International Journal of Microbial Science, Volume 1, Issue 1, December 2020, pp.47-53
Available online at https://internationaljournalofmicrobialscience.com/

Review

Microbial Engineering for Natural Disaster Management: Review

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Article Info

Article history:
Received: November 14, 2020
Accepted: December 1, 2020
Published: December 10, 2020

Keywords: Natural disasters, Microbial, Engineering, Disaster Management

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Abstract

The risk of an outbreak of natural disaster increased in recent years due to climate change, pollution, and imbalance in the environment. As a result, sudden rise of infectious disease and damage to the ecosystem has occurred. The lack of potable water, sanitization and maintenance of hygiene, food and displacement of people led to increase in communicable disease. The catastrophic situation occurs due to natural calamities like flood, earthquake, cyclone, and volcano, which damages the environment, human life, and animals, reducing global economic growth and public health. Various strategies are used to manage the effect of natural disasters. Microbial engineering could be used as a supportive approach for various pre and post-disaster management strategies. For effective implementation of microbial engineering in management strategies requires knowledge of Microbiology, Ecology, biochemical mechanisms and field engineering. Due to microbes' ubiquitous nature and small sizes, these can be successfully manipulated for desired functions in question.

1. Introduction

A natural disaster is unfavorable result that occurs due to earthquake, flood, volcano and cyclone. It causes enormous damage to the water ecosystem, land, and human as well as animal life, which is not good. It is calamity [1]. A disaster like a tsunami, earthquake, which results in the displacement of people may be responsible for the spread of infectious disease. The destructive catastrophic event puts millions of lives at risk. Management of natural disaster is poor and there is unavailability of a technique that can reduce the effect of natural disaster.

There are ways that may be helpful in post-disaster management, for example, by immediate rescue of people, by providing food and water, rehabilitation of people and sanitization. Disaster often leads to poverty. After the disaster, infectious diseases and vector-borne disease such as cholera, typhoid, and diarrhea are increased. Displacement of people is the reason for the contagious disease [2]. It is essential and necessary to manage it. In this review article, we examined potential of microbial engineering as a supportive approach for the various pre and post-disaster management strategies and probable role of microbial robots in disaster management.

2. Catastrophic situation:

A natural disaster is a consequence in nature that damages nature and troubles the safety of the locality [3]. It damages the natural ecosystem and human life and generates outbreak of infectious disease, vector born disease, and lots of health problems. Hydro-meteorological disaster includes flood. It is the frequent natural disaster, and most of the infectious diseases are caused by flood due to displacement of people and contaminated water. Earthquake is an example of geophysical disaster. The outbreak of infectious diseases may occur due to the displacement of people having limited access to food and safe water.

Flood is frequently occurring natural disaster. It is one of the significant reasons for deaths and a primary reason of loss of economy [5]. The 1953, storm was terrible to strike on the North Sea region of the Netherland, Belgium and England, where more than 1,800 people drowned. Farms got washed due to flood. As well, it caused loss of farmland in the huge amount [6]. The volcano is one of the major natural disasters as it occurs uncertainly, and affects the environment, health of people and economy.

Gases which come out of volcanic eruption are hazardous to human health as those affect the mucus membrane and upper respiratory tract [8]. Mt. Tambora is one of the destructed eruptions ever occurred in history, where 1, 20,000 people lost their lives. In Indonesia, a series of violent and destructive volcanic eruptions occurred on August 27, 1883. Its frequency was very high that it could make seven rounds worldwide; it killed 36,000 people in the world [10]. Earthquake is an extremely damaging natural disaster. It causes the shaking of the earth surface. It has a lot of side effects. It damages geological feature, infrastructure and damages human and animal life [28].

In Haiti, a huge deadliest earthquake occurred on January 12, 2010, where 212,000 deaths occurred, 512000 wounded, and 1000000 became homeless [12]. Peru earthquake occurred on August 15, 2007; it destructed Peru's western coast, where 514 people killed and 1090 injured [12]. Cyclone is one of the most harmful natural disasters, in which, air mass is travelled around low atmospheric pressure.

