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Environmental Pollution and Chronic Disease Management – A Prognostics Approach

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1. Introduction

In many metropolitan cities, environmental pollution has a substantial impact on social and cultural well being. Statistically provable direct heath effects may require further studies to establish the influence on the community and the public healthcare system. The combined effects of fossil fuel burning and economic growth have negative impacts on health and financial costs in many areas. The main research objective aims at exploring the links between environmental pollution and health related problems. The inherently slow and reactive response over generations has repeatedly made corrective actions after an incident but not before and sometimes becomes too late. Also, health and safety precautions are often not properly exercised in a pre-emptive manner. Any proactive measure through proper early warning and environmental control methodologies would certainly yield a reduction in preventable illnesses as well as health degradation that result from improper care and environmental pollution.

Pollution is not only a problem in the community as a whole. Even at home, indoor air pollution causes a wide range of health-related issues (Bruce, 2000). The impacts of pollution on human health must therefore be assessed both for indoor and the broader outdoor environment. Since the industrial revolution of the 19th century, health hazards related to discharge of toxic chemicals and heavy metals from manufacturing plants has also become a more serious health issue. Air pollutants can travel hundreds of miles causing respiratory problems and chronic diseases. Heavy metal and toxic chemical deposits enter the food chain through the food chain and water supply (Nasreddinea, 2002). As health of the general population degrades, more people require medical attention that will eventually stretch healthcare resources to their limits.

Work on reducing health problems directly or indirectly caused by environmental pollution is urgently needed because demand on public health services is expected to grow substantially over the next two decades as a direct consequence of population aging in most developed countries (Christensen, 2009). In many cases, chronic disease is avoidable if appropriate actions are taken especially among senior citizens given access to the appropriate assistive technologies.

The environment has a substantial impact on both chronic and infectious disease (Hall-Stoodley, 2004). Take, for example, water contamination that was caused by massive flooding in Queensland, Australia, during summer 2011. The sewer system was overwhelmed by a sudden influx of water within a relatively short period of time that led to contamination of the region's water supply system. A soaring number of cases of ascariasis and giardia were reported soon after the floods. Pathogens such as bacteria, parasites and viruses responsible for spreading a range of infectious waterborne diseases across vast distances, can affect both drinking and recreational water (Colford, 2007). While a clear relationship exists between water contamination and infectious disease, the impacts on chronic diseases may not be obvious although the long-term health hazards are thought to be even more serious with a higher risk of fatality as a direct result of bladder cancer and chronic ingestion of arsenic in drinking water (Cantor, 1997).

Industrial processes such as mining, manufacturing and petroleum distillation discharge a vast amount of toxic chemicals. Even a small amount of highly toxic organic compounds can cause genetic disorders that lead to cancers and birth defects. The problem associated with an imbalance of aquatic ecosystems due to environmental pollution must therefore be thoroughly addressed. The process of managing industrial waste and pollution relates to both direct impact on human health and a broader scope of food contamination as animals along the food chain accumulate toxins in their fat and flesh from their food. The extent of contamination in the food chain increases as the toxin accumulates while propagating further up the food chain (Pereira, 2004). In an example of paralytic shellfish toxins, where the toxins first enter the food chain through waste discharged from a factory into the water eco-system. The chemicals are soaked up by shellfish that in turn becomes food of other animals that are ultimately consumed by humans. A range of other hazardous problems are also observed during this process, for example, some chemicals can cause genetic mutation that leads to cancer (Landrigan, 2002). The impacts of both microbiological and chemical contamination across the food chain must therefore be closely examined.

Water contamination is only one of the many examples of pollution-induced chronic disease contributor. Another classic example is the close relationship between second hand cigarette smoking and lung cancer (Arden Pope III, 2002). Essentially everything that we take, from the air we inhale to the water we drink and the food we eat, can potentially pose serious health risk. The primary objective of this chapter is to thoroughly investigate the relationship between environmental pollution and chronic disease in the perspective of health management and prevention by first taking a look at why health management is more difficult to address in some countries than others. Although this is generally a more serious problem in developing countries with inadequate sanitation infrastructures and policies, it may not necessarily be true that industrialized nations are less prone to pollution-induced health risks.

All these entail the collection and subsequent analysis of data from different sources; these include environmental pollution, disease prevalence, demographic variables, climatology and historical weather data analysis. To analyze such data for health management and planning, an efficient system such as prognostics and health management (PHM) is needed. PHM is a methodology widely used in different sectors of electronics for accurate prediction and computation modelling of system health degradation and maintenance (Lau, 2011). The term 'prognostics' simply means prediction of what is likely going to happen, as in medical science where prognostics has been used in the forecast of global pandemics (Wong, 2006). To understand how this puts into the context of health management for environmental health and chronic disease, we first take a look at the definition of PHM in engineering from *wiki*:

Prognostics is an engineering discipline focused on predicting the time at which a component will no longer perform a particular function. Lack of performance is most often component failure. The predicted time becomes then the remaining useful life (RUL). The science of prognostics is based on the analysis of failure modes, detection of early signs of wear and aging, and fault conditions. These signs are then correlated with a damage propagation model. Potential uses for prognostics is in condition-based maintenance. The discipline that links studies of failure mechanisms to system lifecycle management is often referred to as prognostics and health management (PHM), sometimes also system health management (SHM) or - in transportation applications - vehicle health management (VHM). Technical approaches to building models in prognostics can be categorized broadly into data-driven approaches, model-based approaches, and hybrid approaches.

From this definition, prognostics and health management (PHM) methodology has been used in the electronics industry to predict the system's *health* degradation thereby determining a product's remaining useful life. The word *health* here refers to a product's operational state, very similar in the context of a person's health and well-being. Putting these into the context of a human body as a *system*, which consists of sub-systems such as immune system and digestive system. Under certain circumstances, the health of a sub-system can degrade. Think of the case where predominant bacteria is accumulated in the stomach resulting in the reduction of nitrate and nitrite (Sobkoa, 2005), the bacteria will continue to grow while the environmental conditions remain unchanged and before they run out of space or nutrients. In this particular example, PHM can be used to model the growth of bacteria inside the stomach and how digestion is affected such that a number of corrective actions can be taken before the situation worsens. Put it quite simply, PHM as implemented in electronics, can also be applied to healthcare management in very much the same way. One of the key focus of this chapter is to discuss how PHM can assist with health management for environmental health and chronic disease. We shall look at the relationship between environmental pollution and chronic disease by exploring a number of different attributes. We shall commence by taking a look at the broader scope of public health.

