, & Anderson, 2007; Hawkes, 2014; Savel & Foldy, 2012). The editorials discussed about applying the IT on monitoring food borne diseases, the carbon monoxide, and also discussed on the application of new population health technologies on PH domains. For example, this paper talks about the PHI approaches to environmental health initiatives in USA. In 2001, the CDC first initiated the PHI approach by developing the environmental health specialist network information system (EHSNIS). This system was a web-based application which can be accessed from anywhere through the Internet. This system provides useful tools in food borne diseases outbreak environment assessment, risk assessment of the Listeria in retail environment, and information on private wells. The editorial further suggests that the large amount of data with scarce useful information is a problem with the current environmental health system. Although, this web-based system can be accessed by all the people and anyone can report in it without exposing their identity, improving the data quality and developing the data collection, analysis and dissemination protocols are still a challenge to the system. The report also suggests that regularly updating the data collection tools and developing the new analytical techniques could be very beneficial to improve the environmental health and outbreak detection functions.

This article (Eng, 2005) discusses about the application of the emerging population health technologies (PHT) in the environmental and in general to the PH research and practice. In environmental health, the technologies e.g., wearable sensors can be very effective to detect the air quality experienced by an individual in a real time. The sensors capture the data and transmit the information through internet to the web-based database. This can be analyzed by the environmental health specialists to detect the quality of the air or the environment. People can have real time information about the quality of the environment and thus relocate in a safer place if required. Another article (Graber et al., 2007) discusses to implement the carbon monoxide detectors in residences and work places to detect the level of the carbon monoxide. This article presents that there should be such system in place at all geographic locations, and long-term study on the low exposure to carbon monoxide to the general population can be conducted with such detectors.

Similarly, this article (Hawkes, 2014) is about the web based Atlas implemented in London, where people can visit the website and see the health status of their vicinity in terms of chemical exposure of health conditions by inputting their postal code in the Atlas. However, such system provides only the relative risk, not the absolute risk. However, people can see the environmental conditions of their locations. Also, this article (Savel & Foldy, 2012) presents that due to innovation in remote sensing (GIS), websites, and smart phones and other wireless devices, it has made possible to detect the environmental health problems in terms of time and place in a real time. These technologies have also made possible to have crowd sourcing (getting information from a large number of population at a single time), and find out the information seeking behaviour of the people.

Summary of the findings:

Table 6. Tabular presentation of the overall finding of the environmental health surveillance.

Focus of the research/discussion	Qualitative studies	Quantitative studies	Other reviews	Editorials
Reporting from clinical/laboratory to PH units		1	1	
Population-based studies		2		
Application of GIS in PH programs	3		2	
Web based disease monitoring system	1		1	2
Food sources diseases monitoring system				1
Application of mobile phones				1
*Others				1
Total	4	3	4	5

*Others represents the articles that discussed about the different types of modern population health technologies (PHT) such as carbon monoxide detectors, sensors, remote sensing devices etc.

The table no. 6 shows the gist of all the included articles and their scoping in terms of the area of research and discussion presented in the in depth analysis above.

8.3.6 Natural disaster management

8.3.6.1 Number of articles

There are a total of 9 articles included in natural disaster management.

8.3.6.2 Study settings with number of studies

Among the 9 articles, 5 (55.5%) articles were from USA and the rest of the articles were each from UK, Canada, France, Kenya, Switzerland, and Thailand.

8.3.6.3 Types of articles/methodology

There were only 3 (33.3%) qualitative and quantitative studies, 4 (44.4%) editorials and 2 (22.2%) other review articles.

8.3.6.6 In-depth analysis to the included articles:

Qualitative study:

There is one qualitative study (Toutant et al., 2011) in this PH domain. This study, also discussed in the previous section (8.3.5.6 environmental health), is about a web-based software called SUPREME used to monitor the meteorological condition which was applied to monitor the heat waves in the province of Quebec during the summer of 2010. This system is useful to detect the disasters caused by meteorological conditions, to monitor the health effects caused by these events, and take prompt preventive measures.

Quantitative studies

There are two quantitative studies (Harrison, Harrison, & Smith, 2008; Josseran et al., 2009) included in this PH domain. The study (Harrison et al., 2008) is a survey conducted in 2007 among the health care centers situated across USA. The main objective of the study was to estimate the IT infrastructure capacity of the US health care centers that could be used during natural disasters. The data obtained from the Health Care Information and Management Systems Society (HIMSS) analytics database. The result of the study showed that among the total 2,877 health care organizations in 2007, (2,667) 92% had functional wireless local area network (LAN) to tackle the natural disasters and emergencies; however, only about 12% of hospitals have the tablet connection and handheld personal digital assistants (PDAs); whereas only 20% (562 hospitals) have the handheld personal computers. This article discusses that local, regional and national coordinated efforts are required to establish disaster management system. The article also discusses about the need of GIS system, need of web-based information sharing system for the emergency planning, early identification of the gaps in the disaster management system including the information system, use of satellite and radio telephone-landline, and mobile-based SMS are all essential components required for the disaster management.

Another quantitative study (Josseran et al., 2009) also discussed in the previous section (8.3.5.6 Environmental health) applies the ED based SS in 49 hospitals across France to find out the types of diseases people suffer due to the heat waves during the summer of 2006.

Other review:

There are two other review articles (Thieren, 2005; Foldy, 2004). In this article (Thieren, 2005), the author presents a need to establish a health information system during humanitarian emergencies covering a large number of people. The sudden emergency situations require a timely and meticulous information system however the emergency itself makes it difficult to obtain required data. To tackle this problem, the article presents that a coordinated efforts among all the stakeholders working in the emergencies is vital by creating a health information system. The information technologies such as hand held devices could be used to record the personnel interview to avoid time, and obtain authentic data. Also, the remote sensors, and GIS can help to find out the picture of the area affected, number of households, and number of people affected in that location. The electronic reporting on drug and inventory stock situation, and demographic characteristics of the affected population is required. Finally, the article stresses to cross validate the number of morbidity and mortality data before making them public.

Another article (Foldy, 2004) provides recommendations on improving the surveillance system before any kinds of PH emergencies such as natural disaster happen. To improve the system, the actions to be ensured are: improving both the input and process, and ensuring faster and surer action. To improve the input, the data should be mined from multiple sources e.g., ED, laboratories, or mass media. To improve the process, there should be a coordinated reporting mechanism, creating alert mechanism, and creating secure website to rapid dissemination and sharing of information, and ensuring the technical and human resource capacity to tackle the problem as needed. Finally, the emergency actions of the natural disasters should be based on response plan, and should be based on the information and communication system.

Editorials:

There are 4 editorials included in this PH domain (Boulos & Honda, 2006; Freifeld et al., 2010; Houser, Manger, Price, Silvers, & Hart-Hester, 2009; McIlwain & Lassetter, 2009). These editorials discuss primarily about the establishment of GIS, mobile phones, and EMR system to monitor and contain the natural disasters.

For example, this article (Boulos & Honda, 2006) discusses about the application of web GIS to gather images from multiple sources and shows an example of its application after the 2004 Indian Ocean tsunami. The map sharing was considered effective to collect data from multiple sources and the use of mobile devices. It was considered an effective tool to enhance the process. Similarly, the article (Freifeld et al., 2010) (also discussed in section 8.3.1.6 Infectious/communicable diseases monitoring) discusses about the application of the smart/mobile phones in remote and poor resource settings for outbreak detection and natural disaster management. Its application has been identified on communicating with the field level PH workers, collecting the data, and applying the GIS for identifying the geographic location. Also, the crowd sourcing was considered to be an important tool complementary to traditional monitoring system rather than replacing it, because in many instances the data requires rigorous investigation and validation before using.

Further, this article (McIlwain & Lassetter, 2009) discusses the establishment of the interoperable electronic HIE system in Mississippi after the hurricane Katrina occurred in 2005. The establishment of EMR system in hospitals, nursing homes and home care center. This article also talks about the 3 types of data architecture: centralized, federated (distributed), and hybrid model. The centralized data repository architecture refers to the system where all the patients' data from all health care centers are deposited at the central level data bank. The main advantage of this system is that, there is less chance of data duplication. In contrast, the federated model allows the data collections deposition at the individual health care center level. They have a complete control over their data. The hybrid model contains the features of both of these models, where data is deposited at both central and individual health care centers. However, the health care centers can have a control over their certain data for privacy purpose.

Summary of the findings:

Table 7. Tabular presentation of the overall finding of the natural disaster management.

Focus of the research/discussion	Qualitative studies	Quantitative studies	Other reviews	Editorials
Reporting from clinical/laboratory to PH units based studies		1	1	1
Population-based studies		1	1	
Application of GIS in PH programs				2
Web based disease monitoring system	1			
Application of mobile phones				1
Total	1	2	2	4

The table no. 7 presents the overall finding discussed in the in-depth analysis above.

8.3.7 Injury surveillance

8.3.7.1 Number of articles

There are a total of 8 articles in injury surveillance.

8.3.7.2 Study settings with number of studies

Among the total 8 articles, 4 (50%) were from USA and UK with two articles representing each of them. The rest of belonged to China, South Africa, and rest of the Europe.

8.3.7.3 Types of articles/methodology

5 (62.5%) out of 8 articles were qualitative, quantitative and/or mixed articles, and the rest were other reviews and editorials.

8.3.7.4 Evidence relating to use of Information Technology and Informatics concept

The result of the study revealed that there are only four type of IT discussed/used in this PH domain. These were EMR/EHR/electronic registry, websites, statistical/analytical software, and GIS which were used in 7 (87.5%), 4 (50%), 3 (37.5%), and 1(12.5%) of the total articles, respectively.

8.3.7.5 Evidence relating to the use of Informatics concepts

The result showed that most of the articles 5 (62.5%) applied both data retrieval and data transmission/-communication informatics concept; whereas, only 2 (25%) articles used data collection. A single article discussed/used data analytics, data storage and interoperability. Non-of the articles discussed/used data security, information sharing and knowledge management.

8.3.7.6 In-depth analysis to the available literature

Qualitative studies:

There are two qualitative studies included in this PH domain (Cinnamon & Schuurman, 2010; Downing & Wilson, 2005). A pilot study was conducted by Cinnamon and Schuurman (Cinnamon & Schuurman, 2010) to find out the feasibility of applying free ITs called social web (based on google docs and spread sheets) and geo spatial web (GeoWeb) tools in a resource constraint areas. The study was conducted for a period of one month in Cape Town public hospital named Groote Schuur Hospital (GSH). Approximately 1000 traumatic patients visit the hospitals each month. The types of injuries were found to be mostly road traffic accident (RTA) and violence. A trauma registry and data management system were created and implemented. The data were initially collected from the patients in paper forms, and later were transcribed into google doc, an online data entry form. The web based geocoding tools called BatchGeocode and Mapalist were also integrated into the system. Hence, the system could be used to visualize the geographic location of the incidents and the location of the hospitals. A total of 730 patients's data were entered into the system, for one month period. The study showed that an online data entry portal can be used in the trauma units of hospitals, and further epidemiological studies can be conducted. The study found that applying the freely available social google docs and GeoWeb tools can be a good opportunities in low and middle income countries (LMIC).

In another study (Fenton & Lowndes, 2004), an experience on establishing the regional accident and emergency (A and E) surveillance system in West Midlands region of England is presented. First of all, in 2000, A and E surveillance system was created by the Department of Public Health and Epidemiology at the University of Birmingham. All the 21 hospitals across the regions participated. The data pertaining to the accidents were collected by the surveillance system from these participating hospitals. The surveillance system captured over 5 million injury-related data from the participating hospitals. This was the first system that captured such a massive amount of data that could be used for the surveillance and research in England. The data collected were focused on the sports accident, road traffic accident, firework injury, assault, self-harm, and others. The research was focused on to find out the seasonal variation and demographic characteristics, epidemiology of assault, ankle sprain incidence, and incidence among the older people. The data were gathered from two sources: administrative data of local governmental and PH agencies. This surveillance system could be potentially used to find out the accident rates among specific population groups and devise necessary preventive actions tailored to their socio demographic characteristics, causes, and location of the injury. The main problem was also associated with the data standardization among all the hospitals and technological use. Not all the hospitals had the electronic reporting system in place.

Quantitative study

There are two quantitative studies included in this study (Newcombe, Lyons, Jones, & Patterson, 2005; Petridou et al., 2004). Both of these studies were surveys conducted to measure the injury prevalence with ED-based injury surveillance report.

This study (Newcombe et al., 2005) is a survey to measure the home-based injuries caused by the effects of the built-in physical environment of houses in a county of UK. The study compared the physical characteristics of the houses, and the numbers and types of the injuries occurred in those neighborhoods. The housing-related data were collected directly through visiting the houses. The data included floor type, housing type (detached, semi-detached, flat conversions, purpose-built flats, and terraced housing), and the date the house was built. The demographic data were obtained from the database of National Health Service Administrative Register (NHSAR) by matching housing related data for each household. The injury-related data were collected from the All Wales Injury Surveillance System (AWISS) for the period of 1999-2000. The study integrated and compared the data from all of the 3 data sources, described above, for the period of 1999 to 2000. The study found that integrating the three databases was effective way to find out the physical and demographic characteristics of the injury. One particular type of housing was found to be associated with the increased incidence of injury. The IT applied here were the electronic registry used in ED and administrative databases. Similarly, another study (Petridou et al., 2004) conducted in Greece compared the data of population-based survey on injury prevalence to the ED based injury surveillance data. People were asked to recall the injury for the previous year and the data for the same year were compared with the ED data. The study found that creating an injury surveillance database in ED is effective than surveying injury data from people due to the recall bias.

