Mobile application proposal for mapping of multi-drug resistant bacteria information management: A study applied in a Brazilian city

Marcio Rodrigo Santos
Setor de Ciências Sociais Aplicadas, Universidade Federal do Paraná - UFPR, Curitiba, Brasil.

Lucas José de Souza
Setor de Ciências Sociais Aplicadas, Universidade Federal do Paraná - UFPR, Curitiba, Brasil.

Egon Walter Wildauer
Setor de Ciências Sociais Aplicadas, Universidade Federal do Paraná - UFPR, Curitiba, Brasil.

Suelen Balero de Paula-Petroli
Centro de Ciências da Saúde (CCS), Universidade Estadual de Londrina - UEL, Londrina, Brasil.

Floristher Elaine Carrar-Marroni
Centro de Ciências da Saúde (CCS), Universidade Estadual de Londrina - UEL, Londrina, Brasil.

Abstract

The mapping and identification of multi-drug resistant (MDR) bacteria in affluents and effluents requires updated data on their reality and context. However, the process of analyzing these results is still slow and sometimes ineffective due to the lack of adequate technological mechanisms. This article presents the development of a mobile application as a tool for the information management system using geolocation and dashboads to map collection points, as well as resources to analyze the results obtained. The M.I.T. APP Inventor was used in the project along with PHP PDO and MySQL technology in the web server layer. The preliminary results indicated an interesting alternative solution to the specialists' requirements to contribute to management and decision-making, as well as a useful tool for interested health agents.

Keywords: App Inventor; Information Management; Mobile Application; Multi-drug resistant bacteria;

1. INTRODUCTION

Currently, antimicrobial resistance (AMR) is considered a public health problem worldwide, responsible for difficult-to-treat infections associated with high mortality rates and high health care costs[1]. The increase in AMR in clinically important bacteria is associated with the extensive or inappropriate use of antimicrobials in human and veterinary medicine, in agriculture and livestock. Although the consequences are clinical, studies have proposed that the spread of AMR is not restricted to health facilities, since antimicrobial resistant bacteria have been found in effluents and sewage treatment plants (STP) [2]

[3] [4].

Effluents and STP have been proposed as important reservoirs of multi-drug resistant bacteria and antimicrobial resistance genes (ARGs) are considered pollutants emerging from the environment. These aquatic environments act as critical points for the horizontal transfer of ARGs, since their high bacterial load and compounds that include antibiotics, heavy metals and biocides, which even in low concentrations, exert selective pressure on the antimicrobial resistance, allow an even wider spread of ARGs between environmental bacteria and human pathogens [2] [5] [6].

Hospital effluents, in particular, may have different ARGs profiles when compared to other aquatic environments, due to different patterns of use and frequency of antimicrobials [5]. These effluents are made up of human excrement and therefore reflect bacteria resistant to antimicrobials and the original ARGs from clinical sources [7]. Bacteria and genes reach the effluents and the remnant of the processing in the STP can contaminate rivers and lakes, constituting an AMR reservoir at constant risk to the health of humans and animals [8].

The concept of "one health" or "a single health" gained notoriety due to the concern to combat AMR in all affected environments and sectors, such as human and veterinary medicine, agriculture, environment, economy, among others [6]. The most recent Global Action Plan on AMR developed by World Health Organization (WHO) was published in 2015 and, based on the concept of One Health, establishes five objectives for the control and prevention of AMR, among which we highlight: Increase awareness of how AMR is developed in different environments through the characterization of new resistance mechanisms; and to monitor the incidence and prevalence of the main microorganisms, in order to establish surveillance and research programs and have greater support and investments from governmental organizations, industries and health agencies [9]. Based on this objective, we seek to employ Wastewater-Based Epidemiology, a new epidemiological tool with the potential to act as a complementary approach to current infectious disease surveillance systems and as an early warning system for disease outbreaks, that is, by going beyond the laboratory and hospital data [10].

Thus, the objective of the research is to propose a mobile application that supports the management of information on the theme of antibiotic resistance of microorganisms found in treatment plants, rivers and lakes. The application concatenates georeferenced data from the collection points with the quantitative results of the microbiological tests of the collected samples and provides the information allowing the monitoring and decision making based on reliable information and in real time. The study is been running in the city of Londrina - Brazil in a partnership between the researchers and the Department of Pathology, Clinical and Toxicological Analysis, Health Sciences Center, of Universidade Estadual de Londrina (UEL), the local public university, which facilitated the implementation of the application and the collection of samples in strategic points of the city.