2. Cultural and environmental impacts on public health

This section addresses the link between culture and environment that causes health concerns. For example, numerous mishaps have been reported in various developing countries as a direct result of excessive coal mining over the past decade. Business decision makers have put the sale of coal above the safety of miners and environmental damage. Such sentiment may ultimately lead to irreversible health consequences which far exceed that of the momentary financial gains. This is best demonstrated by the consequential healthcare costs and potential legal compensations that result from these incidents. In many cases, the remedy cost far exceeds that of prevention.

In response to these social and cultural factors that will almost certainly affect the health and well-being of millions of people, this section will concentrate on exploring how proper health management can provide a remedy and improve public health.

2.1 Perception, general health awareness and education

The link between health and general education, personal hygiene and habits has been comprehensively studied at the turn of the millennium (Lorig, 1996). (Kickbusch, 2001) suggests that there is a significant gap between developing countries and industrialized nations of which literacy is becoming increasingly important for social, economic and health development. Perception and awareness plays a vital role in disease control. In the case of infectious disease spread, pathogens can easily be spread from one person to another without any precautions. As a person coughs, air-borne disease spread by droplet infection can reach surrounding human traffic such that anyone who walks past can be caught off guard. Common sense may tell us that there are certain precautionary measures that can be taken to minimize the risk of disease spread. However, the threat must first be realized for an action to be taken, like a person will cover the mouth before coughing only with the knowledge that communicable diseases such as influenza can be spread through dispersion of air-borne transmission by droplets (Roy, 2004). The person should also understand the need of disposing of the tissue properly after use. This simple example reminds us the importance of general health awareness for disease prevention.

The issue of disease prevention, particularly for chronic diseases where some symptoms may not exhibit themselves for months or even years, delayed diagnosis may lead to premature mortality. Health degradation is sometimes gradual without any pain or discomfort until a series of other complications are developed. Although regular medical check-ups can detect or prevent illnesses and diseases, this also requires general awareness and the perception of needs. To elaborate on the details of chronic disease problems related to health education, the next section will look at a case study of coal mining and the nearby inhabitants.

2.2 Environmental health and energy supply

Soaring energy costs put tremendous pressure on the coal mining industry as coal is widely used for power generation as well as conversion into liquid biofuel. The impact of coal mining on health can affect both miners and nearby inhabitants. Health management policies are required to address different environmental circumstances for everyone concerned.

The primary health concern is air pollution. The air quality of an underground coal mine is usually regulated by a gas drainage line where toxic gases are pumped out and neutralized. Exposure to volatile organic compounds (VOCs) is one of the major toxic chemical risks on the human respiratory system (Manuel, 1999). It is estimated that as much as 4.23 g of methane is released per 1 kg of underground-mined coal (Spath, 1999). The idea of utilizing prognostics for the investigation into cumulative coal-mine-dust exposure of coal miners was proposed in (Bourgkard, 1998) such that a PHM system such as that illustrated in Fig. 1 can collect air samples from various parts of the mine shaft and to regulate the air quality as well as triggering an alarm when toxic gas concentration reaches a predetermined threshold specific to the gas measured.

This monitoring system consists of three key components, namely gas sampling sensor network for data acquisition, prognostics module for system monitoring with data analysis module for statistical modelling. The analyzed data is used to regulate the mine shaft ventilation and to trigger an alarm should an evacuation due to dangerous level of gas become necessary. Gas sampling is accomplished by analysis of solid particles and chemicals for the presence of a range of VOCs.

Gas concentration surveillance methods can be classified into three regression classes, namely linear regression, Poisson regression and regression with ARIMA (Autoregressive Integrated Moving Average) error structures (Jiang, 2007). Covariates such as miners' work shift indicators, seasonal trends with harmonic terms, and coal export indicators are often included in the regression models. By applying fuzzy ontology for assessment (Tho, 2006), ventilation control can be activated by using prospective estimation for the modeling of pollutant flow within the mine shaft. Known information is used to estimate the VOC spread and the change in concentration over time.

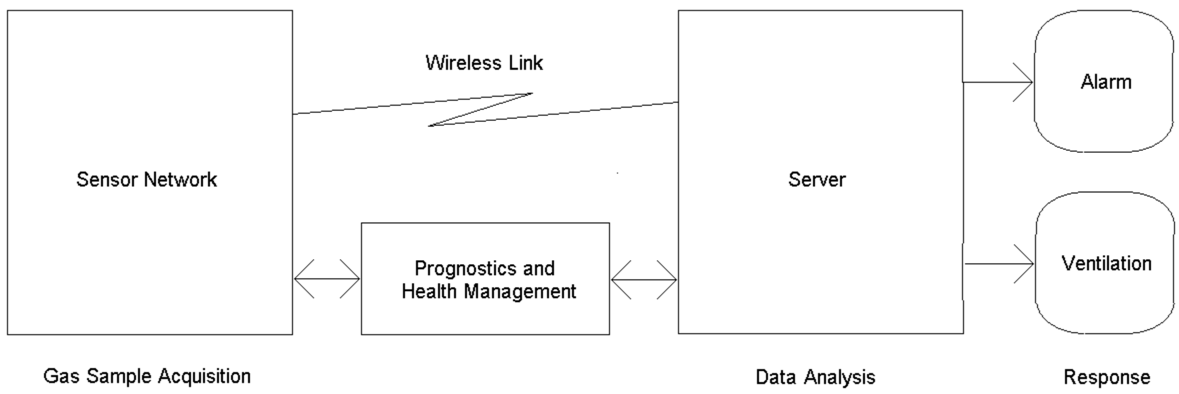

Fig. 1. A prognostics and health management system for air quality monitoring

Coal dust can also affect local residents surrounding a mining site. While we discuss issues related to indoor air quality and health in the next section in more detail, it is important to address the link between health management and those living nearby. Policies related to safe mining is therefore an important issue to look at. For example, the decision between opencast and underground mine development would, among various economic and practicality factors, have an implication on compromising between the hazards to miners working in the mine and the extent of environmental pollution to the surrounding areas. In adition to coal dust, opencast mining also produces a large amount of toxic gases such as methane and sulphur dioxide which can cause acid rain (Heinberg, 2009). Further, soot emission is also known to cause climate change (Karl, 2003). Coal pollution dust can also enter the food chain in areas where argricultral activities exist and toxic waste water can be discharged into rivers and underground without undergoing proper treatment. The discharged water combined with runoff from mine tailings can cause pollution to surface water and groundwater in mine areas resulting in soil contamination. Excessive discharge of water can also cause land to subsidence, such risk is even more prominant around coastal mines since water being pumped out from the mines can be combined with sea water that consequently leads to contamination of surrounding water sources.

