Selection of 10 Emerging Technologies in 2017: Pollution & Contamination Response Technologies for Sustainable Development of Korea†

Jonghwa Park[1,*], Yoon A Kim[1], and Seung Ryong Lee[1]

Abstract

In 2017, KISTEP selected 10 emerging technologies, based on the issue of 'Environmental Pollution in Daily Life'. The issue of 'Environmental Pollution in Daily Life' was subdivided into 10 pollutants for further study, and detailed research was conducted to identify public needs through literature review, social data analysis, public polls, and review by specialists. Candidate emerging technologies were identified based on the database of future technologies, news clippings, and the recommendations by specialists. The final list of 10 emerging technologies were selected from the candidate pool through priority assessment by specialists and researchers, followed by social and economic impact assessment.

The selection for this year was focused on emerging technologies to counter environmental pollution in daily life, and support Korea's sustainable development. Environmental pollution has been intensified by past government policies prioritizing economic growth over environment. Damage from sensory and information pollution, which were not recognized as pollution in the past, has been increasing. Selection of public goods-related technologies as emerging technologies is expected to have significant implications.

Keywords: environmental pollution, 10 emerging technologies, sustainable development

1. Introduction

The increased influence and rapid development of science and technology have led to higher expectations regarding the social roles of emerging technologies. Nowadays, technologies are not only considered as the growth engine for new industries, but also as the means by which to address important issues faced by society, such as social stratification, low fertility and population aging, and climate change. National projects such as Research & Solution Development and public benefit programs are currently being operated. For effective utilization of limited resources, strategic selection of core technologies is needed. In this regard, research on the methodology to effectively assess core technologies based on thorough assessment of societal changes and public needs.

KISTEP has annually selected and announced 10 emerging technologies since 2009, and since 2013, has incorporated the betterment of future Korea as a focal perspective. KISTEP's selection process

Division of Technology Foresight, Korea Institute of S&T Evaluation and Planning (KISTEP), 12F Dongwon Industry Bldg., 68 Mabang-ro, Seocho-gu, Seoul, 06775, Korea

* Corresponding author: parkjh@kistep.re.kr

† This paper is based on the study for annual selection of KISTEP 10 Emerging Technologies as summarized in Issue Paper 2017-01 published by KISTEP.

emphasizes the social role of technologies, by first selecting the core issues of future Korean society, and then selecting emerging technologies with both technological and economic impacts, and the capacity to address these issues. The issues considered thus far include the aging of society, increasing safety hazards, increasing inequality, and the need to enhance the quality of life and social trust.

Among the numerous issues arising as side-effects of technological development prioritizing economic growth, the emergence of new types of pollutions has been attracting public attention to the role science and technology can play in sustainable growth. Despite technological developments, environmental pollution is still a serious issue. Especially over the last decade, new pollutants such as particulate matters have emerged, which have high impacts on human health. Light, noise, and odor, which were originally not considered as pollutants, are becoming bigger concerns due to industrialization and urbanization, further emphasizing the role of science and technology in providing solutions to social issues.

Table 1 shows an overview of the selection process of KISTEP Emerging Technologies. The selection process consists of two stages: analysis of future needs and selection of emerging technologies. The analysis of future needs was conducted in five stages: selection of target issues, literature review on pollution, big data analysis, identification of detailed issues & needs, and public survey. The selection of emerging technologies was conducted in four stages: compilation of technology pool, identification of candidate technologies, selection of emerging technologies, and in-depth analysis for each technology.

Table 1. Selection process of KISTEP Emerging Technologies

Stages	Steps	Methods
Analysis of Future Needs	Selection of target issues	- Review of domestic and international research
	⇩	
	Identification of issues and future needs	- Survey and analysis of current trends - Expert reviews - Big data analysis on social media
	⇩	
	Survey of public needs	- Public poll on mobile platform
	⇩	
Selection of Emerging Technologies	Candidate pool of future technologies	- Utilization of diverse data sets and internal DB - Analysis of means of addressing each future need through science and technology
	⇩	
	Selection of 10 emerging technologies	- Review by internal research staff and technological experts - Technology prioritization evaluation
	⇩	
	In-depth analysis of emerging technologies	- Trend analysis of research, industries, and markets of each technology - Economic and social impact analysis of technology

2. Analysis of Future Needs

2.1. Issues for the Selection of 2017 Emerging Technologies

'Enviornmental Pollution in Daily Life' was selected as a core issue in Korean society in 2017, through a comprehensive review of news, media, and major domestic and international future issue reports by internal and external experts. At a summit held during the 70th United Nations General Assembly in September 2015, the Sustainable Development Goals (SDGs) of the "The Agenda 2030 for Sustainable Development" was ratified and has been in effect since January 2016. The SDGs propose 17 goals and 169 tasks to bring concerted actions of the international society for next 15 years, for humanity and the Earth. (UN, 2016) The three pillars of economy, society and environment were adopted as the main agendas, and the SDGs were proposed as a means to resolve socioeconomic issues including poverty and human rights, and environmental issues regarding climate change, depletion of ozone layer, and loss of biodiversity. Many of the goals closely relate to the issue of environment, for example, 6. Clean Water and Sanitation, 7. Affordable and Clean Energy, 11. Sustainable Cities and Communities, 12. Responsible Consumption and Production, 13. Climate Action, 14. Life Below Water, and 15. Life on Land.

The Global Risks Report 2016 by the World Economic Forum (WEF) categorized risks to the global economy into economic, environmental, geopolitical, societal, and technological risks, and identified 29 risk factors. The report recognized the adverse effects from daily life pollution and environmental pollution including climate change, biodiversity loss and ecosystem collapse, man-made environmental catastrophes, failure in urban planning, food crises, and water scarcity as major environmental and social risks, and included information issues including critical information infrastructure/network breakdown, cyberattacks, data fraud and theft) as technological risks.

In the 2016 Environmental Performance Index (EPI), which is biannually reported by Yale University and Columbia University, Korea was ranked the 80th out of 178 countries. In particular, Korea was ranked 173rd in air quality due to the impact of particulate matters, and was also found to be vulnerable in fields of public health, climate, and energy. Korea's relatively low EPI relative to GDP reflects its emphasis on economic growth without sufficient measures to manage pollution.

Based on the aforementioned results of literature review and internal workshops, various pollution and contamination caused by human activities were selected as target issues. This includes not only conventional forms of environmental pollution such as air, water, and soil pollution, but also includes recently emerging issues such as sensory pollution[2], chemicals in daily life, and mismanagement of invasive species. The topic also encompasses the concerns related to nuclear power plant incidents intensified by the earthquake which occurred in Gyeongju region in September 2016, and includes issues regarding radiation exposure in daily life. It also covers information pollution issues caused by unnecessary or erroneous information on the Internet, which tends to intensify with progressive informatization. The responsibility of resolving these manmade pollution and contamination occurring as side effects of industrialization lies with humankind. It aims to emphasize the role of science and technology in resolving these issues.

2.2. Analysis of Pollution and Contamination

Types of pollution from industrialization can be categorized into daily life pollution, radiation risk, and environmental pollution. Pollution in daily life

2 Seonsory Pollution refers to 3 major types caused by light, noise and odor, which distrupts vision, audibility, and sense of smell

includes sensory pollution from light, noise and odor, information pollution, and chemicals in daily life. Radiation risk refers to issues related to nuclear power plant incidents and radiation to which people are exposed in daily lives. Environmental pollution includes pollution of air, water, and soil, and disruption by invasive species.