2. INFORMATION MANAGEMENT

Information Management (GI) is characterized by [15] [16] [17] as a cycle of related processes capable of transforming data into information that contribute to decision making and the creation of new knowledge. The information management ecosystem can be defined as:

i) **Identify information needs**: Firstly, the need for information is recognized, it presupposes a clear understanding of the area of operation of the organization and its main competitors made through a mapping of the sources of information relevant to the context [17]

ii) **Acquisition of information**: According to [18], information acquisition comes from information needs. [17] explains that the acquisition of information must combine two approaches, automated and human exploration.

iii) **Organization and storage of information**: [18] states that they are two main purposes: to find sources of experience and to retrieve reports of previous work or similar problems. For [15] classification and storage presuppose the determination of how users select and access information from the chosen repository to store it

iv) **Dissemination of information (Communication):**The information is distributed according to the needs indicated by each user. [19] believes that the better the organizational communication, the more optimized the distribution of information to its user. In the model proposed by [18], the distribution and sharing of information are necessary conditions for perception and interpretation

v) **Use of information:** For [19], this is the most important stage of the entire Information Management process. The use of information and its combinations allows the emergence of new knowledge, which can feed the corporate information cycle, in a continuous process of learning and growth. Presents three ways of using information: creating meaning, building knowledge and making decisions [18].

Another aspect that is within the information management cycle is the area of information visualization, which condenses aspects of computer graphics, human-computer interaction, cartography and data mining, in order to combine them, transforming data into images or graphics [20]. It can be divided into two main aspects: the structural modeling, which aims to detect, extract and simplify information hidden in the data and the graphic representation of the structural modeling performed [21]. The techniques related to the visualization of information seek to represent, through graphic elements, the information contained in a determined domain of application, so that these elements can bring to the human being the correct interpretation and understanding to deduce new knowledge [22].

3. MATERIALS AND METHOD

The nature of the research is applied, as it intends to generate knowledge for the solution of a given problem, with a descriptive objective, as it allows the description of a certain phenomenon, in this case, informational modeling for the monitoring of MDR bacteria at collection points of the city of Londrina - Brazil.

The App Inventor tool was used to develop the application, maintained by the Massachusetts Institute of Technology (MIT), which allows the creation of applications for smartphones and tablets using the Android operating system. The database used to persist the collected data was MySQL and, in the service layer, the PHP PDO language was used to persist the data through HTTP requests in the MySQL relational database.

To implement the geolocation functionality, OpenStreetMap, which provides the manipulation of points on the map and the delimitation of regions. A meteorological system was also integrated through a web service that, based on the current GPS coordinates, informs the region's temperature when collecting samples.

The modeling of the application started with the delimitation of its scope, followed by the definition of the users' profile, so that the system modeling process was being adapted in relation to its usability, so that the application could make the entire information management cycle available to facilitate monitoring and decision making.

4. Results and Discussion

The application is simple and intuitive, a map is displayed on the front end to locate the markers placed where the collection is carried out, and to allow data update and the visualization of the sample collection points by geolocation. It is possible to define the date / time, the description of the collection and the type of place where the water sample is being extracted (Affluents and Effluents). A second registration step occurs later, the laboratory analysis of the samples. It is possible to record the genes detected in the samples and the results of the isolates recovered, where the cultured bacteria are identified at the level of gender and species and subjected to antimicrobial susceptibility tests (AST). New data can be entered by multiple users at the same time, and the data is updated between them. Finally, there is the data visualization route, which, through interactive panels, allows monitoring the data collected and analyzed in real time. The application's functionalities are summarized in Table 1, with their respective descriptions:

Table 1 – Features and Description of Mobile Application

Feature	Description
(1) Registration of the collection point by geolocation	Register user information at the sample (wastewater and suface water) collection point. (Location via GPS, Date and Time of collection, Weather at the time of collection, Brief description of collection)
(2) Registration of genes detected in the samples	When the sample is collected and analyzed in the laboratory, it is possible to register the genes found in the wastewater and surface water. From the mapped genes, it is possible to add which antibiotic the pool of bacteria in the sample are resistant to, creating a catalog of antimicrobial resistance.
(3) Isolates Recovered data registration	In addition to the quantification of antimicrobial resistance encoding genes directly from wastewater and surface water (2), the collected samples are seed in specific culture mediums. Cultivated bacteria are identified at the level of genus and species and undergo AST. Resistance determinants are detected and the isolates are subjected to molecular typing tests. With this, it is possible to describe and map bacterial species, elucidate their sensitivity profiles, their arsenal of antimicrobial resistance encoding genes and the presence of clones, including epidemic clones called high-

	risk clones. We also seek to establish a possible route of dissemination and/or contamination of important bacterial species in the hospital environment to the environment.
(4) Data visualization	The system information is saved in a relational database (MySQL) and the system allows selecting (SELECT) registered data in order to generate interactive and dynamic graphs that can be manipulated in order to allow the management of information, generating knowledge and contributing decision making.