It caused damage to building, and people around the coastal area [29]. The Bhola cyclone was extremely damaging as it killed 3,000,000 people in the affected area in 1970 [14]. On April 29, 1991, Bangladesh was hit with a most destructive cyclone, in which, 240km/hr wind speed was recorded. Claiming death due to cyclone was 1, 45,000. It was one of the largest natural disasters [15].

3. Post-disaster effect:

Post-disaster is the condition that occurs after a disaster. Human life gets significantly affected after any natural disaster [18]. Plants and animals too severely exaggerated after a natural adversity. The major impact of disaster causes deaths, injuries and damage to physical infrastructure (residential housing, roads, telecommunication and electricity networks, and other infrastructure [18]. Interruption of electricity supply, as well as telecommunication, causes heralds in routine daily life. [19].

Also, a large quantity of solid waste accumulates in construction waste, dead animals, and damaged trees. The waste, if not collected, and not adequately get disposed of, creates severe problems. It causes nauseous as well as foul smell. Again, this contaminates water bodies, thereby causing various water-borne as well as vector-borne diseases like diarrhea, cholera, typhoid, dengue malaria, hepatitis, leptospirosis and others. If the diseases get spared at the community level, it causes deaths, and this community-level spared of diseases exerts additional pressure on health care facilities.

In Bangladesh an outbreak of diarrheal disease after flooding was reported in 2004 involved more than 17,000 cases. Outbursts of leptospirosis occurred due Typhoon Nail in Taiwan, Republic of China, in the year 2001 the same scenario was reported in Mumbai, India and in Argentina after flooding in 2000; 1998 respectively. Due to meteorological events such as cyclones, hurricanes, and flooding, vector breeding sites get affected which results in the transmission of vector-borne diseases. Initially, flooding may wash away existing mosquito-breeding sites but standing water and overflow of rivers can create new breeding sites. Due to this situation vector population get increase and disease transmission rate get accelerated.

Usually person to person transmission is never seen in the case of tetanus; instead it is caused by a toxin secreted by the anaerobic tetanus bacillus *Clostridium tetani*. Around 106 cases of tetanus, including 20 deaths, occurred in Aceh and peaked during 2 ½ weeks after the tsunami [19]. Natural disaster leads to food insecurity. It poses a significant problem of food security because of several reasons; such as migration of people from their settlements, deaths of people, decrease in agriculture productivity and increase in food prices as well as essential commodities [26].

4. Disaster Management

Disaster management can be defined as the organization and the management of resources and responsibilities for dealing with all humanitarian aspects of emergencies, particularly preparedness, response, and recovery, to lessen the impact of disasters [27]. Prompt and appropriate action should be taken to mitigate the effect of disasters. Safe and convenient accommodation, including uninterrupted supply of foods as well as health care facilitates should be available. To prevent outbreaks of various diseases after any natural disaster adequate supplies of clean water per person for drinking, bathing, washing and excreta disposal should be ensured also various kinds of waste accumulated during the situation should get properly managed.

Vector control is the primary public health concern for community level transmission of various diseases. To control various vector-borne diseases, appropriate actions should be taken, for example, the regular spreading of insecticides to control vectors as well as pest, proper and effective waste management, and distribution of insecticide-treated nets in public health distribution programs for effective management of various vector borne diseases.

Public health vaccination programs should be conducted for sheltered populations after a natural disaster. Regular sanitation practices should be carried out to stop the community level spread of diseases. Supply of medical commodities should be regular, also healthcare workers and medical personnel should get properly trained to handle health crisis due to natural disaster [33]. Disaster prevention, mitigation, preparedness, response and recovery are the important steps disaster management cycle.

