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# Application Analysis of Various Geophysical Methods in Volume Calculation of Different Landfills

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## Abstract

Garbage disposal has gradually become a key issue faced by environmental governance. What must be controlled in garbage disposal is the calculation of garbage volume. In this paper, according to the different landfill conditions of a landfill in Anhui, including: covering soil, overlying HDPE membrane, overlying concrete, etc., combined with the physical differences between the rock mass and the garbage at the bottom of the landfill. The landfill covered with HDPE membrane adopts the transient electromagnetic method, the landfill covered with soil layer adopts the high-density electrical method, and the landfill covered with concrete adopts the combination of transient electromagnetic method and ground penetrating radar. At the same time, Combines the borehole data to determine that the resistivity value of the interface between the garbage and the soil was 29 Ω·m. Finally, the sections of multiple survey lines can accomplish three-dimensional stereoscopic that calculate the distribution and actual volume of the garbage. This method is used to determine the final investment cost.

## Keywords

Garbage Volume, Geophysical Exploration, Transient Electromagnetic Method, High-Density Electrical Method, Ground Penetrating Radar

## 1. Introduction

In recent years, with the substantial improvement of the national economic level, the problem of garbage has gradually become an important part of environmental governance. More and more garbage disposal methods are used in landfills, resulting in soil and groundwater pollution problems seriously affect daily life.

One of the main problems faced in the process of garbage disposal is the calculation of garbage volume. The determination of garbage volume directly affects the subsequent treatment methods and costs. As a non-destructive testing method based on the physical property difference of the detected target layer, geophysical exploration can select appropriate geophysical exploration methods according to the landfill conditions of different landfills to realize the target layer detection. U.S. Army Crops of Engineers, 1995 new applications in waste surveys. This handbook provides a number of methods for solving environmental and engineering problems with geophysical methods. It mainly includes seismic wave method, electrical method and electromagnetic method, gravity method, magnetic method and remote sensing method. Among them, for the purpose of environmental investigation, the pipeline trenches buried in the ground were successfully surveyed, and the pollution range and the boundary range of the landfill were detected. In 1998, a status report entitled "Applying Geophysical Methods to Survey DNALS" was jointly compiled by the US Environmental Protection Agency, the Department of Defense (Army, Navy, and Air Force), the Department of Energy, and the Department of the Interior [1] (U.S. Environmental Protection Agency, 1998). The report introduced the high-precision three-dimensional electromagnetic method, electrical impedance perspective technology, seismic wave method, seismic wave amplitude migration technology, cross-well radar, etc. have been applied. The selective use of these methods has shown that the geophysical method can detect pollution and uncontaminated soil to define the scope and depth of contamination. Lindsay N. Meads *et al.* [2] [3] used the resistivity imaging method combined with the drilling verification data to determine the waste range, aqueduct channels and aquifers of a landfill in Alberta, and combined the resistivity imaging data to complete the landfill efficiently and accurately. The 3D geological model was established. In China, the application of geophysical exploration methods in landfills is relatively late. In 2002, Zhao Zhangyuan *et al.* focused on the use of environmental geophysics to rapidly detect the pollution status of groundwater, radiation environment and various hidden pollutants, and further put forward In 2004, Cheng Yexun *et al.* [4] [5] [6] detected the possible leakage locations of typical garbage dumps from electrical method, electromagnetic method, geological radar method, geothermal method, and sampling chemical analysis method. The apparent resistivity of soil and groundwater is around 10 Ω·m, which can be characterized as polluted, and the spatial location of underground pollutants is given; in 2010, Liu Zhaoping [7] [8] adopted a variety of different geophysical methods for different types of garbage, combined with Geological and geophysical characteristics of the region were analyzed to compare the roles and capabilities of different geophysical methods in delineating and monitoring the extent and diffusion trends of landfill contamination [9]. In 2013, Chen Yaojun [10] [11] carried out the comprehensive application of Rayleigh wave method and geological radar method in filling boundary detection of landfill waste, and found out the distribution location and distribution form of filling boundary of waste landfill.

Comparative analysis of drilling verification results proved that. It is effective and reliable to use the Rayleigh wave method and the geological radar method to find the filling boundary of the landfill [12] [13] [14] [15].