2.2.1. Sensory Pollution

Korea's light pollution severity is ranked the second highest among G20 countries, following Italy (90.3%) (Falchi, F. et al., 2016). Of 125,000 total civil complaints over sensory pollution reported and registered in 2015, the majority were related to noise and vibration. Floor impact noises in apartments sometimes develop into conflicts between neighbors; in Hanam, Gyeonggi, complaints over floor noise escalated to the murder of a couple in their 60s who lived in the upper floor in 2016. During the last decade, civil complaints regarding odor increased 3.4-fold, and in particular, complaints from outdoor workplaces located in designated odor management zones were dramatically increased. Regarding the source of odors, 65% originated from eateries, agricultural manure, and sewers, and approximately 13.2% of total civil complaints regarding odor concerned residential facilities and small businesses, including printing services and laundry facilities. The increased ambiguity of the boundary between residential and commercial areas has been intensifying noise and odor pollution issues. Public concern over the adverse effects of sensory pollution on the human body is rising. Human exposure to light exceeding a certain level of luminosity suppresses the secretion of melatonin, a biorhythm controlling hormone, which results in increased fatigue, a weakened immune system, and growth impairment for children. Exposure to excessive noise results in an increased heart rate, contraction of peripheral blood vessels, and digestive disorder, and can lead to the long–term effects of blood circulation disorder from hormone secretion at the endocrine glands, and excessive stress.

2.2.2. Chemicals in Daily Life

Risks of products with substances which may induce endocrine disruptors, nanomaterials, and hazardous chemical substances were increased. Endocrine disruptors have emerged as one of the top 3 environmental issues, along with ozone layer depletion and global warming, raising concerns over the possible worldwide threat to the ecosystem. According to the UNEP report *Marine Plastic Debris and Microplastics*, it is estimated that 4.8 million to 12.7 million tons of plastic washed into the oceans in 2010 alone. Public anxiety regarding exposure to chemicals in daily life has increased following the lethal humidifier sterilizer issue of 2016 [3], as illustrated by massive refund incident of Median toothpaste. Insufficient education and information on chemicals in daily life has intensified public anxiety.

The adverse effects of endocrine disruptors and nanomaterials on the human body and environment are severe and difficult to detect. During the humidifier sterilizer incident, there was a great deal of conflict in terms of proving the sterilizer's impact on the human body, and the majority of reproductive system disorders induced by endocrine disruptors require a long time before symptoms occur. Nanomaterials may be absorbed into the human body through the use of nanomaterial products, and cause brain or cardiovascular disease (Kim, E., 2010). There are reports of decreased fertility, feminized male reproductive organs, thyroid malfunction, and immune system issues in wildlife caused by

3 Oxy humidifier sterilizer incident caused 239 deaths and 1,528 cases of serious fibrosis in lung tissue (Asian Citizen's Center for Environment and Health).

contamination from endocrine disruptors (Kang, C., 2007), which may lead to a decrease in the population and ecosystem collapse in the long-term. Microplastics may accumulate in the food chain, as predators ingest contaminated prey (Greenpeace, 2016). Residual nanoplastics may discharge toxic chemicals into seawater, or may adsorb marine chemicals, both resulting in the induction of toxic materials in the marine ecosystem (Greenpeace, 2016).

2.2.3. Information Pollution

Information pollution refers to the adverse effects of information overflow as society becomes informatized.

The present study focuses on adverse social phenomena originating from information exchange through SNS and the Internet. Information pollution was categorized into information overload, harmful information, information behavior, and associated negative social phenomena were classified accordingly to examine their respective causes. Excessive provision of information due to developments in SNS leads to a decline in perception, decrease in work efficiency, and psychological damage. Information fatigue syndrome causes symptoms such as impaired judgement, anxiety, increased self-doubt, and scapegoatism. According to the SNS Usage Statistics of Korea in 2011, 40% of SNS users answered that their stress was increased by using social media (Dong-A Ilbo, 2011), and some even avoid using SNS due to various reasons including feelings of relative deprivation. Diversification of SNS and Internet media leads to an increase in malicious posts (comments), false information, and spam email. Damage from the proliferation of false information through SNS is characterized by the uncertainty of responsible parties due to the process of proliferation and exaggeration. "Post-truth," which was selected as the word of the year by Oxford Dictionary in 2016, means "relating to or denoting circumstances in which objective facts are less influential in shaping public opinion than appeals to emotion and personal belief." The issue of school violence and bullying has extended from physical violence to the emotional violence of cyber-bullying, and in particular, closed SNSs (instant messaging such as Kakaotalk) are usually the forum for cyber-bullying.

Differences in individual behavioral tendencies (fact-checking) exist when faced with information overload, and serves as the source of various social conflicts. Neglecting to fact-check results in the proliferation of harmful information. Recently introduced systems of SNS, including autocomplete suggestions or automatic adapted information provision, leads to exposure to biased information, if individuals do not make an effort to seek out diverse opinions. Repeated exposure to biased information may lead to the increase in mutually slanderous posts. Lack of individual and social awareness has also lead to rampant violations of copyrights and privacy.

2.2.4. Radiation Risk

Exposure to radiation can occur in our daily lives. Laborers who handle radioactive materials are at risk of repeated exposure. Contaminated food and products may lead to internal exposure. High level radioactive waste from nuclear power plants and industrial facilities increases risk of radiation accidents. Terrorism activity using radioactive material from industrial, medical and experimental equipment can also pose a threat.

Due to the increased risk of earthquakes on the Korean Peninsula, risks of nuclear power plant accidents has increased. Following the Gyeongju earthquakes of September 2016, fears that Korea is no longer safe from earthquakes arose, which led to concerns over nuclear reactors designed to

withstand earthquakes up to magnitude 6.0 on the Richter scale. Kori Nuclear Power Plant in Busan is the largest nuclear power plant complex in the world, and if an accident were to occur, the number of casualties is estimated to be approximately 20 times that of the Fukushima accident due to the high population density (Greenpeace, 2012).

Emergency response is also needed for possible nuclear power plant accidents in neighboring countries. On February 2, 2017, Tokyo Electric Power reported that the highest radiation level of 530 sieverts (sv) per hour was measured at the containment vessel of reactor 2 in Fukushima Daiichi Nuclear Power Plant. Thus, the anxiety over Japanese radiation continues, especially after the Fukushima Daiichi nuclear accident in 2011 (The Hankyoreh, 2017.2.3.). This level of radiation is 7 times higher than 73 sieverts, which was measured one year after the incident in 2011. Human exposure to 73 sieverts can lead to death in less than a minute. Currently, there are 13 nuclear power plants on the Chinese shores near the Korean Peninsula, and more than 100 plants are under construction or in the planning process. Therefore, international measures to mitigate the damage in the event of possible accidents involving Chinese nuclear power plants are required.

2.2.5. Invasive Species

Korea's EPI ranking for Biodiversity and Habitat has continued to fall for the last 4 years, and Korea was ranked the lowest compared to other countries in 2016. Many non-indigenous species that were imported without review as pets are already classified as invasive species by other countries or have the potential to turn invasive. Problems arise as these species are frequently abandoned. There are cases in which certain species were imported for a specific purpose, but later failed to achieve their intended purpose and became an invasive species. Giant apple snails were adopted for eco-friendly farming, but their high reproduction rate and appetite led to damage to agricultural produce, and the deterioration of the ecosystem.

