Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

STT03-01 Room:102A Time:May 23 09:20-09:35

Aeromagnetic survey using an unmanned autonomous helicopter over Tarumae volcano

HASHIMOTO, Takeshi[1*], KOYAMA, Takao[2], KANEKO, Takayuki[2], OHMINATO, Takao[2], YOSHIMOTO, Mitsuhiro[3], Eiichi Suzuki[4], YANAGISAWA, Takatoshi[5]

[1]ISV, Fac. Sci., Hokkaido Univ., [2]ERI, Univ. Tokyo, [3]Fac. Sci., Hokkaido Univ., [4]Fac. Eng., Hokkaido Univ., [5]JAMSTEC

1. Introduction

Recently, a remote measurement technique using an unmanned autonomous helicopter is being developed (e.g. Kaneko et al., 2010). Further improvement of suitable instrumentation and operation techniques are, however, necessary for the application to volcanic fields. Hokkaido Regional Development Bureau (HRDB) has similar type of helicopters for the purpose of disaster survey in hazardous zones at an emergency. The authors and HRDB performed a field experiment by using the helicopter over the summit atrio of Tarumae volcano in 2011. Aerial imaging, experimental installation and collection of a seismometer unit, and an aeromagnetic survey were conducted in the fieldwork. We report the results of the aeromagnetic survey, which was the first low-altitude, dense magnetic survey for Tarumae.

2. Measurements results and data processing

The aeromagnetic survey was performed on September 27, 2011 over the summit atrio. The unmanned helicopter (YAMAHA RMAX-G1) was used as a platform with the aid of real-time differential GPS navigation. Magnetic field was recorded in the Geometrics G858 optical-pumping magnetometer at 10 Hz sampling. Differential magnetic field was obtained taking the simple subtraction of the field at the grounded reference station to reduce the magnetic variations of upper-atmospheric origins. In this study, we inverted the magnetic anomaly map into a non-uniform magnetization model using the code of Kaneko et al. (2010) with a small modification. We modeled the topography-related anomalies by using the 10m-mesh DEM which was provided Geospatial Information Authority of Japan (GSI). Non-uniform distribution of magnetization was modeled as an ensemble of vertical prisms of 100 x 100 m size. In the inversion, we evaluated the objective function as the sum of the L2 norm of the difference between modeled and measured fields, and the norm of the deviation magnetization. We here did not fix a priori the DC component of the magnetic anomaly. We performed the inversion for several values of the DC offset to obtain the optimized se t of model parameters which minimizes the ABIC.

3. Modeling result and discussion

We obtained an averaged magnetization as 5.3 A/m. The summit lava dome showed the magnetization of 3-6 A/m. Meanwhile, relatively small magnetization of 2-4 A/m was estimated at the southeastern part of the dome (which is called 'crater A') and the areas around Nishiyama and Higashiyama mounds at the crater rim. In contrast, northwestern part of the atrio showed relatively strong magnetization (5-8 A/m) compared to the dome itself. These results are consistent with the rough estimation by Sakuma and Murase (1956) based on the magnetic inclination anomaly by using a uniformly magnetized ellipsoid, in which magnetization of the dome and the edifice is estimated as 6-8 A/m and 2-3 A/m, respectively. Such variability may be attributed to the difference in magnetization between blocky lava and pyroclastic deposits, as well as to chemical demagnetization due to persistent fumarolic activity at several vents.

From the viewpoint of an aeromagnetic survey, high positioning repeatability is one of the most advantageous features of such an unmanned autonomous helicopter. Optimized operation of the system would enable us to detect temporal changes associated with volcanic activity in the future.

Acknowledgments: The authors express sincere thanks to Muroran Development and Construction Department, and Sapporo Development and Construction Department of HRDB for the cooperation in the field experiment using their unmanned helicopter. Yamaha Motor Co. Ltd. is deeply acknowledged for their technical support in the field operation. We thank S. Okuyama for the preconditioning of the DEM used in the modeling. This study was supported by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan, under its Observation and Research Program for Prediction of Earthquakes and Volcanic Eruptions.