According to the different landfill conditions of the landfill, including: covering soil, overlying HDPE membrane, overlying concrete etc. Different landfill conditions require different geophysical exploration methods, combined with the physical differences between the rock mass at the bottom of the landfill and the garbage, different methods are used to determine the bottom interface of the garbage. Finally three-dimensional stereoscopic is performed by using the sections of multiple survey lines to calculate the distribution range of the garbage. In this paper, the transient electromagnetic method is used for the landfill covered with HDPE membrane, the high-density electrical method is used for the landfill covered with soil, and the combination of transient electromagnetic and ground penetrating radar is used for the landfill covered with concrete. The method is used to determine the bottom interface of the garbage and find out the distribution range. Finally, using the sections of multiple survey lines to perform three-dimensional interpolation, the distribution range and actual square quantity of garbage can be calculated. This method is used to determine the final investment cost

## 2. Project Overview

A landfill covers an area of about 290,000 $m^2$, as shown in **Figure 1**, including an old landfill, a sanitary landfill (including the first and second reservoir areas),

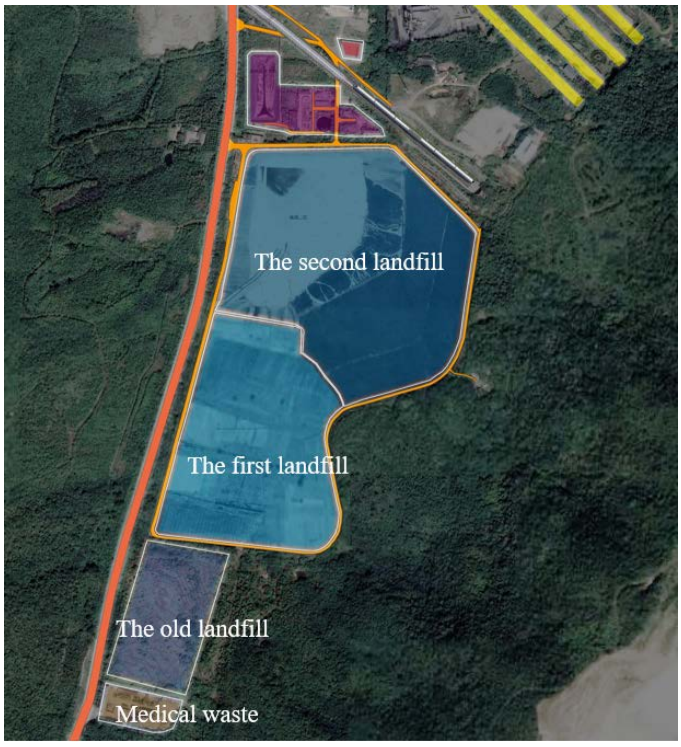


**Figure 1.** Analysis of the status quo of the landfill.

sewage treatment stations and non-production areas, etc. Among them, the old landfill was built in 1999, covering an area of about 35,000 $m^2$. It used natural valleys for simple landfill without any anti-seepage measures. In 2010, the simple closure (covering soil and geotechnical composite drainage network) was completed. The first reservoir area of the sanitary landfill started construction in 2004 and was put into operation in 2009; the second reservoir area started construction in October 2009 and was completed in November 2011.

## 3. Method Principle

Due to the large amount of leachate in the garbage dump, the resistivity of the garbage dump is low, and there is a big difference in resistivity with the surrounding strata. Contact-type transient electromagnetic method; the overlying soil layer of the old landfill area can be smashed into the electrode to supply power, and the contact-type high-density resistivity method is considered; there are also landfills under some areas of medical waste, because the surface is concrete and cannot be smashed. The input electrode and the burial depth are relatively shallow, so consider using a combination of transient electromagnetic method and ground penetrating radar.

### 3.1. High Density Resistivity Method

The high-density resistivity method is still based on the difference in the electrical conductivity of rock and soil, which studies the distribution law of conductive current in the ground under the action of artificially applied stable current field. Its theoretical basis is the same as that of the conventional electrical method, the difference is the method technology. The high-density resistivity method is actually an array exploration method. During field measurement, all the electrodes are only required to be arranged on one measuring line, and the fast and automatic data acquisition can be realized by using the program-controlled electrode conversion device and the micro-electromechanical measuring instrument. The measurement results are sent to the computer, and the given interpretation software is used for data processing and various graphical results about the distribution of the geoelectric cross-section are given.

