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The Potential of Biosensor as an Early Warning Tool for Disaster Risk Reduction at Regional Level

Potensi Biosensor sebagai Sebuah Alat Amaran Awal bagi Pengurangan Risiko Bencana di Peringkat Wilayah

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ABSTRACT

Recently, there is an increasing rate of environmental pollution cases reported, and that is closely related to technological hazard. Environmental monitoring (EM) is an approach to detect environmental risk before it develops into a disaster. Disaster Risk Reduction (DRR) is an important concept in reducing the impacts of hazards and disasters to social, economy and environment, especially at a regional level. Biosensors have been developed to detect pollutants and hazardous chemicals that are frequently and potentially found in the environment as a result of anthropogenic activity and as part of the natural phenomena. Efforts are focus in developing biosensors that are applicable in EM, some suggested biosensors could replace the conventional chemical analytical methods, but not all of them are practical. To evaluate the feasibility of biosensors in assisting EM in DRR, an analysis of articles published on biosensors in related field was carried out. Based on the evaluation, we concluded five major aspects to be considered when biosensors are to be applied as an early warning system tool in DRR at regional level, namely complexity of real sample, need of continuous environmental monitoring data, reproducibility of data, on-site testing and roles in risk characterization. This paper will help in the assessment of the applicability of biosensor in EM and as part in the DRR, and also as a guide to designing biosensor for EM purposes.

Keywords: Biosensor; early warning tool; disaster; environment

ABSTRAK

Baru-baru ini, terdapat kadar peningkatan jumlah kes-kes pencemaran alam sekitar yang dilaporkan, dan itu adalah berkait rapat dengan bahaya teknologi. Pemantauan alam sekitar (EM) adalah satu pendekatan untuk mengesan risiko alam sekitar sebelum ia berkembang menjadi bencana. Pengurangan Risiko Bencana (DRR) adalah satu konsep yang penting dalam mengurangkan kesan bahaya dan bencana sosial, ekonomi dan alam sekitar, terutamanya di peringkat serantau. Biosensor telah dibangunkan untuk mengesan pencemaran dan bahan kimia berbahaya yang sering dan berpotensi dijumpai di dalam alam sekitar akibat daripada aktiviti antropogenik dan sebagai sebahagian daripada fenomena semula jadi. Usaha dengan memfokuskan kepada pembangunan biosensor yang boleh diguna pakai di EM, beberapa biosensor yang disyorkan boleh menggantikan kaedah konvensional analisis kimia, tetapi tidak semua daripada mereka adalah praktikal. Untuk menilai kemungkinan biosensor dalam membantu EM dalam DRR, analisis artikel yang disiarkan dalam biosensor dalam bidang berkaitan telah dijalankan. Berdasarkan penilaian, kita membuat kesimpulan lima aspek utama yang perlu dipertimbangkan apabila biosensor digunakan sebagai alat dalam sistem amaran awal dalam DRR di peringkat serantau iaitu kerumitan sampel sebenar, keperluan data pemantauan persekitaran yang berterusan, kebolehulangan data, pada- ujian tapak dan peranan dalam pencirian risiko. Kertas kerja ini akan membantu dalam penilaian kesesuaian biosensor dalam EM dan sebagai sebahagian dalam DRR, dan juga sebagai panduan untuk mereka bentuk biosensor untuk tujuan EM.

Kata kunci: Biosensor; alat amaran awal; bencana; alam sekitar

INTRODUCTION

Disaster Risk Reduction (DRR) is "the concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events." as defined by UNISDR (UNISDR terminology on disaster risk reduction 2009). UNISDR does not define natural occurring calamities

as "natural disasters", but as "natural hazards." DRR is a systematic procedure that is carries out to identify, assess and reduce the potential risks caused by natural hazards and disasters. During the opening of the UN General Assembly Informal Thematic Debate on DRR (UNISDR News Archive 2011), Ban Ki-moon, the United Nations Secretary-General, ever mentioned:

> The international community must learn to manage and maintain a truly global response to disasters caused by natural hazards and make the most effective use of resources. The more governments, UN agencies, organizations, businesses and civil society understand risk and vulnerability, the better equipped they will be to mitigate disasters when they strike, and thus, save more lives. The more governments, UN agencies, organizations, businesses and civil society understand risk and vulnerability, the better equipped they will be to mitigate disasters when they strike and save more lives.