Keywords: geomagnetic field, Tarumae Volcano, unmanned helicopter, magnetic total force

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STT03-02 Room:102A Time:May 23 09:35-09:50

Effective vertical acceleration correction in airborne gravity measurements

KUSUMOTO, Shigekazu[1*], SEGAWA, Jiro[2]

[1]Graduate School of Science and Engineering for Research, University of Toyama, [2]Tokyo University of Marine Science and Technology

In Japan, air-borne gravity measurement systems mounted on helicopters have been developed since 1998. In particular, the helicopter-borne gravity measurement system, SEGAWA Model was developed in 2000. The SEGAWA Model consisting of all measuring systems excluding the global positioning system (GPS) is made in Japan, and has a high reproducibility of 1.6 mGal. However, some data correction methods, such as the vertical acceleration correction, the horizontal acceleration correction and the digital filter, could still be improved and optimized. In this study, we report on an optimized vertical acceleration correction method having the largest amount of correction calculations after observations.

The vertical acceleration correction subtracts the vertical acceleration due to the movement of a helicopter from data measured by a gravity meter. The SEGAWA Model measures the acceleration including both gravity and vertical accelerations of a helicopter and outputs data at a 0.1 s interval. Meanwhile, the vertical acceleration of a helicopter would be calculated from the data of the helicopter location measured by a GPS at a 1 s interval. Thus, there is a difference in data quality between the calculated vertical acceleration and the measured vertical acceleration by the gravity meter. In order to avoid the deterioration of gravity anomalies due to this problem, we improved the transformation procedure of the sampling rate, and the unification of the signal intensity.

In order to improve the transformation procedure of the sampling rate, we introduced a lag time. When transforming the data given by the sampling rate of 0.1 s measured using the gravity meter into the data given by the sampling rate of 1 s, we staggered the initial calculation time during the transformation in order to obtain the highest correlation between the calculated vertical acceleration and the measured vertical acceleration. Meanwhile, in order to improve the unification of the signal intensity, we applied the digital filter (a running mean of 3 s) to the vertical acceleration data due to the movement of the helicopter, and made the signal intensity between the measured data and the calculated data the same. As a result, the reproducibility was improved by approximately 1 mGal. These improvements also reduced the window width of the digital filter by approximately 50 s, and there was no serious quality deterioration in the gravity anomalies.

Keywords: air-borne gravity measurement, helicopter-borne gravity measurement system, vertical acceleration correction

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STT03-03 Room:102A Time:May 23 09:50-10:15

Airborne electromagnetic investigation of the freshwater potential in northern Sumatra after the Tsunami of 2004

STEUER, Annika[1*], Bernhard Siemon[1], Uwe Meyer[1]

[1]Federal Institute for Geosciences and Natural Resources (BGR)

The earthquake at the west coast of northern Sumatra, Indonesia, and the tsunami of 2004 caused the loss of life of a huge number of people and the destruction of houses, basic infrastructure and public facilities. With the tsunami large scale saltwater intrusions crept over the coastal regions and destroyed thousands of shallow water wells. The supply of a sufficient amount of potable water in all populated areas was complicated as many water pipes were broken by the earthquake and a huge number of dug wells were unusable. Many new drillings were not successful in finding potable water due to the lack of information about local hydrogeological conditions. Therefore, the Indonesian and German governments set up a project dedicated to re-install the public life of the people living in the coastal regions of northern Sumatra. The focal point of this ”HELicopter Project ACEH” (HELP ACEH) was water assessment along the shorelines of Aceh. In order to get a fast overview on the remaining freshwater resources and to assist the Indonesian authorities as well as numerous aid organisations in finding suitable locations for drilling new water wells three helicopter-borne surveys including electromagnetics, magnetics and gamma-ray spectrometry were conducted by the airborne group of the German Federal Institute for Geosciences and Natural Resources (BGR) from August to November 2005 (Siemon and Steuer, 2011).

As the mineralisation of water correlates with its electrical conductivity and therefore freshwater and saltwater can be distinguished in general, it was hoped that electromagnetic data would reveal freshwater resources not destroyed by the tsunami, particularly close to the populated coastal areas. The target areas were the city of Banda Aceh with the district of Aceh Besar on the north coast and the area on the west coast between the towns of Calang and Meulaboh in the district of Aceh Barat (Siemon et al., 2007). In addition to that, Coca-Cola Foundation Indonesia (CCFI) funded a further survey on the north-east coast around the town of Sigli in the district of Aceh Pidie (Steuer et al., 2008).