Mixed studies:

There is only one mixed study (Liu, Li, Cui, & Jackson, 2009). This study was conducted by the Shantou- Emergency Department Injury Surveillance Project (S-EDISP) in the largest injury surveillance hospital of China. The aim of the study was to evaluate the injury surveillance system for a one year period from April 2006 to March 2007 based on the injury surveillance guideline developed by WHO and CDC-US 2001. The IT applied was the electronic registry applied in the data recording for the injury surveillance in the hospital. The result of the study found that the accuracy rate of using the injury surveillance form provided by the S-EDISP project was about 80%. The study evaluated the surveillance system based on 3 methods: retrospective evaluation; process evaluation; and system environment evaluation. The retrospective evaluation included checking the number and types of injuries in the past one year. The process evaluation was conducted by observing how well the patients identification and data reporting is conducted, and system evaluation was conducted by observing the necessary logistics and the technical capacity of human resources.

Other reviews:

There are two other review articles in this PH domain (Woodhall, 2005; EUPHIN, 2003). The article (Woodhall, 2005) comes up with the idea that the homeland security (bioterrorism surveillance), car crashes or traffic accidents (injury surveillance), and emergency response systems should have a single interoperable information infrastructure. For such infrastructure, the article presents about the National Emergency Alerting and Response Systems (NEARS) initiative, which is an interoperable emergency messaging system. This initiative is applied by 50,000 individual agencies across the USA. The NEARS is endorsed by the emergency services, fire department, 9-1-1, emergency medical services (EMS), and law enforcement. The information regarding all kinds of injuries, traffic incidents, medical emergencies, and hazards can be exchanged with the various partners such as transportation, emergency management agencies, hospitals, PH, law enforcements, and others. The NEARS framework contains 5 architectural layers: transport; data standard; facilitation services; agency application, and polices and protocols. The transport layer includes an internet based, wired, or wireless communication among the various interagency. The second layer used data standardization among the various partners for standard language exchange. The third layer includes facilitation services that enables for data accessibility, security, access control, digital right management, identity management, and authorization. The fourth layer include the agency application. The applications are state wide GIS system tool, web based emergency management tool, and complex computer aided dispatch systems (CAD). These applications should include the uniform software across all the agencies to manage data, enhance interoperability and distribution protocol. Final layer includes the formulation of policy and protocols that clearly specifies the regulations on accessibility, responsibility, confidentiality, use, and receiving of the data. The NEARS has made it possible to get real time data on the traffic condition of the road, road traffic accidents, and any other hazards in the specified community.

Another review article (EUPHIN, 2003) presents the European Union Public Health Information Network (EUPHIN) which was established in EU to exchange the information among the member states through a secure internet or through a secure virtual private network. EUPHIN has been an effective platform for monitoring the injuries and infectious diseases in the member states EU.

Editorials:

Finally, there was one editorial (Henry & Hannan, 2005) included in this PH domain which talks about the population-based trauma registry from the New York state. The editorial discusses that the New York state wide population-based trauma registry is better to predict the efficiency of trauma centres over the administrative databases of the states. Hence, this editorial prescribes to continue on using the state wide population-based trauma registry and conduct more research based on the registry to find out the trauma related causes and population characteristics that can support for the better patients care and prevention program.

Summary of the findings:

Table 8. Tabular presentation of the overall finding of the injury surveillance.

Focus of the research/discussion	Qualitative studies	Quantitative studies	Other reviews	Editorials	Mixed studies
Reporting from clinical/laboratory to PH units based studies	1	2			1
Population-based studies				1	
NHIS			1		
Web based disease monitoring system	1		1		
Total	2	2	2	1	1

The table no. 8 portrays the gist of the in-depth analysis conducted in this PH domain.

8.3.8 Occupational health hazard

8.3.8.1 Number of articles

There are 3 articles in occupational health hazard.

8.3.8.2 Study settings with number of studies

Among the three articles, 2 were from USA and one from Switzerland.

8.2.8.3 Types of articles/methodology

The result found that 2 articles followed quantitative study methodology and a single article followed mixed study methodology.

8.2.8.4 Evidence relating to use of Information Technology and Informatics concept

The result of the study showed that 2 of the 3 articles in this PH domain included websites; whereas 1 article discussed/used EMR/EHR/electronic registry and mass media. None of the articles discussed/used any other IT.

8.2.8.5 Evidence relating to the use of Informatics concepts applied

The study found that the only informatics concepts applied were data storage, data transmission/ communication, and information sharing. Each of them were applied in 2 of the 3 articles.

8.2.8.6 In-depth analysis to the included studies

Quantitative studies:

There are 2 quantitative studies (World Health Organization, 2004; Massawe, 2013). Among them, this study (World Health Organization, 2004) is a survey conducted to measure the number and nature of the chemical incidents found in the international chemical incident database created by the International Programme on Chemical Safety (IPCS) throughout the first year of its launch, from August 2002 to July 2003. The IPCS is a program initiated by WHO in collaboration with the International Labour Organization, and the United Nations Environment Programme. The IPCS initiated three joint activities: compilation of the international databases of chemical incidents, piloting of global chemical incident alert and surveillance system, and ChemiNet (an international communication network). The data on the international chemical incident database was captured from the ProMED-Mail and GPHIN. The ProMED-Mail is an internet based international reporting system for infectious diseases or chemical incidents. Also, the GPHIN is a program implemented by the Heath Canada to monitor global disease outbreaks, bioterrorism threats, and chemical accidents based on international news and electronic media. The result of the survey showed that 436 incidents occurred globally during the study period. The incidents took place among 57 countries across the world, however the 8 countries represented nearly three quarters of the incidents: USA (169; 38.8%), Australia (21; 4.8%), New Zealand (11; 2.5%), France (10; 2.3%), United Kingdom (58; 13.3%), Canada (19; 4.4%), India (19; 4.4%), and China (18; 4.1%). The reasons of the chemical incidents were the explosions, fires, industrial processes causing exposure, and transportation of chemicals by rail, road, or sea. Among these incidents only 65% of them took an appropriate action to protect the public's health. The actions included: evacuation of the workers and community people, providing shelter, immediate road and railway closure, preventing people to consume foods brought from contaminated lakes/waters, and declaring emergency in the given location of incident.

Additionally, this article (Massawe, 2013) discussed in the previous section (8.3.5.6. Environmental health) is a survey conducted among the US state environmental health specialists and PH managers to find out the current status, future information need and research capability to manage the ENP from the industrial and superfund sites. The study highlighted a knowledge gap among the state level focal persons on remedial techniques and emphasized a need to establish an information sharing database to impart appropriate knowledge on material handling techniques and disposal techniques accessed by the local, state, and federal environmental health workers.

Qualitative study:

There is one qualitative study on this PH domain (Brown, 2008). The study provides a description about a relational database called “Haz-Map”, constructed to map the diseases of occupational exposure with respective agents. The types of hazards included were biological, chemical, and radiation hazards. However, the hazards related to physical injuries, repetitive motion, noise, heat, and cold were not included in the database. The database has a capacity to show a relationship among the types of the agents, associated hazards, signs and symptoms, job tasks, and the industry associated with that agent. This database can be accessed from the NLM webpage. It was the first of its kind that could manifest a relationship of a specific exposure to its diseases. By 2008, the Haz-Map contained 1,534 biological and chemical agents, 122 signs and symptoms, 212 diseases, 276 types of jobs, 621 industries, 51 industrial processes, and 26 non-occupational activities. The web based database is an open source database that can be accessed by all the occupational professionals and general public to expand their knowledge and take precautions. The required information from the database can be accessed using the data query. A further improvement in the database can be inclusion of the hazards associated with the physical agents e.g., cold, fire, work place injuries etc. Also, there is no mention that where the information into the database is gathered.

Summary of the findings:

Table 9. Tabular presentation of the overall finding of the occupational health hazard.

Focus of the research/discussion	Qualitative studies	Quantitative studies
NHIS		1
Web based disease monitoring system	1	1
Total	1	2

The table no. 9 depicts a picture of the in depth analysis conducted above.

8.3.9 Public health awareness

8.3.9.1 Number of articles

There are 80 articles included in this PH domain.

8.3.9.2 Study settings with number of studies

The result of the study revealed that 57 (71.3%) of the total 80 articles are from USA, 8 (10%) are from UK, 4 (5%) are from Canada and Japan, and the rest are from other 16 different countries across the world.

8.3.9.3 Types of articles/methodology

Among the total articles, equal 14 (17.5%) articles represent both quantitative and qualitative studies, 24 (30%) other reviews, 23 (28.8%) editorials, 4 (5.0%) mixed studies, and a single article is empirical study.

8.3.9.4 Evidence relating to use of Information Technology

The result indicated that 78 (97.5%) of the total articles discussed/used websites in the public health awareness domain. Among the remaining articles, EMR/EHR/electronic registry, e-mail, and GIS were discussed/used in 18 (22.5%), 10 (12.5%) and 9 (11.3%) of the total articles respectively. Less than 10% of the articles discussed/used mobile phones, mass media, and other information technologies.

8.3.9.5 Evidence relating to the use of Informatics concepts

It was found that 72 (79.1%) of the total articles discussed/used information sharing, and another 50% discussed/used data transmission/ communication among the total articles. Data storage, data collection, data analytics, and data security were discussed/used in less than 10% of the articles; whereas, knowledge management was not discussed/used in any of the articles of this PH domain.

8.3.9.6 In-depth analysis of the available articles

Although all the studies included in this category were used to create awareness among the general population or a specific group of a population, these articles are further categorized based on the application of the information technologies on them.

Qualitative studies:

An in-depth study on the available literature shows that there are total 14 qualitative studies included in this PH domain. Among them, 6 articles (Achterberg, Kramers, & Van Oers, 2008; Brown, 2008; Cohen, Franklin, & West, 2006; Henner & Charles, 2002; Wilk & Verschuuren, 2010; Wilkinson & Coyle, 2005) are related simply with web based health information sharing with the public. These articles mainly applied the websites for disseminating the health-related information to the general population and other stakeholders e.g., politicians, policy makers, and media etc. For example, these articles (Achterberg et al., 2008; Wilk & Verschuuren, 2010) present about the EUPHIX (European Public Health Information and Knowledge System) that was implemented in July 2008 in EU. The main aim of that web based system is to share the PH-related intra-national, national, and regional information among the member countries of the EU.

The web based information sharing system helps to inform politicians, policy makers, academicians, media, and general public about the current state of the PH related indicators and activities across the EU. Similarly, another article (Wilkinson & Coyle, 2005) focusses on the public health observatory (PHO) system used in UK in 1990. The PHO is an internet based health monitoring system that is used for disease surveillance, public health awareness, and monitoring by PH professionals for the disease monitoring and research.

Further, there are 4 qualitative surveys (LaPelle, Luckmann, Simpson, & Martin, 2006; Telleen & Martin, 2002; Watkins, Bendel, Scott-Samuel, & Whitehead, 2002; Gjelsvik & Buechner, 2006) conducted to find out the effectiveness of the health information system (HIS). For example, a study (LaPelle et al., 2006) was conducted to assess the barriers of information access and identify the health information seeking behavior in 2003 and 2004. Series of interviews and focus group discussions were conducted with a state level PH staffs. This study found that there were many websites which provided useful health information, however these are often duplicative, found without screening and lack validity and robustness. The study highlighted the need of a single web portal for disseminating all PH information instead of many websites for the same information. It also emphasized the need of a notification system that is specific to the interest of individuals. Although there are existing systems, such as Listservs, that are complimentary for such notifications, the information provided often lack screening. Therefore, it requires more screening to enhance the quality of internet based notifications. It also highlighted to establish a better mechanism to screen health information available in search engines.

Two studies (Brownstein et al., 2008; Yi et al., 2008) are related with applying GIS system to enhance the geospatial information related to the PH. In this article (Brownstein et al., 2008), a global disease monitoring system called Health Map is discussed (also discussed in the section 8.3.1.6 infectious/communicable disease monitoring). The Health Map uses google maps as a GIS platform. However, the article (Yi et al., 2008) presented new prototype of GIS system called Epidemiological Visual User Environment (EpiVue), which was tested (in 2008) in two data sets: Washington State Cancer Registry and Washington State Center for Health Statistics. This is a free available open source software. It can store the data and present its spatial visualization. It includes R statistics and google maps for making it interactive. A person can upload the data using MS excel or comma-separated values text format. This article suggests that this type of the software is highly valuable for environments with resource constrain.

The rest 2 diverse studies are related with adopting different types of ITs for health promotion (Lewis & Burton-Freeman, 2010), and application of NLP (Keeling et al., 2011) for improving the web based information sharing. The article (Keeling et al., 2011) applied the NLP to find out grey literature from the search engines (google). The study found that using the NLP by indexing the search query terms could enhance the capability of grey literature search from 28% to 55%. The study further recommends to improve the search terms by selecting more specific terms. Also, a faster NLP and more advancements in the architecture should be a priority in the future to develop this field.

Overall, all of these articles have applied websites as a major component to impart the useful health information to the public.