Source: Authors

The application is in prototyping and Figure 1 shows the navigation screens, being (a) points registered via geolocation; (b) dashboard graphs generated after analyzing and registering the data of the samples collected:

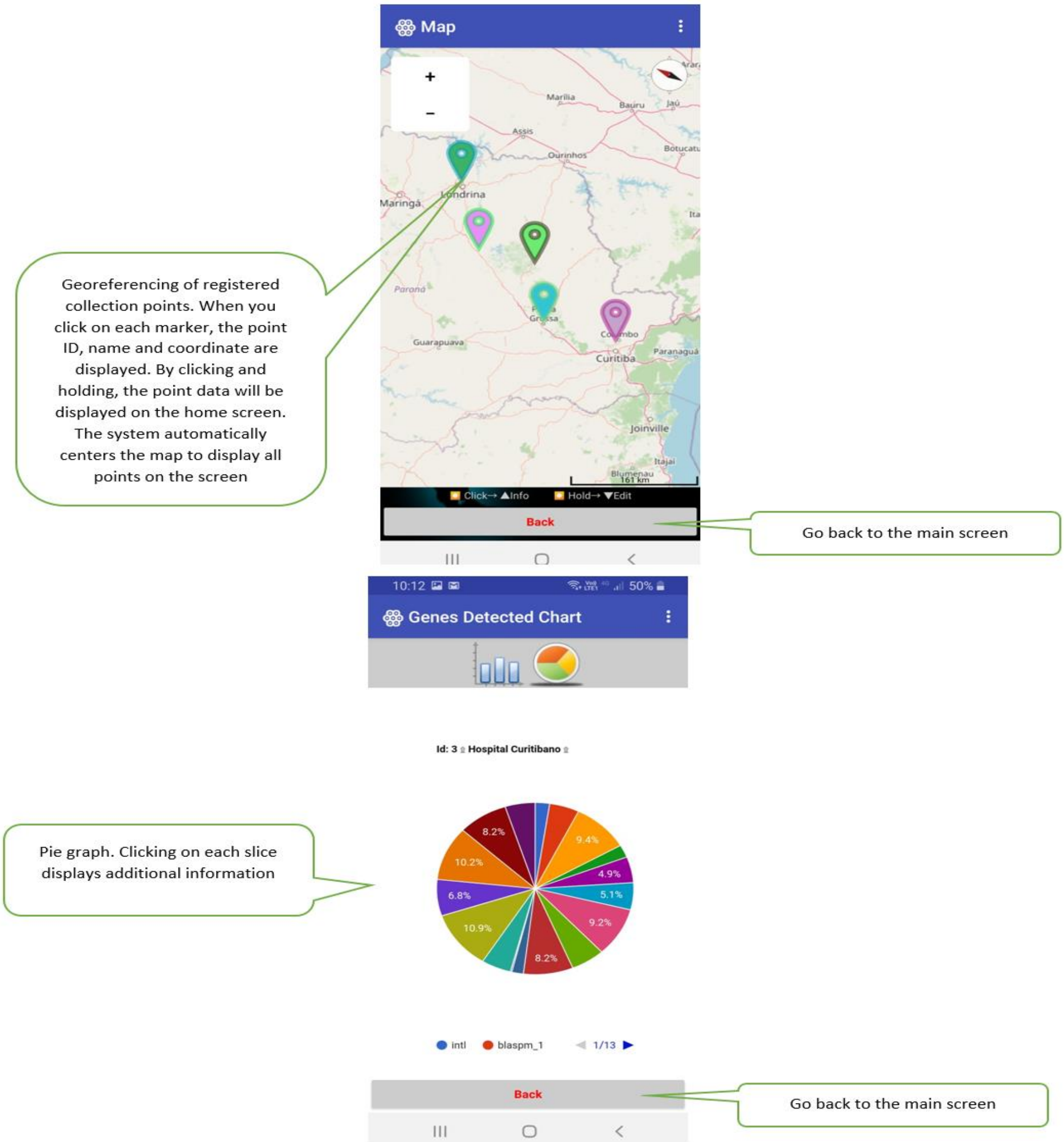

Figure 1. application screens

The information architecture is represented in Figure 2 by means of a diagram, which contemplates the information management cycle and the steps that the application meets:

