

A Review on the Historical Development of Environmental Specimen Banks

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Abstract. Environmental Specimen Banks (ESBs) are facilities that archive samples from the environment for future researching and monitoring purposes. In addition, the long-term preservation of representative specimens is an important complement to environmental studies and monitoring practice. This article presented detailed information about ESBs in the world, and reviewed the history and current status of ESBs in China. Besides, crucial should leave 8 mm of space above the abstract and 10 mm after the abstract.

1 Introduction

Over the past few decades, as a result of rapid population growth, intensive agriculture activities, industrialization and urbanization, large amounts of persistent organic pollutants (POPs) have been released into the environment. These pollutants not only have adverse effect on the health of human beings, but also pose threats to the well-being of generations in the long run [1]. Thus, understanding the sources, fate and behavior of POPs and their impact on human beings requires long-term intensive monitoring efforts. Environmental monitoring studies have been indispensable in the exploring and understanding of the environmental fate and behavior of POPs [2].

The idea of archiving biological and environmental samples for retrospective analysis has been recognized as a vital component for assessing the risks from chemical substance released into the environment. The chemical analytical approaches are expected to provide the database with deeper insights into chemical processes and hazardous situations. Such a detailed knowledge could further be used for environmental protections, regulations and pollution control measures, in which direction and to which extent technological developments or modifications are made. Therefore, the function and significance of ESBs have been acknowledged widely.

ESBs are facilities that archive various samples which have been treated with standardized procedures and passed the unity test. Environmental samples that are stored can be used to monitor the environmental state of pollutants, identify environmental problems, and study the correlations between cause and effect [3]. The sample materials can be used many years after the samples were collected. Therefore, when new or improved analytical techniques become available or a new interest arises for a certain contaminant that was not considered important in the past, samples from ESBs can be used for analyzing its temporal trends and predicting its exposure risks. The

basic premise of a ESB is to collect and process environmental samples for archiving without changing their original chemical composition and preserve them in a stable environment for future analysis [4]. Thus, ESB can be considered as an important long-term observation system for taking measures to protect the global environment as well as for checking the efficacy of the actions taken by governments and international organizations to curtail or control the pollution by persistent contaminants [2].

2 Historical development of ESBs in the world

The history of specimen banks dates back to the 1960s when the first bank was established in Sweden at Swedish Museum of Natural History, since then the importance of proper preservation of environmental specimen started to be realized, resulting in the establishment of several other ESBs worldwide. Currently, major ESBs in the world include German Environmental Specimen Bank at Federal Environment Agency, U.S. Environmental Specimen Bank Group at National Institute of Standards and Technology, Canada's National Aquatic Biological Specimen Bank and Database at the Canada Centre for Inland Waters/Environment Canada, Canadian Wildlife Service Specimen Bank at National Wildlife Research Centre, Japanese Environmental Specimen Bank for Global Monitoring (es-BANK) at Center for Marine Environmental Studies and Japanese Environmental Specimen Time Capsule Program at National Institute of Environmental Science (NIES).

The ESB at the Swedish Museum of Natural History (SMNH) has been established for more than forty years, and acted as a powerful tool for national contaminant monitoring and eco-toxicological researches [5]. In cooperation with the Swedish Environmental Protection

Agency (SEPA), contaminant monitoring programs were set up in 1980 for studies of residue levels of persistent pollutants and their effects on biota in terrestrial, freshwater and marine environments [6]. The ESB also stores older samples of animal tissues and organs from different research projects on environmental effects of noxious substances. The homogeneous and continuous series of samples are also used for retrospective chemical analysis to analyze the levels of new or recently discovered contaminants. The ESB has tissue samples from more than 260,000 organisms, mostly from animals but also from plants (moss). The majority of the samples are stored at -30 °C and -80 °C, and certain types of samples are stored dry at room temperature.

German ESB started its development in the late 1970s, and stored environmental specimens from representative ecosystems in conditions which would prevent the chemical decomposition over a period of decades. The sampling started in 1985 and the types of sampling areas include ecosystems close to conurbation, riverine ecosystems, marine ecosystems, forestry ecosystems, nearly natural terrestrial ecosystems and agrarian ecosystems [7]. The ESB also archives various human samples, including blood, blood plasma, urine, saliva, and hair. Scientists have made extensive attempts to track the pathways of chemicals in the human bodies as well as their fate and transformation. The human samples aid in the analysis of which pollutants are likely to cast adverse effects on human health, and how these effects change over time. Since 2007, with the safety of commercial chemicals being more and more realized, the German ESB has become irreplaceable in evaluating the effectiveness of regulations related to hundreds of thousands of commercial chemicals, and further protecting the health of humans and the environment against adverse effects caused by these chemicals [8].