The health risks posed to miners and their associated costs also need to be addressed. Among a long list of complications that can be developed including hearing impairment, neuromuscular disorders, rheumatism, chronic obstructive pulmonary disease (COPD) and acute respiratory infection (ARI) (Hnizdo, 2003); pneumonia caused by coal dust inhalation is perhaps the most serious fatal occupational diseases to hit coal miners. The cost of treating these diseass and compensation can be staggering.

Different energy sources may be responsible for different kinds of environmental pollution with varying degree of negative impacts on human health and how far the effects can be felt. Even so-called clean energy may not be totally free from causing pollution. For example, wind energy may be widely regarded as a clean energy source. Rotating wind turbines causes pollution in the form of noise although most of them may be installed far away from residential zones (Pedersen, 2004). Elevated level of noise produced from a wind turbine is often resulted from deficiency linked to lubrication and component wear (Gray, 2010), pollution control through noise control can be accomplished using the following prognostics approach: A prognostics system typically consists of a variety of onboard sensors, data acquisition systems, and signal processing and analysis algorithm. Application of prognostics based maintenance technology to wind turbine has the potential to significantly reduce induced noise and increase turbine reliability by enabling condition-based maintenance (CBM) thus enabling advance detection of dry lubricants as well as component tear and wear. Detection of faults in their early stages provides an opportunity to carry out necessary maintenance work prior to a turbine degradation that may generate excessive noise.

Among various energy sources commonly used over the past decade or more, nuclear energy is perhaps the deadiest that can kill many people over a long period of time spanning across decades due to radioactive pollution as a direct cause of many acute and chronic conditions (Andia, 1998). Although excessive discharge of radioactive pollutants does not occur often, once it happens the situation can be critical as radiation is released into the environment that can travel for thousands of miles across the world. Well-known accidents include the 1986 Chernobyl reactor meltdown in the former Soviet Union, Three Mile Island incident in the USA and more recently Fukushima nuclear plant in Japan overheated after an earthquake triggered tsunami damaged the plant's power supply to the cooling system. Note that the word 'meltdown' is appropriately used in a nuclear reactor disaster to describe the blast. This is because commercial nuclear reactor fuel is not enriched to the radioactive materials used in nuclear weapons intended to cause massive explosions. In the case of a meltdown, the core temperature inside the nuclear fuel rods casues the solid rod to melt, turning in liquid. As the happens the molten radioactive materials of the fuel rods would react with ground water (Caldicott, 2006). The wide range of fatal health problems will be seen for the decades to come as there is currently no known cure to radioactive poisoning as the damage to human tissue is irreversible.

2.3 Health management, policies and public reactions

Earlier in the section we have discussed the health management issues related to perception and general awareness. The role of health management and policies can differ significantly from country to country. While this chapter will not touch on politics, there are a number of issues that should be addressed. Take the table salt snatching example in March 2011 following the Fukushima nuclear incident in Japan, rumours triggered panic buying of table salt around the Greater China region (Pierson, 2011). Fear was sparked by internet rumours that salt consumption can ward off radiation exposure. Further panic was also driven by the theory that salt in future may be produced from radiation-contaminated sea water. Without citing any references, it should be obvious to readers that common table salt as a remedy and that production of salt by radioactive-pollution affected sea water cannot possibly be true.

Sometimes rumours are not totally unfounded. There are perhaps some related facts, such as in this particular example, iodine salt can yield a lower absorption of certain radioactive exposure (Mettler Jr., 2002). People with no knowledge on how radiation may affect human health can be driven to respond to rumours in an inappropriate way. Further, no effort has been made on finding out whether table salt sold on the market is iodized and they lack the knowledge of understanding the difference between iodine tablets and iodized salt. This is a classic example of an overreaction by people to rumours.

Whether people are willing to learn from past experience is another issue that health management needs to addressed. By recalling the SARS (Severe Acute Respiratory Syndrome) epidemic was initially erupted in China's Guangdong province in 2003, rumours claimed vinegar could be used as a disinfectant and kill the SARS virus (Rosling, 2003). Like stockpiling table salt in 2011, people responded in exactly the same way when they stocked up excessive quantities of vinegar some eight years earlier.

These examples, showing how people react to rumours, provide an insight into the importance of carefully planned policies in anticipation of public reactions. Certain clues may be made available to policy makers for prediction of how general perception will be driven.

3. Environmental monitoring technology

To assist with health management for prevention and control of environmentally related diseases, a general understanding of methodologies in monitoring environmental pollutions that cause a range of chronic diseases and premature death is vitally important. Environmental monitoring relies heavily on sensors and wireless networks that connect the sensors together. Wireless sensor networks provide a range of solutions for monitoring different sources of pollutions from the air we breathe to the water we drink. Different sensors exist for different applications.