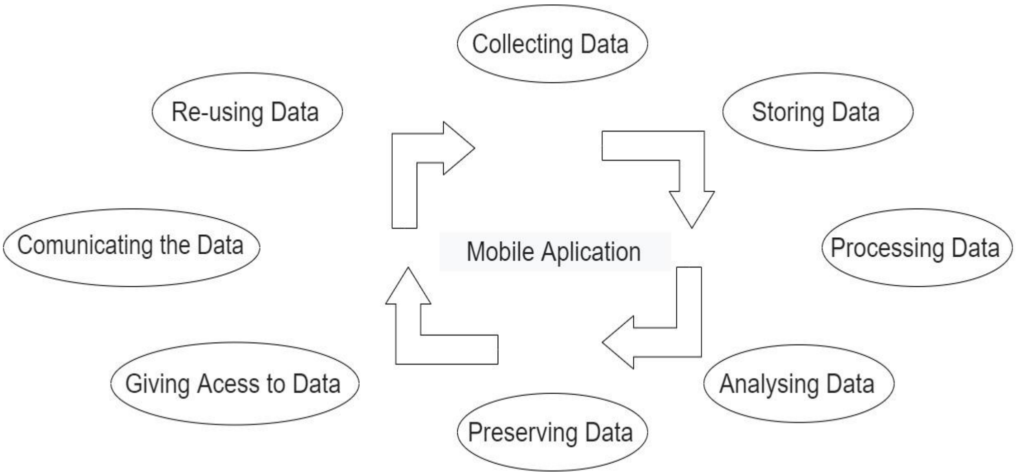

Figure 2. App information management cycle. Adapted and adjusted from McGee and Prusak (1993) and Davenport (1998).

The life cycle of the application is summarized in eight stages, being the collection of wastewater and surface water samples, the recording of data by geolocation at the time of collection. After the samples are processed and analyzed in the laboratory, the data are preserved and indexed in order to allow those interested in accessing the data, either for quantitative analysis or for internal consultations for correction or changes in the results obtained.

Finally, the data is communicated and made available for viewing through an interactive dashboard that generates consultation reports in real time. At the end of the life cycle, the data can be reused or stored for future reference to support predictive and temporal mathematical models of the data.

5. Conclusion

Wastewater-Based Epidemiology (WBE) is a new surveillance technique that has potential to act as a complementary approach for current infectious disease surveillance systems. The analysis of antmicrobial resistance genes together with bacterial monitoring could give a more representative reflection of health of a community, undestanding of disease and resistance circulating within a population. The ability to rapidly monitor the spread of MDR bacteria and resistance encoding genes, in real time, based in the analysis of wastewater and surface water, in well-defined geographical areas, could act as a key that providing information for prevention, intervention and control of MDR infections outbreaks.

Through the prototyping of a mobile application, this article proposes an information management model to support from the structured data collection, the organization, treatment and availability of data so that it is possible to consolidate a database on MDR bacteria, resistance determinants and the their dissemination routes in aquatic environments with potential hazards for a population.

The case study conducted in the city of Londrina in a partnership between researchers from UEL and UFPR point out in preliminary results the satisfaction of users with the usability and the ecosystem in which the data are transformed into information.

Dashboards allow a broader analytical view and with the potential to expand with other data sources. In general, it is expected that the mobile application can still be complemented with quantitative models allowing the expansion of data sources and the amount of data collected, in order to expand the reach and use of the application.

7. References

[1] OPA (2017) Folha Informativa – Resistência aos Antibióticos. Disponível em:<www.paho.org/bra/index.php?option=com_content&view=article&id=5664:folha-informativa-resistencia-aos-antibioticos&Itemid=812>

[2]Turano, H., Gomes, F., Medeiros, M., Oliveira, S., Fontes, L. C., Sato, M. I., &Lincopan, N. (2016). Presence of high-risk clones of OXA-23-producing *Acinetobacter baumannii* (ST79) and SPM-1-producing *Pseudomonas aeruginosa* (ST277) in environmental water samples in Brazil. Diagnostic microbiology and infectious disease, 86(1), 80-82.