U.S. Environmental Specimen Bank Group, based out of the Hollings Marine Laboratory in Charleston, South Carolina, has initialized a diverse set of programs and researches. The group includes NIST's Marine ESB and Reference Material Production Facility with long-term archival of well documented and preserved specimen for both retrospective and comparative environmental health analysis; a nuclear magnetic resonance (NMR) facility to support structural biology, metabolomics, and natural product researches; informatics; and NIST's Pacific Islands Project. The group has been involved in government, academic, and private partnerships resulting in programs geared towards promoting the development of cooperative and collaborative scientific researches for a better understanding of marine resources and environmental health. The Marine ESB include marine mammal tissues, mussels and oysters, fish tissues, seabird eggs, and peregrine falcon eggs and feathers. Many of these specimens have been analyzed retrospectively to determine time trends of various emerging contaminants of in the environment and as part of a multi-agency effort to determine health trends in marine animals.

The Canada's National Aquatic Biological Specimen Bank (NABSB) is located in a dedicated facility at the

Canada Centre for Inland Waters in Burlington, Ontario. The NABSB holds more than 37,000 samples of fish and invertebrates collected over the last 30 years of environmental monitoring in Canada. Researches conducted using samples from the NABSB have produced more than 60 scientific publications, reports and book chapters. The National Wildlife Specimen Bank stores over 900,000 biological sub-samples taken from 200,000 tissue samples of over 800 species. Scientists use these samples to conduct researches on contaminant monitoring and effects of toxic chemicals on the environment. These researches help develop science-based regulations controlling the use, distribution, application, and disposal of chemicals. Established in 1963 as the Canadian Wildlife Service Specimen Bank, the National Wildlife Specimen Bank gives scientists the unique ability to use historical environmental specimens to: screen for new chemical contaminants; retrospectively analyze emerging contaminants of concern; conduct analysis in the future using more sophisticated analytical equipment.

The Japanese es-BANK is an orderly system of collection, archiving, cataloging and management of biological and environmental specimens from all over the world and provide them to a wide range of researchers within and outside the university for monitoring studies on environmental toxic substances. 1,300 species and 100,000 specimens were collected from Asia, Europe, Australia, North/South America and Antarctic, Arctic, North/South Pacific, North/South Atlantic, Indian and Antarctic Oceans during the last 50 years [9]. The pilot ESB was constructed at the National Institute for Environmental Studies(NIES) in 1979 and started a collection of samples under the program "Studies on the method for long-term environmental monitoring" in 1980

[10]. During the pilot phase, the specimens were mainly stored at -20 °C. In 2004, long-term storage using liquid nitrogen vapor (-150 °C) was completed in the Environmental Specimen Time Capsule Building. Also, there is a Time Capsule program for the systematic collection and banking of various kinds of environmental specimens representing the current environmental status in Japan.

The Norway ESB has been collecting environmental samples from across the nation, and acted as an important tool for the pollution status monitoring of varied organic pollutants. The Norway ESB is owned by the Ministry of Climate and Environment and managed by the Norwegian Environment Agency. The Norway ESB contains frozen samples of animals, plants, air and mud from across Norway and the Arctic. The samples become time capsules preserving the present environmental state, and they can provide valuable information in the future. The Italy Mediterranean Marine Mammal Tissue Bank collects and preserves biological samples collected from marinemammals along the Italian coasts of the Mediterranean Sea, in cooperation with the University of Padova, the Italian Ministry of the Environment, the Institutes for Animal Health, and several other non-profit Italian organizations dedicated to the marine mammal researches. Those ESBs all mentioned collected typical

specimens are shown in Table 1

Table 1. Comparison Between Various Country's ESBs

Name of ESB	Established time	Types of archived specimen
Swedish ESB	mid-1960s	otter, grey seal, harbor seal, ringed seal, osprey, white-tailed sea eagle, peregrine falcon
German ESB	1970s	algae, mussels, fishes, herring gulls, human specimens (blood and urine)
U.S. marine ESB	1989	marine mammal tissues, mussels and oysters, fish tissues, seabird eggs, and peregrine falcon eggs and feathers.
Canada's National Aquatic Biological Specimen Bank and Database	1977	trout, walleye, whitefish, alewife, rainbow smelt, slimy sculpin, plankton
Canadian Wildlife Service Specimen Bank	1963	birds, mammals, fishes, reptiles, amphibian, invertebrates
Japanese Environmental Specimen Time Capsule Program	1979	fishes, shellfishes, marine sediments, airborne particulate matter and human breast milk
Japanese Environmental Specimen Bank (es-BANK)	1960s	birds, fishes, reptile & amphibian, seal & sea otter, terrestrial mammals, cetacean & sea cows, invertebrate & others
Norwegian Environmental Specimen Bank	1993	animals, plants, air and mud from across Norway and the Arctic
Italy Mediterranean Marine Mammal Tissue Bank	2002	fin whale, sei whale, Risso's dolphin, Ziphiidae, arbour porpoise, striped dolphin, killer whale, humpback whale, common bottlenose dolphin

