Frequency characteristics and impedance as a criterion for purity by the monitoring of soil

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Abstract – Electrical Impedance Spectroscopy (EIS-method) is a reliable method, widely used in various fields of science and practice, allowing to measure impedance. Impedance measurement scheme can be presented as Randles model. The frequency characteristics of the clean and contaminated soil are substantially different.

Keywords – EIS-method, Randles model, Soil monitoring, Frequency characteristics, impedance.

The UN Standing Committee on Ecology defined environmental monitoring as a system of repeated observations on components and factors of the environment in spatially scale and consistently in time with specific purposes in accordance with monitoring programs [7]. Monitoring usually refers to processes in which observations are made over time and it is a special system for repeated observations and analysis of one or more elements of the environmental conditions, intended to register, evaluate and predict.

In the Bulgarian national system for environmental monitoring one the land - shaft, lands and soils are specific monitoring objects. The measurement generally refers to processes in which qualitative or quantitative properties are determined, as a rule. The main soil parameters, subject to measuring, with regard to soil contamination include: presence and concentration of heavy metals and metalloids, total nitrogen content \((N_{tot})\), nitrate nitrogen, ammonia, phosphorus, organic carbon, robust response of the soil \((pH)\), electrical conductivity, total carbon and persistent organic pollutants - 16 PAH, 6 PCB, 15 – chloro - organic pollutants, and others [6]. The needs of environmental monitoring, the frequency of sampling and measurement, allocations of sampling points and polygons, applied monitoring methodology should be determined correctly [8].

A wide variety of approaches and methods are applied in the soil monitoring systems, but most of the conventional methods for soil monitoring are direct, purely laboratory methods, expensive. Therefore, the use and maintenance of calibrated and verified tools for monitoring and measurement should be ensured, as well as the development and application of devices and software. The Electrical Impedance Spectroscopy (EIS-method) is a commonly adopted method in many areas and in practice it is used for the measurement of electrical resistance, also for obtaining the frequency characteristics of the impedance of porous materials, as is the soil. The method allows to create a profile of soils differing in composition, which shows the moisture content (moisture regain) and is indicative regarding mineral content and in some cases pollution level [2], [3].

The scheme of measurement can be depicted in the form of Figure 1 and it shows the equivalent scheme, originally proposed by John Randals (John Edward Brough Randles), for modeling of surface electrochemical processes [1], [4], [5]. Randals model is simple, while the real electrochemical systems are usually more complex, but it is the basis for more complex cases.

![Fig. 1. Randles model](image)

where:

\( R \) - soil resistance \([Ω]\),

\( R_п \) - polarization resistance \([Ω]\),

\( C_{dc} \) - double layer capacity \([F]\).

When the circuit has not only active but reactive elements as well, and the current is sinusoidal with circular frequency \(ω\), then the Ohm's law can be generalized, and the participating variables become complex.

In the frequency domain the dependence for the impedance has the form:

\[ Z(ω) = R + jωC_{dc} \]

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\[ Z(j\omega) = R + j\omega X \quad (1) \]

Frequency characteristics for Z can be written as complex numbers in algebraic form.

For the Impedance readings at Randals model is formed [5]:

\[
Z = R + \frac{1}{1 + \frac{1}{R_n + \frac{1}{Z_{dc}}}} \quad (2)
\]

The frequency characteristics - real frequency, imaginary frequency, amplitude - phase characteristic, amplitude - frequency, a phase - frequency are calculated and analyzes regarding the purity of the soil.

For this purpose five measurements of different depths have been made on soils gathered from the North-Eastern regions of Bulgaria [3]. The measurements for the non-contaminated soil are at frequencies: 2000, 6000, 10000, 15000, 20000 Hz, at a temperature of the air 28 degrees, 25.6 degrees for the soil and a depth of 0-20cm and 40-60cm.

The measurements of the contaminated soil are made for the same frequency diapason of depths: 0-20cm, 20-40cm, 40-60cm. They are processed in Matlab and some of the obtained results are systematized and presented below.

\[
\begin{align*}
\omega &= \begin{bmatrix} 12560 & 37680 & 62800 & 94200 & 125600 \end{bmatrix} \\
\text{>>f} &= [2000,6000,10000,15000,20000] \\
\text{>>}\omega &= 2\pi \times f \\
\text{>>Re1} &= [1271,1268,1265,1260,1249] \\
\text{>>Im1} &= [-195,-101,-23,73,167] \\
\text{>>Re2} &= [890,909,909,909,901] \\
\text{>>Im2} &= [-188,-68,-9,65,131] \\
\end{align*}
\]

The results are presented in fig1 and fig.2. The top two graphics are for clean soil. The bottom three graphics are for contaminated soil.
In fig1 are presented amplitude – frequency characteristics.
In fig. 2 are presented phase – frequency characteristics. The graphics are presented in Mathlab.