5. Disaster management cycle:

Prevention phase involves the actions taken to eliminate or avoid natural harmful events and their effects [30]. Mitigation-strategies put in place to minimize the effect of a disaster. Initial actions are taken immediately after the event. It involves saving lives of people and to minimize the hazards created by a disaster. Recovery is regaining the community to normal. Ideally, the affected area should be put in a condition equal to or better than it was before the disaster took place [34].

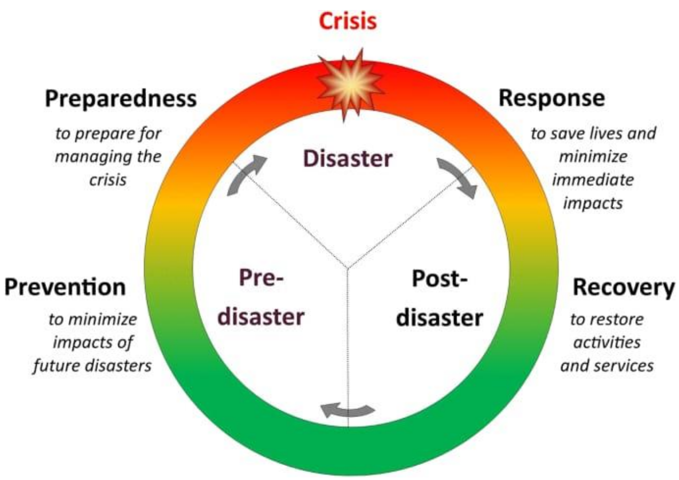

Figure 1: Disaster management cycle [31].

6. Role of microbial engineering in natural disaster:

6.1. Disasters associated with climate and agriculture:

As per the current scenario of climate change, the future of agriculture is seems to be in danger. Climate change and climate-related disasters directly influenced biotic and abiotic factors that are the main parts of agro ecosystems leading to global food insecurity [25]. Climate change and related disaster events have adversely influenced plant physiology which ultimately led to decreased agricultural productivity, thereby causing significant economic losses in the agri-food sector in the last decade. In this context, drought stress is the most problematic stress in the current scenario of climate change [25].

Microbiome engineering may be used to overcome this situation. It has recently emerged as an alternative to modify and promote positive interactions between microorganisms and plants to improve plant fitness in stress condition [25]. Microbial engineering may be applied to enhance the fertility of soil, which is usually gets reduced during heavy rain fall and flooding. In the recent years, our understanding about the composition, diversity, function, and plant microbiome dynamics has significantly increased due advances in high throughput sequencing techniques [24]. Genetically modified microbes may become very effective biofertilizers as well as potent biopesticides. Engineered plant-microbe interaction may become useful for survival of agricultural crops in the extreme stress condition.

A next green revolution is required in the current scenario of climate change to achieve complete food security in coming years, with innovative and advanced methods as well as approaches to achieve more sustainable development of agriculture. In this context, the study and use of complete microbiomes or core microbiome from extreme environments could represent a promising alternative to increase crop yields under various stress conditions [25]. Microbiome engineering has been proposed as a new platform for the next green revolution [25].

6.2 Genetically Modified Microorganisms (G.M.O.s) for reduction of pollutants:

Natural disasters such as volcanic eruption, earthquake, forest fires and flooding generate many pollutants in the form of heavy metals and toxic gases as well as chemicals. G.M.O.s could be efficiently used for their reduction. Bioremediation is an economical and safe alternative compared to other physicochemical methodologies for abetment of pollutants [27]. Microbial engineering could be used to develop strains of microbes having capabilities to metabolize diverse range of pollutants in short period of time.

Bio-augmentation is one of the approaches of bioremediation, in which microbes, either single or as a mixed consortia, are added to polluted sites for removal of contaminants. This can be performed either by adding microorganisms that are having natural metabolic capabilities for removal and/or degradation of toxic compounds [27]. This unique feature for microbes having ability to degrade huge array of pollutants is due to plasmids, carrying novel genes. Bio augmentation can also results in the transfer of plasmids containing the necessary genetic material among the diverse populations of microorganisms.