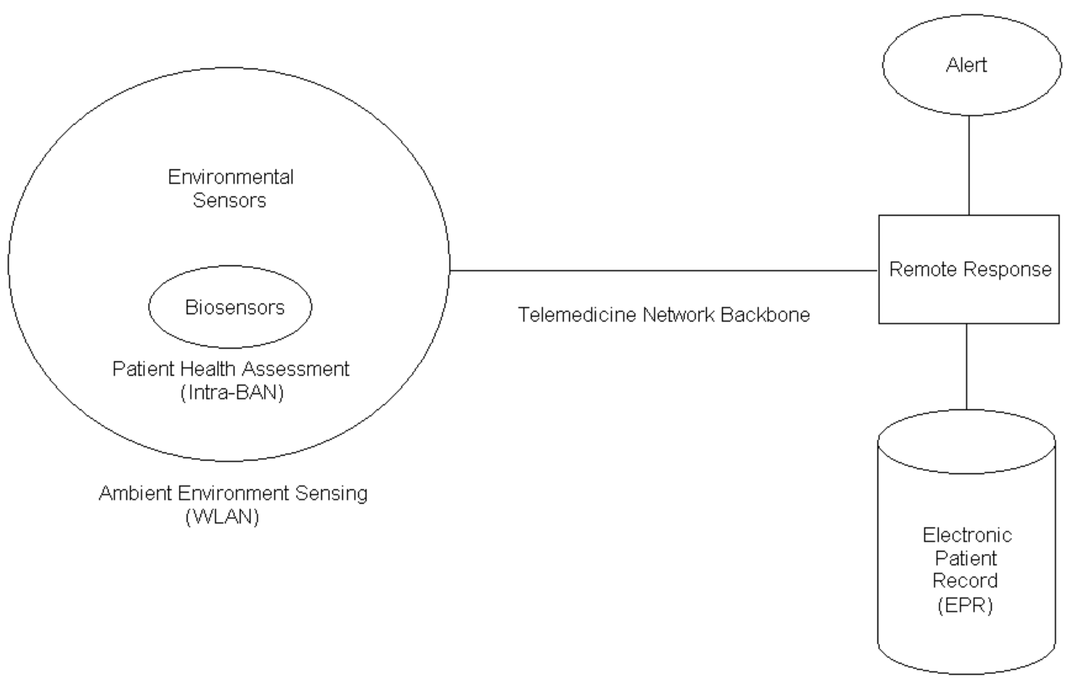

Fig. 2. Environmental health monitoring system

A wide range of sensors are deployed in different locations to monitor different parameters. These cover both human health and the surround environment

3.1 Sensors

A sensor is defined by (Carstens, 1992) as a device that provides a usable output signal in response to a specified measurement parameter, for example, methane gas concentration, or humidity. A sensor generally operates by translating physical, chemical, or biological phenomena into an electrical signal utilizing physical or chemical effects that corresponds to the measured value or through energy conversion from one form into another. To make any meaningful use of the measurement obtained from a sensor, it is necessary to have some means to connect the sensor to an electronic circuitry so that the raw measured value can be interpreted in a meaningful way. For example, by measuring the relative humidity of air, it would be necessary to have some kind of electronics that reads what the sensor picks up and translate it into an output such as an LCD (liquid crystal display) panel to be read. This is essentially to say that an interface, such as an electronic device, is necessary to connect a sensor to the outside world. In the case of serving environmental health management applications, sensors are broadly classified into three major groups, namely physical, chemical, and biological.

The types of sensors used in environmental monitoring are listed in Table I. Thermal sensors are resistance thermal detectors (RTDs), thermistors, thermocouples, or semiconductor junction diodes. The signals generated by most sensors are in electrical form with an output generated either as a voltage or a current that corresponds to the reading. Four major types of electrical sensor commonly used are inductive, thermal, capacitive, and Hall effect sensors; and these parameters can be used to represent different attributes. Mechanical sensors usually take a direct measurement of a change in property of a certain parameter and convert it into another energy domain. Humidity refers to the water vapour content in the air, usually measured with capacitive, resistive, or thermal conductivity humidity sensor. Absolute humidity is the ratio of the mass of water vapour to the volume of air whereas relative humidity (RH) to the ratio expressed in percentage of the moisture content of air compared to the saturated moisture level at the given ambient temperature and pressure. Biosensor makes use of biological materials or biologically derived materials to detect analyte that combines a biological component with a physicochemical detector component. Different types of biosensors include electrochemical, optical and piezoelectric sensors with enzymatic catalysis, electrodes, or biological receptor elements. Chemical sensors detect composition and concentrations of a substance to be measured. They make use of electrochemical, mass humidity or thermochemical sensors.

Type	**Parameter**
Thermal	Temperature, heat flux, heat dissipation
Electrical	Voltage, current, resistance, inductance, capacitance, impedance
Mechanical	Length, acceleration, flow, force, torque, stress, strain, density, strength pressure, acoustic power
Humidity	Relative humidity, absolute humidity
Biological	pH, molecular concentration
Chemical	Chemical concentration, molecular mass, reactivity
Optical	Intensity, phase, wavelength, polarization, transmittance, refractive index
Magnetic	Magnetic field, flux density, permeability, direction, flow

Table 1. Types of Environmental Sensors

In most sensor networks that are set up for environmental health applications, they typically consist of a combination of different sensor types. Management of different type of disease has different requirements on what and where to measure. Each sensor collects its reading and communicates with a console in a polling system such that all sensors are individually and sequentially addressed one after another. In theory, sensors irrespective of types can be polled together, for example, chemical sensors sensing the presence of gaseous hydrocarbon substances can be connected in the same network as a humidity sensor that senses water vapour. However, each of these sensors requires its own electrical interface in order to convert the reading into a form that is suitable for transmission to the console.

Optical sensors can take the form of photoconductors, photoemissive, photovoltaic, and fibre optic variants. All they have in common is that they all produce an electrical output based on the intensity of light that reaches a photocell. Finally, magnetic sensors respond to the change of a certain effect such as:

- Galvanomagnetic effect, manifested as a Hall field and carrier deflection
- Magnetooptic effect, which is any one of a number of phenomena in which an electromagnetic wave propagates through a medium that has been altered by the presence of a quasistatic magnetic field
- Magnetoresistance, which is the property of some materials to change the value of their electrical resistance when an external magnetic field is applied
- Magnetostrictive effect, where the imposed magnetic field causes strain on a certain material

The parameters which are to be monitored in the environment as well as human health can be selected based on their relationship to functions that are vital to the operating conditions, where it is possible to be implicated in an elevated risk of developing a health problem or trigger a symptom of an existing condition. Selection criteria are usually based on knowledge of the critical parameters established by the ambient environment and medical history of the patient. Sensing of multiple parameters can be accomplished using one single sensor system that can measure multiple types of parameters such as temperature, humidity, air pollution, and toxins. Systems that can realize multiple sensing include a sensor array which contains several different sensing elements internally; a sensor system can also include external ports for additional sensors to be attached such that it can support a combination of various sensor nodes.