Quantitative studies:

There are a total of 14 quantitative studies included in this PH domain which are (Adily, Westbrook, Coiera, & Ward, 2004; AlSaadi, 2012; Angell, Hemingway, & Hartwell, 2011;

Czaja, Sharit, & Nair, 2008; Ferron et al., 2011; Fahey & Weinberg, 2003; Hsu et al., 2012; Lee, Giuse, & Sathe, 2003; Linkins et al., 2006; Makimoto, Ashida, Qureshi, Tsuchida, & Sekikawa, 2005; Pryor et al., 2002; Tao, 2009; Twose, Swartz, Bunker, Roderer, & Oliver, 2008; Ward, Spain, Perilla, Morales, & Linkin, 2008). All of these articles are the descriptive surveys except the article (Ward et al., 2008) is a non-randomized control trial, which was conducted among the clinicians. For example, a survey (Linkins et al., 2006) was conducted to find out the knowledge and attitudes of the parents of school age children about the need of immunization registry. The electronic registry can be used as a reminder to the parents about the immunization. Similarly, another study (Fahey & Weinberg, 2003) was conducted to find out the accuracy of the information stated in 21 different websites by LASIK about Lasik surgery. In this study (Ward et al., 2008) a group of doctors were provided with handheld computers and web based information about the usefulness of reporting; whereas another group did not receive either of those. The study found that the group of doctors having e-mail notification and information on websites had increased number of report sending; whereas the control groups had a decrease in number of reporting in the same period. The survey reports represented various group of population.

Mixed studies:

There are a total of 4 mixed studies (Childs, 2004; Zyl & Dartnall, 2010; Hessler, Soper, Bondy, Hanes, & Davidson, 2009; Huber, Dietrich, Cugini, & Burke, 2005). All of which are cross-sectional studies conducted using both qualitative and quantitative study techniques. The studies are focussed on the web based information sharing system. For example, this study (Childs, 2004) was conducted using the focus group discussion and a survey to find out the effectiveness of the health education contents on internet among the general population. Similarly, this study

(Hessler et al., 2009) was conducted applying by an online survey. This survey focus on knowledge and attitudes of the local, state, and regional PH officials regarding the HIE system implemented in USA..

Other reviews:

There are a total of 24 other review articles. Out of these 24 articles, 18 of them are related to the web based information sharing (Braithwaite & Haggard, 2006; Cashen, Dykes, & Gerber, 2004; D'Auria, 2012; Eldredge et al., 2004; Eysenbach, 2011; Eysenbach, 2009; Frew & Bernhardt, 2005; Friedman & Parrish, 2006; Haggard & Burnett, 2006; Hill, Cooke, Jenner, & Somervaille, 2005; Hobson, Haines, & Van Amburgh, 2010; Irani, Bohn, Halasan, Landen, & McCusker, 2006; Johnson et al., 2004; Love & Shah, 2006; Rudolph, Shah, & Love, 2006; Solet, Glusker, Laurent, & Yu, 2006; Trewin et al., 2008; Vasconcellos-Silva, Castiel, & Rivera, 2003). These articles apply the websites to disseminate PH information and raise awareness for a specific PH problem in general public. Six of these articles (Friedman & Parrish, 2006; Haggard & Burnett, 2006; Irani et al.; 2006; Love & Shah, 2006; Rudolph et al., 2006; Solet et al., 2006) also discussed the web based data query system (WDQS) implemented in several states of the USA since early 1990s. These systems are constructed to make the state level PH information (e.g., health statistics, demographic survey reports) accessible to the public. In some jurisdictions, the WDQS also incorporated internet based GIS (IGIS) system with the WDQS, which provides accessibility to watch the PH information with the visual maps. For example, this article (Grigg, Alfred, Keller, & Steele, 2006) talks about integrating the IGIS called CHARTS with the WDQS in 2001 in Florida. All the 67 counties across Florida used the system. The system helped to display the county level socio-demographic and health status with geographic information.

Further, one article (D’Auria, 2012) discussed about the application of google search for health information. It also shows that google has been used not only to get health related information but also to find out all kinds of clinical information ranging from diagnosis, treatment and physiological conditions. Another two articles (Eldredge et al., 2004; Eysenbach, 2011) discussed about mining the websites for monitoring the disease search-trend among the general population which was defined as ‘infoveillance’ and its study as ‘infodemiology’. This paper talks about the possible advantages of the system and highlights a need of further studies on it.

Among the rest articles, 3 articles (Fulcher & Kaukinen, 2004; Grigg et al., 2006; Zwakhals, Giesbers, Mac Gillavry, van Boven, & van der Veen, 2004) are related to the application of the websites and GIS to create awareness. For example, this article (Zwakhals et al., 2004) is about the Dutch National Atlas of PH, which is a web based system that includes GIS related with the PH related information that is used for information sharing with a large number of people as well as for the policy and practice purpose. The general public uses the information for awareness, whereas policy makers use it for further policy making. The number of visits to the Atlas is also monitored to find out the general interest of the Dutch public, which is further incorporated in future policy making. Similarly, another article (Fulcher & Kaukinen, 2004) presents that the application of GIS can be vital to create awareness among the targeted population enabling them to make a coordination among the less advanced communities, and find the required causes and solutions. It also enables health care workers of that county to find out the causes, solutions, and devise a better plan.

The 3 final articles are related with the use of websites along with mass media (Adair, 2012), mobile phones (Smith & Keliy, 2002), and e-mails (Wilson, 2006) for public health awareness. For example, this article (Smith & Keliy, 2002) is about a telemedicine program to support mental health support program from a distance. It is also tailored to support patients with information sharing by clinicians. It applied mobile phones for counselling and educating mental patients and a website-based health awareness and education programs targeted to create awareness among the affected population.

Editorials:

There are a total of 23 editorials in this PH domain. Among them, 19 editorials focus on the application of the websites for the health information dissemination by the PH units (Bailey, 2004; Dykes & Bakken, 2004; Foster, 2005; Friedman, 2006; Friedman & Parrish, 2010; Frohlich, Karp, Smith, & Sujansky, 2007; Harr & Bella, 2010; Hampton, 2008; Venture, 2007; Mann, Lloyd-Puryear, & Linzer, 2006; Mitka, 2003a; Mitka, 2003b; Pollock, 2008; Rosenbaum, Burke, Benevelli, Borzi, & Repash, 2005; Schumacher, 2006; Whitener, Van Horne, & Gauthier, 2005; Wilcox, 2004; World Health Organization, 2005; Wilkinson & Ferguson, 2010). These articles applied websites for sharing information with the general public.

As an example, in one article (Bailey, 2004), writer puts forward the perspectives on the future of Africa's Information system. The author explains that establishing an internet based knowledge sharing system can be very effective to increase knowledge about HIV/AIDS among the African population. Similarly in another article (Rosenbaum et al., 2005) the author talks in general about the development of the web based NHIS and its implication to PH policy. This paper also discusses on health policy regarding maintaining the patients' privacy and accountability. It emphasizes on strong necessity to increase the patient's privacy while sharing the data through internet. Similarly, in another article (Harr & Bella, 2010), the writers express their perspectives on the use of internet or mobile phones in Canada by the Government of

Canada to increase the awareness of PH related issues among the Canadians. It also provides some of the challenges the Canadians are facing with these issues, some of which are: digital divide (no access to internet to many people) and no effective knowledge about how to use the internet. It also says that many people search information through search engines e.g., google, instead of visiting the specific website of an authentic organization. Also, the governmental information provided in the sites, in most of the times, are not accessed by the users or are not in the form understood by the general users. Therefore, the report recommends to: create an information system at each provinces and territories in the local language and/or simple English language; create and coordinate for a single web portal system for all the provinces and territories to reduce the redundancies of the information through various provincial sites; create a mechanism to reduce the digital divide among the less advanced population by providing the internet access to local public libraries. Also this paper (Mann et al., 2006) is about the communication among the clinicians, PH workers and the general public. The application of the e-mail and electronic registry by the PH workers and clinicians are discussed as an important tools to inform the general public about their immunization or other health status. It also discusses that using such registry helps to the clinicians to find out the patients histories in time and maintain healthy practices. These registries also help the PH professionals be informed about the immunization status of a given population and intervene an appropriate action. The integrated information system can also help the patients and other pre-approved users to know their health situation in time.

Among the remaining 4 articles, two editorials (Conn, 2010; Freifeld et al., 2010), in addition to the application of the websites, discuss the application of mobile phone, The article (Conn, 2010) discusses that the innovation in information technology, especially in the mobile applications, are becoming a potential tool to capture the time and place of the disease attacks (e.g., asthma). Similarly, this article (Bickmore, Giorgino, Green, & Picard, 2006), published in 2006, presents several communication models for health education and behavioral change. The first model consists of interactive voice response (IVR) via telephone, which was considered to be a successful model for behavior change. Second model, a hypothetical model proposed for the future, consists of automatic knowledge based dialog system. The third is a conversational speech based dialog system. Such system is still under development and includes automated speech processing, NLP, and speech synthesis and generation. The fourth system consists of embodies conversational agents in which an animated character emulate the facial expression and hand gesture during virtual face to face interaction. Lastly, one article (Fulcher & Kaukinen, 2003) focusses on the application of the GIS.

Empirical study:

There is only 1 empirical study (Wolfe & Sharp, 2005). In this paper, the study was conducted to assess the use of internet by the anti- and pro-vaccination groups to create their respective viewpoints to create public awareness. This report recommends a future research on how PH education campaigns can impact anti-vaccination campaigns and also the effects of the anti-vaccination websites on the parental attitudes.

In general, the main discussion in this PH domain in the literature is about the application of web based information dissemination system by the local, state and federal PH departments. The majority of the articles included in this PH domain applied the websites to create health awareness among the general population and therefore this could be the reason the websites were used in the most of the times in this PH domain.

Summary of the findings:

Table 10. Tabular presentation of the overall finding of the public health awareness.

Focus of the research/discussion	Qualitative studies	Quantitative studies	Other reviews	Editorial	Mixed studies	Empirical study
Population-based studies		14			4	
Application of GIS in PH programs	2		3	1		
NHIS	4					
Ethnographic studies						
Web based disease monitoring and/or health awareness system	6		18	19		1
Application of mobile phones				2		
*Others	2		3	1		
	14	14	24	23	4	1

*Others represent all other articles which are not represented in the above list such as different types of new health devices, improvement in the NLP system for health education, and articles representing combination of mass media, mobile phones, e-mail etc.

The table no. 10 shows an overall picture of the in-depth analysis made above in this section.

8.3.10 Non-communicable/chronic disease monitoring

8.3.10.1 Number of articles

There are 49 articles included in this PH domain.

8.3.10.2 Study settings with number of studies

The result of the study showed that among the total 49 articles, 33 (67.3%) of the total articles were from the USA, 7 (14.28%) are from rest of the Europe, 4 (8.2%) were from Canada, and the rest articles were from the 12 different countries across the world.

8.3.10.3 Types of articles/methodology

The result also found that there were 15 (30.6%) quantitative studies, 11 (20.4%) qualitative studies, and 16 (32.7%) other reviews articles. Among the rest articles, 7 (14.3%) were editorials.

8.3.10.4 Evidence relating to use of Information Technology and Informatics concept

The articles included in this PH domain showed that the majority of the articles 42 (82.4%) discussed/used EMR/EHR/electronic registry and almost half 25 (49.0%) discussed/used websites. Further, GIS and telephone-landline were discussed/used in 12 (23.5%) and 8 (15.7%) articles respectively; whereas, statistical/analytical software and DP algorithm were in equal equal portion of 11.8% of the articles. Finally very few articles, that is, less than 10% used e-mail, mass media and mobile phones. In contrast, NLP and automated speech processing were used in non-of the articles.

8.3.10.5 Evidence relating to the use of Informatics concepts

Among the 49 articles included in this PH domain, only data collection and data transmission/communication were applied in more than half the articles (29(56.9%) and 28 (54.7%) respectively). Further, a significant number of the articles discussed/used data retrieval 22 (43.1%) and information sharing 15 (29.4%). There were only less than 20% of articles that used interoperability, data storage, and data analytics. In contrast, knowledge management and data security were discussed in very few articles (3 (5.9%) and 1(2%) of the articles respectively).

8.3.10.6 In-depth analysis to the literature

Qualitative studies:

There are a total of 11 qualitative studies in this PH domain. These studies are the case studies and qualitative research conducted applying qualitative methodology to the different kinds of PH programs. Three articles (Barton, Kallem, Van Dyke, Mon, & Richesson, 2011; Buck et al., 2012; Yoon et al., 2006) are related with the data reporting from clinical units to PH units, 4 articles (Bédard et al., 2003; Forand, Talbot, Druschel, & Cross, 2002; Robertson & Nelson, 2010; Scott, Curtis, & Twumasi, 2002) are focused on application of GIS in PH program, and 4 articles discus narcotic drug monitoring and reporting via website (Jauncey, Indig, & Kaldor, 2003), insurance claims based surveillance (Marshall et al., 2002), statistical/analytical software (Surjan et al., 2006), and an ethnographic study on the causes of data error (Høstgaard & Pape-Haugaard, 2012).