The electromagnetic surveys revealed several potential freshwater resources and areas of saltwater occurrences were mapped in detail. Many requests by aid organisations for information on the local geological and hydrogeological conditions for planned water wells were evaluated and could be successfully answered in most cases. Close to the coasts, however, the investigation depth of the HEM system was constrained due to highly conductive near-surface saltwater and, thus, ground-based time-domain electromagnetic measurements were necessary to reveal deeper coastal freshwater resources. The combination of airborne and ground-based electromagnetic techniques together with a hydrogeological reconnaissance survey increased the efficiency to estimate the freshwater potential. The airborne geophysical surveys helped to close the gaps between task-force measures and long-term planning as well as between spatial surface mapping and local borehole data. Particularly airborne electromagnetics proved to be a very efficient tool to supply hydrogeological baseline data for rehabilitation programs.

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Steuer, A., Siemon, B. and Eberle, D. (2008): Airborne and Ground-based Electromagnetic Investigations of the Freshwater Potential in the Tsunami-hit Area Sigli, Northern Sumatra. Journal of Environmental and Engineering Geophysics, 13(1): 39-48.

Keywords: helicopter-borne electromagnetics, electromagnetics, tsunami, groundwater, saltwater intusion

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STT03-04 Room:102A Time:May 23 10:15-10:30

Applicability of grounded-source AEM to coastal areas: Comparison between Kujukuri and Awaji Island cases

ITO, Hisatoshi[1*], KIHO, Kenzo[1], Hideshi Kaieda[1], Koichi Suzuki[1], TSUKUDA, Kazuhiro[1], MOGI, Toru[2], Akira Jomori[3], YUUKI, Youichi[4], ABD ALLAH, Sabry[2]

[1]CRIEPI, [2]Hokkaido Univ., [3]NeoScience Co., [4]Oyo Co.

Understanding geological and hydrogeological characteristics in coastal areas is vital because they are the places where most people live and work. Especially, it is important to delineate underground distribution of fresh and saline waters to maintain sustainable development in coastal areas and also for siting of geological disposal of nuclear wastes. As for the latter case, it is desirable to increase the depth of investigation to at least 300 m. To this end, a grounded-source airborne electromagnetics (AEM) is more suitable than conventional AEM. Firstly we applied GREATEM, a type of grounded-source AEM, to an alluvial plain, Kujukuri, where sedimentary rocks and shallow water prevail. The results were remarkable in that a reliable resistivity structure was obtained to a depth of 300-350 m both on land and offshore and low resistivity structures prevail both on land and offshore. We then applied the GREATEM method to northwestern Awaji Island, where granitic rocks crop out onshore. From this survey, we obtained underground resistivity structures to a depth of 1 km onshore and to a depth of 500 m offshore. The results were feasible in that onshore resistivity is much higher than offshore but were not acceptable in that the absolute resistivity value onshore was much lower than the true one. To circumvent this problem, a 3 D inversion technique is currently under development.

Keywords: airborne electromagnetics, coastal area, Kujukuri, Awaji Island

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STT03-05 Room:102A Time:May 23 10:45-11:10

CONDUCTIVITY RESOLUTION BY VARIOUS HELICOPTER BORNE TEM SYSTEMS

VERMA, Saurabh[1*], MOGI, Toru[2], Sabry Abd Allah[2]

[1]National Geophysical Research Institute, [2]ISV, Faculty of Science, Hokkaido University