From there, we understand that the major aim for DRR is to minimize the social, economic and environmental vulnerabilities, in order to deal with the damage caused by the natural hazard based disasters. In term of saving lives from avoidable deaths, it is carried out with the objective to increase the ability of the social community to be able to foreseen, handle, withstand and recover from the impact of extreme natural events (Wisner et al. 2003). With proper DRR approach, it is possible to achieve that particular objective. UNISDR and UNDP stated that DRR framework that works towards increasing the level of prevention, mitigation and preparedness of a society against the adverse impact of natural hazards, should be done within the broad context of sustainable development (UNISDR 2004).

Technological hazard is "A hazard originating from technological or industrial conditions, including accidents, dangerous procedures, infrastructure failures or specific human activities, that may cause loss of life, injury, illness or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage" (UNISDR 2009). With increasing anthropology activities in pursuing better development and better quality of life, more and more technological hazards have been released into the environment, intentionally and unintentionally. Plenty of reports regarding the increasing harmful environmental pollutants detected from the human habitat ring the alarm of having a fast and accurate analytical technique to assist the monitoring process. In the closer decade, many researchers have been putting more and more effort into making the biosensor as a tool in environmental monitoring (EM) for DRR. According to International Union of Pure and Applied Chemistry (IUPAC), biosensor is a self-contained integrated device that is able to provide well-defined quantitative or semi-quantitative analytical data through a biochemical receptor (biological recognition element) which is connected directly to a transducer (transduction element) (Thevenot et al. 1999). Biosensor is made up of a receptor, which will combine with the target molecules and a signal tranducing component, which changes the coupling of targeted molecules into measurable signals (de Las Heras et al. 2008; de Las Heras et al. 2010). Figure 1 illustrates a simple biosensor. Some biosensors can work on their own by showing the analysis outcome by changing colour, some need to be coupled with advances in microelectronics and fiber optics to measure their responses.

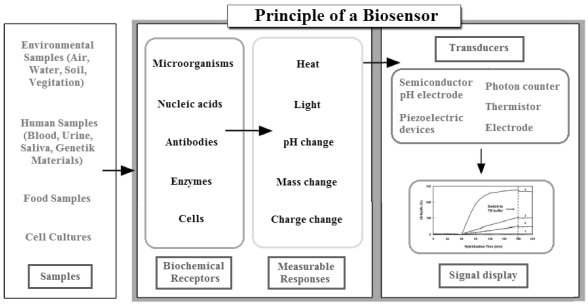

FIGURE 1. Concept and principle of a biosensor (Adapted from Grieshaber et al. 2008)

The history of biosensors can be traced back to 1962, when an experiment on entrapment of glucose oxidase (GOX) onto a Clark oxygen electrode by using dialysis membrane was published by Clark, whom was then known as the father of the biosensor concept (Clark & Lyons 1962). Biosensors have been used in many sectors, namely process control, medical applications, mining, military, clinic, quality control, agriculture, veterinary medicine, bacterial and viral diagnostic, industrial wastewater control, drug production and etc (Sandana 2006; Liu & Lin 2005). Recently, many reports that it also managed to detect environmental pollutants ranging from heavy metals, pesticides, genotoxin, phenol, organic pollutants and more (Schmidt & Pei 2011). These findings have open up the window of possibility of using biosensor as a screening tool in environmental DRR. However, with the current

achievement, is it possible? We simplified the possible role of biosensor in EM and the development of technological disaster with increasing severity level and time. Figure 2 illustrates the stages in EM, where biosensor (early warning tool), RA and risk management come in with increasing level of pollution. From the illustration, we stated the relationship of the severity of technological hazard, with the formation of technological disaster.