The frequency characteristics amplitude - frequency and phase - frequency of the clean and contaminated soil extract are substantially different - fig.2, fig.3. In rainy weather the soil has good conductive abilities, under certain chemical contaminants and in these cases $Z=(101-102)\,\Omega$. The soil contaminated with nitrates is a good conductor and the frequency characteristics are not affected by the depth of the probes, or by the frequency. The conductivity of water soluble electrolytes in the soil correlates with the concentration of the organic and micro organic elements. In terms of the environment increased levels of conductivity of the soil shows possible non-organic mineral pollution. The ammonium nitrate changes the electrical characteristics of the soil [4]. The graphics of the amplitude - phase characteristic are also indicative [5], that can be used with the same success.

Thus, by using the EIS method the content of fertilizer in the soil can be observed. This is especially important in the sanitary-protection zones of water catchments for drinking purposes, because the monitoring includes not only observation, but an assessment of the actual condition of the environment as well as forecasting its changes, and depending on the range, the tasks and directions. The purpose of monitoring is not only a passive observation of facts but also for conducting experiments, as well as process modelling as a basis for forecasting.

References

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Client-Server System for Improving Ecological Conditions of the Environment

Dijana Jagodić¹, Dejan Vujičić¹, Siniša Ranđić¹

Abstract – This paper describes the client-server system that was designed to improve ecological awareness of the society. Illegal landfills represent a big problem nowadays, and communal services cannot deal with them all, particularly because some of them are on unknown locations. The presented system can help communal services to better track illegal landfills and to react accordingly, but also any other communal problems can be reported. System is composed of Android client application, which is used to send information about ecological problems. These records are sent to the server, where the dispatchers review the issue and react accordingly to the problem. Users can send coordinates and description of the problem location, to facilitate problem solving process.

Keywords – Android, client-server, ecology, illegal landfills, waste management.

I. INTRODUCTION

Natural resources are the key factor of the economic prosperity of a country. In order to be used at a maximum level, they need to be preserved and exploited in ecologically acceptable manner. However, with the technological development and increase in manufacturing production, the problem of waste management emerges as one of the major issues. The resolving of this problem not only involves the state legislations and regulations, but also the social responsibility of the companies and the whole society. While the companies’ ecological responsibilities are primarily regulated by laws and inspections, the awareness of the society, particularly in developing countries, such as Serbia, is at low level. There have been numerous campaigns to increase ecological education in Serbia, but unfortunately, the reality is less than satisfactory.

Illegal landfills and undesirable disposal of communal waste are major factors in disturbing of natural balance. Large number of metal cans, plastic packaging, and even hazardous toxic materials are just dropped in nature and left to the mercy of ecologically responsible individuals. The degradation period of these materials can be longer than hundred years, some of them cannot be degradable at all. Their presence influences not only the soil, but also the watercourses and the ecological environment at a whole.

This paper describes the client-server system that is designed to help the community and state to overcome these ecological issues by suggesting larger involvement of the society and individuals in this process. The people are given a chance to prove their ecological consciousness by reporting any illegal landfills or any sort of dump sites they stumble upon. In this way, the proper cooperation between the society and communal services can bring long expected balance to the environment.

The chapters in this paper are organized as follows. The second chapter brings the issues in waste management, particularly with the communal waste, packaging waste, and illegal landfills. In the third chapter the client-server system for reporting of ecological problems is described. The final chapter summarizes the whole matter.

II. WASTE MANAGEMENT – MAJOR CHALLENGE OF THE MODERN SOCIETY

The waste management policy at European Union level is defined in Waste management strategy. It is based on hierarchy of principles, where the biggest priority is given to the prevention of waste formation, then to reusability and recycling, energy regeneration, and finally, to the waste disposal [1].

It is considered that Republic of Serbia belongs to the group of countries with low level of waste management. The following problems have been emphasized [1]:

- Omissions in applying the laws regarding waste management and ecological preservation;
- Lack of infrastructure;
- High costs and irrational organization of waste management;
- Low level of quality of service;
- Insufficient concern and enrollment of society and individuals into environmental problem solving.