Besides, the plasmids are used as vectors for genetic transformations among the microbes. Genetically engineered plasmids could become effective for bioremediation. Recent advances in the field of molecular biology have been applied to microbial genetic engineering to construct microbial strains having novel features with desirable characteristics [27].

There are several reports that show the development of recombinant bacterial systems for the degradation of various pollutants. The Chakraborty group created the first genetically engineered microbe in 1971 [36]. The patent for this was approved in 1980 by the United States Supreme Court. The genetically modified microbe was a variant of *Pseudomonas* and was capable of degrading crude oil constituents. For effective implementation of microbial engineering as management strategies it requires knowledge of microbiology, ecology, biochemical mechanisms and field engineering [26].

6.3 Microbial engineering and biosensor technology:

Biomedical engineering plays an important role in practical health care delivery and is governed by multi-disciplinary clinical and research teams those are engaged in developing strategies for the diagnosis and management of many medical conditions. Further, biomedical engineering has demonstrated a remarkable capacity to restore health systems in resource-limited environments by improving diagnosis and treatment. For rapid identification, a cellphone-based light microscope has been demonstrated potential for clinical identification of malaria and tuberculosis by using the fluorescence with light-emitting diode (L.E.D.) excitation [23]. The rapid onset of calamities and their overwhelming effects work together to increase injury and deaths in affected areas. In resource-limited settings, confirmatory laboratory tests are rarely available.

6.4. Role of microbes in climate change:

Recently, climate change and global warming is a serious concern. Microbes are involved in many natural processes, like cycling of nutrients such as carbon and nitrogen. Microbes play both positive and negative role in climate change, making them a vital component of climate change models. The role played by microbes in climate change cannot be ignored. Both natural and human-persuaded fluctuations of carbon dioxide, methane and nitrous oxide are conquered by microbiology. Microbial engineering may be a useful tool for reducing greenhouse gases either by low emission or by maximum greenhouse gas absorbance [35].

6.5 Role of microbes in absorbance of toxic radiation:

A nuclear emergency triggered by a natural disaster can be the most complex calamity to handle. There are some microbes, capable of absorbing nuclear waste and by engineering them, the possible damage due to radioactive waste could be minimized up to some extent [36].

7. Conclusion:

A natural disaster has an adverse effect on the ecosystem caused by various types of calamities like earthquakes, floods, volcanic eruptions, cyclones, and drought. Disaster cannot be aborted, but it is possible to reduce its effects. In turn, post-disaster management is essential to achieve fast recovery. Microbial engineering may be used as a supportive approach for the various pre and post-disaster management strategies. According to the hostile field conditions, designing genetically modified microbes is the main limiting factor leading to the success in the area of disaster management. The effective release of engineered microbes is challenging due both technical and ethical obstacles which leads to constraints. Further, it needs lots of research and field study in future.

Acknowledgement:

The authors are thankful to Dr. B. S. Yadav, Principal, Karamshi Jethabhai Somaiya College of Arts, Commerce and Science, Kopargaon and Rajesh Dhakane, Department of Microbiology, Jayawantrao Sawant College of Commerce and Science, Pune, Maharashtra, India, for their valuable comments to improve the quality of this manuscript.

Authors' Contributions:

AP: Developed an idea. YC, NS, JP, and JM: Analyzed the data.

Competing Interest: Authors declare that no competing interest exists among them.

Ethical Statement:

Since it is a review article, ethical permission was no required. **Grant Support Details:** This work was not funded by any agency.

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Cite this article as: Pawar A, Chaudhari Y, Sonawane N, Patil J, Maule J. Microbial Engineering for Natural Disaster Management: Review. Int. J. Micro. Sci. 2020;1(1):47-53.