The helicopter borne TEM (HTEM) survey technology is fast, effective, and in true sense a technology of the 21st Century as its genre and wide-ranging applications have increased exponentially since the year 2000. Most of the HTEM systems comprise a large transmitter loop source and a small receiver coil located concentrically or at a point above the transmitter loop that is flown below the helicopter. A couple of exceptional systems are GREATEM and FLAIRTEM that respectively employ a grounded cable and a large loop on ground as transmitters. Contemporary HTEM systems employ a wide variety of primary pulse shapes and transmitter moments to stimulate the subsurface in order to elicit response of geological targets. Frequency contents of these pulses determine the nature of decay response of various types of conducting terrains ranging from highly resistive Archaean granitic gneisses to highly conducting coastal regions with saline water. Numerical modeling is carried out to particularly examine and compare the dB/dt response of these terrains as seen and distinguished by various HTEM systems flying airborne transmitting loops (FLTx) and the GREATEM (GRTx) system. For FLTx systems we have also computed the response considering an ideal rectangular pulse for the purpose of comparison. It is found that the HTEM systems employing rectangular pulses yield fastest decaying transient response and provide the best conductivity discrimination among the FLTx systems. The next to follow are the systems that employ trapezoidal pulses. In this case the decay rate is somewhat slower and the conductivity discrimination is reduced slightly. Similar behavior is observed for the HTEM systems employing sinusoidal and triangular pulses with the latter showing the slowest decay rate and the least discrimination capability. It may also be noted here that slower decay rates also imply that as compared to the HTEM systems employing rectangular pulses, those employing trapezoidal, sinusoidal and triangular pulses see the same geological terrain as increasingly more conducting. Computations for the GRTx system reveal that for highly resistive terrains the decay rates for the FLTx and GRTx are found to be comparable. However, for increasing terrain conductivity, the decay rates for the GRTx slow down considerably and are distinctly separate for various conductivities. Thus the GRTx system provides much better conductivity discrimination as compared to various FLTx systems. The results underscore the advantage of GRTx system that uses the galvanic stimulation of the ground at a fixed spatial location in comparison to the FLTx systems that employ a flying transmitter loop in inductive mode with continuously varying location.

Keywords: AEM

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STT03-06 Room:102A Time:May 23 11:10-11:35

Airborne Gamma-Ray Spectrometry Surveys in Austria - An Overview

AHL, Andreas[1*], MOTSCHKA, Klaus[1], SUPPER, Robert[1]

[1]Geological Survey of Austria

The Geological Survey of Austria (GBA), Department of Geophysics, has been conducting airborne geophysical surveys since the beginning of the Nineteen-Eighties. The current aerogeophysical system includes an airborne gamma-ray spectrometer (AGRS) used for measuring the natural and anthropogenic radioactivity. The AGRS is equipped with eight downward and one upward looking NaI(Tl)-detectors. The AGRS system of the GBA is designed to cover a broad range of applications like geological mapping, geotechnical applications and radiation protection.

The processing of the AGRS-data mainly follows the IAEA guidelines. The data processing includes aircraft and cosmic background correction; radon background correction; Compton correction using stripping ratios calculated from measurements over four transportable calibration-pads and height correction. The parameters to calculate elemental concentrations are determined from repeated flights at different heights over a calibration profile. In order to consider the topography effect, measured concentrations are calculated in respect to the point on the earths surface closest to the detector.

Furthermore, we recently developed a vegetation correction for coniferous forests. The vegetation correction uses the first and the last reflection of the laser altimeter to characterize the vegetation. This vegetation correction has been successfully applied to several survey areas since its introduction.

Besides measuring the abundances of potassium (K), uranium (U) and thorium (Th), the AGRS-system is able to detect Caesium-137 (^{137}Cs). In contrast to K, U and Th, ^{137}Cs is entirely of anthropogenic origin. After the Chernobyl atomic accident in April 1986, radioactive elements were transported through the atmosphere for long distances and distributed over vast areas. Depending on rainfall during this period, which caused a washout from the radioactive cloud to the ground, the soil in the affected regions was contaminated by ^{137}Cs to varying degrees. Although much of the ^{137}Cs content has already decayed (30.17 years half-life), notable amounts can still be detected in Austria.

In 1990 the GBA conducted an airborne survey in an area called Hausruck, located at the northern edge of the Alps. This survey is not only interesting because it achieved our goals in mapping gravel, but because it is also a good example of the benefit of AGRS over non-energy discriminating instrumentation (like Geiger counters). The northern part of the survey area shows a relatively high level of natural radiation. Due to rainfalls on the northern hillsides of the Alps in the time after the Chernobyl accident, there remains an increased concentration of anthropogenic ^{137}Cs in the southern part of the survey area. In this situation the total amount of radiation caused by natural and anthropogenic radiogenic elements is nearly the same in the entire area and only energy discriminating instruments like NaI(Tl)- or Ge(Li)-detectors are able to identify and map the distribution of man-made radiogenic contamination.