Physical attributes of a sensor includes its physical size, form factor, weight, case or housing, as well as how it is mounted according to their operating environment. In a body area network (BAN), the sensor's physical size and weight may become the most important selection criterion since limitations of movement for attaching the sensor or due to the inaccessibility of locations to be sensed can affect its wireless communication capability.

3.2 Communication networks

A communication network can be either wired or wireless. The former uses conducting wires and the latter relies on electromagnetic waves. Their common task is to convey information from one point to another (point-to-point). A transmitter that sends information from the source to two or more receivers is said to be point-to-multipoint. Generally speaking, the choice between wired and wireless depends on the trade-off between security and reliability versus mobility and flexibility (Varshney, 2002). In particular, the saving in terms of implementation and material costs without wires in point-to-multipoint communications can sometimes be very significant. In environmental monitoring, an array of sensors is interconnected across different areas, making wireless communications the best option.

Fixed WiMAX networks provide broadband distribution services in urban environments as last mile access for a diverse range of applications with carrier frequencies in excess of 10 GHz (Stamatelos, 1996). There are a number of issues that have to be considered when designing a WiMAX system in the frequency range spanning from 10 to 66 GHz. At these frequencies, multipath does not have any significant impact since high gain antennas with narrow beamwidth can be used for short paths (Fong, 2003). System performance is greatly affected by link availability under various atmospheric conditions. Also, line-of-sight (LOS) or near line-of-sight is normally necessary between antennas. The selection of carrier frequency depends primarily on spectrum allocation by local authorities and operational conditions; the choice of operating frequency is also determined by population density and rainfall statistics.

Although WiMAX offers a more economical alternative to wired networks in many point-to-multipoint scenarios making it particularly suited for environmentally-related chronic disease monitoring, in some areas a WiMAX network may share the same portion of the spectrum with other nearby communication networks and systems. Moreover, data transfer is carried out in a very harsh environment subject to numerous causes of signal degradation and atmospheric phenomena; these include interference, rain-induced attenuation, and depolarization. Frequency planning for an allocated spectrum uses multiple sector systems with each sector supported by a base station of the access service network (ASN) serving a cell site. Uncontrollable factors such as rain-induced attenuation and depolarization must be considered to ensure adequate network availability.

The concept of the Fresnel zone is central to virtually any outdoor environmental monitoring network. The dimensions of the Fresnel Zone can be calculated by simple geometry and the Fresnel zone distance is obtained the difference between the direct path and the indirect path.

Height restriction is often imposed in urban areas where maintaining an unobstructed path for LOS may be virtually impossible. Fig. 3 shows the variation in radio hub distance for first Fresnal zone clearance where the demand for foliage clearance increases as the carrier frequency increases; at least 10 m of clearance is necessary to avoid disproportionate loss. This is a very important consideration for environmental monitoring because any signal that is blocked by physical obstacles would mean the information gathered for a given location is simply lost. Ensuring network reliability and availability entails thorough understanding of the network structure. Similar to passive optical networks (PONs), fixed WiMAX exhibit the same characteristics of the point-to-multipoint topology (Lu, 2007). In this context, network optimization can be realized through deployment of scheme comparable to cascaded arrayed waveguide gratings (AWGs) due to their cyclic property (Zhang, 2009). Both WiMAX and PON share the same topology given a fixed routing such that the position and placement of communicating nodes can be optimized in much the same way as the cascaded AWG structure in PONs so as to optimize how much bandwidth each communicating node can receive. Redundancy is often required in a tree topology to combat the occurrence of link outage that can be addressed by the reliable scheme (Ansari, 2004). Network deployment considerations therefore require careful planning of where each sensor is mounted.