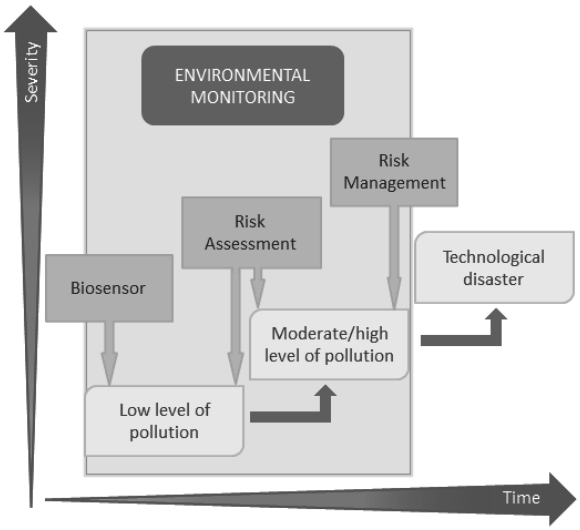

FIGURE 2. Stages in Environmental Monitoring

Conventionally, the hazard identification and hazard assessment steps in human health risk assessment (HHRA) on chemical pollutants in our surroundings were done via exposure to animal models in laboratory and via chemical analysis using advanced instruments or the combination of both. Cairns and Mounts (1990) ever stated that the concentration or intensity of a chemical could be measured with instruments, but only living organisms that can be used to study the toxicity effects of that chemical. That statement somehow encourages the use of animal testing in assisting the risk assessment (RA) process during that era, and it is still being practising by some researchers nowadays. A wide range of organisms that had and still involving in the current RA studies are vary species of algae, fish, daphnia and bacteria (Benecke et al. 1982; van der Schalie et al. 2001; Gu & Choi 2001). As for the HHRA, dose-response data collected from the exposure of environmental pollutants to animal models is used in the exposure assessment later on. It depends on the creation, collection and analysis of data collected from varies species of organisms, terrestrial and aquatic. The assessment results will need to be processed and integrated with organisms, which are with higher level of biological organisation (Munkittrick & McCarty 1995; Munns 2002), when the uncertainty/variability factors (UFs) are taken into account (EPA 2013).

Until today, EM process is usually done by analytical chemistry approach. Analytical chemistry is "the study of the separation, identification, and quantification of the chemical components of natural and artificial materials" (Holler et al. 1996), which can be categorized into classical and instrumental. Classical methods involved separation approaches and qualitative analysis via the physical properties, such as melting point, colour and odor. Instrumental analysis methods are those involving specific instruments that are invented to fulfill the specific field of need. It measured physical quantities of the pollutant, such as conductivity, light absorption, fluorescence or luminescence. In monitoring air quality, instruments like opacity meter is used to measure the presence of haze in the air, scrubbers are used to capture the air pollutants, absorption plates are used to trap air pollutants such as sulfur dioxide on a reactive plate for pollution measurement and chemiluminescence continuous analyzer is used to measure the content of nitrogen dioxide (NO_2) in the air. Water quality monitoring is usually carried out by (i) physical testing, which is the measuring of parameters such as total suspended solids (TSS), turbidity and temperature; (ii) chemical testing, which involves the measuring of pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and the measurement of nutrients (phosphorus and nitrate compounds), total petroleum hydrocarbon (TPH) and metals via standard protocols and instruments.

These instruments are able to detect a wide range of environmental pollutants present in environmental physical factors whether in water, air or soil. EM is a routine process, where environmental samples are collected from the environmental sources periodically. Some of them are run 24 hours a day. Depending on the analysis methods, some environmental samples will be analyzed directly, and some will be pre-treated with specific methods according to the related protocol, and later they will be analyzed using the related instrument operated by well-trained handler. EM via chemical analysis gives very accurate data especially on the types and intensity (concentration) of a group of environmental pollutants appear in the samples. The

use of advanced chemical analysis instruments to assist in the EM process as part of the effort of DRR can be traced back to decades ago (PSP 1990).

BIOSENSOR IN DRR, YES OR NO?

Biosensor research is a hot research area recently, and the trend of the sensor research is moving more extensively towards that direction. Many biosensors that are applicable in medical science and health care have been commercialized and bring good returns. For instant, glucose biosensor is very sensitive and accurate in measuring the glucose level of the patient. Some researchers ever mentioned that biosensor is a hope to replace the current expensive, huge in size and time-consuming chemical analysis instruments in EM and DRR. We are curious about how close that thought is to the reality. After comparing the pros and cons of both approaches, we have come out with a list of five major areas of concern, which play the significant roles in determining the possibility of that to happen in a quinquennium. The discussion will be carried out by comparing biosensor achievements with conventional analytical methods.

COMPLEXITY OF REAL SAMPLE

The real sample in DRR usually refers to the on-site water, air or soil samples. In the environment, real samples usually exist in the form of a mixture, which is a combination of several pollutants, chemicals and particles blend together in the form of liquid, solid or gas. Real polluted water sample for example, would have a number of heavy metals, pharmaceuticals, pesticides, surfactants, grease and oil, small insoluble organic and inorganic particles, household and industrial wastes, pathogenic microorganisms and more co-exist in it. The chemical and physical characteristics of the water, such as the pH (acidity or alkalinity), the colour, the odour, the salinity and the cloudiness would have interfered with the results of the analysis process. When dealing with real environmental sample testing, there comes the mixture of the expected and unexpected pollutants. The approach that has the ability to analyse the real sample without any additional pre-treatment steps is the one that is chased after by the researchers. It would be the "ideal approach" for EM and DRR.