Chapter 27 in the Serbia’s application for membership of the European Union is regarding environmental conditions. In its document from 2011, it is said that Serbia has implemented crucial laws in line with the recommendations from EU, particularly in terms of waste prevention, reuse, recycling, and recovery. However, the major problems are emphasized as low waste collection rates in rural communities and vast number of illegal landfills [2]. In 2012, Serbia was successful in terms of registration and reporting on waste, but still, the waste collection rate in rural areas remains an issue [3]. By opening a regional waste management center in Pirot in 2013, Serbia moved on toward better waste management society. However, European Commission suggested that landfilling should be used only as a necessity, if there are no other waste management methods [4]. In 2014, a new waste management facility was opened and Serbia has had seven EU compliant regional landfills. European Commission emphasized the necessity of closing illegal landfills [5]. A regulation on the
plan for reducing packaging waste in period 2015 – 2019 was adopted by Serbia in 2015, but its implementation mainly depends on resolving “systematic weaknesses in the implementation of environmental projects” [6]. This paper addresses this problem, by suggesting larger enrolment of society and individuals in the preservation of ecological environment.

A. Communal Waste

The data about communal waste are collected via reports from local communal services. Some indicators regarding communal waste for the period 2011 – 2014, are given in Table I [7].

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of generated waste (millions of tons)</td>
<td>2.71</td>
<td>2.62</td>
<td>2.41</td>
<td>2.13</td>
</tr>
<tr>
<td>Amount of collected waste (millions of tons)</td>
<td>2.09</td>
<td>1.83</td>
<td>1.92</td>
<td>1.67</td>
</tr>
<tr>
<td>Amount of reused waste (tons)</td>
<td>N/A</td>
<td>N/A</td>
<td>24843</td>
<td>14521</td>
</tr>
<tr>
<td>Average percentage of waste collection (%)</td>
<td>77</td>
<td>~70</td>
<td>80</td>
<td>~80</td>
</tr>
<tr>
<td>Average daily amount of waste per capita (kg)</td>
<td>1.01</td>
<td>0.99</td>
<td>0.92</td>
<td>0.81</td>
</tr>
<tr>
<td>Average yearly amount of waste per capita (tons)</td>
<td>0.37</td>
<td>0.36</td>
<td>0.34</td>
<td>0.30</td>
</tr>
</tbody>
</table>

From Table I, it can be seen that the total amount of generated waste is decreasing, starting with the year 2011, which is in accordance with the data from the European Environment Agency, where many countries reported decreased amount of communal waste in 2014 [7].

B. Packaging Waste

Packaging waste management is primarily related to preservation of natural resources. Some indicators regarding packaging waste for the period 2011 – 2014 are given in Table II [7-10].

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of market released packaging (thousands of tons)</td>
<td>343.66</td>
<td>344.25</td>
<td>321.58</td>
<td>327.71</td>
</tr>
<tr>
<td>Amount of reused waste (thousands of tons)</td>
<td>96.12</td>
<td>126.20</td>
<td>87.95</td>
<td>102.67</td>
</tr>
<tr>
<td>Percentage of collected paper and cardboard packaging (%)</td>
<td>79.31</td>
<td>72.35</td>
<td>63</td>
<td>62.8</td>
</tr>
<tr>
<td>Percentage of collected plastic packaging (%)</td>
<td>3.83</td>
<td>13.8</td>
<td>15</td>
<td>16.3</td>
</tr>
<tr>
<td>Percentage of collected wood packaging (%)</td>
<td>8.54</td>
<td>2.08</td>
<td>8</td>
<td>7.5</td>
</tr>
<tr>
<td>Percentage of collected metal packaging (%)</td>
<td>0.16</td>
<td>0.46</td>
<td>4</td>
<td>4.7</td>
</tr>
<tr>
<td>Percentage of collected glass packaging (%)</td>
<td>7.96</td>
<td>11.32</td>
<td>10</td>
<td>8.7</td>
</tr>
</tbody>
</table>

Packaging waste management has important ecological, social, and economic aspect. Packaging waste, depending on its category, has very long time of recycling. For example, it takes 500 years for degradation of one aluminum can. Degradation of PET packaging takes 100 years. Glass packaging will never degrade [11].