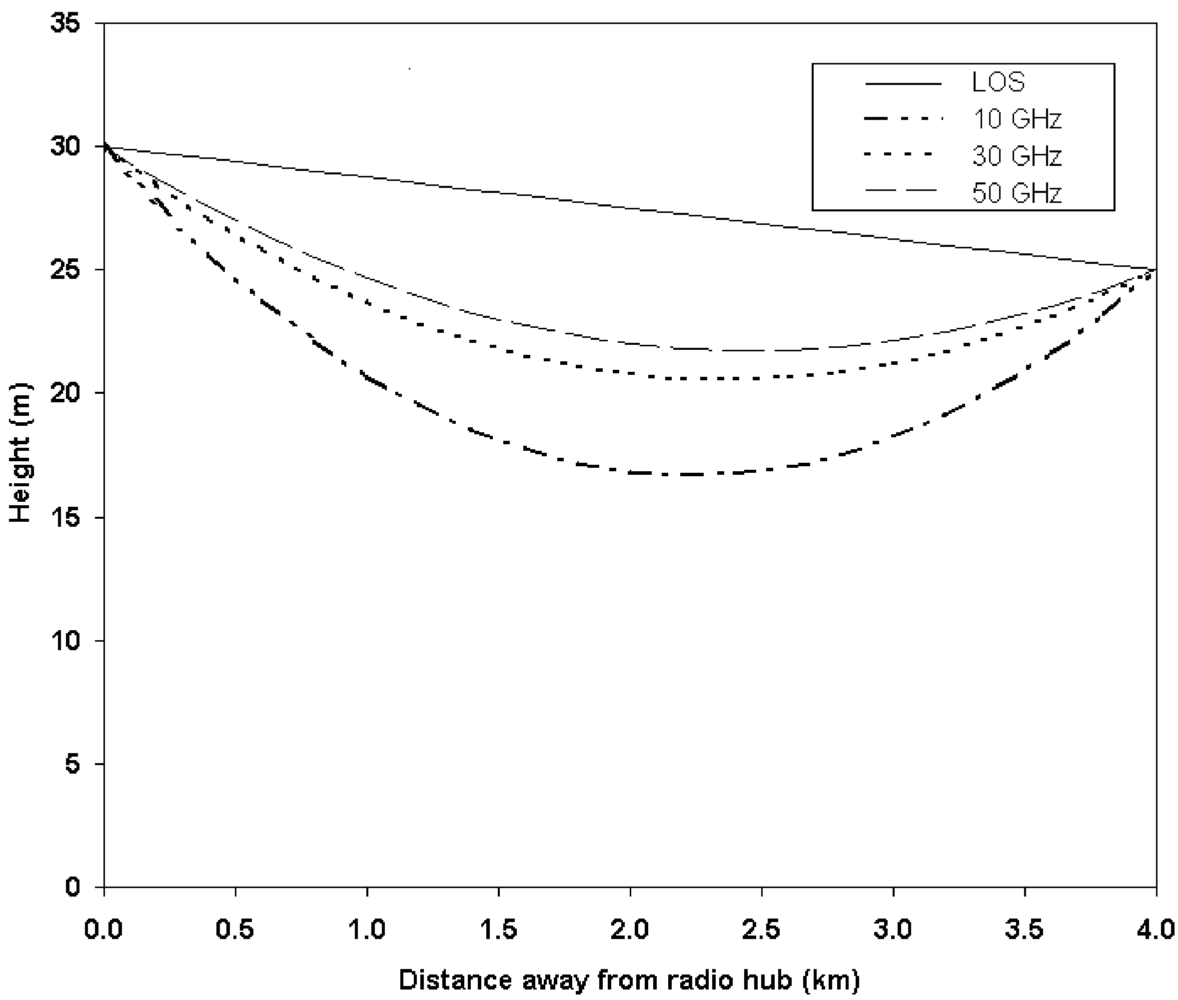

Fig. 3. Fresnel zone clearance for wireless environmental monitoring systems

Wireless communication systems play a significant role in the monitoring and prevention of environmentally related chronic disease. In addition to pollution monitoring, health monitoring provides information technology (IT) solutions for both passive and active prevention with wireless telehealth technology (Fong, 2011). We shall illustrate this by following through an example with asthma patient care, which is known to be a chronic disease closely associated with both indoor and outdoor air pollution (Koenig, 2005).

3.3 Environmental monitoring for asthma patients: A case study

Environmental monitoring for asthma patients is an important topic since some ten percent of Americans are reported to be asthma sufferers according to the US Centers for Disease Control and Prevention (CDC) statistics. Air pollution is a well-known trigger for asthma symptoms. Indoor air pollution is becoming a serious health issue as a range of chemicals found in many homes such as acid aerosols and volatile organic compounds (VOCs) can trigger asthma symptoms (Koutrakis, 1992). The biosensors need to measure and record a patient's peak flow breathing for refractory asthma management. Improving indoor air quality by reducing indoor particulate pollutant concentrations will provide a vital means of improving asthma patients' health. Reduction of respiratory health risk to asthma patients through ubiquitous healthcare entails a series of longitudinal health data to be coupled with detailed monitoring of personal exposure is necessary such that an accurate estimation of the exposure-response relation for air pollutants from various sources can be established.

Among a number of environmentally-linked chronic diseases, asthma alone contributes to over 13 million ambulatory care cases annually for outpatients with asthma as primary diagnosis and hospitalization of almost half a million cases with an average length of stay of three and a half days according to the figures published by the US CDC in its report entitled 'Asthma Prevalence, Health Care Use, and Mortality: United States, 2005–2009'. Many of these cases would have been avoidable if appropriate actions were made to prevent asthma symptoms from being triggered. A healthier living environment to reduce asthma symptoms can be provided by ubiquitous healthcare solutions in monitoring environmental pollutions. Wireless sensor networks provide a range of solutions for monitoring different sources of pollutions in the patient's home by monitoring any changes in concentration of various pollutants.

To thoroughly address this problem for patients living in rural areas, the first necessary step is to provide swift response to a patient when the disease symptoms are triggered. This issue is particular important in the context of rural areas where a lack of skilled healthcare professionals can cause substantial delay in getting medical attention. Telemedicine system that supports remote camera control with a stethoscope for remote auscultation implemented for this purpose. The stethoscope installed at the patient's home would allow a remote respiratory therapist to hear the heart tones and oscillations while simultaneously controlling the camera to see the patient. Through technological advances in telecommunications, many people who require special attention can live alone with the assurance that help is always available and they are taken good care of. Wireless telemedicine is particularly suitable for rural areas and people with limited mobility such that support can be provided to those who live alone with the assurance that they are well looked after. For example, a comprehensive system may be installed at an elderly home with features such as fall detection, smoke and flood warning system.

To address the issue of indoor air pollution that affects asthma patients, spatial and spatio-temporal models used to investigate pollutant distribution, so that information about both space (location) and time will be utilized. Pollutant prediction at unmeasured sites, and pollutant prediction over time. One major challenge is to achieve a comprehensive view of air quality by combining time series of multiple pollutants at different rooms, spatio-temporal measurements with different instruments, and different level summary statistics. To integrate multiple data streams and capitalize the complex dependence across time and space, it is of both theoretical and practical importance to develop a hierarchical model with conditional sub-models defined hierarchically at different levels. The uncertainty is apportioned to different levels and propagated through the hierarchy, which also provides a formal way to borrow strength between various components and improve the precision of statistical inference.

4. Pollution-induced diseases: Challenges for policy makers, medical professionals, and the general public

Having looked at various issues surrounding general education and perception, this section will look at how policy makers can strike an optimal balance between business interests and community well-being. These also have impacts on driving down public healthcare demands and reduce avoidable hospitalization. In a major catastrophe, the risk of causing panic and chaos can further complicate any recovery efforts. Authorities often face the challenges of censoring what kind of information should be released to the media (Massey, 2006). Numerous mismaps throughout the world in recent years have shown that what to release at which stage is vital during a significant event, be it a major disease outbreak or environment disaster. Any inappropriate action can lead to mass hysteria. While the general public usually relies heavily on the media that usually obtain updates from government press releases (Adam, 1999) even though the authorities and the media soemtimes have opposing views regarding sharing and disseminating information to be released to the public. How and when information should be released is therefore an important issue to be addressed in response to a crisis.

Any situation that may lead to problems related to environment-induced diseases has further implications than the link between authorities and the general public. For example, any disclosure delay may lead to treatment postponement. Sometimes, symptoms may not be detected for a long time, such as the case of short term explosure to a dose of very high energy Gamma-ray radiation (Veenema, 2003). The announcement of any radiation leakage may spark mass evacuation and panic. The legacy may well continue for a long time due to contamination of the food chain (Salunkhe, 1961). The impact on any swift action taken by policy makers can greatly increase the chance of survival for many and health professionals require up-to-date information in anticipation of an influx of patients for urgent treatment. Analysis of disease transmission and control often entails mathematical modelling for integration into the process of public health decision making (Keeling, 2007).