[3] Karkman, A., Do, T. T., Walsh, F., &Virta, M. P. (2018). Antibiotic-resistance genes in waste water. Trends in microbiology, 26(3), 220-228.

[4] Ory, J., Bricheux, G., Robin, F., Togola, A., Forestier, C., & Traore, O. (2019). Biofilms in hospital effluents as a potential crossroads for carbapenemase-encoding strains. Science of the Total Environment, 657, 7-15.

[5] Wang, Q., Wang, P., & Yang, Q. (2018). Occurrence and diversity of antibiotic resistance in untreated hospital wastewater. Science of the Total Environment, 621, 990-999.

[6] Fouz, N., Pangesti, K. N., Yasir, M., Al-Malki, A. L., Azhar, E. I., Hill-Cawthorne, G. A., &Ghany, M. A. E. (2020). The contribution of wastewater to the transmission of antimicrobial resistance in the environment: Implications of mass gathering settings. Tropical medicine and infectious disease, 5(1), 33.

[7] Paulus, G. K., Hornstra, L. M., Alygizakis, N., Slobodnik, J., Thomaidis, N., &Medema, G. (2019). The impact of on-site hospital wastewater treatment on the downstream communal wastewater system in terms of antibiotics and antibiotic resistance genes. International journal of hygiene and environmental health, 222(4), 635-644.

[8] Sakkas, H., Bozidis, P., Ilia, A., Mpekoulis, G., &Papadopoulou, C. (2019). Antimicrobial Resistance in Bacterial Pathogens and Detection of Carbapenemases in *Klebsiella pneumoniae* Isolates from Hospital Wastewater. Antibiotics, 8(3), 85.

[9] World Health Organization. (2015). Global antimicrobial resistance surveillance system: manual for

early implementation. World Health Organization.

[10]Sims, N., &Kasprzyk-Hordern, B. (2020). Future perspectives of wastewater-based epidemiology: monitoring infectious disease spread and resistance to the community level. Environment international, 105689.

[11]World Health Organization. Report on Global Priority List of Antibiotic-Resistant Bacteria to Guide Research, Dicovery, and Development of New Antibiotics. Available online: https://www.who.int/medicines/publications/global-priority-list-antibiotic-resistant-bacteria/en/ (accessed on 26 June 2019).

[12]Frost, I., Van Boeckel, T. P., Pires, J., Craig, J., & Laxminarayan, R. (2019). Global geographic trends in antimicrobial resistance: the role of international travel. Journal of travel medicine, 26(8), taz036.

[13] Talon, D. (1999). The role of the hospital environment in the epidemiology of multi-resistant bacteria. Journal of Hospital Infection, 43(1), 13-17.

[14]Tarricone, R., Rognoni, C., Arnoldo, L., Mazzacane, S., & Caselli, E. (2020). A Probiotic-Based Sanitation System for the Reduction of Healthcare Associated Infections and Antimicrobial Resistances: A Budget Impact Analysis. Pathogens, 9(6), 502.

[15]Checkland, P., & Holwell, S. (2006). Data, capta, information and knowledge. Introducing information management: The business approach. London: Elsevier, 47-55.

[16]McGEE, J. V., &Prusak, L. (2004). Gerenciamento estratégico da informação. Elsevier Brasil.

[17] DAVENPORT, T., & PRUSAK, L. (1998). Conhecimento Empresarial, Editora Campus, Rio de Janeiro, RJ.

[18] Choo, C. W. (2003). A organização do conhecimento: como as organizações usam a informação para criar significado, construir conhecimento e tomar decisões. São Paulo, Brazil: Senac São Paulo.

[19] BEAL, A. (2004). Gestão estratégica da informação: como transformar a informação em fatores de crescimento e de alto desempenho nas organizações. São Paulo: Atlas.

[20] Correa, R. F., & Vieira, J. M. D. L. (2013). Representações visuais para recuperação de informação na BDTD-UFPE. Perspectivas em Ciência da Informação, 18(4), 18-34.

[21] Chen, C. (2004). Informationvisualization: Beyondthehorizon. Springer Science & Business Media.

[22] Freitas, C. M. D. S., Chubachi, O. M., Luzzardi, P. R. G., & Cava, R. A. (2001). Introdução à visualização de informações. Revista de informática teórica e aplicada. Porto Alegre. Vol. 8, n. 2 (out. 2001), p. 143-158.