As mentioned earlier, some of the EM via chemical analysis requires pre-treatment of the real samples before the analysis, and some do not. Pre-treatment processes are aimed to remove undesired disturbances in the real samples before proceed with the chemical analysis steps. It usually involve mixing of certain chemicals (e.g.: acid) with the real samples prior to analysis. Taking monitoring of water sample as example, based on the recommended protocol, there is a minimum sample volume required (usually ranging from 50 – 150 mL), water samples need to be stored in specific material of containers, samples have to be acidification with acid sulfuric to $pH < 2$, plenty of reagents have to be prepared and so on. There is also a guideline on how to transport and store the water samples (PSP 1990). As for chemical analysis using invented instruments, some of them besides the need to pre-treat the real samples, it is a much more specific approach in EM in current time. Due to its working principle is based on the chemical properties of the pollutants, where different ions and pollutants will definitely give out unique and specific signals. The signal obtained will be very case-sensitive and one-for-one. When all of the impurities and possible disturbances are removed via the pre-treatment process, analytical instruments will be able to detect all ionic pollutants that exist in the pre-treated mixture of real samples. It is also capable to list out the ionic pollutants which co-exist in the real samples, and also their specific concentration of each.

Biosensor is a sensor made up of biological materials (enzymes, bacterial cells, nucleic acids (DNA or RNA and so forth), antibodies, microorganisms, and etc), which are basically proteins as part of them. Proteins are well known to be denatured by high temperature and extreme pH, either too acidic or too basic. That is a drawback because proteins tend to dysfunction, not only in the above environmental conditions, they also tend to bind with ionic compounds and results in folding and alteration in their structures. Although many reports that their biosensors do not interfere much by the free ions and physical conditions in the real samples, but in some extent, the so-called "real samples" are samples prepared in the laboratory, under very stringent conditions, with de-ionized water, adjusted optimized pH, salinity issue eliminated and with known chemical added. The ion interference studies also are basically studies on the exposure of the "real samples" consisting of several frequent environmental existing ions, with known concentrations (as they are prepared by

the researchers themselves) to the biosensors. The results could not represent the real situations of the actual polluted environment; it also could not give the whole picture of the biosensor response when it is exposed to environmental real samples.

Besides the issues of interference, specificity in targeted pollutant detection is also an aspect to consider. This raised the questions as below:

Is the biosensor specific? Does the biosensor only give out signal when that particular pollutant exists? Or it also will give out signals when other pollutants bind to it (False signal problem)? Is the binding site of the biosensor only couple with the targeted pollutant? Or will it also bind to other non-target pollutants?

If the binding site of the biosensor will have mismatch with non-targeted pollutants, it's not a reliable tool in EM, because we could not be sure about what environmental pollutants actually exist in the real samples when the signal is given out. Again it back to the complexity of the real samples, many pollutants exist all at once in the samples. If the biosensor fabricated is only specific to ionic substances, it might bind with anionic pollutants, cationic pollutants or zwitterionic pollutants. Then there are hundreds of thousands type of pollutants that potentially trigger the signal of that biosensor. Say if the biosensor has a more specific binding site: it only binds to anionic pollutants. Again, the same confusing situation will occur, because there are more than 100 types of anionic pollutants that can exist in the environment. To be specific and accurate is a major issue in EM. In general, biosensors built up of enzymes and nucleic acids are specific to one or more groups of related compounds, while antibodies biosensors are specific to one compound or closely related group of compounds. In term of specificity to a group of related pollutants, biosensors work well. But in term of to be highly specific to a particular type of atoms or molecules, it is still not. So far there is no reported biosensor that can work as an ideal tool, which is specific, accurate and do not require pre-treatment steps in EM with real environmental samples yet.