4.1 An overview on air pollution and prediction methods

Air pollution is one of the major environmental factors in chronic disease. Main sources of air pollution include manufacturing industry, fossil fuel power generation and motor vehicles (Mayer, 1999), this is a far more severe problem in metropolitan cities where roads are crowded with frequent lengthy traffic jams. Over 200 vehicles can be queued up in a kilometer of road that keep releasing contaminants in the exhaust gas emissions like carbon monoxide, toxic hydrocarbons and nitrogen oxides (Zhang, 1995). Rapid industrialisation and urbanisation of many developing countries over the past decades also accelerate the air pollutin problem with pollutants emissions from electricity generation, petrochemical industry and a growing number of motor vehicles. Although individuals can help by reducing the amount of energy usage with a bit of common sense; monitoring, detecting, and, control of urban air pollution, as well as to improve decision making and creation of sustainable air quality strategies are all necessary actions for air quality improvement. This would entail identification of correlations and casual relationships among different social, geographic, networks and environmental factors through data mining and statistical learning models and algorithms. A fuzzy ontology framework with multiple data sources of global satellite aerosols and pollutants data would be necessary to predict impacts on human health in different areas.

Monitoring air quality requires handling multiple data sources of pollutants-related data. Within each data source there are usually multiple series. Directly applying existing surveillance algorithms into those multiple datasets will reduce computational complexity.

Complexity reduction is particularly important in situations where rapid successive measurement is necessary so that any adrupt change can be detected.

4.2 Disease transmission and the environment: Infectious vs. chronic

Infectious disease requires three elements to spread from one person to another as illustrateed in Fig. 4. The pathogen is carried by some kind of medium, such as air and fluid, as in the case of droplet transmission. Once it settles down on a host, it can also travel across the world via airplane passengers or even wild birds as the infected host (Li, 2004). The environmental plays an important part in how quickly a disease is carried over a medium. For example, (Woo, 2006) studied the transmission of infectious disease in a wet market. Regulations governing operation and hygene of places such as markets and restaurants would prevent the transmission of diseases from animals to a human host.

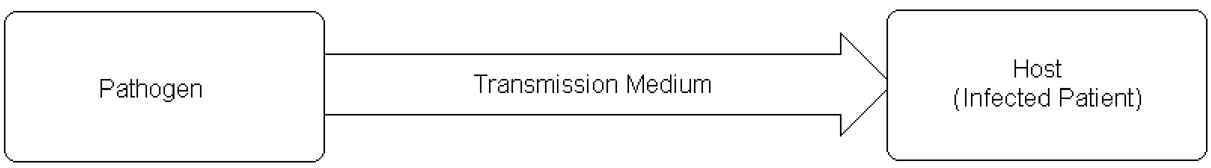

Fig. 4. Infectious disease transmission

A person is prone to infection when all these three elements are present. While it is impossible to eliminate the host, certain measures can control the environment to prevent the pathogen from growing. The transmission medium can also be disrupted if appropriate measures are taken. For example, a person uses alcohol-based hand sanitizer can make the environment, i.e. the hands, safe from bateria. Likewise, when the bateria is subdued the likelihood of the hands being the transmission medium for the bateria is significantly reduced.

The transmission of pathogen from a source can be either direct or indirect. The former is usually through close contact with another host whereas the latter often entails a contaminated fomite such as gastrointestinal pathogens. When the pathogen reaches a host via the medium, it needs a portal of entry, usually the respiratory or gastrointestinal tracts, to enter the host in order to cause an infection. Environmental control and policies can. To some extent, reduce the reduce the spread of an infectious disease, these include disinfection or sterilization, and immunization for people who are particularly vunlerable, like small children and chronically ill patients.

Environment and policies also play a significant role in the control and prevention of chronic disease. Section 2.2 briefly discussed a number of occupational hazards related to the coal mining and nuclear power industry. Occupational health and safety is an important topic to prevent environmentally induced chronic diseases. Measures such as prognostics would be able to predict the development of certain chronic diseases related to work activities. Generally, environmental monitoring for infectious diseases require close surveillance of the breeding grounds of pathogens as well as the transmission media. In chronic disease management the concentration of certain pollutants relevant to the particular condition of interest as well as around the patient's body are of primary interest. The ambient environment needs to be safegarded prevention surveillance in chronic disease just as important as providing a safe place to minimize the risk of an injury. People who need to routinely perform certain tasks are more prone to chronic diseases, such as the case of chronic back pain reported by many health professionals especially among dentists (Andersson, 1999). Ensuring a safe and healthy work environment remains an important aspect of reducing the risk of chronic diseases.

4.3 Laboratory vs. real-life chronic disease management

When conducting experiments in a laboratory environment, observation of activities usually include three steps, namely symptom identification through prognosis, detection through diagnosis, and providing subsequent remedies. In carrying out each of these steps and manipulating the captured data, their time values are collected in segments. The treatment time can be defined as the summation of these three time values. Statistically, the probability distribution of the treatment time cannot be defined as a certain known distribution, and how to utilize segmental information for treatment effectiveness verification may differ in a controlled environment so that the result can be far less effective in real-life situations. The observations from laboratory experiments usually do not take into consideration any changes in the ambient environment can commonly occur in real-life, and the symptoms identified in the verification stage are naturally produced during experiment. The two sets of data captured from different environments, that is, the laboratory data verses the field data in real-life situations, do not have a direct relation due to the differences in the experimental environment. In order to make use of laboratory data for chronic disease management in the real-world, data fusion is a necessary step before conducting integrative verification. This is primarily performed to integrate different sources of data in order to yield improved information than can be derived from each single data source. The simplest method of fusion is to take a weighted average of redundant information obtained from multiple data sources.

The Bootstrap method is used in statistics as a computer-based method for used for uncertainty analysis that does not require any a prior assumptions for the unknown distribution of experimentally observed data. This is an important feature for disease management since the actual environment surrounding a patient cannot be known. It makes use of the given patient's health information and simulate the unknown distribution through resampling of the available data. Resampling creates an ensemble of data sets, where each set is replicated from the original samples (MacKinnon, 2004) and creates new data sets by sampling with replacement. Given that the laboratory data and the actual field data are two different characterizations from the same sample under two different environments and due to the random nature of the data, these two different data sets can be considered as two evidences from different information sources within the same time frame.