As can be seen from Table II, reusability of packaging waste has increased over years, but still it represents less than a third of an amount of market released packaging. Also, paper and cardboard packaging represent the major part of packaging waste. This issue can be resolved by building more recycling factories and waste management facilities, which is key principle in the Strategy of the waste management for the period 2010 – 2019 of the Republic of Serbia [12].

C. Illegal Landfills

Data from 2014 show that there are total of seven sanitary landfills in the Republic of Serbia, and two are in the process of getting a working license. Communal services dispose communal waste to a total of 120 landfills. It has been located 3085 old and wild landfills. However, these data are collected from total of 142 municipalities. Landfills were not located in 15 municipalities, while 13 municipalities didn’t send any data [7]. The location of illegal landfills in the Republic of Serbia, not including province of Kosovo and Metohija which is under temporary control of United Nations, is shown in Fig. 1 [13]. Yellow markers represent illegal landfills, and red markers represent communal services’ landfills.
III. PRACTICAL REALIZATION OF THE SYSTEM

The system for reporting of ecological problems is comprised of client Android application and server for data acquisition and representation.

A. Client Android Application

The Android application layout is shown in Fig. 2.

The field Type of problem is designed to select one of the three categories that the system is able to report:
1. Illegal landfill;
2. Other communal problems;
3. Inspection services.

The primarily target of reporting are illegal landfills, but some minor communal problems such as garbage on the public areas, can be reported as well. The third category is designed for reporting other communal problems not necessarily related to landfills.

The user may enter its name, phone, and e-mail address. If the user enters its phone or e-mail address, than by selecting the option from Notification method drop-down field, it can be notified about taken actions on the problem solving. The only obligatory field is Description of problem, in which user enters text describing the nature of the problem. The location of the troubleshooting place can be retrieved via GPS service inside the mobile phone, or by manual selection by placing the marker on the included map.

Another useful feature is the image of the problem, which user can take with camera on its mobile phone or select from device storage and send it together with other data. By clicking on the button Submit, the problem is sent to the server.

B. Server Side of the System

The data are sent to the server by using the SOAP – based Web service. Image is sent as an array of bytes. The Web service is written in C# and it stores all the data in the database, together with the current date and time. The Web service acts as a mediator and represents more secure and reliable solution to accessing database.

Server – side application is written in PHP. It is intended for use in the dispatcher center of the communal services. Pictures are retrieved from the database by using base64_encode PHP function, which encodes the byte representation of the stored image and displays it in PNG file format. For geolocation, the Google Maps API is used.

At first, users must enter their credentials to access the system. When accessed, they can view all the reported problems in two manners: as a list sorted by time of reporting, or on a map. The list view is shown in Fig. 3. (Please note that the images are taken from [14] and [15] and together with locations are used solely as a demonstration and may not represent the actual state on the field.)

Fig. 2. The layout of Android client application

The list shown in Fig. 3 consists of date and time of reporting, category (Type of problem field), problem description, its image if available, and location on the map.

The map view of reported problems is shown in Fig. 4. (Please note that locations and images are arbitrary and may not represent the actual state).

Fig. 4. Map view of reported problems
As can be seen from Fig. 4, different types of problems are represented with different colored markers. By checking the categories from top right corner, all corresponding markers are shown on the map. Clicking on the marker shows the info window in which the description and image of the problem is displayed. The user can click on the image and the bigger picture is displayed. Also, the user can delete the entry by clicking on the button Delete.

IV. CONCLUSION

Ecological environment preservation is one of the biggest challenges of the modern society. The enrollment of every part of the system is necessary in order to achieve this goal. Naturally, it all ends with the common citizens and their understanding of key principles of ecological balance. The education system needs to emphasize the major problems and to provide proper solutions and recommendations to solve this issue.

The amount of waste is constantly increasing and its management is of crucial importance. The planned construction of landfill and recycling facilities is of biggest importance. However, low ecological awareness of the society and lack of discipline and regulation enforcement leads to the formation of illegal landfills and dump sites that are not properly supervised. Furthermore, this brings misbalance to the ecological environment and can cause pollution of soil and watercourses.

In this paper, the client-server system for reporting ecological problems is presented. It consists of a client Android application that is intended for use among citizens, and server side, that is supposed to be used within communal services. Users can take a picture of a problem and send its coordinates to facilitate the issue solving process.

There are some indications that this system will be used by the communal service in the city of Čačak. If this becomes true, then the system can be slightly modified to adapt to the real situation on the field. Furthermore, by implementing this system, the citizens will have better insight in the work of communal service and entire municipality management.

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