The annual loss to the global economy caused by invasive species has reached approximately 1.67 trillion KRW (Institute for European Environmental Policy (IEEP). 2016). There has been an increase in invasive species due to advancements in vessel and aircraft technology, increased immigration and travel, trade liberalization, and increased international trade. According to "Global Exchange and Accumulation of Non-native Plants," a paper published in the journal Nature, 13,168 invasive plant species have been spread outside their native habitat due to human intervention. This number accounts for 3.9% of the world's plant species, and is almost equal to the total number of indigenous plants found in Europe. In 2008, damage in Europe caused by invasive foreign species amounted to approximately 16 trillion KRW (The Kukmin Daily, 2015), and damage to agriculture caused by insects amounts to 30 to 40% of the global yield, with which 1 billion persons could be fed (The Segye Times, 2016). Some alien species can act as carriers of certain diseases (mainly insects), and a number of them are reported to be physically hazardous to humans. Examples include yellow fever, Japanese encephalitis, malaria, Zika fever, and African sleeping sickness. Global health costs caused by invasive insects, including mosquitoes which carry dengue fever, are estimated as 6 billion USD (The Segye Ilbo, 2016).

2.2.6. Air Pollution

The annual number of days on which particulate matter warnings were issued is increasing every year (Seoul Air Quality Information), and measures to monitor and mitigate PM2.5 are insufficient. International air pollution indices report that Korea's air pollution is quite severe. In the Better Life Index

(BLI) of 2016, Korea was ranked the lowest among 38 countries regarding air quality. Korea was also ranked 160th in the EPI regarding air quality. According to the OECD report "The Economic Consequences of Outdoor Air Pollution," Korea will face the highest premature mortality rate and the biggest economic damage from air pollution among member states in 2060. It is predicted that if Korea does not take additional measures to mitigate air pollution, the premature mortality rate in Korea will steeply increase by 3.1-fold, from 359 deaths per one million population in 2010, to 1,109 deaths per one million population in 2060. Korea is the only country among the major OECD member states with a premature mortality rate forecast exceeding 1,000 deaths. Korea would also suffer from the largest economic damage, reaching up to 0.63% of the GDP. It is predicted that annual worldwide GDP loss, from increased medical costs, decreased labor productivity, and decline in agricultural yield, due to diseases caused by air pollution would reach 1.6 trillion USD (3,015 trillion KRW) in 2060.

While larger particulate matters (PM10) entering through the nose and the mouth only reach up to bronchial tubes and lungs, ultrafine particulate matters (PM2.5) may reach the alveoli, where gas exchange takes place, and affect blood vessels and other organs. Thus the impact of ultrafine particulate matters needs to be assessed continually. According to WHO, a 10$\mu g/m^3$ increase of PM2.5 will lead to an 0.9% increase in the mortality rate, an 1.3% increase in the mortality rate from respiratory diseases, and an 1.1% increase in the mortality rate from cardiovascular diseases. Ultrafine particulate matters were classified as Grade 1 carcinogens in 2013. According to a Taiwanese study on 23,000 subjects, long-term exposure to PM2.5 increased the chance of liver cancer (Pan, W. C., 2015). Air pollution may not only directly affect organisms, but also have impacts on soil and water pollution through meteorological phenomena. Air pollutants may move through air and accumulate in coastal waters, damaging the marine environment. Sedimentation of nitrogenous pollutants has been linked to the steady increase of nitrate concentration in the East Sea, Yellow Sea, and East China Sea (Kim, I. N. et al., 2014).

2.2.7. Water Pollution

The numbers of days in which algal blooms appear in Nakdong River is increasing, from 100 days in 2013, to 143 days in 2014, and to 171 days in 2015. Eutrophication caused by organic matters in domestic sewage and manure is the cause of algal bloom, which turns the water into "dead zones" uninhabitable to fish and other aquatic organisms. Water pollution may impact the human body and give rise to social issues. Heavy metals and organic compounds from synthetic detergents and agricultural pesticides do not degrade and pollute the water, threatening the aquatic ecosystem. These chemical compounds may also accumulate in the human body through consumption of water or marine products. Such adverse effects may also lead to insufficient clean drinking water, and a lack of water resources. The Ministry of Environmental Protection of the People's Republic of China's considerable spending on the prevention of water pollution suggests a potential boom in the water quality management business. Due to the greater demand of sewage treatment expected, China's sewage treatment market is expected to grow to reach CNY 69.6-86.7 billion within the next three years (Xinhua News Network, 2015).

2.2.8. Soil Pollution

Urban expansion leads to the development of former industrial, army base, and mining areas, turning soil pollution which took place in the past into serious socioeconomic concerns. Following the

large-scale relocation of the US armed forces in Korea, serious soil pollution was found in areas formerly used as bases by for more than 50 years. Reported cases include oil contamination in Gimje US missile base, oil and benzene contamination in Noksapyeong station near Yongsan base, and detection of dioxin in Camp Market of Bupyeong (Ecomedia, 2015). Numerous cases of soil pollution being detected in former industrial areas, after multiple changes of ownership, have led to conflicts over attribution of responsibility. Because the soil is immobile, large amounts of contaminants may not be visually apparent, and even pollution tests of nearby regions mostly show clean results (Park, Y. H., 2002). Although soil pollution is contained a limited area, the contamination persists even after eliminating its source. there is also the possibility of additional pollution through the spread of pollutants to other media, including nearby subterranean water, rivers, and air (Park, G., 2012). Recently, contamination near livestock burial grounds has been identified as another cause of soil pollution (Ryu, J. G., 2014). Because burial grounds offer suitable conditions for pathogenic microorganisms, there is high possibility of zoonotic viruses existing in leachate. If the leachate is not treated in the early stage, there is a risk of secondary environmental pollution in nearby groundwater and rivers, as well as in surrounding soil. Because excavation is legally allowed after 3 years from the livestock burial, the implementation of measures to treat the leachate is urgent. Increase in loss of soil is also caused by urbanization. Net value of Korean surface soil is approximately 26 trillion KRW, and the average volume of annual loss of soil is 32 tons per 100 ha, which is almost 3 times the average of 11 tons among OECD countries.

2.3. Identification of Issues and Needs Related to Pollution

Specific issues and needs closely related to pollution in daily life and environmental pollution in Korean society were identified, through literature reviews, and professional consultation. A total of 33 environmental issues and 58 needs from 10 types of pollution were identified. The four phases of the disaster management process, which are Prevention, Preparedness, Response, and Recovery, were reinterpreted and applied to addressing pollution in daily life and environmental pollution.

-Prevention: Activities designed to eliminate or reduce the possibility of pollution by eradicating or reducing its causative substance. Such activities include diagnosis, preventive measures, and mitigative measures.
-Preparedness: Activities designed to reduce the damages and negative impacts of pollution. Such activities include establishing an early warning system, prediction measures, real-time diagnosis, managing harmful factors, physical and environmental risk analysis and ·assessment.
-Response: Short-term measures designed to stop the dispersion of and reduce the impact of damage, and reduce the possibility of secondary damage by rapidly responding to pollution. Such activities include purification, elimination, dispersion preventing measures, and the use of personal hygienic items.
-Recovery: Long-term measures designed to recover the damaged environment to the original state, and includes recovery, waste processing, and resource recovery.