5. Prognostics and health management for disease control

We shall conclude this chapter by covering condition-based monitoring techniques on health deterioration. Prognostics techniques have been proven for effectively predict the remaining useful life of a given system. Similar methodologies can be applied to monitoring the state of human health subject to different environmental impacts, such as chronic diseases caused by contaminated water supplies and acid rain.

The most common existing methods for detection of an outbreak include temporal and spatial surveillance. In reality, the disease incident data are likely to be heterogeneous, correlated, and often exhibit seasonal patterns over time. Efficient detection and prognostics methods under these situations are lacking. Effective mitigation strategies and resource management require new scientific theory and approaches that are needed for disease spread simulation, diagnostics, prognostics, and forecasting methods. The public healthcare infrastructure needs a mechanism for comprehensive real time infectious disease data collection, monitoring and management during the early stage of an outbreak. Accomplishing this will require data mining and forecasting approach for diagnostics and prognostics of real time monitoring and acquisition of infectious disease data collected during outbreaks. Besides, for timely outbreak detection, bio-surveillance and syndromic surveillance approaches will also be needed for prompt detection by monitoring disease symptoms or correlated indicators to effectively gather and analyze suspected cases through use of small-world-like model which has been widely reported in Europe in recent years (Lee, 2009). In addition to monitoring confirmed incidents, efficient spatio-temporal surveillance algorithms will be part of the key infrastructural elements for monitoring multiple streams of data including disease symptoms, correlated indicators, and confirmed incidents.

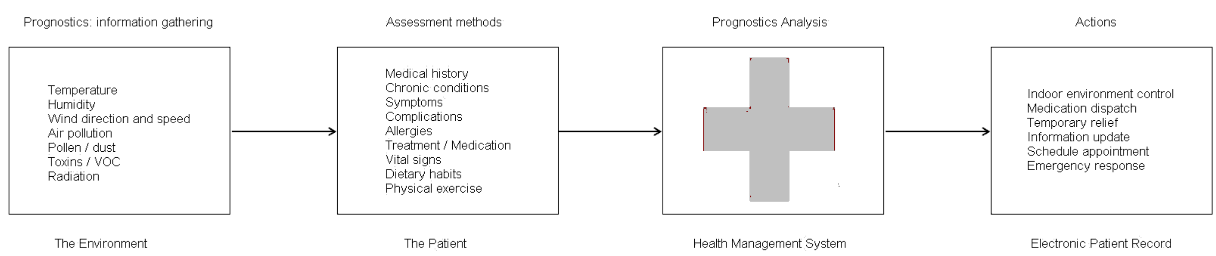

Fig. 5. A prognostics framework for managing chronic disease

The first step involves an overall environmental assessment, where environmental condition, patient's health, vital signs, current medications taken, and any symptoms exhibited are the inputs to perform an assessment. Based on the assessment results, it is possible to prioritize the necessary actions to take and the potential health risks. The existing sensor data (both ambient environment and patient's health), recent monitored data, and medical history and electronic patient record can also be used to identify the health condition. Based on this information, the monitoring parameters and sensor locations for PHM can be determined.

Chronic Disease management entails an active approach that tackles any signs of symptom at the early stage of the disease cycle to minimize the impact of disease progression and potential health complications. PHM makes use of early warning of health degradation to provide early treatment thereby improving the health of patient diagnosed with certain conditions so to avoid the risk of further complications and interventions at a later stage. Fig. 5 shows the framework for prognostics for managing environmentally linked chronic diseases. Environmental data obtained from various locations of different pollutants can be monitored and analyzed using prognostic methodology. Different implementation approaches can be adopted individually or in combination. The principle of PHM is to utilize current information and forecast the future condition. Information about the patient's current health can be used for prediction of any further complication. Chronic disease management involves the monitoring of environmental conditions that may trigger a symptom and to alert all registered patients who have been diagnosed with chronic disease.

Further, prognostics can be used to identify patients with elevated risk of developing a chronic condition. For example, by monitoring the health condition of an obese patient who is known to be prone to developing diabetes, necessary precautionary actions can be proactively taken to reduce such risk. The patient can be of different stage from free of disease to early stage of disease without exhibiting any signs or symptoms. PHM is particularly suited for managing patients with multiple chronic conditions and special health needs. Based on the definition of data driven prognostics, we can intepretate Fig. 5 as utilizing monitored current environmental conditions and assessment data related to patient health. The principal advantage to data driven prognostics is that it can often be deployed quicker and cheaper compared to other approaches, and that it can provide comprehensive coverage of symptoms and signs; making it particularly suited to managing the fluctuating nature of illness. To the patient, information obtained can also be used for assisting with adjustments of lifestyles based on changes to health condition. Disease management with environmental monitoring technology serves as a means of caring for patients with chronic conditions. Prognostics and health management methodology provides an assistive option for decision support and condition-based monitoring for active prevention.

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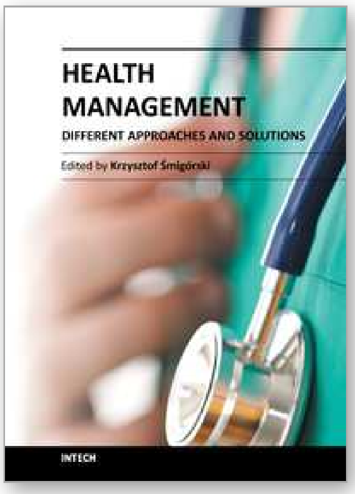

Health Management - Different Approaches and Solutions

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The development in our understanding of health management ensures unprecedented possibilities in terms of explaining the causes of diseases and effective treatment. However, increased capabilities create new issues. Both, researchers and clinicians, as well as managers of healthcare units face new challenges: increasing validity and reliability of clinical trials, effectively distributing medical products, managing hospitals and clinics flexibly, and managing treatment processes efficiently. The aim of this book is to present issues relating to health management in a way that would be satisfying for academicians and practitioners. It is designed to be a forum for the experts in the thematic area to exchange viewpoints, and to present health management's state-of-art as a scientific and professional domain.