Among the articles focused on data reporting from the clinical units to PH units, in this paper (Barton et al., 2011) a project named diabetes data strategy (Diabe-DS) was implemented in 2009 to use the clinical diabetes data in PH practice and research purpose. The project identified and standardized diabetes-specific vocabularies termed as common data elements (CDE) and established the interoperable system between PH units and clinical units. This article further recommended to develop and standardize disease-specific common data elements for the other types of chronic diseases as well. Similarly, another article (Buck et al., 2012) discusses about the primary care information project (PCIP) which was implemented by New York City-DoHMH in 2005. The main aim of the project was to establish a distributed network system in which the individual clinical/ambulatory units are connected to the central hub through server. The individual units send data to the server every night through a secure connection. To maintain the security of the patients' data, only the aggregated data is transmitted to the hub. The data is stored in a central database. The system helps to investigate and monitor the unusual trends of diseases. By 2011, a total of 532 clinical practices joined the PCIP, serving a total of 2.5 million patients per year. Main functions of the system were: distribute the reports to the network practices and PH units; provide interface for reviewing and downloading the results; provide secure messaging directly to the EHR inbox of the clinical practices and PH units. This system could be very good in monitoring the disease trend; however, a potential weakness of the system is that "the patients visiting to the health care practices may not be a full representation of the whole population in such systems" (Buck et al., 2012).

There are 4 articles (Bédard et al., 2003; Forand et al., 2002; Robertson & Nelson, 2010; Scott et al., 2002) which have focused on the applications of GIS in PH program. For example, this article (Bédard et al., 2003) is a case study of spatial on-line analytical processing (SOLAP) system used in Quebec, Canada in 2002 (also mentioned in the previous section (8.3.5.6. Environmental health). This article presents the integration of GIS and On-Line Analytical Processing (OLAP) technologies for decision support to PH experts. By applying geomatics technologies for decision support, users can access environmental and health-related geo-spatial data at a single interface. The main goal is to provide the high quality environmental and PH related data, support the decision making process by the PH specialists, and generate a new knowledge. Such system can be applied for both infectious and chronic disease monitoring and environmental surveillance of disease causative factors. The article highlights that "this type of system is only in the market very recently but do not have flexibility to satisfy the need of multidimensional spatial-temporal analysis (Bédard et al., 2003)".

Similarly, in this article (Scott et al., 2002) study was conducted applying the GIS system in mapping the cancer in KwaZulu- Natal, South Africa. The main aim of the study was to find out the geographic variation of cancer and explore the possible aetiology and risk factors associated with the geographic variations or structures. The cancer registry data were collected from the 3 major urban hospitals in 1997. A total of 3764 reported cancer cases were retrieved. The geographic information of the patients were also captured along with related socio demographic variables. The result indicated that the majority of cancer patients were concentrated in the urban and relatively higher developed areas of the province compared with the less developed areas of the province. It was concluded that this distribution of the disease is due to the poor access of the less advanced population to health-care facilities. The article suggests that the cancer health information system can be well supported by the GIS system, which can help in identifying the appropriate location during PH program planning and disease reporting. Another study (Robertson & Nelson, 2010) also discussed in the previous section

(8.3.1.6 Infectious/communicable diseases monitoring), recommended on establishing the internet based GIS support system and standardizing data coding and formatting. Similarly, in the last article (Forand et al., 2002), the New York City-DoHMH conducted GIS mapping of the congenital malformation among various counties of the state using hospital data with alongside of codes. To sum up, the GIS was mostly applied using the hospital based data to map chronic diseases. Also, there is a discussion on the system development of GIS system to map the chronic diseases. The analytical techniques embedded in the GIS system have the potential of analyzing geographic location, sources of the diseases, and investigating socio demographic characteristics of the affected population.

The remaining 4 articles are focused each on narcotic drug monitoring and reporting via website (Jauncey et al., 2003), insurance claims based surveillance (Marshall et al., 2002), study on statistical/analytical software (Surjan et al., 2006), and causes of data error on child health information system (Høstgaard & Pape-Haugaard, 2012). The study (Høstgaard & Pape-Haugaard, 2012) explored the reason of data error in Danish national database child health information from April 1st, 2009 to June 1st, 2011. The study found that the most of the data errors occurred while entering the data by the nurse while they measure the physical characteristics of the children. Nurses often take data while at home visits or school clinics visits where they have to maintain relationship with parents. Therefore, they often write down in a piece of paper and enter data later at office. However, many of the information gets altered during that process. Hence, this paper suggests that Danish Information Technology System needs to be restructured and work place reporting environment needs to be understood very well before adding extra responsibilities to busy health care providers such as nurses. The study (Jauncey et al., 2003) is about a case study on system called Drug Related Outcomes: Population

Surveillance (DROPS), implemented in New South Wales (NSW) Australia. An automated web based reporting system was developed that could be accessed by the authorized users e.g., field workers and authorities via a secure web based network. This system was helpful in measuring the total burden of the problem, which was used in designing the program in the affected area in a more timely fashion.

In conclusion, the qualitative studies have applied the electronic registry for data reporting, website for data reporting and monitoring, and GIS for mapping the diseases.

Quantitative studies:

There are a total of 15 quantitative studies. Out of them, 8 articles are focused on the hospital based studies (Bottle & Aylin, 2008; Dausey et al., 2008; Dellefield, 2004; Jain, Sathar, Salim, & Shah, 2013; Jazieh, 2003; Pavlin et al., 2004; Powell et al., 2003; Trepka et al., 2009). These studies were conducted to find out the effectiveness of disease reporting and monitoring system in hospitals, to verify the effectiveness of the system, and to measure the prevalence of some diseases. The main IT applied are hospital based electronic registry and telephone-landline. The diseases and programs studied are Asthma, psychiatric problems, ulcer, arthritis, overall hospital level morbidity and mortality, MCH program, and mammography data.

As an example, this study (Pavlin et al., 2004) was conducted in military-treatment facilities (MTFs) of US army health facilities from July 2001 to Aug 2002. The main aim of the study was to find out the possibility of tracking the trend of psychiatric illnesses by comparing psychiatric medication prescription through ambulatory clinics and medication sale from pharmacies. The result indicated that the comparison gives a precise prediction of finding the mental status of the military personnel and their families. Similarly another study (Jain et al.,

2013) conducted in Pakistan from 2007 to 2009 among 31 hospitals located at the district headquarters across all the nation. This study illustrates that the reporting is monthly, and the computer system for monitoring and surveillance is only functioning at the central level. This study further suggests to implement an electronic reporting system from the district to the central level for reporting and communication so that it could improve the maternal and child health condition in the country. This study also highlights a need to connect the various level of hospitals to make the reporting faster and efficient. This study (Dausey et al., 2008) was conducted to test the telephone-landline based surveillance for timely call response. 74 health departments were randomly selected across the USA and tested their performance. A total number of five calls were made to each state health department to report an emergency health problem at a local health facility by pretending to be an affiliated doctor or a nurse. The calls were made between 8 am to 5 pm Monday to Friday. The time to get an action officer was measured. The study found that the telephone-landline based surveillance can get an action officer within less than 30 minutes and concluded this type of communication as an effective mean of disease surveillance.

Furthermore, there are 4 articles that are focussed on population-based surveys (Lankinen et al., 2004; Mukhtar, Murphy, & Mitchell, 2003; Oliva et al., 2007; Weitzman et al., 2012). These studies were conducted to find out the attitudes of the PH authorities, PH workers, and patients on usefulness of IT application in PH program. The main IT discussed/applied electronic registry and website. For example, a web based survey (Weitzman et al., 2012) was conducted among the personal health record users over 18 years of age from Boston area in 2009. The aim of the study was to find out their attitude on sharing their personal health records with the out-of-hospital clinical facilities or PH bodies. The study showed that the majority of people are interested in sharing their personal health information to PH units or out of hospital clinical health care facilities, with very few number of people with absolute reticence. Another study (Lankinen et al., 2004) was conducted among national PH authorities responsible for vaccine vigilance of all the member states of the EU countries, including Norway and Switzerland. The survey was conducted from 1999 to 2000. The main objective of the study was to find gaps in the systems for reporting adverse events following immunization (AEFI) in all the western European countries. The study identified the areas to be improved in the reporting system, which includes capacity building of the human resources and integrating the silos system with the national system. The study concluded that integrating the monitoring system across all the countries would be effective to deal with such problem. The study also recommended to establish a linkage of epidemiological and immunization data from all the hospitals. It also highlighted to make the data on the adverse effects publicly available.

There are two studies focussed on GIS system (Ghetian, Parrott, Volkman, & Lengerich, 2008; Roberts, Hulsey, Curtis, & Reigart, 2003). The study (Roberts et al., 2003) was a retrospective paper to find out the association of childhood lead poisoning with the years the houses were constructed. The map was gathered from Charleston County with information of old housings and the household information of the affected children. The study found that the children born before 1950 had 3 times higher level of lead in their blood than the children born after 1978.

In conclusion, the quantitative studies were focused mostly on surveying the existing hospital based program and and attempted to investigate the knowledge and attitudes of people or PH workers on specific topics. The main emerging concepts in this domain are: studies on the application of phones in surveillance, people’s generosity in sharing their personal data with the

PH units, and an example on a developing country (Pakistan) suggesting that to improve the MCH programs, the developing countries need to develop the electronic reporting system in their countries.

Other reviews:

There are a total of 16 other review articles in this PH domain. Among them, 7 articles (Messiaen et al., 2008; Glaser et al., 2005; Fan, Blair et al., 2010; Lewis et al., 2011; Orlova et al., 2005; Shapiro, 2007; Soucie, McAlister, McClellan, Oakley, & Su, 2010) are related with clinical, hospital, laboratory, and school based data reporting mechanisms. The data is transmitted electronically to PH units, the information exchange is mostly interoperable, and GIS system has been applied in many of the articles. For example, this article (Messiaen et al., 2008) discusses about the information system named CEMARA (centers maladies rare), which was established in 2003 in France to collect information from patients suffering from rare diseases. Twenty five out of 132 labelled reference centers (RCs) across the France were involved. The main objective of the system was to support reference centers on coordination among the related centers and hospitals, follow up patients and conduct the longitudinal epidemiological studies. The information system of CEMARA has many features mainly: scalability, portability, reliability, accessibility, and cost effectiveness. The architecture is web based and contains several databases: production database, geographic dictionary database, and the thesaurus database. CEMARA system is also interoperable with the French hospital information system with data transfer capability. CEMARA is collaborated with the Ministry of health, the national institute for health surveillance, and the national health insurance fund to exchange information on patients and family care, and conduct cost effectiveness analysis. The GIS is incorporated to assess the geographic distribution of rare diseases. Over 11,803 records have been included in this system by 2007. This report shows that the ICD-10, which is used in reporting diseases at hospital settings, doesn't include many rare diseases. Therefore the system CEMARA was also linked with the program named Orphanet. The Orphanet helps in ontological support to the CEMARA. Orphanet provides a shared ontology to each thesaurus of CEMARA, which can be uniformly used by experts from the several RCs. Based on this article, it is discernible that this type of interoperable electronic data sharing system for rare diseases have many advantages as some of them are already mentioned in the objectives. However, there are more areas to be further improved. Firstly, there is a need to incorporate more clinical sites in the France. Secondly, the article further recommends to develop query capacity in GIS system. The CEMARA don't have a capacity of allowing query in GIS.

Similarly, the article (Orlova et al., 2005) discusses a prototype system applied to monitor new borne cares (within 48 hours of birth). These cares are: newborn metabolic disorder screening; newborn hearing screening; immunizations; and communicable diseases. An automatic electronic reporting system is built from the clinical units, laboratory system to the PH units in different states of the USA in 2004. The HL 7 message standard is used for data reporting, where the information is interoperable from the health care providers and PH units.

Another article (Glaser et al., 2005) focusses on the importance of linking cancer registry data with spatial data and neighborhood-level data that can analyze temporal relationship of the social, environmental and demographic factors associated with cancer. For example, association of childhood cancer with certain chemical exposures. This article recommends that there is a need for more publications, funding and training for research capacity building to advance the cancer surveillance system.

There are 2 articles which are related with NHIS for cancer (Shortliffe & Sondik, 2006) and diabetes (Desai et al., 2003). In this paper (Shortliffe & Sondik, 2006), a future vision for national cancer monitoring system is envisioned. The article proposes a local, state and federal level electronic data network system to be implemented. The electronic reporting system should be online and automatically integrated among local hospital, private clinics, community health care centers, research bodies, and libraries to the regional and national PH units. The article shows that the main challenge for establishing such system is rather political, financial, and logistical than technical in nature. The associated challenges highlighted are: physicians' reluctance to use the IT system because they consider that IT is not directly beneficial to them, it is only helpful for health systems and payers; the lack of data standardization in reporting; and poor coordination among the local health departments are some challenges highlighted.

There are two articles focused on the maternal and child health program. The first article (Scheuerle, Vannappagari, & Miller, 2009) discusses the new type of disease monitoring system, called pregnancy registry implemented in the USA. In this registry, pregnant women, with their consent, are enrolled into the monitoring system throughout their pregnancy. The physicians or midwives monitor their health outcomes and report the data as necessary via phone or e-mail. This monitoring is longitudinal and is conducted on mothers who are taking any medications during their pregnancy to find out the effects of the medications. Another article (Padilla, Cutiongco, & Sia, 2003) focusses on child health information system in monitoring birth defects. In this report the congenital malformations reporting system in Philippines is discussed. The main reporting areas are from the hospital and pathological reports, however 70% of the mothers give birth at home, which shows that the current scenario doesn't represent the actual burden of the problem. It suggests using the village based maternal and child health workers or mother groups to collect the data on any congenital malformations occurred at the community level would be a better strategy to capture the actual congenital malformation problem in Philippines.