Table 2. Identified issues and needs related to pollution

Pollution	Major Issues	Needs	Process
Light Pollution	- Concerns over harmfulness of light pollution on the human body - Lack of specific standards for Korea - Lack of proper recognition and regulation on light pollution	- Automatic control of excessive lighting (depending on time, place, situation, etc.)	Prevention /Preparedness
		- Reform of regulations on lighting of public facilities (upward light, lighting time, etc.)	Prevention /Preparedness
		- Development of products that help the recovery of personal biorhythm	Response
		- Risk assessment system and standards that consider individual (age, gender, etc.) and environmental differences	Response
Noise Pollution	- Increasing conflicts from noise in residential areas (Floor impact noise, and noise from community facilities, etc.) - Increase in noise and vibration pollution near construction sites and traffic facilities - Lack of specific standards on sound quality	- Active noise control and reduction	Response
		- Inexpensive and lightweight soundproofing materials and facilities for households	Preparedness
		- Effective education on noise-related etiquette	Preparedness
		- Price reduction and longevity improvement of noise reduction technology (in household appliances, transportation, etc.)	Prevention /Preparedness
		- Personalized noise standards (based on gender, age, experience, etc.)	Preparedness
Odor Pollution	- Lack of laws related to odor in residential and urban areas - Difficulty in control (Difficult to assign responsibility as odors arise from multiple causes, and difficult to record as odors disperse)	- Establishment of system for living odor control (Establishment of living odor standards and related guidelines that fit domestic situation)	Prevention /Preparedness
		- Monitoring of odor sources in daily life	Preparedness
		- Installation and maintenance of customized odor reduction facility based on the odor source	Prevention /Preparedness
Chemicals in Daily Life	- Insufficient information on chemicals in daily life - Rising concerns over the harmfulness of chemicals in daily life (fake products, endocrine disruptors, nanomaterials, etc.)	- Setting customized chemical material safety guidelines based on use method (inhalation, ingestion, skin penetration, etc.) and users (particularly vulnerable groups such as elderly people) and providing information	Prevention /Preparedness
		- Development of substitute materials for hazardous chemicals (endocrine disrupters, etc.) in consumer chemical products	Prevention
		- Securing the safety of consumer chemical products in a complete cycle of production, distribution, consumption and disposal	Prevention /Preparedness
		- Simple and accurate method to identify fake products	Preparedness
Information Pollution	- Privacy invasion - Infringement of copyright - Spread of malevolent posts - Lack of critical judgement regarding information - Spread of polarized opinions	- Automatic identification of malicious comments (development of algorithm and UI)	Prevention /Preparedness /Response
		- Educating the public through media (in ethical/functional aspect)	Prevention

Pollution	Major Issues	Needs	Process
		- Information source tracking and fact-checking	Preparedness /Response
		- Providing opportunity to be exposed to various information	Prevention /Preparedness
		- Filtering excessive information (based on personal information)	Preparedness
		- Copyrighting, identifying, and tracking of posts and content in all forms	Prevention /Preparedness /Response
		- Enhancing security and awareness of personal information	Prevention
Radiation Risk	- Safety concerns due to natural disasters - Safety concerns on food and beverages contaminated by radiation - Concerns over the influence of environmental radiation on the human body - Possibility of accidents from careless handling of industrial/medical radiation sources	- Closure of aged nuclear power plants	Recovery
		- Safe management of radioactive waste	Recovery
		- Prevention of nuclear plant accidents caused by accidents and disasters	Prevention /Preparedness
		- Provision of accurate information on presence of radioactive contamination in daily life such as in food ingredients and building materials	Preparedness
		- Real-time monitoring of radioactive contamination in neighboring countries	Preparedness
		- Replacement for industrial use of radioactivity such as in nondestructive testing equipment	Prevention
		- Safe management of medical radiation devices and radiation sources and scientific management for human safety	Preparedness
		- Accurate verification of effects of radiation on human body	Preparedness
		- Rapid decontamination in the event of radiation exposure	Response
		- Development of therapeutic agents for patients with radiation exposure	Response
Invasive Species	- Increase in invasive species due to abandonment and release of foreign species and pets - Increasing risk of extinction for indigenous animals and plants, and increasing damages to farm produce due to invasive species (spotted lanternfly, etc.) - Lack of social system related to invasive species (sanctions, monitoring, alert, education, etc.) - Lack of scientific, economic, and quantitative assessment of the damages caused by invasive species	- Improving the efficiency of invasive species monitoring	Preparedness
		- Finding measures to effectively remove invasive species without harming the ecosystem	Response /Recovery
		- Strengthening quarantine to prevent unintentional introduction of invasive species (particularly organic matter, plants and insects that can cause disease)	Prevention /Preparedness
		- Strengthening regulations on dangerous invasive species sold as pets, and strengthening the social system to prevent abandoning of pets (pet registration system, etc.)	Prevention /Preparedness

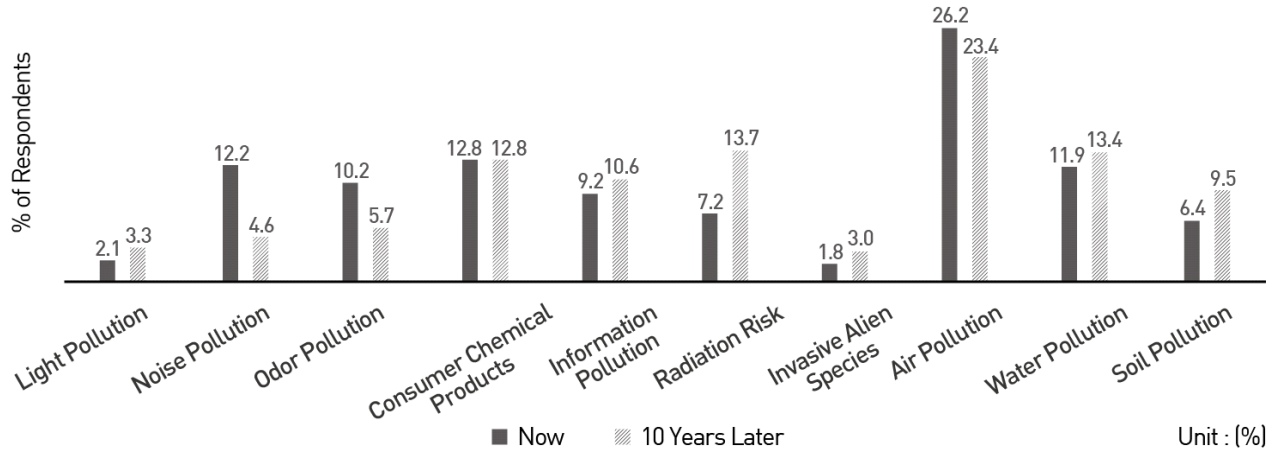
Pollution	Major Issues	Needs	Process
		- Education and promotion of the dangers of invasive species	Prevention /Preparedness
		- Database systematization for ecosystem management	Preparedness
Air Pollution	- Lack of verification on the influence of ultrafine particulate matters on human body and ecosystem - Increased occurrence of ultrafine particles - Continued emission of exhaust gas from the use of fossil fuel	- Understanding the cause of ultrafine particulate pollution	Prevention
		- Improving efficiencies related to purifying and removing ultrafine particles (Regional/National)	Response /Recovery
		- Expanding the real-time ultrafine particle monitoring system to the national level	Prevention
		- Improving the accuracy of ultrafine particles forecasting	Preparedness
		- Assessing influence of ultrafine particles on human body and ecosystem	Preparedness
		- Researching and developing products that prevent the absorption of ultrafine particles by the human body, and that helps to release ultrafine particles from human body	Response
		- Supplying low-cost exhaust gas filters for deteriorated automobiles	Preparedness
Water Pollution	- Increased occurrence of green & red tide - Health risk to aquatic ecosystem - Lack of water resources	- Accurately analyzing the cause of the increased occurrence of green & red tide and prediction of massive outbreak of them	Prevention /Preparedness
		- Reducing the cause of green & red tide (wastewater treatment, non-point pollutant management, etc.)	Prevention /Preparedness
		- Researching and developing methods for removing green & red tide in an eco-friendly way	Response
		- Preparing environmental standards for the protection of the aquatic ecosystem	Preparedness
		- Expanding the reuse of wastewater and the recovery of reusable substances and energy	Recovery
		- Efficiently distributing water resources	Recovery
Soil Pollution	- Deterioration of soil quality (vulnerable soil, improper management of landfill and burial sites) - Increase in disputes regarding soil near pollution source - Threat to soil ecosystem - Increase in soil loss	- Expanding the reuse of soil	Recovery
		- Continuously monitoring soil pollution near landfill and burial sites	Prevention /Preparedness
		- Improving the accuracy of tracking soil pollution and ground-water contamination	Response
		- Reducing the costs of purifying polluted soil	Response
		- Preparing environmental standards for the protection of the soil ecosystem	Preparedness
		- Engaging in eco-friendly urbanization that minimizes soil loss	Preparedness