3 The development of ESB in China

In the past few decades, the economy of China is in the golden development period, and conflict between the environment and economy is also in the most pointed and sensitive stage. China's social and economic development has brought a lot of pollutants to the environment [11]. Furthermore, the volume of wastewater has increased dramatically with the booming of economy, and large amounts of wastewater, gas and solid have caused great burdens on China and the global environment. In recent years, China is facing serious environmental problems such as water and air pollution and biodiversity loss, which have seriously threatened human health, ecological security and the sustainable development of China [12]. Recognizing importance of the environmental pollution caused by extensive economic growth, Chinese government has taken a series of measures for environmental protection [13]. At the same time, some scholars are devoted to the study of environmental issues in China, analyzing the risk of various chemical pollutants, including heavy metals, persistent organic pollutants and endocrine disruptors, which have showed bioaccumulation, biomagnification, and long-range transport potential [14]. However, there are very few data available in China for temporal trends of these substances in the environment. However, due to the lack of archived samples, almost no retrospective studies on emerging

substances have been conducted in environmental samples, which is unfavorable to find the sources of contamination and make effective countermeasures to protect the environment.

Since 1990s, six ESBs have been established in China for varied purposes, and most of them are located in Beijing and Shanghai. Soil and sediment are main specimen types, probably due to the convenience in sample collection and storage. In 1992, China's first ESB was established by China Environmental Monitoring Center in Beijing, and soil samples were collected from 29 provinces in China, along with sediment samples which were collected from the Yangtze River, Songhua River and the Pearl River [15]. In 1994, the second ESB named the Biological Environmental Specimen Bank (BESB) was built by the Laboratory of Nuclear Analytical Techniques, Institute of High Energy Physics, Chinese Academy of Sciences [16], and human tissue samples from Tianjin were archived and stored at -70 °C, including 112 liver samples, 20 renal samples, 20 cardiac samples and other tissue samples from accidental death. In 1998, the third ESB was built in Shanghai under the cooperation of the Shanghai Academy of Environmental Sciences and Shanghai Institute of Nuclear Research [17], and water, sediment and dust samples were the major specimen types.

In 2006, there were two ESBs established in Shanghai and Beijing separately. One is the Resource-Sharing Platform of Polar Samples called BIRDS, which was

organized by the Polar Research Institute of China. The BIRDS consisted of Biology Depository, Ice-Snow Depository, Rock Depository, Deep Space Depository, and Sediment Depository. From 2007 to 2013, a total of 6,744 samples were collected continually every year from two polar areas, which can be used to conduct studies on polar environment. The other ESB was affiliated to the Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, which is the first 1,000-Level Purification ESB in China, and sample types include sediment, soil, water, dust, fish, and bird.

China Ocean Specimen Bank was built in 2001, and put into use in 2007. China Ocean Museum consists of sample warehouse, laboratory, database, exhibition hall and office and other parts, with a total area of more than 3000 square meters. The sample warehouse consists of three types of professional warehouses: normal temperature storehouse, 4 °C sample storehouse and -20 °C sample storehouse, which keeps the cobalt-rich crusts, polymetallic nodules, hydrothermal sulfides obtained from various oceanic survey voyages since 2001

The Yangtze ESB (YESB) program started in 2011 with the approval of the Ministry of Science & Technology and the Ministry of Finance. It is devoted to the long-term storage of representative environmental and human specimens from the Yangtze River Basin. The project started back in 2010 and became operational in 2014. Recently, the YESB has started the establishment of a long-term environmental monitoring program in the Yangtze River Delta, but not limited to this area. The YESB is expected to provide invaluable specimen resources for real-time and retrospective analyses of conventional and emerging pollutants as well as for ecotoxicological researches, and to provide scientific basis for environmental management and decision making. The YESB has an area over 2,000 square meters for specimen preparation, storage, pretreatment, and analysis, and has archived more than 3,000 specimens, including soil, lake and marine sediment, sewage sludge, human hair, and fish.

4 Perspective

ESB has been playing vital roles in the sound chemical management processes by supporting environmental monitoring and revealing long-term changes of pollutant levels in the environment. Now, it is expected to contribute to the international chemical management processes more efficiently by networking and collaborations among ESBs as well as supporting establishment of new ESBs particularly in developing countries. Environmental specimen banks have become an essential part of the fundamental research infrastructure for environmental sciences. Compared to the developed countries, China's Environmental specimen bank is clearly in its infancy. It is necessary to establish pilot studies to test the collection, storage and evaluation of representative environmental samples in regional ecosystems in China. Implementing research projects based on environmental specimen bank is the basis for updating sample collection specifications, getting more government support, understanding changes in environmental quality, and better setting environmental

policies. Extensive cooperation with other international organizations in response to global environmental issues. Therefore, more systematic collection, scientific research, and international cooperation are fundamental ways to better develop ESB for illustrating the intensive environmental changes in China and the world.

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