Among the remaining articles, 4 articles (Finnerty, 2003; Smith & Keliy, 2002; Trewin et al., 2008; Scotch et al., 2010) are about the application of website and/or mobile phone. For example one article (Smith & Keliy, 2002) is about applying mobile phone and website for counselling and educating mental patients. In another article (Trewin et al., 2008) the Norwegian program called the Norhealth is discussed. A web based system, which monitors both infectious and non-infectious diseases and is used to create awareness among the general population, media, students, politicians and policy makers. The system includes many PH indicators based on European Community health indicator (ECHI). Users can use the system to download data and make their own table and maps. This system further requires development in incorporating more diseases in the fact sheet, translating the fact sheets into English, and enhancing its visual appeal and interactivity.

Finally, this article (Rushton, 2003), discusses about the application of GIS system in PH program and clinical decision support system. The geocoding of the data collected in PH data collection system can be applied in the geo-information processing system of the GIS science. Embedding the spatial analytical technique to find out the geographic and socio-demographic characteristics of chronic diseases such as cancer. It also can be applied for mapping the environmental factors e.g., water sources, layers of geology, sources of water and air pollution, and electricity. The article envisions that there is a need for a geo-reference data system to be monitored by agent-based search systems to alert the PH specialists. It is also necessary to plan PH programs of higher disease risk areas. Cancer is an example for such system with the development of the cancer registries. The article also suggests that in order to make a more responsive clinical decision support system the spatial data and PH data should be compatible to merge more easily. Besides, the paper also proposes more training for the PH workers on the application of the GIS system.

Editorials:

There are a total of 7 editorials included in this PH domain (Eng, 2005; Fairchild et al., 2007; Lowry, 2008; Rubertone & Brundage, 2002; Suresh, Thangavel, Sujatha, & Indrani, 2005; Trevathan, 2011; Wolpert, 2005). Among these articles two articles discuss the congenital anomaly surveillance system (Lowry, 2008; Suresh et al., 2005). The first article (Lowry, 2008) present national and provincial Canadian congenital anomaly surveillance system as well as providing recent developments of such systems in other parts of developed countries. According to this article, the congenital system is not very well developed, as most of the data is received from the hospital discharge and represent only the congenital information of the perinatal condition. The follow up information is mostly missing. The information is also missing if there was miscarriage due to congenital anomalies. The problem is severe in bigger countries such as Canada, England and Wales whereas the smaller counties like Norway and Finland have more efficient surveillance. Another article (Suresh et al., 2005) recommends creating a birth registry for the congenital anomaly surveillance in India. The types of birth registry can be descriptive, analytical and preventive, and can be applied both at the hospital level and population level. The data should be collected based on a standardized format in a database.

In addition, two articles (Trevathan, 2011; Wolpert, 2005) discuss on creating web based electronic registries for diseases. The article (Trevathan, 2011) foreshadows the importance of establishing the population-based epilepsy surveillance system in USA. So far BRFSS is the only mean to obtain general information about epilepsy. Similarly, the article (Wolpert, 2005) presents the importance of family history reporting by family members in a secure web-page through which clinicians can observe and monitor genetic diseases/disorders while diagnosing patients.

Among the remaining articles, this article (Fairchild et al., 2007) talks about the need of enhancing the data security system in electronic databases, the article (Rubertone & Brundage, 2002) talk about the Defense Medical Surveillance system (DMSS) of USA. Medical data about the arm forces from the beginning to the end of their career is archived in a central database of Defense Medical Surveillance system (DMSS). This is the central repository, which can be accessed on permit, has played a vital role in disease surveillance and epidemiological studies in Defense forces of USA. This electronic system has played a key role to detect any disease in time as well as take action as needed.

Finally, the editorials shed light on enhancing the electronic data security system, and the principles and application of emerging population health technologies. For example, artificial intelligence, nanotechnologies, microelectromechanical systems, etc. for the prevention of diseases and promotion of healthy life style (Eng, 2005).

Summary of the findings:

Table 11. Tabular presentation of the overall finding of the non-communicable/chronic disease monitoring PH domain.

Focus of the research/discussion	Qualitative studies	Quantitative studies	Other reviews	Editorials
Reporting from clinical/lab to PH units based studies	3	8	7	1
Pharmacy based studies				
Population-based studies		4		
Application of GIS in PH programs	4	2	1	
NHIS			2	2
Ethnographic studies	1			
Testing and developing statistical/analytical software in PH programs	1	1		
Child health information system			2	
Web-based disease monitoring	1		2	3
Insurance claim based studies	1			
Electronic data security				1
Application of mobile phones			2	
Total	11	15	16	7

The table no. 11 represents the area of the research or discussion presented in the in-depth analysis of the articles included in this PH domain.

8.3.11 Public health policy/system and research

8.3.11.1 Number of articles

There are a total number of 168 articles included in this PH domain.

8.3.11.2 Study settings with number of studies

The majority of the article 111 (66.1%) are from U.S.A; furthermore, U.K., Canada, and Australia constitute 11 (6.5%), 8 (4.8%), and 7 (4.2%) of the articles respectively. Collectively these four countries represent 81.5% of the total articles; the rest of the articles are from different countries across the world.

8.2.11.3 Types of articles/methodology

More than one third 61 (35.7%) of the articles represent qualitative, quantitative and/or mixed studies combine. The other reviews are higher in quantity than any other categories contributing 58 (34.5%) of the total 168 articles. The rest of the articles are mostly editorials 46 (27.4%), two narrative literature reviews (1.2%), and only one article (0.6%) being the empirical literature review.

8.3.11.4 Evidence relating to use of Information Technology and Informatics concept

The four fifth 134 (79.8%) of the total articles in this PH domain discussed/used EMR/EHR/electronic registry, followed by 97 (57.7%) of the articles by website. Also, the GIS was the third most popular Information technology discussed/used in this category, which was used in 26 (15.5%) of the total articles. Less than 10% of the total articles composed remaining

ITs. Automated speech processing, NLP and mass media were the three least common IT in this PH domains forming less than 3% of the articles.

8.3.11.5 Evidence relating to the use of Informatics concepts

The result also indicated that data transmission/ communication was the most commonly discussed/used informatics concept with 119 (70.8%) of the total articles, followed by information sharing with 89 (53.0%), data collection with 73 (43.5%), and data retrieval with 6 (38.1%) of the total articles. The least used informatics concepts were knowledge management, data security, and data analytics foubd in less than (5%) of the total articles.

8.3.11.6 In-depth analysis to the articles

Qualitative studies:

There are a total of 43 qualitative studies included in this PH domain. Out of them 11 studies are related with national or state level PH information system (Cibulskis & Hiawalyer, 2002; Curioso, Peinado, Rubio, Lazo-Escalante, & Castagnetto, 2009; Herman, Marcelo, Marcelo, & Maramba, 2005; Hernández-Ávila et al., 2013; Hufanga & Hodge, 2012; Junping et al., 2009; Kitur, 2012; Lippert & Kverneland, 2003; Loonsk, McGarvey, Conn, & Johnson, 2006; Swart, Bleeker, & De Haes, 2002; Vallejo Serrano, 2004). These studies discuss about the data reporting and monitoring system by using electronic devices, such as computers, websites, and mobile phones implemented by the Ministry of Health of different nations. For example, this article (Curioso et al., 2009) shows that in Peru the NHIS is fragmented in many different systems. The internet based reporting and mobile phone based disease monitoring system is in a pilot stage and the reporting is often paper based and takes months to receive reports at the national level. Even in the internet based reporting, interoperability is a prominent issue. Another study (Hufanga & Hodge, 2012) provided strategies on developing Pacific regional health information system in 14 different pacific countries. The strategies included were: advocacy; institutional capacity building; strengthening the information and communication technologies; improving data integration and quality; develop policy and guidelines; and enhance the sustainable governance. Additionally, another study (Hernández-Ávila et al., 2013) found that the main driving force in implementing electronic reporting system in Mexico was correlated with improved reporting; whereas, the setbacks were physicians' no interest on using the specific reporting codes (e.g., ICD-10) and no political support on sustaining these system. Moreover, this study (Herman et al., 2005) showed that an ethnographic approach is required while implementing a new information system, which signifies a need for assessing the perceived need and cultural practices. It also showed that field level health care staffs were not capable of using the new technologies, which necessitates training/capacity building before implementing such ITs.

There are 7 articles (Buck et al., 2012; Hurt-Mullen & Coberly, 2005; Schoenman, Sutton, Elixhauser, & Love, 2007; Smith et al., 2007; Rolnick, 2013; Walker et al., 2005; Zhang, Xu, Shang, & Rao, 2007) that are related with hospital based SS and information sharing in between clinical and PH units. For example, this article (Zhang et at., 2007) presents that in China approximately 35% to 40% of the hospitals have real time electronic reporting system. However, regional variation exists, where above 80% hospitals at and above district level hospitals have electronic disease reporting systems as opposed to 27% below district level. The major challenges that the Chinese hospital based reporting is facing are data standardization on vocabulary and coding, shortage of trained human resources, financial deficit, and technical problems etc. Further, in another study (Rolnick, 2013) the authors discuss due to the rise in EHR system there is a very high potential of applying electronic data for PH policy and practice; however the available commentaries on data use are focused more on data security system than on social value of the available data. The author describes that in the USA the public and private enterprise are holding the data due to the weak intellectual property law. Therefore, the author demands for a better access to the electronic data to ensure its best use on PH actions. One article (Buck et al., 2012) also discussed in the previous section discusses about the Primary Care Information Project (PCIP) implemented by DoHMH in 2005 in New York City, USA. The study shows that patients using the health care may not be a full representation of the whole population in such systems.

There are two articles (Achterberg et al., 2008; Wilkinson & Coyle, 2005) that applied website to disseminate PH information for the PH policy makers. The article (Achterberg et al., 2008) is about the European Public Health Information and Knowledge System (EUPHIX) that was implemented in June 2008 in EU. The main purpose of the internet based system is to share the PH related intra-national, national and regional information among the members of EU. The web based information sharing system helps to inform politicians, policy makers, academicians, media, and general public about the situations of PH related indicators and activities across the EU.

There are 6 articles that focus on the child health information system (Fehrenbach, Kelly, & Vu, 2004; Hastings, 2004; Hoyle & Swanson, 2004; Hoff, Ayoob, & Therrell, 2007; Singh & Hinman, 2010; Lier et al., 2012). Among them, 4 articles are about qualitative surveys on the child health information system among parents and students; whereas, one study is about the national immunization registry (Lier et al., 2012). The last article is about the long term follow-up study of new borne child with disability (Singh & Hinman, 2010). The main ITs applied in these articles were electronic registry.

In this article (Lier et al., 2012), the national immunization program (NIP) has a national electronic vaccination register called 'Praeventis'. This register includes all the data from local level to national level. This immunization register has several advantages including: ability to measure the vaccination trend; conduct epidemiological research on causes and adverse effects of vaccines, and identify the high-risk population. The article recommends to link the vaccination data with clinical register to conduct more specific vaccine-related research on etiology and outcome. Similarly, the study (Hastings, 2004) was conducted to find out the perspectives of parents of children in need of special care. In their opinion the integrated child health information system is an important part of their child care and it improves the accuracy and timeliness of the information need. However, in their opinion it is not the principal aspect to be improved.

There are 2 articles that discussed an interdisciplinary approach for implementing PHI system in PH (Kuhn et al., 2008; Pappaioanou et al., 2003). For example, this article (Kuhn et al., 2008) discussed the interdisciplinary collaboration for the improvement of PH system and research. It states that at the very early stage of HI education, there should be a focus on interdisciplinary domains, particularly medicine, engineering, biology, social science, PH, informatics, and economic science to bridge the gap among different disciples and systems. This article presents that the main areas to focus in the PHI research are: health care supporting system e.g., telehealth, avenues of health care/PH and population interaction, information technology structure for research in nutrition and chronic diseases, and web based counselling and interaction tools for health promotion and public awareness. In another study (Pappaioanou et al., 2003), data for decision making (DDM) project initiated by USAID were implemented in 4 countries in South America, Africa and Asia. This study suggests that implementing a communication system in a country is more effective when an interdisciplinary approach is implemented alongside of enhancement of PH programmers'/experts' skills. For example, integrating the management skills, epidemiological and statistical knowledge, knowledge of social and political factors, and economic evaluation stills etc. The study showed that it was a successful approach to achieve the ultimate goal.

Similarly, 4 articles (Olvingson, Hallberg, Timpka, & Lindqvist, 2002; Olvingson, Hallberg, Timpka, & Greenes, 2002; Melton, Manaktala, Sarkar, & Chen, 2012; Richards, 2007) are population-based qualitative surveys. For example, the survey (Richards, 2007) was conducted among PH students to find out the usefulness of PHI in the PH domain at present and for the future.

The remaining 6 articles (Caillouet, 2007; Irestig & Timpka, 2010; Lopez & Blobel, 2007a; Orlova & Lehmann, 2002; Reeder, Hills, Demiris, Revere, & Pina, 2011; Salinas-Miranda, Nash, Salemi, Mbah, & Salihu, 2013) focus on the research on PHI architectural development. For example, this article (Lopez & Blobel, 2007a) proposes an architecture called generic component model (GCM) developed by eHealth competence center, Regensburg. The architecture was tested in Columbia health care system. The study finds that GCM has the capacity of integrating the national PH and clinical information system in a semantically interoperable manner. This article also presents that in the health care domain the architectures existed are: European committee for standardization (CEN) standard architecture for healthcare information systems (CEN ENV 12967), health level-7 (HL7) development framework (HDF), and service oriented architecture for HL7 (SOA). These frameworks have different levels of capacity to integrate the PH and clinical data. The proposed architecture GCM applies the HL7 domain knowledge and also excerpts concepts from the advanced architecture approaches applied in software engineering e.g., open distributed processing – reference modelling (RM-ODP), model drivel architecture (MDA), and SOA. The article presents that in most scenarios, the PH and clinical care facilities data systems have different ontological system which causes difficulty to integrate the data into a single national system. For this purpose, there is a need to standardize national data system both in the developed and developing countries.