CONTINUOUS ENVIRONMENTAL MONITORING DATA

Continuous EM refers to a long term ongoing monitoring process of the environmental pollution situations. This is important because environment, which is the living space for human and organisms is not static, it keeps changing its face with the help of different natural cycles (water cycle, carbon cycle, oxygen cycle etc) and also by anthropogenic activity. For instance, the type and concentration of pollutants in the air of a specific area, for example City A, at different moment (whether by month basis, week basis, day basis, hour basis, minute basis or even second basis) will be different. Certain factors will contribute to the changing of air quality and pollutants intensity:

1. The phenomena of wind, where the air moving from a colder place to a warmer place, the blowing wind will bring in other pollutants from other places (City B, C, D…) to City A, and at the same time, brings air pollutants in City A to the next station.
2. The involvement of water cycle, where the surface water in City A is being evaporated and brings along the pollutants which exist in the water, into the air. Raining as part of the water cycle also contribute to alter the pollutant contents in the air, when the rain water dissolve and remove part of them from the air and bring them along into the water sources.
3. The anthropogenic activities, such as the release of toxic gases and chemical vapors from the factories into the air, the spraying of pesticides, the use of motor vehicles, the open burning activity (burning of food, firewood, rubbish, forest etc) and so on, all contribute to the change of pollution level of the air in City A. Every single addition or discontinuation of human activities will make changes in the air pollutants contents and types.

To put it in a nutshell, environment never stop changing, the pollution levels and conditions also the same. A proper EM, which can be used to monitor every single moment of the studied environmental factors, must possess the ability to work continuously. Continuous EM provides us updates from time to time, and allows early detection of potential hazards. This will enable RA to be carried out earlier and thus allows early prevention and solution steps to be carried out. Only the continuous EM will work best in DRR.

Chemical analysis works well in fulfilling this criterion. An analytical instrument is able to analyze a huge set of data at once, giving out a precise data of the pollution situations and can be used in RA and DRR. For example there is a mass spectrometry

known as inductively coupled plasma mass spectrometry (ICP-MS). It is used in the detection of metals and non-metals at very low concentration (as low as part per trillion, $1/10^{12}$). Although the sample preparation and pre-treatment steps for ICP-MS is crucial, which involved the complex filtration process, the dissolve of sample in 2% ultrapure nitric acid (HNO_3), with a total dissolved solids content to be <0.2% and a long list of protocol (Talbot & Weiss 1994), but it could give very accurate data. It can be used to detect metals such as arsenic (As), cadmium (Cd), copper (Cu), iron (Fe), Lead (Pb), Manganese (Mn), Nickel (Ni), Silver (Ag), Zinc (Zn) and chromium (Cr) (PSP 1990). To provide continuous EM, conventional chemical analysis instrument can be used in a continuous monitoring system, which is built close to the targeted environment, with an automated sampling system installed. The sampler will take samples of the environment at a programmed time interval or under programmed conditions. These systems record data on specific parameters, such as colour, conductivity, dissolved oxygen content, pH and turbidity on a routine basis. It is also possible to examine a wide range of potential environmental pollutants with the help of specific analytical instruments. This is a very commonly used EM system in many countries.

Biosensor on the other hand, can provide real-time monitoring data as compared with conventional analytical methods. It is usually small in size (miniature) and portable. It does not require a complicated sampling process. An optimized pollutant-specific biosensor can work just well to confirm the existence of a specific pollutant on the spot, within a few minutes. It is rapid in responding and providing data. But in terms of providing continuous EM data, it is less practical. The stability of the biological materials in the biosensor is easily influenced by the physical factors of the environment. Changing in the environment temperature will cause the alteration or denaturation of the biomaterials, thus distort the accuracy of the data. Biomaterials such as microorganisms (e.g.: bacteria and algae) have their lifespan, they age with time and eventually died. This has somehow increases the difficulty level to maintaining the stability and viability of the biosensor, and also in terms of accuracy and preciseness of the continuous EM data. Coming to continuous EM, it means dealing with a very huge data set regularly and consistently. If an automated monitoring system was to set up with biosensor, it requires a huge quantity of biosensors and a big space to store and dispose them. It also requires a regular replacement of the biosensors with a more viable one and so on. Besides, as mentioned in the previous section, most of the biosensors are not selective to a specific pollutant and are easily interfere by other environmental pollutants in the real sample. The idea of carrying out continuous EM with biosensor is still yet to improve.