### 3.2. Transient Electromagnetic Methods

The transient electromagnetic method is a time-domain electromagnetic induction method. During the detection, a square wave of current pulse is supplied on the sending back line. At the moment when the back edge of the square wave falls, a primary magnetic field is generated that propagates in the normal direction of the sending back line. Under the excitation of the primary magnetic field, the geological body will generate eddy currents, its size depends on the degree of conductivity of the geological body, after the first field disappears, the eddy current will not disappear immediately, and it will have a transition (decay) process. The transition process produces a decaying secondary magnetic field that prop-

agates into the geological body, and the secondary magnetic field is received by the receiving loop. The change of the secondary magnetic field will reflect the electrical distribution of the geological body.

The transient electromagnetic field mainly propagates in the form of diffusion in the earth. In this process, the electromagnetic energy is directly consumed in the conductive medium due to propagation. Due to the skin effect, the high-frequency part is mainly concentrated near the surface, and its distribution range is below the source. The lower frequency part propagates to the depth, and the distribution range gradually expands.

Spread depth:

$$d = \frac{4}{\sqrt{\pi}}\sqrt{t/\sigma\mu_0} \tag{1}$$

Transmission speed:

$$v_z = \frac{\partial d}{\partial t} = \frac{2}{\sqrt{\pi\sigma\mu_0 t}} \tag{2}$$

$t$: spread time;

$\sigma$ : dielectric conductivity;

$\mu_0$ : Magnetic permeability in vacuum.

### 3.3. Ground Radar Method

Ground Penetrating Radar (Ground Penetrating Radar Method) is a geophysical detection method that uses the ground penetrating radar transmitting antenna to transmit high-frequency pulsed electromagnetic waves to the target, and the receiving antenna receives the reflected electromagnetic waves of the target to detect the spatial position and distribution of the target. It actually uses the reflection characteristics of electromagnetic waves of the target body and the surrounding medium to detect the structure and defects (or other inhomogeneous bodies) inside the target body. It is one of the most advanced and convenient instruments for measuring internal defects of objects at home and abroad. The antenna shielding has strong anti-interference, wide detection range, high resolution, real-time data processing and signal enhancement, and continuous perspective scanning.

## 4. Engineering Application Analysis

The total area of the sanitary landfill is about 200,000 $m^2$, the bottom of the landfill is used with 2 mm HDPE membrane and Horizontal seepage prevention of geotextile. The surface layer is made of single-layer HDPE membrane to prevent seepage, and the designed total storage capacity is 3.5 million $m^3$ (The storage capacity of the first storage area is 1 million $m^3$, and the storage capacity of the second storage area is 2.5 million $m^3$), and Currently only the first storage area has been landfilled. The old garbage landfill is mainly landfills mainly landing domestic garbage. The soil layers within the maximum exploration depth (24.00

m) are divided into three categories: artificial accumulation layer, Quaternary flood slope accumulation layer and Silurian sedimentary rock according to the depositional age and genetic type. Part of the medical waste area is covered on the top of the old garbage and covered with concrete.

### 4.1. Measuring Line

As shown in Figure 2, the HDPE membrane covered in a database area cannot be smashed into the electrode power supply, and the non-contact transient electromagnetic method can be used. Considering that the depth of garbage buried can reach 20 m, it is overlapped back with a 2 m side length overlapping loop coil, point distance 2 m, line distance 10 m, a total of 25 test lines, the transmission frequency is 12.5 Hz, the number of superimposed times is 128; as shown in Figure 3, The overlying soil layer of the old landfill area can be smashed into the electrode to supply power. The contact type high-density resistivity method is used to directly smash the electrode into the overlying soil layer. A total of 10 measured lines were arranged to use the wenner quadrupole device. As shown in Figure 4, there are also garbage landfills in some areas of medical waste. The concrete pavement cannot be smashed into the electrode and the buried depth is shallowly within 10 m considering the use of the transient electromagnetic method and the 100 M probe radar method. Among them, the transient electromagnetic uses the pair coil, the point distance is 2 m, the line distance is 1 m, and the coexistence is arranged. Three test lines, the transmission frequency is 125 Hz, the number of superpositions is 128 times.