Another article (Caillouet, 2007) is a case study of the health informatics center of Acadiana (HICA) established in Louisiana, USA. The center helped to identify the local needs, formulate the local policy, and plan county-specific policy for health information system. It also assisted to identify the health information needs of the population in natural disasters like Katrina or Rita hurricane of 2005 and supported program evaluation in some counties. The main IT applied was electronic registry and telephone-landline. Similarly, the article (Irestig & Timpka, 2010) discusses about developing conflicts management system by establishing the responsibility and legitimacy mechanism before the implementation of any PH information system.

And finally, there are 5 articles that specifically focus on the application of IT in the PH policy research. Out of them, two articles (Eriksson et al., 2007; Ma et al., 2008) are related with the application of the statistical/analytical software, one article (Buchan et al., 2010) is focused on the DP algorithm, one article (Karras, Huq, Bliss, & Lober, 2002) discusses the application of mobile phone for patients waiting time for medication, and the last article (Scotch, Yip, & Cheung, 2008) is evaluates the application of GIS. Among the articles that applied statistical/analytical software, this article (Ma et al., 2008) talks about the structured application framework for Epi Info (SAFE), which is a free software and is more compatible to be used in developing countries. Also, the article (Buchan et al., 2010) that discussed DP algorithm presents the application of an algorithm called IMPACT on chronic heart diseases (CHD).

In general, the qualitative studies are the case reports or qualitative survey reports of PH programs that were implemented by applying the information technologies or planned to improve the PH information system, immunization system, and to provide useful information on implementing the interdisciplinary approach for the PHI research and practice.

Quantitative studies:

There are a total of 16 quantitative studies. Among them, 5 articles (Alfonsi et al., 2012; Lyon, Bardhan, Barker, & Wilson, 2006; McKenna, Sager, Gunn, Tormey, & Barry, 2002; Linkins et al., 2006; Ronveaux et al., 2005) are related with the descriptive studies on child immunization program. As an example, this study (Linkins et al., 2006) is a survey assessing the knowledge and attitudes of the parents of school age children about the need of immunization registry. The electronic registry that can be used as a reminder to parents about the immunization.

The 7 studies (Calciolari & Buccoliero, 2010; Foldy, 2007; Lofthus et al., 2005; Vidor, Fisher, & Bordin, 2011; Gyllstrom, Jensen, Vaughan, Castellano, & Oswald, 2002; Magruder, Burke, Hann, & Ludovic, 2005; O'Mahony et al., 2007) are hospital and health care system based descriptive studies focused on the usefulness of the electronic databases. For example, one study (Lofthus et al., 2005) was conducted among all the electronic databases of Norwegian hospitals to compare the discharge reports of fracture patients on electronic registry and medical records. As the study compared the two data sources: medical records and electronic discharge registry reports, it was concluded that there were variations in several hospitals-based data that lead to 19% variation in the national electronic database.

The 4 studies (Merom, Bauman, & Ford, 2004; Patel, Nowostawski, Thomson, Wilson, & Medlin, 2013; Savas, del Junco, Bastian, & Vernon, 2009; Zins et al., 2010) are population-based studies that are conducted to find out the knowledge and practice of people towards application of certain ITs to prevent diseases of PH importance. For example, this study (Patel et al., 2013) was conducted to measure the smoking rate of the active drivers. A mobile application is used by the drivers to enter the data that is retrieved in a web based on-line repository. This study showed that mobile applications can be an effective instrument in implementing the field research in PH.

Other review:

There are a total of 58 other review articles. Among these articles, 8 articles are related with the NHIS in general (Iron, 2006; Lumpkin & Richards, 2002; Macfarlane, 2005; McMurry et al., 2007; Shortliffe & Sondik, 2006; Snee & McCormick, 2004; Tabunga, 2012; Wu, Zhao, & Wu, 2005). In these articles, great insights have been expressed for the development of NHIS. For example, this article (Lumpkin & Richards, 2002) discusses NHIS in general. The paper recommends some important areas to be improved in a NHIS based on the health insurance portability and accountability act USA 1996; these include: uniform data standards on definition, content, and format on PH and clinical information; adopting interoperability standards; and privacy regulations on all the information system. The paper also discussed that the main advantages of implementing national electronic data reporting system in NHIS are automated data reporting system, efficient use of hospital discharge data, and rapid investigation of outbreaks. However, there are many challenges such as: slow adoption of data standards; proliferation of stand-alone systems; lack of coordination between city and state systems; and timely delays in reporting. Further, this article (Macfarlane, 2005) discusses about the development of health information system in low and middle income countries. The paper presents that developing countries can integrate social and economic data sources from different jurisdictions for poverty reduction and health promotion, however there remains challenges such as finance, trained human resources, and political will power.

There are 13 articles that are about child health information system (Freeman & DeFriese, 2003; Hinman, Atkinson, et al., 2004; Hinman, Eichwald, Linzer, & Saarlas, 2005; Hinman, Saarlas, & Ross, 2004; Linzer, Lloyd-Puryear, Mann, & Kogan, 2004; Padilla et al., 2003; Papadouka et al., 2004; Ross, Hinman, Saarlas, Lloyd-Puryear, & Downs, 2004; Saarlas et al., 2004; Therrell, 2003; Wild & Fehrenbach, 2004; Wild, Hastings, Gubernick, Ross, & Fehrenbach, 2004; Wild, Richmond, de Merode, & Smith, 2004). For example, this study (Hinman, Atkinson, et al., 2004) is about the principles and functions required to a national integrated child health information (ICHI) system. The report suggests that since childbirth, new born babies undergoes many investigations and assessments, such as immunization, vital registration, screening for congenital disorders, and etc. Consequently, an integrated approach to access these different data sources would be a better avenue to understanding the comprehensive health status of the child. For this purpose, since 1998, genetic services branch, division of services for children with special health care needs, maternal and child health bureau, health resources and services administration (HRSA/MCHB), started an initiative to establish integrated child health information system to include new borne screening system, and to coordinate the child care program’s 4 main jurisdictions: newborn dried blood-spot screening; early hearing detection and intervention; immunizations; and vital registration. According to the article, there are 19 principles of ICHI system some of which are: easily accessible system; fulfilling the needs of stakeholders; accountability and responsibility to the information; monitored data; and shared cost. Similarly, the core functions are: ensured confidentiality and security; establish data recording system within two weeks of child birth; establish a unique identifier; and apply electronic data exchange system; automatic needs determination system; and tracking the child health as a follow up for a short time period. This is only a theoretical system that was proposed by the study; however establishing such system requires a massive amount of improvements. Similarly, in another paper (Ross et al., 2004) it was stated that in order to establish an electronic integrated child health information system on a national level, 5 tasks have to be accomplished are: reengineering the vital records to ensure it is compatible to integrate with other system; establishing uniform standard and requirements; develop a policy with business case, that is, mutually agreeable and benevolent to all stakeholders; establish a system that can be accessed by the patient and family member; and create a network of research group who will be responsible to understand and document the changes to the child health status over a period of time.

There are 5 articles related with the application of website for disease monitoring and research (Braithwaite & Haggard, 2006; Cheung, Yip, Townsend, & Scotch, 2008; Eysenbach, 2011; Eysenbach, 2009; Wilson, 2006). Among them, two articles (Eysenbach, 2011; Eysenbach, 2009) provided insights on the development and application of infoveillance and infodemiology. The infoveillance refers to a web based surveillance system that mines the websites for disease surveillance. The study of such surveillance system is termed as infodemiology.

There are 4 articles (Kaiser et al., 2003; Martin et al., 2002; Croner, 2003; Heitgerd et al., 2008) that are related with the application of GIS in PH policy system and research. For example, in this article (Croner, 2003), the application of GIS was discussed for all level of PH governance, that is, for the local, state, and the federal level. The paper discussed that the GIS system can exist in two ways, static and dynamic. In the static GIS, the image is only viewed by the users and important information is gained, however in the dynamic GIS, maps can be accessed, and interacted with it. The maps can be customized based on the query of the users and the predetermined set of criteria by the users. The PH related variables pertaining to a neighbourhood can be viewed using the dynamic GIS. This paper also discusses that the GIS system can be applied in an environmental data of a neighbourhood, for example, exposure to chemicals, physical environment, water, land, and air quality. of a given neighbourhood. The integration of GIS in the internet possesses many advantages, however important precautions have to be applied some of which are the importance of data security, interoperability, confidentiality, and conflation. The federal government can implement GIS system to avoid the silo reporting system and make it more interoperable among all level of PH systems. An important drawback associated with the web GIS was people may identify the problematic neighbourhood and can move from the location for the security purpose. The paper provided a future vision of a GIS system in which GIS can be governed through national spatial data infrastructure (NSDI) - a federal level body which will coordinate all activities related with the GIS system. The internet has a central role for its system development where the GIS internet interoperability should depend on space-time scan statistics, satellite data, mobile geo-processing, and data sharing within standardized privacy, and security policy which are also the challenges. Similarly, another article (Martin et al., 2002) discussed about the application of GIS for malaria control in three South Africa counties. The GIS augmented by the space data from the space satellite were used for mapping the malaria burden in different neighbourhood, which helped in framing the policy and implementing the malaria program.

There are 8 articles that are related with data linkage among various jurisdictions for PH research (Boyd, Funk, Schwartz, Kaplan, & Keenan, 2010; Jutte, Roos, & Brownell, 2011; Lopez & Blobel, 2007b; Noble, Panesar, & Pronovost, 2011; Roos, Menec, & Currie, 2004; Shapiro, 2007; Staes, Xu, et al., 2009; Tamang et al., 2006). For example, the article (Staes, Xu, et al., 2009) used a grid system for the data linkage among various stakeholders e.g., lab, hospitals, PH units, states and federal units. The grid system provides an added benefit to share the data among the various jurisdiction. In such system, a single user can have access to data through a secure portal. The data transmission is automatic, and data owners have total control over data for security. This technology has a potential to integrate and analyze health services and population data in a real time fashion. The Utah Department of Public Health (UDPH) implemented this system to integrate data from Utah department of air quality and monitor station, vital birth records, and ZipCodes. Similarly, the article (Shapiro, 2007) evaluated the usefulness of the HIE system among the clinical, laboratory, population health monitoring system, and drug surveillance system to the PH units. The paper showed that the HIE can be very useful for disease monitoring and program effectiveness.

There are 8 articles that discuss the application of electronic database/registry in PH research in general (Ali et al., 2006; Arzt, 2010; Balas, Krishna, & Tessema, 2008; Etheredge, 2007; Gijsen & Poos, 2006; Hu et al., 2005; Lopez & Blobel, 2006; Thew, Jarvis, Ainsworth, & Buchan, 2010). For example, in this article (Thew et al., 2010) Atlas and Method box systems were developed and implemented in England. These systems are used to share and retain the experts' knowledge and thoughts. The Atlas applies two system: data pre-processing and data query in the database. The pre-processing includes data collection, cleaning, standardizing, and integration. Similarly, the method box system includes interoperability feature among experts and share the pertinent information among the partners. E-lab is used for operating these systems. These are the newly developed concepts. Similarly, this article (Etheredge, 2007) discussed the potential of application of EHR/EMR records for the research in health care system. This suggests that the EHR records have a great potential of applying the research capacity for the policy and practice in the Health care system of a nation.

Similarly, there are 5 articles which are related with the interdisciplinary approach in the PHI research and practice (Altman et al., 2008; Balas & Krishna, 2004; Chismar, Horan, Hesse, Feldman, & Shaikh, 2011; Howell, Pettit, Ormond, & Kingsley, 2003; McDaniel, Schutte, & Keller, 2008). For example, in this paper (Chismar et al., 2011) the use of cyberinfrastructure is discussed for PH research. It recommended a multidisciplinary approach of incorporating all the stakeholders of a society e.g., sociology, PH, research and health services to have a successful research. In another article (McDaniel et al., 2008) there are comprehensive discussion about the development of PHI. The article suggests that the latest technological development ushered to shift the health information system into the new paradigm of genomic research, population health research as well as into the national PH system infrastructure development, for example, immunization system, health care system, information management system etc.

Finally, among the remaining 7 articles, 3 articles focus on the PHI system development (Morse, 2007; Broome & Loonsk, 2004; Yasnoff et al., 2000), for example this article (Broome & Loonsk, 2004) talks about the basic component required for the PHIN system developed by CDC in USA for standardizing the data transfer, and health information system in USA. This sets standard protocol for local, state and federal clinical, laboratory, and PH units and has major 5 PH functions: detection and monitoring, data analytics, knowledge management, alerting, and response. The CDC also has set 9 IT functions which are: automated exchange of data; use of electronic clinical data; manual data entry for event detection; lab result information exchange; management of possible case; analysis and visualization; directories of PH and clinical personnel; PH information dissemination and alerting; and IT security and critical infrastructure protection.

The remaining articles focus on application of mass media (Adair, 2012), application of statistical/analytical software (Bures, Otcenásková, Cech, & Antos, 2012), application of IT for genetic research (Scotch et al., 2010), and a general discussion on widespread availability of data (Mabry, 2011) and their implication for PH policy/system and research.