Table 3. Survey respondents information (Area/Age)

Area	Number of People	Age Group	Number of People
Seoul/Gyeonggi area	90	10s	90
Gangwon area	90	20s	90
Chungcheong area	90	30s	90
Jeolla area	90	40s	104
Gyeongsang area	90	50s	89
Jeju area	90	60s	77

Note : The number of respondents in their 40s was increased, as there was a limited number of respondents in their 50s and 60s in Gangwon and Jeju area.

Figure 1. Comparisons of answers from respondents on pollution & contamination (Present/10 Years Later)



2.4. General Survey on Pollution

A survey was conducted to understand the general public's awareness on pollution and contamination, with the purpose of using the survey data in selecting emerging technologies. A survey was conducted on 540 respondents via mobile devices, classified by area and age.

2.4.1. Critical Analysis of Top 10 Types of Pollution

Air pollution was considered the top priority, both for the present and for 10 years from now.

Radiation risks, water pollution, and soil pollution were expected to worsen 10 years from now.

Noise pollution and odor pollution were considered important now, but their importance was expected to decrease drastically in 10 years.

2.4.2. Critical Analysis on Top 10 Pollution Issues

A comparison on the selection rates by item revealed that there are issues considered as difficult to solve even in a ten-year time period.

Issues regarding insufficient water resources and

radiation risks due to accidents or natural disasters were expected to gain bigger recognition in 10 years.

3. Selection of Emerging Technologies

3.1. Identifying Candidates of Emerging Technologies

The candidate technology pool was formed through an expert review of potential candidate technologies using diverse research paths that reflect recent trends in technology development and social needs for new technologies. Technologies that satisfy social and technological needs were chosen from those registered in KISTEP's internal database and the database of future technologies selected and announced by domestic and overseas institutions. Future technology related contents of 'KISTEP News Clipping (Domestic press / Online news DB, Nov 2015 ~ Oct 2015)' was analyzed. Future technologies reflecting social needs in Korea were identified. In addition to reviewing potential emerging technologies selected through the above processes, technological experts also suggested the inclusion of technologies related to domestic and environmental pollution issues in order to address the related needs. The final candidate technology pool was formed after reviewing the relevance with future needs.