### 4.2. Data Interpretation

Due to the limited space, different landfill conditions are selected to explain a typical section. The remaining lines are explained according to this explanation method.

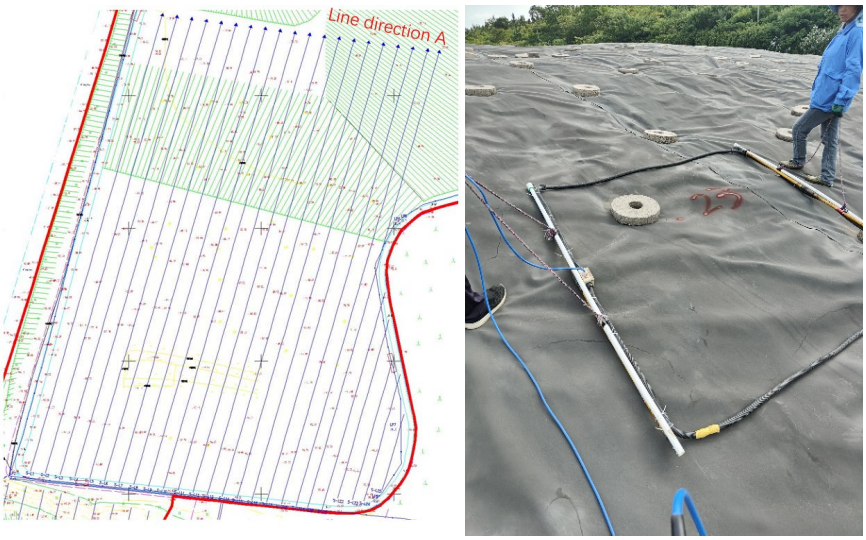


**Figure 2.** The layout of the landfill area in the first storage.


**Figure 3.** Survey line layout of old landfill area.

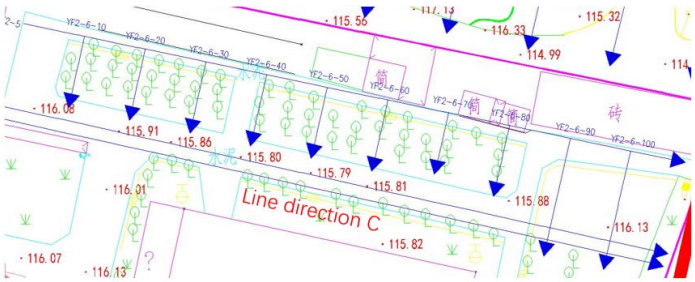


**Figure 4.** Survey line layout of the medical waste area.

The first storage area selects L-8, as shown in **Figure 5**, combined with the apparent resistivity section diagram of the transient electromagnetic treatment, the intercourse of the apparent resistivity is displayed, and the resistance rate from shallow to deep vision has gradually increased. The rate distribution range is about 70 - 80 ohm·m. It is speculated that the apparent resistivity distribution of the percolate in the landfills is about 30 - 40 ohm·m. Among them, as shown in the position in the figure, there are some low-resistance abnormal areas in the individual locations distributed at the bottom of the garbage landfill, and the visual resistance rate can be as low as 30 ohm·m. It is speculated that there may be some leakage.