Editorials:

Among the 47 editorials included in this PH domain, 13 articles (Baker & Porter, 2005; Detmer, 2010; Doe, 2010; Fairchild et al., 2007; Fenton, 2005; Flowers & Ferguson, 2010; Hagland, 2012; Hanrahan, 2007; Lee & Gostin, 2009; Sondik, 2008; Wilkinson & Ferguson, 2010; Wilkinson, 2003; Warren, 2008) only discussed the application of electronic registry in PH and the associated factors, for example, the privacy, ethical issues on data sharing, and policy requirement and implications related with its application. These articles also discussed some EHR frameworks developed in the recent years in the world. For example, this article (Detmer, 2010) discussed the importance of enhancing patients' privacy while conducting any forms of population-based or in vivo health research through applying the electronic health record system. This paper (Doe, 2010) discusses the breach of health information and the required policy to prevent such problems. In the paper the author discusses on the American recovery and reinvestment act 2009 also known as health information technology for economic and clinical health act (HITECH) enacted in 2009 in USA. It states that if there is any information breach, the notification must be sent within 60 days after the discovery of the breach. If there is a breach of more than 500 people, the notification must be broadcasted/published in a public media. Similarly, one article (Baker & Porter, 2005) discussed on the application of HAN on bioterrorism surveillance and its implication to the PH policy, and two articles explain about public health observatories that are used for data sharing among a wide range of organizations (Wilkinson & Ferguson, 2010; Wilkinson, 2003).

Further, there are 17 articles (Boyd, 2003; Fountain, 2004; Kukafka, 2005; Kun, Ray, Merrell, & Kwankam, 2008; Marshall, 2004; McGrail & Black, 2005; Lurie, 2002; Nakayama, 2006; Nitzkin & Buttery, 2008; Rosenbaum et al., 2005; Savel & Foldy, 2012; Houser., 2009; Hirdes, 2006; Stansfield, 2005; Kalsbeek, 2008; Kamper-Jørgensen, 2008; Rehle et al., 2004) which discussed about the PHI system development and research applying the information technologies primarily the websites, electronic media, and GIS. For example, in this article (Savel & Foldy, 2012), the application of PHI for the disease surveillance is discussed. The main opportunities in PHI, as per the authors, are application of EHR system and HIE in the existing health care and a PH system that can fulfil the following 3 PH requirements: syndromic surveillance, electronic reporting from clinical departments, lab, and immunization registry. Some of the challenges according to the article are: exchanging wide range of PH data in a faster and easier fashion considering the limited funding and regulations on sharing different kinds of data, and data security. The article concludes that combining disparate sources have a high potential of depicting a bigger picture of the PH problem than using a single silo system. Also there should be a capacity development training programs for the health care workers on PHI. Similarly, these articles (Kamper-Jørgensen, 2008) discussed the three generations of data system: the first generation is only about collecting vital statistics for administrative purposes;

the second generation is about calculating rates and ratios of the data to make national and international comparisons; and the third generation depicts the integrated knowledge system that integrates data and provides an analytical information with evidence based knowledge. The third generation system has just emerged in the 21st century. The emergence of electronic data handling and data integration for knowledge synthesis is augmenting for the third generation of the PH information system. The article presents the European Public Health Information System (EUPHIS) as an example of the third generation of PH information system which integrates data from a wide range of population and geographic area and accessible data and figures to the general public. According to the article, on establishing the third generation of data system in PH, the social and political factors has to be considered.

Similarly, there are 6 articles (Landis, Kratz, Spaans-Esten, & Hanrahan, 2007; Lurie & Fremont, 2009; McIlwain & Lassetter, 2009; Plescia & Engel, 2008; Raths, 2009; Shapiro, Mostashari, Hripcsak, Soulakis, & Kuperman, 2011) that are related with data exchange in between health care and PH departments. For example, this article (Shapiro et al., 2011) discusses applying HIE to improve the PH system. The article applies the electronic HIE at various areas of health care and PH system such as: mass casualty events; disaster medical events; clinical care; reporting from lab and clinics; PH alerting both at individual and population level; and PH investigation and quality measurement of the programs. Similarly, another article (Landis et al., 2007) portrays the secure public health electronic record environment (SPHERE) implemented in Wisconsin department of health and family services. The main purpose of the system was to securely record the maternal and child health (MCH) related data and report, monitor, and evaluate the MCH program activities. Some of the activities are: case visitation; immunization; preventive services; prenatal and post-partum status; home safety; and child passenger seat assessment etc. The future envision for the system was that there should be a software which could be used in handheld devices; the field level data could be entered into the device even in absence of Internet and it will be automatically transmitted once it comes in connection to the internet.

Among the remaining 10 articles, 3 articles (Cowper, 2004; Eng, 2005; Kun, 2008) discussed the interdisciplinary approach for the PHI research and practice, 2 articles (Shiffman, 2004; Williams & Hollinshead, 2004) are the integrated child health information system, 3 articles (Dykes & Bakken, 2004; Harr & Bella, 2010; Wilcox, 2004) are the web based information sharing system and remaining are application of GIS (Ricketts, 2003) and global disease monitoring system (Burns, 2006).

Narrative literature review:

There are 2 narrative literature review articles in this PH domain (Coiera, Lau, Tsafnat, Sintchenko, & Magrabi, 2009; Khan et al., 2010). Among these 2 articles, this article (Coiera et al., 2009) conducted literature search on clinical decision support system (CDSS) with a focus on CDSS evaluation and safety, its impact to the biomedical informatics, consumer, and PH. This article presents that the clinical decision support system is now beyond the use of clinical purpose; it has emerged into the biomedical, consumer, and PH practice domain. Due to the development in EHR/EMR, grid computing, and data integration among various jurisdiction, CDSS is now being applied by the PH users in PH research and outbreak detection purposes. The automatic reporting is helpful to improve the completeness of notification and ensure data quality. It can also be used in integrating in real time spatial-temporal analysis system with statistical techniques and IS system. It also recommends the incorporation of the additional environmental and other non-medical data to be incorporated in the system. The data is also applied in the genomic research and outbreak detection based on genomic sequencing.

In this article (Khan et al., 2010), GIS is in use by PH system of 111 countries - 58% of the total countries across the world for disease surveillance. Such prevalent use is possible due to the development of cloud computing, an electronic wireless information system, and special-purpose computing. The application of GIS were in disease mapping, vaccine trials, analysis of trials data, vaccine-safety trials programme, global health information for disease control, epidemiology and control of helminthiasis, and finally pandemic planning and prediction. This paper suggests that the potential areas of GIS application is yet to be developed. Policy making and underdeveloped setting are examples of such potential GIS applications. Since most of the under-developed settings/countries have to be supported by international organizations and the GIS is not much applied in policy making.

Summary of the findings:

Table 12. Tabular presentation of the overall finding of the PH policy system and research.

Focus of the research/discussion	Qualitative studies	Quantitative studies	Other reviews	Editorials	Mixed studies	Narrative literature reviews	Empirical literature review
Reporting from clinical/laboratory to PH units based studies	7	7	8	6		1	
Population-based studies	4	4			1		
Testing and Improving the DP algorithm	1						
Application of GIS in PH programs	1		4	1		1	
NHIS	11		8				
Testing and developing statistical/analytical software in PH programs	2		1				
Web based disease monitoring system	2		5	5			
Application of IT in Genetic studies			1				
Application of mobile phones	1						

Child health information system	6	**5**	13	2			
Interdisciplinary approach in PHI	2		5	3			
PHI architectural development	6		3				
Application of electronic registry			8	13			
*Others			2	17			1
Total	43	16	58	47	1	2	1

*Others include the application of various types of ITs for e.g. mass media, GIS, websites etc. for the system development of the PHI research and practice.

The table no. 12 provides the picture of an overall finding of the in-depth analysis conducted above in PH policy/system and research PH domain.

Chapter 9: Discussion

9.1 Overall finding on scoping the field

Based on the literature search that was conducted during this thesis, this is the first attempt to scope the field of PHI and explore the areas of research and practice in various domains of PH and ITs. Following the scoping review methodology proposed by Arksey and O'Malley and later refined by Levac and colleagues (Levac et al. 2010), and Colquhoun and colleagues (Colquhoun et al. 2014), the existing PHI-related literatures published in MEDLINE-PubMed are mapped in terms of PH domain, ITs domains, and informatics concepts used/discussed domains.

Overall, there are a total of 486 articles in MEDLINE that are related with PHI. Over four fifth of the articles are from USA, UK, Australia, and Canada, and the rest are from other parts of the world. Also, it is important to note that USA has two third of the total publications alone. Although, the PHI was first introduced by Dr. Fried and colleagues in 1995, the articles were found only since 2000. This could be because previous studies were focussed only on medical/clinical informatics. Another reason could be that the innovation in the ITs especially World Wide Web, easy-to-use computer technologies, mobile devices statistical/analytical software, DP algorithms, GIS technology, etc. and their application to the field of PH are quite recent. Therefore, this thesis tried to present a comprehensive picture of the literature published in MEDLINE in the past 15 years since 2000.

Further, about half (49.0%) of the articles follow either qualitative, quantitative, or mixed study methodology and rest are narrative literature review, empirical literature review, systematic review, other reviews, and editorials. Furthermore, above one third of the articles (34.6%) are related with PH policy/system and research followed by infectious/communicable disease monitoring with one fourth of the articles (27.4%). However, if infectious/communicable disease monitoring, outbreak detection, and bioterrorism surveillance are combined together, they constitute about three fifth (57.5%) of the total articles. In fact, the three PH domains: infectious/communicable disease monitoring, outbreak detection, and bioterrorism surveillance are essentially the same, only separated to make a more specific analysis. The PH domains: emergency response, environmental health, natural disaster management, injury surveillance, and occupational health hazard represented relatively less number of publications. They contain 3 to 16 articles in each of them contributing only less than 10% of the total articles included in this study. It might indicate that there are not enough discussion or research on these PH domains applying the ITs.

The most popular information technologies in the scientific literature are EMR/EHR/electronic registry, websites, and DP algorithm; whereas the least popular information technologies are mass media, mobile phones, NLP, and automated speech processing. The above stated ITs, in aggregate, represent less than 10% of the total articles. Notably, there were only 2 articles where automated speech processing was discussed/used. The finding is contradictory to the traditional thinking that mass media and mobile phones are most widely used information technologies and hence should have been extensively discussed/used in the scientific community. In fact, these were discussed in only 6.3% of the total articles.

Additionally, the most widely applied informatics concepts are data transmission/ communication, data collection, and data retrieval; whereas, data storage, data security, and knowledge management are the least used informatics concepts in the existing literature. The fact that there are not many articles discussing data security, implies that the current literature has not emphasized on the security system.

9.2 Overall findings in research and practice

The existing literature from MEDLINE-PubMed was categorized into 11 different PH domains; moreover, the research and practice on application of ITs in the respective PH domains were analysed. The existing literature indicated that there has been a lot of advancements in ITs and their application in various domains of PH. The application of the ITs in the various domains of PH, and the need for further advancements in their research and practice is discussed in the following sections.

9.2.1 Infectious/communicable disease monitoring, outbreak detection, and bioterrorism surveillance

Currently, the majority of the articles included in infectious/communicable disease monitoring, outbreak detection, and bioterrorism surveillance have discussed the application of electronic reporting system from the hospitals, ED to the PH units for the purpose of SS. More specifically most of the studies focused on the initiatives taken after 2001 by many state level PH departments and CDC of USA; therefore, the majority of the studies represented the USA.

Further, the IT such as DP algorithm, statistical/analytical software, and GIS were also tested for their efficiency and effectiveness in many articles. The DP algorithm and statistical/analytical software were tested both at the community settings and at the hospital settings; however, the majority of the articles tested them in a simulated data. Hence, there is a need to test these ITs in authentic data as well. Further, the different DP algorithms were applied by various PH departments in the same district or state causing the data integration difficult. The uniform DP algorithms should be applied across all the PH departments. The studies also showed that the DP algorithms and statistical/analytical software were internet based, nevertheless integrating both of these ITs in a single interface is also an identified as a challenge.

Additionally, there are several types of DP algorithms and statistical/analytical software that can be applied for the same purpose, and there is a need to test the effectiveness of these ITs in the different data sources. Furthermore, a systematic review to find out the quality and efficiency of DP algorithms as well as statistical/analytical software applied in PH system is required.

There is an innovation on internet based open source statistical/analytical software by a French team (Pelat et al., 2007) that can be used by the field level health workers with little knowledge of statistics; meanwhile there is a need to test the system in other developing parts of the world so that it can be applied in other places as well.

The existing GIS systems featured with the space-time disease surveillance system have to be installed on a computer, and there is a need of an internet based GIS system that can be applied by the field level health workers (especially from the developing countries). An internet based system being developed by the Massachusetts department of PH called Automated Epidemiological Geo-temporal Integrated Surveillance (AEGIS) (Reis, Kirby et al., 2007) is an open source internet based system that can be applied in any parts of the world. Although it is still under development, further research need to be conducted to configure the system suitable to the other parts of the world, especially to the developing countries.

The application of mobile phones were found to be used in resource-constraint areas of the world for reporting natural disaster, infectious diseases, and disease outbreaks. The application was short message sending (SMS) by field level workers to the central electronic database enabled with the DP algorithms in Philippines and China. There is a need to conduct a systematic review to find out how the mobile based disease reporting is assisting for disease monitoring at present in different parts of the world.