REPRODUCIBILITY OF DATA

Reproducibility refers to the ability for the specific study or experiment data to be reproduced again. It is one of the major principles of scientific methods and relies on *ceteribus paribus*, a Latin phrase which is usually refers to "all other things being equal" in English, which in scientific experiments means the control and standardization of all variables. The reproducibility of an experiment can be studied by repeating the entire experiment with the same measures and parameters, and compare the outcome with the previous identical experiment. If the results from both experiments are the same, it is said to be reproducible. Reproducibility of data is one of the aspects to consider when choosing a suitable analytical method for EM and DRR. The reproducibility of the data somehow tells how the valid and correct the data is. In term of EM, reproducibility refers to how close the individual data of an analytical system to one another when it is exposed to the same measures of pollutant several times. In a simpler statement, if the analytical system/tool is exposed to the identical environmental samples (which are prepared from the same environmental sample), and the data obtained are similar or exactly the same, it is said to be reproducible. The higher the reproducibility of an EM data, the more reliable the approach is.

In term of reproducibility, most of conventional chemical analysis approaches are able to produce reproducible data. This is due to the working principle of the analytical chemistry approaches is usually based on chemical reactions. By way of illustration, graphite furnace atomic absorption spectrometry (GFAAS) is a reliable spectrometry technique that has been used in routine EM. It is also used in measuring the concentrations of trace elements (metals and non-metals) in geological, food, clinical and biological samples. In environmental analysis, it is used to examine wastewater, polymers composites, ceramics, and also alloys (Butcher & Sneddon 1998). GFAAS is based on the absorption of light by free atoms

of interested pollutant in specific frequency and wavelength. Different atom of pollutant will absorb light at different frequency and wavelength. These reactions are very specific and reproducible. It is specific, because every environmental pollutant has its own chemical structures, and each component in the structures has its own molecular weight, charges and unique chemical properties. The chemical analysis approach which works fundamentally based on the chemical reactions with specific chemicals, will eventually give out specific outcome. Provided that the amount of the pollutants is the same in both repeated exposure measurement, and all of the independent variables are controlled and kept constant, the analytical instrument is able to reproduce the data. From the aspect of reproducibility, EM with analytical instruments is reliable.

Reported biosensors some are with high reproducibility but some are not. The type of biosensors with higher reproducibility usually involved biomaterials like enzyme and DNA. While for biosensors with lower reproducibility, normally are fabricated using microorganisms. Bacteria are one of the microorganisms which are widely used in preparing a biosensor due to their economic, simple protocols and ability to measure non-polar molecules (which are mostly not responsive to analytical instruments). However, there are also reports stated that the responds of the bacterial based biosensor are different from one batch to another. This is most probably due to mutation of the bacteria cells. Any organisms have the ability to undergo mutation when they are exposed to pollutants and radiations. Microorganisms have a higher rate of mutation as compared to human. Besides, the growth rate of the microorganisms also will be disturbed by environmental temperature, availability of nutrients and the length of incubation time. During the process of culturing the microorganisms, these factors are those that determine how good the quality of the microorganism yields. Take bacteria culture as an example, bacteria cells need to be harvested during the lag phase of their growth to have the optimum responds. The culturing process of the bacteria is ranging from several hours to several days depending on the species. A different of several minutes or hours in harvesting when culturing from batches will results in the different in the intensity of the bacteria. When the same protocol of biosensor fabrication is carried out, but with a different in the bacteria concentration, the resulted biosensor will also have altered in signal intensity and so on. Thus, biosensors which are fabricated from microorganisms are prompt to have reproducibility problem.

Besides that, lifespan as mentioned earlier is also a factor which contributes to low reproducibility. A well maintained analytical instrument will perform just the same way for the same pollutant sample throughout the time. It does not have the problem of aging and dying. While for biosensors, there is an "expiry date" for them. We can understand this by illustrate biomaterials as living organisms or part of organic materials, they get old and eventually stop functioning, or they undergo decomposition process and finally lost their availability to detect the pollutants. Of course instruments have lifespan too, but theirs are much longer as compared to biosensors. Biosensors usually have lifespan ranging from few days to few months. Before the total loss of signal (a sign of expiration) of the biosensor, its signal drops gradually when it gets older. This, again, raises the data reproducibility issue of biosensor.