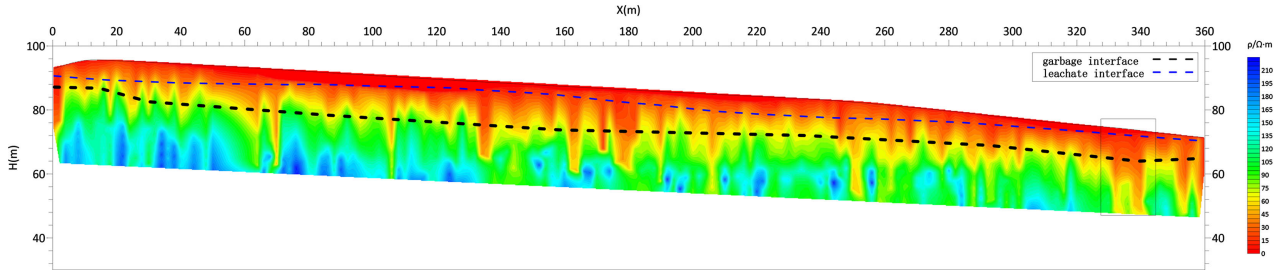


**Figure 5.** The first storage area L8 transient electromagnetic apparent resistivity section diagram.

As shown in **Figure 6**, the old landfilling area is selected from the L-25, which is located in the middle of the sanitary landfill area. The measured line set from north to south. From shallow to deep vision resistance, the overall range is better. The apparent resistivity is distributed at about 60 - 70 ohm·m. It is speculated that the scope of the visual resistance of the garbage body in the landfills is about 30 - 40 ohm·m. 2 low-resistance abnormalities are speculated that the location of the garbage distribution may be connected with the groundwater.

As shown in **Figure 7**, the transient electromagnetic measurement line of the medical waste area is located on the south side of the road of the medical waste area. The measured line set up from west to east. The overall visual resistance is distributed above 80 ohm·m. Starting at 30 meters, there are large area of low resistance abnormalities, which continues to 90 meters in the measuring line. The resistance value is below 30 ohm·m. It is speculated that it may be the location of the garbage distribution.

### 4.3. Drilling Verification

As shown in **Figure 8**, Combined with the old landfill area survey line 25 high-density electrical method apparent resistivity cross-sectional view, the three verification drills of AlJ06, AlJ10 and AlJ12 are arranged is soil. Among them, the drilling and coring results of ALJ12 are shown in **Figure 9**, 0 - 1.2 m is soil, 1.2 - 21.6 m is garbage, and 21.6 - 22m is soil. Through the actual exposure of drilling and the visual resistance of high-density electrical method, the resistance of the bottom of the garbage and soil division is about 29 ohm·m. Other subsequent locations are similar to this verification method to determine the resistivity value of the top-bottom interface of the garbage and the layered interface of the soil.

### 4.4. Volume Calculation

Based on the bottom interface of the garbage top of each line, each three-dimensional stereoscopic of the old garbage landfill is performed. The spatial distribution characteristics of the garbage body are shown in **Figure 10**. Using the characteristics of the determined resistance value of the interface between the garbage and soil of 29 ohm·m, the three-dimensional volume was calculated to estimate the volume of the old landfill to be about 412,000 $m^3$.

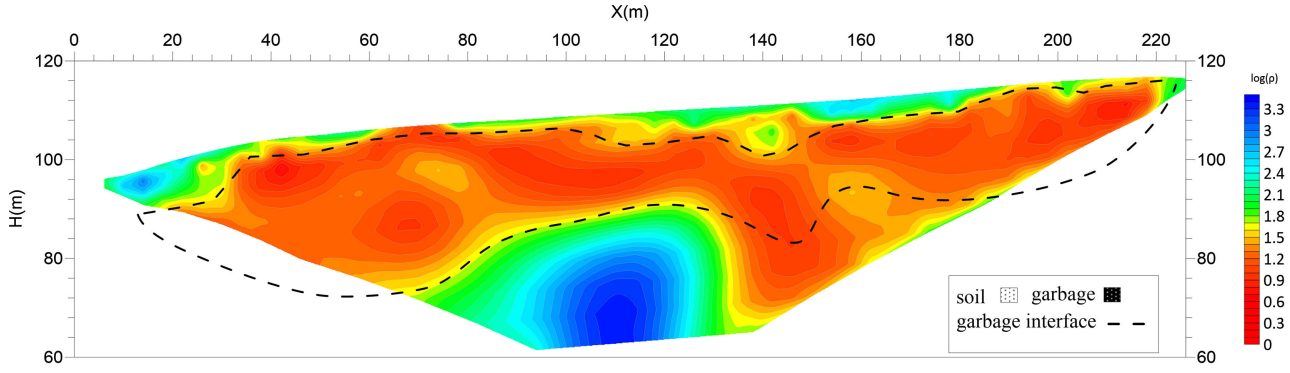


Figure 6. High-density electrical method apparent resistivity cross-sectional view of measuring line 25 in the old landfill area.