In 2009 a multi-sensor airborne geophysical campaign was conducted, which consisted of surveys in Austria and Slovenia. These surveys were designed as test studies for the application of airborne geophysics for landslide investigations. In all of the test sites, minima in the concentrations of ^{137}Cs correlated well with bare surfaces of active landslides, earthflows and zones of higher superficial water flow. One of these survey areas is the test site of Sibratsgfall, a complex of shallow and deep-seated landslides and earthflows. In 2000 the GBA conducted a first survey on this test-site. In 2009 the survey was repeated to monitor changes in geophysical properties of the landslide area. The comparison of the two surveys not only shows minima of ^{137}Cs over the landslide, but also a faster decrease of the ^{137}Cs concentration at the landslide than in the surrounding areas.

Keywords: airborne geophysics, gamma-ray spectrometry

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STT03-07 Room:102A Time:May 23 11:35-11:55

Radioactive cesium distribution released from Fukushima Daiichi NPP by aerial radiation monitoring

KONDO, Atsuya[1*], SANADA, Yukihisa[1], Takeshi Sugita[1], TORII, Tatsuo[1]

[1]Japan Atomic Energy Agency

We measured the ambient dose-rate and the deposition amount of radioactive cesium by using four helicopters in the whole area of East Japan to investigate the influence of the radioactivity that released in the atmosphere due to the disaster of the Fukushima Daiichi NPP (Nuclear Power Plant), Tokyo Electric Power Company (TEPCO), occurred by the East Japan earthquake and tsunami on March 11, 2011. It reports on the measurement technique and the result.

A massive radioactive materials emitted from the NPP was released in the atmosphere due to the disaster and contaminated soils in the wide area in East Japan. Therefore, we have carried out the airborne radiation monitoring (ARM) in the whole area of East Japan, and investigated the influence of the radioactive cesium of the deposition to the ground level.

The ARM can plainly and promptly understand the distribution of the ambient dose-rate and the deposition of radioactive cesium by measuring gamma rays from the urban area to the forest over the wide range. An aerial radiation monitoring has following advantage. (1) The widespread distribution of radionuclides can be measured with short time by less manpower. (2) Descriptive contour maps of the deposition of the radioactive cesium can be depicted. (3) The radioactivity of the mountains and forests can be measured.

We were each equipped with a different measurement system in four helicopters, and they are large-size NaI scintillation detectors (16 x 4 x 2 inches or 16 x 4 x 4 inches) are being used inside/outside of each helicopter in-flight Both counting rates and the pulse-height distribution data (energy spectrum) were detected at each second. We also installed the GPS sensor in the helicopter, and measured the latitude, the longitude, and the altitude of the helicopter at the same time.

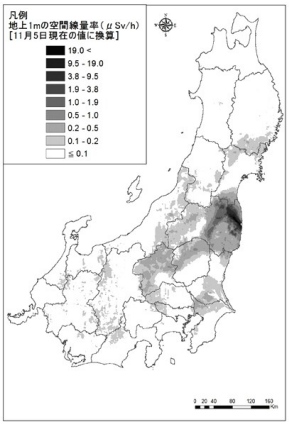
The flying altitude from the ground was obtained by subtracting the altitude obtained by the DEM (digital elevation model) data from that of the helicopter. The attenuation coefficient of air was obtained by flying at some altitudes (150 ? 900 m) in above the test-line selected for the comparison with the ground data. Moreover, the conversion coefficient of the ambient dose-rate was calculated by the comparison of the ambient dose-rate measured by an NaI survey-meter with the counting rate at 1 m height evaluated by using the attenuation coefficient.

Furthermore, the deposition amount of radioactive cesium (Cs-134, Cs-137) on the ground was evaluated according to the dose-rate-to-radioactivity conversion coefficient obtained by the result of the in situ Ge measurement on the ground.

We also made maps of the dose-rate and the deposition of radioactive cesium by using the IDW (inverse distance weighted) procedure as an interpolation method of a GIS software.

The map of the ambient dose-rate is shown in Figure 1. It has been understood for the region where the dose-rate is high to extend from the NPP for northwestward, and wide to Gunma Prefecture from the vicinity of Fukushima City in the direction of the southwest. This map is utilized to determine the decontamination area and estimate the variation of contamination areas.