ON-SITE TESTING

On-site testing in DRR context is about the ability of the pollutant detection testing to be done on the site (targeted environment). If choices are provided, on-site testing would be a better option because that is when real-time monitoring can be done. On-site testing refers to pollutants examination right on the spot. This is crucial to get to know the exact pollution condition at that specific moment in the environment. The on-site real-time pollution data will help in faster decision making and further prevention steps to be initiated during disasters. One of the significant of this is because environment conditions change from time to time. The sample you withdraw from the environmental sources will not remain the same in its original physical and chemical conditions anymore. Take water sample for example, the temperature of the water sample will certainly different from its original source because a different thermal equilibrium process will take place. The algae and microorganisms activity in the water sample also will change the pH, the oxygen content, the turbidity and the amount of organic compounds in the sample. The longer the sample is away from its original source, the lesser accurate is its content to be equivalent to the exact condition of the environment.

Common chemical analysis involved expensive, huge and heavy instruments. They are usually set up in laboratory or monitoring center with specific shock and vibration proof stand or table. EM with analytical methods usually involved periodical sampling by sampler. Samples collected are stored in a specific container made up of pollutant-inert materials, treated with guided protocols (e.g.: acidification, filtration etc) and stored in low temperature and dark condition during the process of transportation to reach the instruments. In spite of the fact that chemical analysis approach can provide very precise and accurate data for stable pollutants, but it could not be used to measure the changeable parameters of the environment. As an example, the establishment of a well requires monitoring of the water quality. It often happened when there were pollutants in the well water, but samples sent constantly to chemical analysis shown negative results. Pollutants are said to be degraded during the process of transportation. With the limitation of the size, sensitiveness and complex protocols which required well-trained operators to perform, it is not possible to carry out on-site testing with conventional analytical instruments.

Biosensors have advantages over conventional analytical methods under this area of discussion. Biosensors are usually calibrated to be small in size, making them portable to be carried around. On-site testing is a selling point of biosensors. If the selectivity issue can be removed, biosensor is a better tool to provide on-site data. One of the most successfully commercialized biosensor in EM was a BOD biosensor. It was fabricated by immobilizing specific species of microorganism, which are able to responds accordingly to the quantity of assimilable carbon compounds in waste waters (Liu & Mattiasson 2002). With BOD biosensor, the testing of BOD analysis can be done right next to the suspected polluted environmental source, and the results will be out within a few minutes. The conventional method to measure BOD, known as the BOD5 protocol, involves the incubation of microorganisms in waste water samples and also the measurement of the volume of the released gases. It requires 5 days to come out with the BOD level of the waste waters. Many organisations actually use BOD biosensor as early warning system for BOD in EM, when the on-site BOD biosensor results show certain level of severity, only then they proceed with the BOD5 standard method to further investigate it. From the above case in point, we can see that to be capable to perform on-site testing is a save in time. Biosensors have the potential to overtake the role of conventional testing protocols in term of this.

ROLES IN RISK CHARACTERIZATION

Risk characterization is the final step of RA, where the data collected from Dose-response Assessment and Exposure Assessment steps are interpreted to finalize the risk of the studied component (hazard) and to assist in further DRR steps. RA is a process which according to UNISDR is "a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability including the physical social, health, economic and environmental dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities in respect to likely risk scenarios" (UNISDR terminology on disaster risk reduction 2009). In HHRA, dose-response assessment is where an assessment is done to describe the relationship between the concentration (amount) and conditions of a pollutant (agent) to the likelihood and severity of adverse health effects of exposed human community (EPA 2012). While exposure assessment measures the numerical estimation (in terms of magnitude, frequency and duration) of dosage or exposure of a pollutant to human in the environment.

Dose-response assessment involves a study on human health related pollutant exposure. Which comprise of the diagnostic of human health and also abnormalities of organs and etc. Exposure assessment implicates the collection of human data on uptake (via ingestion, inhalation and contact) of the pollutant. Both of these assessments could not be perform with either conventional analytical methods or via biosensor approach. Analytical approach can provide complement data for stable metals and non-metals pollutants, while optimized specific biosensors can indicate the attendance of targeted pollutants, but none of them can perform human exposure measurement and disease diagnosis at the same time. Chemistry analysis is suitable to be used in hazard identification and hazard assessment steps in RA, where it gives precise and accurate data. Biosensors are fabricated towards the aim to replace the role of chemistry analysis, thus, it holds the same potential role in assisting the same steps in RA.

CONCLUSION

Biosensors have their advantages over the conventional analytical methods, such as they are very easy to operate, miniature, portable, require minimum sample preparation, can perform with small amount of samples and relatively economic. But, pertinent to the aspects of specificity, continuous monitoring and reproducibility, we would say more works need to be done to improve these aspects before the biosensors can be applied in RA and EM assisting the DRR program.

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