Figure 2. Top 10 items with the highest rates of changing issues in 10 years

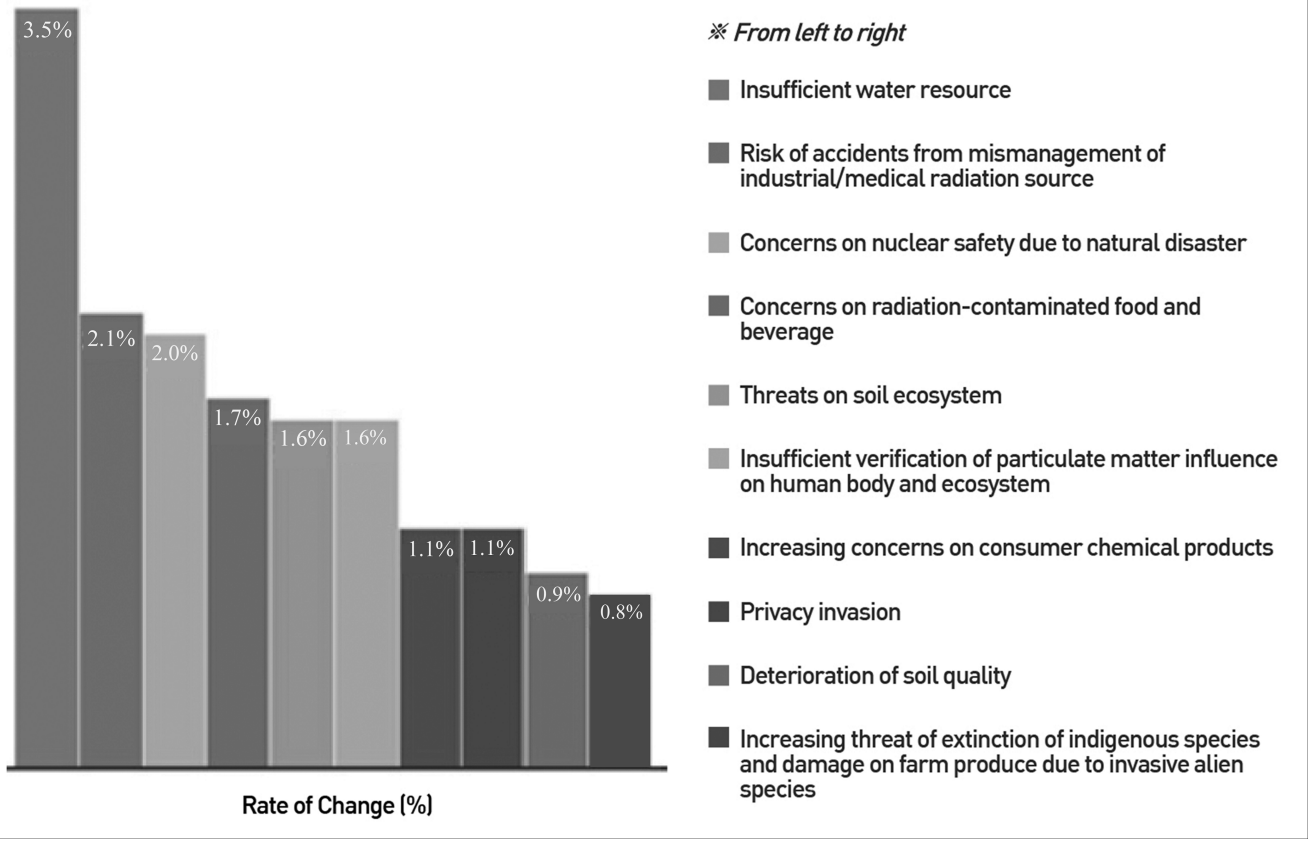


Table 4. Candidate technologies

Pollution	Candidate Technologies
Light Pollution	- IoT-based context-aware dimming technology - Biorhythm customized dimming technology - Light pollution risk assessment technology using model animals
Noise Pollution	- Active Noise Control & Reduction Technology - Ultra directional speaker - Inexpensive and durable noise reduction construction material technology
Odor Pollution	- Real-time odor monitoring and abatement technology - Septic tank / sewerage odor reduction technology - Combined treatment system for odor elimination
Consumer Chemical Products	- Real-time monitoring sensor for endocrine disrupters - Biological and environmental suitability assessment technology for nanomaterials - Environmentally friendly, nontoxic alternative technology for hazardous chemicals - Biocide risk assessment technology
Information Pollution	- Automatic screening technology for malicious posts - Digital watermarking technology - AI based fact-checking technology - Model-based collaborative filtering algorithm - Electronic fingerprint technology
Radiation Risk	- Technology for decommissioning of aged nuclear power plants - Nuclear power plant accident response system - Non-radioactive non-destructive testing technology - Pyro processing - Real-time monitoring system for radioactive contamination - Integrated management system for information on radiation exposure in daily life - Technology for discharging radioactive substances within human body
Invasive Species	- Navigation robot for ecosystem monitoring - Technology for remote monitoring of invasive species - Environmentally friendly technology for elimination of invasive species
Air Pollution	- Eco-friendly artificial rainfall technology using laser - Ultrafine particles monitoring technology - AI-based Korea customized fine dust prediction system - Ultrafine particles removal technology - Vehicle mounted non-powered dust collector - Technology for tracking path and evaluating volume of ultrafine dust generation - Technology for assessing impact of ultrafine dust on the human body
Water Pollution	- Biosensor technology for real-time monitoring of harmful algal tides - Harmful algae removal robot - Environment-friendly green & red tide removal technology - Smart Water Grid - Waste water recycling technology - Marine environmental restoration technology using microorganisms - Technology for real-time monitoring of water quality using satellites
Soil Pollution	- Advanced Domestic Waste Sorting System - City mines - Bio charcoal - Technology for treatment of Soil hazardous heavy metal - Natural material for plant protection - Soil Ecosystem Health Assessment Technology

Table 5. Criteria for evaluation of appropriateness as emerging technologies

Criterion	Contents
Concreteness	• Excluded products and services for which no specific technology can be derived
Novelty	• Excluded products or services that can be produced or provided with the current level of technology, given sufficient capital and political or systemic support
Social and Technological Realization Possibility	• Excluded technologies with significantly low realization possibility within the next 10 years from a technological and/or social perspective

3.2. Results of 2017 KISTEP Selection of 10 Emerging Technologies

After examining the candidate technology pools for appropriateness as emerging technologies, 20 technologies were selected. Evaluation was based on three criteria: concreteness, novelty, and realization possibility. KISTEP's internal research team and experts in each field of future needs participated in the evaluation.

Priority evaluation was conducted by KISTEP researchers and experts in each field on the 20 candidate technologies selected. Priority evaluation was conducted based on four criteria: possibility of actualization within 10 years, capability to respond to future issues, economic impacts, and technological impacts. The evaluation was performed in two-stages by KISTEP researchers and technological experts of relevant fields. Each of the 20 technologies were evaluated and given a score out of 5 for 4 different criteria, and each criteria was assigned weights. Response certainty was also surveyed and reflected in the analysis of survey results. The composite scores for each technology (maximum: 20) were calculated based on weights of each of the four criteria. Two-stage evaluation was performed, with the first stage based on information regarding future needs and technologies, and the second stage based on trend analysis with experts.

Table 6. Evaluation criteria for selection of Emerging Technologies

Criteria	Standards	Weight based on survey
Realization Possibility in 10 years	The possibility of complete development and commercialization of technology, enabling practical use by the public in 10 years	24.3
Capability to Respond to Future Issues	The expected scale of impact from the realization of the technology in terms of the resolution of key issues in the future	31.3
Economic Impacts	The potential of creating added value expected from the realization of the technology	21.3
Technological Impacts	The expected contribution to leading innovative development in the same or other fields of technology	23.1

Table 7. Results of survey for 20 candidate technologies

Rank	Candidate Technologies	Realization Possibility	Responsiveness to Future Issues	Impacts		Overall*
				Economic	Technological	
1	Nuclear Power Plant Accident Response System	3.63	4.25	3.50	3.72	15.27
2	Particulate Matter Reduction Technology	3.69	4.09	3.64	3.66	15.19
3	Real-time 3D Environmental Change Observation Technology	3.59	3.96	3.61	3.82	15.05
4	IoT-based Context-aware Dimming Technology	4.15	3.51	3.38	3.43	14.47
5	AI-Based Prediction System for Particulate Matter	3.41	4.02	3.34	3.41	14.34
6	Advanced Domestic Waste Sorting and Recycling System	3.76	3.63	3.52	3.34	14.28
7	Ecological Restoration Technology using Microorganisms	3.45	3.66	3.60	3.54	14.28
8	Eco-friendly Green & Red Tide Elimination Technology	3.32	3.96	3.53	3.33	14.27
9	Active Noise Control & Reduction Technology	3.48	3.64	3.48	3.53	14.16
10	Non-radioactive Non-destructive Testing Technology	3.45	3.42	3.42	3.61	13.88
11	Real-time Odor Management and Reduction Technology	3.57	3.56	3.28	3.39	13.86
12	Nanomaterial Bio- and Eco-compatibility Assessment Technology	3.49	3.58	3.18	3.49	13.81
13	Sewage & Wastewater Recycling Technology	3.50	3.37	3.49	3.48	13.81
14	Plant Protectant using Natural Substances	3.52	3.43	3.35	3.40	13.72
15	AI Fact-checking Assistive Technology	3.69	3.54	2.97	3.35	13.64
16	Ultra Directional Speakers	3.55	3.56	3.12	3.28	13.60
17	Automatic Online Posting Screening System	3.99	3.55	2.74	2.90	13.35
18	Biorhythm Customized Dimming Technology	3.89	3.06	3.10	3.09	13.11
19	Smart Water Grid	3.47	3.19	3.39	3.07	13.10
20	Risk Assessment Technology using Animal Models	3.36	3.33	2.93	3.10	12.79

* Calculated based on weights determined through survey

The 10 Emerging Technologies were selected based on a priority evaluation of 20 candidates, and specialist/researcher review on the technologies' impact and responsiveness to future issues. Priority evaluation results were considered in conjunction with the technologies' strategic importance to the nation. Multiple technologies were merged based on their similarity, and some of them were renamed to enable easier comprehension. The distribution of technologies was considered based on detailed categorization of pollutants, and technologies applicable to multiple forms of pollution were selected as a priority.

3.3. Social and Economic Impacts of Emerging Technologies

The economic and social impacts that are likely to follow the adoption of the 10 emerging technologies were analyzed, focusing on the individuals and the industries that the implementation of each technology will affect.