Keywords: Airborne survey, Radioactive cesium, Fukushima Daiichi NPP, East Japan earthquake



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STT03-08 Room:102A Time:May 23 11:55-12:15

Airborne gamma ray spectrometry using balloon and radio controller helicopter for decontamination evaluation

IMAIZUMI, Masayuki[1*], YOSHIMOTO, Shuhei[1], ISHIDA Satoshi[1], YUUKI, Youichi[2], HIRATA, Ryoji[2], OKUSHIMA Shuji[1], NAKA Tatsuo[1]

[1]Institute for Rural Engineering, National Agriculture and Food Research Organization, [2]Oyo Corporation

Airborne gamma ray spectrometry (AGRS) is the technique used to measure the energy spectrum and intensity of the radiation. AGRS system is newly developed for evaluation of decontamination. Detector packages for airborne spectrometry are made up of 3-inch diameter NaI crystal with a photomultiplier tube. Resolution is about 7%. Peripheral device consist of laser altimeter, GPS, video camera as well as a typical airborne gamma ray device such as pulse height analyzer, etc. 500g KCl reagent bottle is build in near NaI crystal for standard energy of 1,460 keV of K-40. The gamma ray spectrum over the range of 0 to about 2,000 keV is resolved by airborne spectrometers into 1,024 channels. The target nuclides with the emission of gamma rays in range between 0 to about 2,000 keV are natural nuclides (K-40:1460 keV and Bi-214:1765 keV) and man-made nuclides (Cs-137:662 keV), Cs-134:605, 795 keV).

Institute for Rural Engineering has conducted two experimental decontamination of the rice paddy in Iitate Village which has been included in the planned excavation zone with 20-50 mSv/year due to fallout from the Fukushima Dai-ichi Nuclear Power Plant accident; 1) removal of surface soils by fixation agent (RSS-FA) and 2) mixing soils and removal using water (MSRW). Two methods were evaluated by AGRS mounted on balloon and radio controller helicopter (RCH). Area of B site for RSS-FA test is 10,000m^2 within B paddy field (30,000m^2). Area of C site for MSRW test is 10,000m^2 within C paddy field. Survey area of balloon-AGRS is 225,000m^2 included the test site B and C. Survey spacing is 2.5 m. The spectrometer at height 0.05 m in the air was tows by man-power at speed about 3 km/h (0.83 m/s). Measurements before and after decontamination ware carried out on August 3 and 31, 2011, respectively. Survey area of RCH-AGRS is 600,000m^2 included the test site B and C. Flight height and line spacing was 5 m. Data of both survey is sampled once per 10 second. The balloon AGRS could be used with great success to evaluate RSS-FA and MSRW decontamination of paddy fields (Fig.1). It could exactly identify the places: X, Y, and Z where men trampled on the ground surface. RCH-AGRS could show RSS-FA and MSRW decontamination of paddy and revealed that the low radioactive cesium concentration zone to toward the Niita River, which may be caused by radioactive cesium runoff with rain water. RCH-AGRS is an effective tool for monitoring on secondary rework contamination of fallout as well as decontamination.

Keywords: airborne gamma ray spectrometry, decontamination evaluation, Fukushima Dai-ichi Nuclear Power Plant

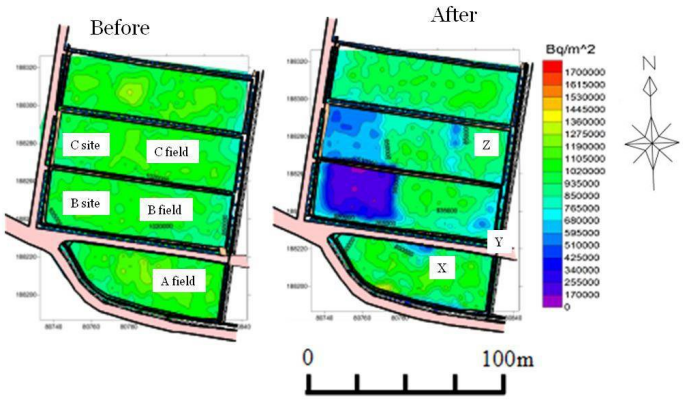

Fig.1 Cs-134 concentration map before and after decontaminations