The in-depth analysis showed that the existing electronic data reporting system needs to be improved in data standardizing vocabulary, data coding, formatting, and should be an interoperable to enable bi-directional communication between clinical and PH departments. The existing system has been applying the ICD-9-CM and ICD-10 data coding systems, and these coding system lack the indicators of abstract concepts (of environmental health and health economics) and rare diseases. Therefore, the hospital based NLP needs to be improved on ontological feature to standardize the indicators of abstract concepts and rare diseases.

There are two systematic studies conducted to find out the ED based SS for ILI and two-way communication between health care and PH workers. The systematic studies focused on other data sources e.g., school absenteeism and work place absenteeism based disease surveillance is also required for ILI, or other infectious and bioterrorism prone diseases. Also, there is a need of further systematic or other scientific studies to find out the health care workers (especially triage nurse, PH workers, and physicians etc.) attitudes on the electronic reporting system and the patients' perspective on the data confidentiality of the electronic reporting system separately.

There were some studies focusing on the laboratory based genetic/molecular typing and monitoring system. The internet based database was created to monitor the existence of pathogens in different parts of the world. Although, the systems are implemented by different countries, there is a need to integrate such databases at the regional and global level so that the monitoring system is prompt.

9.2.2 Emergency response

There were only 8 articles related with the emergency response which were from USA, Australia, and Canada. The available literature showed that the main information technologies applied in emergency response system are telephone and electronic registry. It was found that the existing system in emergency response are primarily based on the telephone call used for ambulance diversion, and use of electronic registry as an EMS databases for the monitoring of the calls with respect to types of the diseases encountered.

The areas to be improved were identified as; a need to improve the system by incorporating the internet based GIS for detecting the exact location of the patients, smart mobile phones for e-mail correspondence, and use of interoperable electronic data reporting system among the various stakeholders e.g., emergency medical dispatch team, 9-1-1, police, paramedic, etc. The electronic databases of the EMS system can also be used for the daily monitoring of the outbreak prone diseases such as ILI, fever, acute diarrhea syndrome etc. there is a need to develop an automated EMS based disease monitoring system that can complement the traditional ED/ambulatory clinics based disease monitoring system.

9.2.3 Environmental health

There are only 16 articles included in this PH domain, among them 50% are from USA and rest are from Canada, France and UK. Among them, the electronic registry, websites, and GIS are the most applied ITs. There are some areas identified to be improved in the various aspects of the reporting system and GIS technologies. One prominent finding that was identified in this PH domain is that there is very little application of statistical/analytical software. It could be because the PH experts are concerned with the immediate data collection for environmental health. The literature search could not find the studies that tested the data applying the statistical/analytical software.

Main areas identified to be improved were: a need of developing the database of the ENPs to enhance the knowledge of the state level health workers on handling the ENPs; application of modern PHT such as personal wearable sensors to detect the real time exposure to hazardous chemical substances; and application of the smart phones/ mobile phones for crowd sourcing and gathering environmental related data. There was a study where GIS was integrated with online analytical processing system (OLAP) for the knowledge discovery and decision making for the environmental health. There is a need to explore how this system is functioning at present. Further studies on how it can be applied in other areas of PH for decision making is necessary. Also, the application of the DP algorithms (mathematical modelling) for the data testing with the ED based diseases and geographic variables to find out the disease association is necessary. Finally, the environmental health can only be improved if there is an interoperable electronic system at the district/state level which can collect data from the local level and integrate it to the national level environmental health monitoring center.

9.2.4 Natural disaster management

The result shows among the 9 articles that were found to be focused on the natural disaster management, above half (five articles) were from USA and the rest articles represented UK, Canada, France, Kenya, Switzerland, and Thailand.

The main systems existed for the natural disaster management system are the web based data reporting system for the heat waves, and hospital based disaster monitoring system. There is a need to collaborate the community people, local stakeholders, local clubs, and local level PH workers during any kinds of natural disaster system. For this, an internet based collaborative network has to be established among the various stakeholders and community people. Further, the ITs such as mobile phones, remote sensing, and GIS could be most important devices during the natural disasters for rapid dissemination of information about the situations (such as casualties, no. of peoples affected, households and geographic location) . For this purpose, the health care workers should be trained a head of time about the effective use of mobile phones, and GIS. Finally, it is proposed to have a disaster management policy and mechanism supported with the IT in every hospitals and PH departments.

9.2.5 Injury surveillance

The finding of this research shows that over half of the total 8 studies are from USA and UK, the rest articles are from Greece, China, South Africa and EU.

The injury surveillance system at present have applied the electronic databases to keep tract of the injured patients and conduct the epidemiological studies accordingly. There are both hospital based and population-based electronic databases of the injured patients. A need to develop integrated injury surveillance databases among the hospitals at the state/regional level is identified which can be used to conduct further epidemiological studies. Further, integrating the modern IT such as smart phones, wearable sensors, and GIS could be helpful to reach to the injured person in time to prevent complications.

9.2.6 Occupational health

In the past, there have been several occupational related incidents in the world for example, chemical incident in an insecticide gas plant of Bhupal India in 1984 (Samarth, Gandhi, & Maudar. 2013) and chlorine gas release in poultry processing plant in Arkansas in 2011 (Centers for Disease Control and Prevention. 2011) etc. which caused many deaths and disabilities. There are many industrialized countries in the world where millions of workers are at risk of being exposed to the physical, chemical, biological, and radiation, agents in a daily basis. With the advent of modern IT, there is an opportunity to minimize or prevent the occupational health related PH problems.

The existing literature showed that there are only 3 articles related with the occupational health that applied the ITs, among them 2 were from USA and one from Switzerland. These studies applied the national and international databases related with the occupational health and diseases. The thesis found that there is a need to create occupational health related open source databases to be constructed among all the industries to empower the industrial workers with the right knowledge and prevent the exposure as possible. The long term epidemiological studies have to be conducted by using databases of the industrial workers being regularly exposed to certain physical or biological agents so that it can be prevented in the future, probably for the next generation. Finally, the ITs such as mobiles, e-mails, and mass media can be used to inform the health workers in a regular basis about the situation of the work place environment and inform them if there are any incidents at the work places.

9.2.7 Public health awareness

The result shows that more than three forth (72%) of the articles are from USA; whereas, and the three western countries USA, Canada and UK collectively constitute over 85% of the total articles. In spite of being the domain of public health awareness, the result shows relatively very few no. of articles used mass media, e-mail and mobile phones, where all of these information technologies have a potential to reach a large number of population. This study also could not find the articles that applied the DP algorithms and statistical/analytical software, it could be because these ITs are not potentially applied in this PH domain, or there are not enough application of these IT in it. One possible way of application of statistical/analytical software could be to measure the effectiveness of PH awareness programs e.g., telehealth program, WDQS, web based information sharing portals etc. by receiving the users' perspectives on the online forms that automatically predicts the usefulness of the given programs.

At an individual level, the developments in the interpersonal communication applying the interactive voice response (IVR) is currently present. However the developments in the automated speech processing such as machine enabled automated knowledge based dialogue system, and even more advanced form of communication with the embodied conversational agents that can emulate the hand gestures, facial expression, and human emotions are some areas to be developed in this PH domain.

At present people are accessing the information from the websites for all kinds of medical and PH related information. However, not all of these websites are monitored for the validity of the information posted in the websites. Therefore, this thesis proposes to develop a check and balance mechanism to monitor the blogs and web pages by an authentic governmental body as possible. Finally, the public health awareness can be enhanced by the use of mobile phones, mass media, websites, or even further research and development in the application of NLP on clearly processing the key words in the web search engines, and in automated speech processing systems.

9.2.8 Chronic/non-communicable disease monitoring

The result of the study found that majority of the articles are from USA, Canada and rest of Europe with two third (67.3%) representing USA, only 10% are represented different countries across the world. The recent global trend of the chronic diseases shows that the chronic diseases are in increasing trend in both the developed and developing countries (Fleischer, Diez Roux, & Hubbard. 2011), the recent advancements in the modern IT can be applied to prevent the chronic diseases and/or provide immediate care.

The result of the study highlighted the application of IT in several areas such as hospital and population-based disease monitoring systems, child health information systems, application of GIS and other ITs. Some of the major findings captured were: a need of improvement in standard vocabulary of chronic diseases; using the data coding for rare diseases in reporting system; standardizing the data among the various silos system to make them compatible to integrate in a national database. Further, a relative lack in the reporting system of the congenital surveillance system and post-immunization adverse effects monitoring system are also identified that needs to be improved applying the IT such as electronic registry or websites. Finally, it was identified that there is a good opportunity to apply the modern IT such as wearable sensors, and smart/mobile phones to provide immediate care for the chronic diseases such as asthma and heart attacks.

9.2.9 Public health policy/system and research

The articles included in this PH domain showed that above 80% of them represented to the 4 countries USA, UK, Canada, and Australia with the USA representing the highest number of articles. Further, the major IT applied were EMR/EHR/electronic registry followed by the website, whereas the least used ITs were automated speech processing, NLP, and mass media. The reason on the relative lack of articles in these ITs could be that the whole scientific community are concerned to improve the coverage of electronic reporting system than enhancing their quality.

The result showed that in developing countries the application of ITs at the hospitals and PH programs are mostly at the central level and sometimes at the district level. The mobile technologies are being applied for data reporting from the local places of some developing countries. There are many challenges identified in the health information system (HIS) of both the developed and developing countries which can be categorized as technical and system related. The technical challenges include: data standardization, coding, and formatting; unavailability of the technological devices; whereas, the system related challenges are: lack of trained human resources; lack of technical support; stand along silo system; lack of political support; and lack of motivation of the physicians on reporting.

To improve the PH policy research and practice, the result found applications of electronic registry, websites, and GIS system in many parts of the developed countries and in some developing countries as well. Some challenges in the application of these technologies were also identified. First, the available commentaries showed that the PH system have mostly focused keeping the data secure and less focused on the social value of the available data. There is a need to improve both of them, that is., to improve the data security system, as well as to expedite the process of availability of electronic data for benevolent use and research. The data should not be kept secret in certain repositories or data-banks or -warehouses. Secondly, the websites are used both for the data sharing avenue among policy makers and as a data mining tool to detect the dynamics of disease search among the population. There is a need to develop the study of web based information mining system as a separate discipline such as 'Infodemiology' that can be enhanced in the future. Thirdly, the application of GIS should be interoperable among the various level of PH and clinical system that can help to improve the decision support system in the health care and PH.

The existing literature did not show evidences of a collaboration of PHI system with the other disciplines especially engineering, biology, social science, and economic science etc., albeit some discussion on the interdisciplinary approach to be applied in the PHI research and practice. To enhance the field of PHI, a collaboration with the other disciplines is inevitable. Students focused on PHI, PH, medicine should have a collaborative education on PHI. Also, the health workers have to be trained with such collaboration.

In the health care domain the system architectures existed are: European committee for standardization (CEN) standard architecture for healthcare information systems (CEN ENV 12967), health level-7 (HL7) development framework (HDF), and service oriented architecture for HL7 (SOA). Although these architecture were being developed and used in many research labs of universities, there is a need to test the comparative effectiveness of these architectural models in different health care systems and settings.

Finally, the PH domain ‘PHI policy system and research’ includes all kinds of the PH related activities, programs and research, a continuous research and development is necessary applying the modern ITs such as automated speech processing, NLP, and mass media that were least used/discussed in this PH domain.

Chapter 10: Conclusion

Globally, only four countries (USA, Canada, UK, and Australia) represent more than 80% of the total studies, with USA being the leading country representing two third of the total articles focused on PHI in MEDLINE-PubMed. Nevertheless the majority of the studies were found from the developed countries, the scoping review showed that the application of ITs in PH is becoming popular both in the developed countries and developing countries. The trend shows that the developed countries are applying the technologies such as DP algorithms, statistical/analytical software, and GIS system in their PH information system, whereas in the developing countries, there is application of the electronic registry concentrated mainly at the national and at some district level PH and clinical units.

Further, there are a lot of studies to test the capacity of the DP algorithms, statistical/analytical software, and GIS systems; there are very few studies concentrated on testing the NLP, or automated speech processing. Finally, it is concluded there have been many research and discussion on the various types of PH and ITs domains in the past 15 years starting from 2000, the PHI system requires further improvements (and continuous research and developments) in the application of new ITs such as wireless devices, remote sensors, wearable devices, remote/ cloud computing etc. on various domains of PH which were scarcely discussed/used in the available literature.

Chapter 11: Limitations

The limitations encountered during this thesis/scoping review have been divided in terms of coverage and format that was followed during the study.

First of all, the scoping review was carried out only in the MEDLINE-PubMed using the MeSH terms. There could be related literatures in other scientific journals such as Scopus or Engineering village which are potentially missed from this study.

Secondly, in terms of the format of the study, the available articles are separated in 11 different domains and are analyzed independently. Hence any article that intersects the PH concepts of two or more PH domains were allocated in all of those domains. Therefore, the analysis may have presented the identical concepts in two or more PH domains while conducting in-depth analysis of the research and practice.

Thirdly, there are many editorials and other review articles that only discussed about application of ITs in some portions of the whole content. It was included to capture the trend of ITs discussion and informatics concepts discussed in the available PHI related discussions.

Finally, the discussion has presented some insights on all the PH domains and IT domains based on the in-depth analysis of research and practice of the existing literature. However, due to the large number of articles and uniqueness of each article, it was impossible to present all the concepts in the in-depth analysis. The most pertinent and prominent concepts were captured, however it may still lack many concepts that require further systematic review to be explored.

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