Table 8. KISTEP 10 Emerging Technologies in 2017

Technology	Details
IoT-based Context-aware Dimming Technology	[Definition] Dimming technology which enhances utilization and energy efficiency through automatic control of the direction and brightness of lighting, by recognizing outdoor conditions; or, which mimics sunlight indoors, enabling customized lighting for personal health care [Applicability] When applied outdoors, saves energy, and prevents crime and light pollution by automatically controlling the lighting's brightness, hue, and angle based on environmental changes (season, climate, etc.) and surroundings (sounds, human movements, etc.). When applied indoors in conjunction with IoT, enables effective biorhythm control, health management and treatment by having the effect of natural light exposure, providing particular benefits for night shift workers, and critically ill patients in intensive care wards
Active Noise Control & Reduction Technology	[Definition] Active noise reduction technology which predicts the occurrence of noise in real-time and generates sound waves of the inverted phase [Applicability] Applicable on public facilities (subway tunnels, airports, expressways, etc.) where noise occurs repeatedly; enables active noise control based on human movement in a home environment
AI Fact-checking Assistive Technology	[Definition] AI-based software which fact-checks in real time during speeches or debates [Applicability] Helps fact-check speeches of politicians, and enables a transparent information service which can prevent false or misleading rumors from spreading
Nuclear Power Plant Accident Response System	[Definition] Integrated nuclear power plant accident response system, which encompasses all technologies needed for different scenarios [Applicability] Plans emergency response against nuclear power plant accidents, such as simulating major accident scenarios, evacuation technologies, information security, physical protection, integrated real-time risk assessment, monitoring and quantification technologies, nuclear accident management robots, AI-based remote surveillance, and automatic responses
Non-radioactive Non-destructive Testing Technology	[Definition] Non-destructive testing technology using non-radioactive substances or devices which can replace the radioisotopes currently used for testing [Applicability] Ensures safe use and fundamentally prevents the risk of misuse for nuclear terrorism by eliminating the risk of radiation

Technology	Details
Particulate Matter Reduction Technology	[Definition] High-efficiency, low cost particulate matter collection and reduction system, which eliminates particulate matters (PM2.5) and causative agents [Applicability] Initially eliminates particulate matters from the source of pollution before diffusion into the air, and effectively reduces particulate matters indoors and outdoors
Eco-friendly Green & Red Tide Elimination Technology	[Definition] Eco-friendly technology which effectively eliminates harmful algae and nutrient salts without environmental side effects [Applicability] Effectively eases green and red tides by selectively eliminating specific harmful algae using algae coagulants made from natural substances
Advanced Domestic Waste Sorting and Recycling System	[Definition] Recycling technology which categorizes waste materials into metal, plastic, paper, etc., maximizing recycling and waste-to-energy recovery [Applicability] Reduces public burden of sorting waste into different categories, and enhanced precision of waste management will dramatically increase the recycling rate of waste materials
Real-time 3D Environmental Change Observation Technology	[Definition] Integrated technology which monitors and analyzes real-time changes in the environment and the ecosystem, using IoT, satellites, and unmanned aerial vehicles [Applicability] Enables real-time monitoring of diverse forms of pollution and contamination, including red and green tides, soil contamination, air pollution, and proliferation of invasive species
Ecological Restoration Technology using Microorganisms	[Definition] Ecological restoration technology using microorganisms to decompose toxic or recalcitrant chemicals [Applicability] Enables oil removal in oil spill situations using microorganisms, eco-friendly processing of food waste using marine protists, production of bio-diesel and other chemicals from biomass, and effective and eco-friendly extraction of valuable metals from waste resources

Table 9. Social and economic impacts of selected technologies

Emerging Technology	Social Impacts	Economic Impacts
IoT-based Context-aware Dimming Technology	• Context-aware lighting can be applied to workplace illumination, the main culprit of light pollution and trespass, and enable night lighting practices and enhances public safety, environmental protection and energy savings. • The development of an active lighting technology for personal biorhythms enables automatic lighting control according to individual physiological conditions, contributing to the promotion of public health.	• European market for lighting control and management systems: USD 1.188 billion ('20) • European market for human-centered lighting: USD 2.42 billion ('20)
Active Noise Control & Reduction Technology	• The development of active noise control and reduction technology can reduce disputes and civil complaints, which not only reduces social costs but also improves the quality of life for the general public	• Global market for automobile noise control devices: USD 1.7 billion ('18)

Emerging Technology	Social Impacts	Economic Impacts
	• The development of active noise control and reduction technology can reduce aperiodic impulse noise generated from construction sites, providing protection for workers' hearing, enhanced work safety and a calm surrounding environment.	
AI Fact-checking Assistive Technology	• The technology will enable immediate fact-checking on speeches in real-time, allowing listeners to differentiate between credible and non-credible speakers, and greatly help in making many political decisions. • The costs previously involved in fact-checking may be reduced, and the technology could also aid media spokespersons and judicial personnel in making just decisions for the society. • The introduction of fact-checking technology will greatly increase media credibility and the general credibility of information in society.	• Global market for media-related AI: USD 1.161 billion ('22) • Global market for natural language processing: USD 18.65 billion ('22)
Nuclear Power Plant Accident Response System	• Nuclear power plant accident-decision making process and citizen evacuation aid systems could be applied to other types of disasters. Casualty numbers and economic damage will be significantly reduced. • Securing the safety of citizens near nuclear power plants and creating a technological emergency response guideline will contribute to relieving the anxiety of citizens and increasing nuclear power plant credibility. • When there are nuclear power plant accidents in nearby states, the technology will help establish a mid- to long-term response to radioactive contamination in the domestic environment (eliminating contaminants, limiting outdoor activities, etc.), and aid in minimizing social disorder and damage.	• Global market for radiation monitoring and detection: KRW 7.2 trillion ('22) • Global market for nuclear accident management robots: KRW 1.8 trillion ('20)
Non-radioactive Non-destructive Testing Technology	• The utilization of non-radioactive non-destructive testing technology can prevent radiation exposure at the source, and greatly increase safety for workers. Also, issues such as difficulties in isotope management, risks of contamination, and limited penetration depth (to minimize radiation exposure) can be overcome. • Development of technologies such as terahertz non-destructive testing will enable material-specific testing and contribute to increasing structural safety, and material/equipment/product reliability, as well as public safety.	• Global market for non-destructive testing: USD 24.23 billion ('22)

Emerging Technology	Social Impacts	Economic Impacts
	• The use of non-destructive testing technology in particular will be expanded, in areas such as identifying foreign substances in food, detecting harmful chemical substances such as drugs and explosives in the mail, testing plastic structures for body cracks in planes, automobiles, ships and structural soundness, as well as new areas such as medical use.	
Particulate Matter Reduction Technology	• Particulate matter generation will be significantly reduced with the development of technologies that reduces particulate matter pollution itself, and secondary damage-inducing gases. • Even when particulate matter pollution occurs, indoor air cleaning and purifying technologies will minimize damage from exposure and provide a safe air environment.	• Global market for indoor air quality control: USD 24.84 billion ('20) • Global market for air pollution management systems: USD 13.8 billion ('16)
Eco-friendly Green & Red Tide Elimination Technology	• This technology is a fusion of biotechnology and environmental technology for the eco-friendly control of green and red tides. Broad mobility, reduced processing time, increased processing volume and other effects will greatly contribute to watershed management and water quality control. • A collaboration with technology that can reuse collected green and red tides as energy, feed and compost will lead to development in zero-energy and non-CO_2 technology. • The dissemination of diverse tide elimination technology available for immediate application will secure the safety and well-being of the public. Clear water resources management will lead to pleasant waterfront areas, increasing ecological value.	• Global market for water and wastewater management: USD 625 billion ('16)
Advanced Domestic Waste Sorting and Recycling System	• Maximized reuse of recyclables as new material and usage of non-recyclables as energy sources will become possible. Such waste sorting system is critical in preparation for resource exhaustion, and securing new energy sources. • The application of domestic waste sorting and recycling technology will redirect the traditional waste disposal systems (such as incineration or landfill) to a more recycling-centered system. • Individual emission sources and intermediate and final disposal plants will be directly connected through underground plumbing. Individual and public housing recycling dumps and street trash disposal cans will be unnecessary, improving the aesthetic value of a city.	• Global market for domestic solid waste management: USD 296 billion ('20)