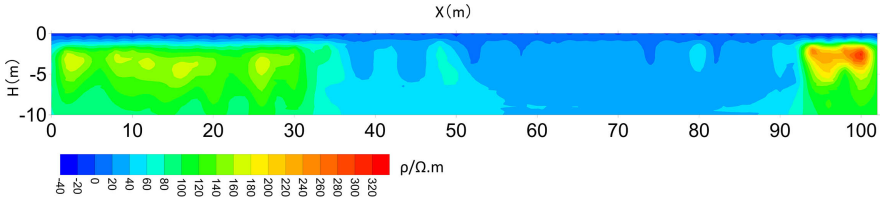


Figure 7. Transient electromagnetic apparent resistivity cross-sectional view of measuring line 2-1 in the medical waste area.

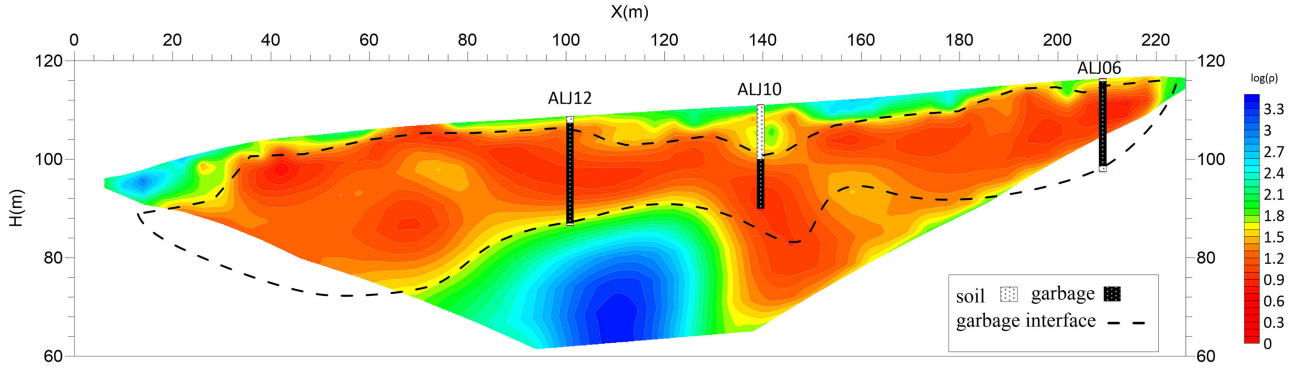


Figure 8. Old landfill area measurement line 25 drilling layout map.

Figure 9. Old landfill ALJ12 drilling core.

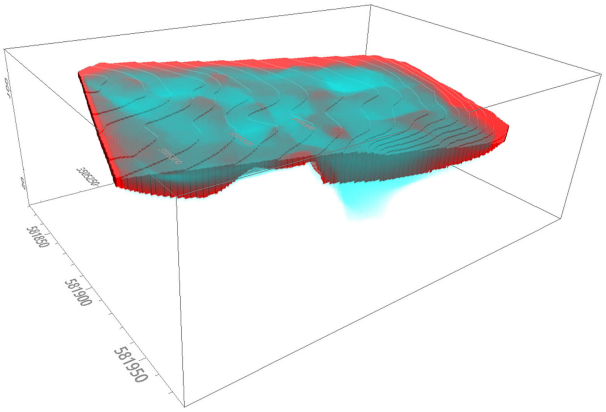


**Figure 10.** Spatial distribution characteristics of garbage in old landfill areas.

## 5. Conclusions

In view of the volume calculation of landfills under different landfill conditions, the resistivity is measured by different geophysical exploration methods. The following conclusions are drawn:

1) The garbage landfill with the overlying HDPE membrane can use the transient electromagnetic method; the garbage landfill with the covering soil can adopt high-density electrical method; the combination of transient electromagnetic and ground penetrating radar can be used for the landfill covered with concrete.

2) Combined with the borehole data and apparent resistivity section diagram, the interface resistance of garbage and soil is about 29 ohm.

3) Using the resistivity values determined at different levels, three-dimensional stereoscopic of each survey line is performed, combined with the determination of the isoline boundary of the top and bottom interfaces of the garbage, the volume surrounded by the two contour lines can be calculated as the volume of garbage.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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