Emerging Technology	Social Impacts	Economic Impacts
Real-time 3D Environmental Change Observation Technology	• Monitoring massive, long-term, gradual and slow environmental and ecological changes will become possible. Understanding the mechanisms of these changes will also facilitate addressing the causes or preparing for the effects. • The development of a real-time 3D observation technology over the general earth environment will continuously reduce the scale of damage, both casualties and economic losses, from natural disasters. • Increased overall real-time 3D monitoring ability across the general ecosystem will lead to scientific, system-based general ecosystem management including contamination tracing. Environmental pollution will be significantly reduced.	• Global market for environment monitoring: USD 20.5 billion ('20) • Global market for environmental testing equipment: USD 1.32 billion ('22)
Ecological Restoration System Using Microorganisms	• Ecological restoration using microorganisms does not require ground excavation using heavy equipment. Pollution levels are contained, and it is economical as well as convenient. • Immediate detection and treatment of contamination in its early stages will be enabled through the development of biosensors and the establishment of a real-time contamination monitoring system. • The chemical industry paradigm of the 21st century will be changed, from a fossil fuel based system to a biomass system, while biotechnology-based and environmentally friendly processes will be advanced.	• Global market for industrial waste management service: USD 750.1 billion ('20) • North American market for microorganism-based ecological restoration: USD 106 million ('19)

4. Conclusions and Implications

KISTEP 10 Emerging Technologies were selected with the goal of constructing a desirable future society, which distinguishes this list from other selections of emerging technologies in Korea. The selection of emerging technologies in Korea is performed mostly by public institutions, and focus on technologies that are more likely to have bigger economic and social effects. However, KISTEP 10 Emerging Technologies is the only assessment that presents a balanced reflections of the ability to cope with needs in the future society and the economic and social impacts. KISTEP 10 Emerging Technologies is significant in that the changes of the future are forecasted based on a different issue every year. The perspectives and methods are adjusted and newly developed accordingly to select emerging technologies, contributing to enhancing diversity and advancing research methodology.

KISTEP 10 Emerging Technologies in 2017 has the following characteristics in issue analysis and technology identification: The discussion of 'Enviornmental Pollution in Daily Life', which is both a public and technological issue, maximizes the issue responsiveness of the 10 emerging technologies. The key issues and needs of citizens were identified through a survey on the public. Mass media (press) and blogs were differentiated during social data analysis for more accurate assessment

of implications and incorporation into issue analysis. Future technologies announced by the media were analyzed and utilized during the selection process to identify technologies addressing Korea's social needs. When analyzing 10 emerging technologies in details, combining analysis of the existing literature and quantitative analysis of patent is expected to provide rich data and improve utilization.

The selection for this year was conducted based on future technologies which can counteract environmental pollution in daily life, and enable the sustainable development of Korean society. Of the Sustainable Development Goals (SDGs) announced by the United Nations in 2015, a fair number are related to the environment. Moreover, the adverse effects of environmental pollution in daily life and problems of an information society were included in the WEF Global Risks Report 2016 as key issues. The effects of environmental pollution are intensifying due to government policies that have prioritized economic growth over environment, and damage from sensory and information pollution, which were not recognized as pollution in the past, is increasing. In particular, the severity of light and air pollution in Korea is among the worst in the world, and urgent solutions are needed. Developing technologies to counteract pollution in daily life and environmental pollution would prevent the costs from further damage, ultimately benefiting the country economically, and enhancing the ecosystem and the quality of life for the public.

It is true that Korea has been lacking in research and development for solving social problems because it has focused on technology development with economic growth as a top priority. This has also resulted in the adverse effects of technology development causing various pollution and pollution. Now that Korea has world-wide scientific and technological leadership, we must focus on sustainability for the prosperity of the whole of humanity. 2017 KISTEP 10 Emerging Technologies provides a new direction for the role of science and technology in building a desirable future for Korea. The research aimed to emphasize the role of science and technology in resolving threats to the ecosystem and the environment that have caused by technological development focusing on economic growth alone. The research stresses the need to break away from the notion of a producer-centered and performance-centered national R&D policy, in which the primary objective is to develop profitable technology and pursue economic growth. The research is expected to serve as an important example where technologies that promote public interest can be emerging technologies of high potential.

References

Asian Citizen's Center for Environment and Health <http://www.eco-health.org/>

Environmental Performance Index <http://epi.yale.edu/>

Falchi, F., Cinzano, P., Duriscoe, D., Kyba, C., Elvidge, C., Baugh, K., Portnov, B., Rybnikova, N., Furgoni, R. (2016). The new world atlas of artificial night sky brightness. Science Advances, 2(6), e1600377

Greenpeace (2016), Plastics in Seafood

Greenpeace (2012), Lessons from Fukushima

Kang, C. G., Lee, S. H., Kim, E. K. (2007), Endocrine Disruptor, Journal of the Korean Medical Association, 50(4), 359-368

Kim, E.(2010), Risk Assessment of Nanomaterials: Issues and Perspectives. Environment Review, 12, 193-206

Kim, I. N., Lee, K., Gruber, N., Karl, D., Bullister, John., Yang, S., Kim, T. W. (2014), Increasing anthropogenic nitrogen in the North Pacific Ocean, Science, 346(6213), 1102-1106

OECD (2016), The economic consequences of outdoor air pollution

OECD Better Life Index <http://www.oecdbetterlifeindex.org/>

Pan, W. C., Wu, C. D., Chen, M. J., Huang, Y. T., Chen, C. J., Su, H. J., Yang, H. I. (2015), Fine Particle Pollution, Alanine Transaminase, and Liver Cancer: A Taiwanese Prospective Cohort Study, Journal Of The National Cancer Institute, 108(3), djv341

Park, G. (2012), Study on the improvement of soil pollution management, Konkuk University

Park, J. and Kim, Y. A. (2017), KISTEP 10 Emerging Technologies, Issue Paper 2017-01, Korea Institute of S&T Evaluation and Planning

Park, Y. H. (2002), Management and Remediation Policy of Contaminated Lands in Korea Ⅰ, Korea Environment Institute

Ryu, J. G. (2014), "Korea should be prepared for soil and groundwater contamination from livestock burial", Water Journal

Seoul Air Quality Information. <http://www.airkorea.or.kr/index>

United Nations (UN) (2016). The Sustainable Development Goals Report 2016

United Nations Environment Programme (UNEP) (2016), Marine Litter and Microplastics