Environmental pollution monitoring using a Web-based GIS in Surakarta

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Abstract. The case of environmental pollution is usually not all exposed onmedia. As such, environmental pollution monitoring needs to be done, hence the government can take legal measures against it. Monitoring environmental pollution will be more effective when involving community. The development of geospatial technologies such as Web-based GIS is helpful for monitoring pollution inenvironment. This is due to the Web-based GIS has several advantages including easy tooperate, easily accessible and able to present data (spatial and non-spatial) in real time. The purpose of this research is to develop a web-based GIS for monitoring environmental pollution. The software was developed using Rapid Application Development (RAD). Software development using technology based on opensource (CodeIgniter, Bootstrap, OpenLayers, and GML). The results show that the utilization of web-based GIS technology for environmental pollution monitoring is easily accessible and operated by user. Furthermore, the trial results show that the utilization of developed web-based GIS technology can operate properly and present data interactively.

1. Introduction

The intensity of environmental pollution incidence has been increasing from year to year in Indonesia, including in Surakarta, such as the cases of pollution in groundwater [1] and in Bengawan Solo river [2]. All environmental pollution occurs due to economic activities (industry) that are less environmentally friendly as well as the negligence of business actors in managing waste from industrial products. There are many more environmental pollution incidents going on, but not all of them are exposed on media which leads to the slow response from the government. Therefore, there is a need for an effort to make the incidence of environmental pollution can be exposed and immediately responded by the law enforcement authority. One of the efforts is by making a web-based GIS information system of environmental pollution monitoring.

The technology of web-based Geographic Information Systems (GIS) is utilized in the application development of monitoring environmental pollution due to its easily accessible and simple to operate by users from various backgrounds of profession and education. The utilization of web-based GIS technology will anticipate the shortage of GIS-based desktop, i.e. in terms of ease of access and usage. Lately, the utilization of web-based GIS technology for various purposes has been growing rapidly. A wide range of development has been done by some researchers such as utilization of web-based GIS for renewable energy after the reconstruction and rehabilitation process in Aceh Province [3], a web-based GIS development for groundwater management in Karanganyar Regency, [4] the utilization of

web-based GIS for land cover monitoring in Mekong Delta, Vietnam [5], and application development of Web GIS to estimate land price [6].

Considering the importance of immediate action from the governmental authority in response to pollution incidence as well as the importance of involving community for a more effective environmental monitoring, in this study, we developed a web-based GIS application that can accommodate both parties. The development of web-based GIS application for monitoring environmental pollution used an opensource-based software. The software used to develop this application included the CodeIgniter Framework, Bootstrap Framework, OpenLayers, and Geography Markup Language (GML). Meanwhile, some previous studies have developed a web-based GIS application with the Server Folders [7], PostgreSQL, PostGIS, and Bootstrap Framework [8]. Web-based GIS application development by using opensource software is profitable because the software is easy to download (accessible), easy to use, and free. The development of this web-based GIS application for environmental pollution monitoring involved several stakeholders including the local government Surakarta City, NGOs, and the community. The purpose of this research is to develop a web-based GIS application for environmental pollution monitoring in the city of Surakarta.

2. Literature

2.1. Environmental Pollution

According to Indonesian Law Number 32 of 2009, the environmental pollution is the entrance or the inclusion of living things, energy, and matter, or other components into the environment by human activities until it goes beyond the environmental quality standard that has been set. Contamination occurs due to the presence of a contaminant source which is any activity that disposes of pollutants. Contaminants usually consist of hazardous and non-hazardous materials. Hazardous and toxic materials, abbreviated as B3 (hazardous and toxic materials), are substances, energy, and other components which because of their characteristics, amount, or concentration, and, either directly or indirectly, can contaminate or damage the environment, and harm to the environment, health, survival of human beings, and other living beings. These contaminants can be solid, liquid, gas, or particle suspended in certain levels into the environment, either through the air, water, or land which eventually will go to human [9].

2.2. Web GIS Application

Web GIS is one of the application developments of Geographic Information Systems (GIS) that represented in the form of web services. It is a combination of GIS technology and the web. There are several methods and software that can be used to develop a web-based GIS technology, including Quantum GIS, Map Server, ArcGIS Online, OpenLayers, and GML (Geography Mark-up Language).

Web GIS is a tool or a product of digital mapping that based on internet network as its medium of communication. Functions of Web GIS as the communication media are to show, deploy, integrate, provide spatial and non-spatial information in various forms (such as digital maps, texts, diagrams), and run the main functions, namely analysis and queries which are still associated with GIS technology through internet network [10].

2.3. Bootstrap Framework

Bootstrap is one of CSS framework that is helpful to design a responsive admin page and the front page of a website. Utilization of the bootstrap framework has been rapidly growing lately due to its open source characteristics and cleaner, lighter, and more responsive template compared to the desktop, tablets, and mobile version. The bootstrap framework also supports some file types such as HTML, CSS, and JavaScript. These advantages of bootstrap make website developers prefer this framework. Utilization of the bootstrap framework to design a responsive website is advantageous because the display of the website will automatically adjust with the type of device you use to access the web [11].

2.4. CodeIgniter Framework

CodeIgniter is a framework for the development of a PHP-based application. It is software to build an open source web application that has an MVC model (model, view, and controller). The advantages of this framework include (a) the construction of the application can be done quickly and easily, (b) easy maintenance, (c) a complete facility available such as pagination, validation, multiple database, ORM, scaffolding, session setting, error handling, etc., so no need to create from scratch and (d) users have more freedom in developing applications. Currently, the latest version of this framework is 3.1.7 and the stable version is 4.0 [12].

2.5. OpenLayers

OpenLayers is a JavaScript-based client application for displaying map data in web browsers and does not depend on the used web server. OpenLayers implements a JavaScript API that is used to build a web-based GIS application. It is similar to Google Maps and MSN Virtual Earth API, but with an important difference. It is free software that was developed for and by the community of Open Source software.

2.6. Geography Markup Language (GML)

GML or Geography Markup Language is one of the computer programming languages like XML that based on spatial or geographic reference. Spatial data that can be included is in the form of point, line, or polygon data.

3. Research Methods

3.1. System development method

The method to develop the web-based GIS application for environmental pollution monitoring is Rapid Application Development (RAD). RAD is a software development method that was invented to compress the time to design and to implement information systems, so it can produce a very short development cycle. Visually, the plot of application development with the RAD method can be seen in Figure 1.

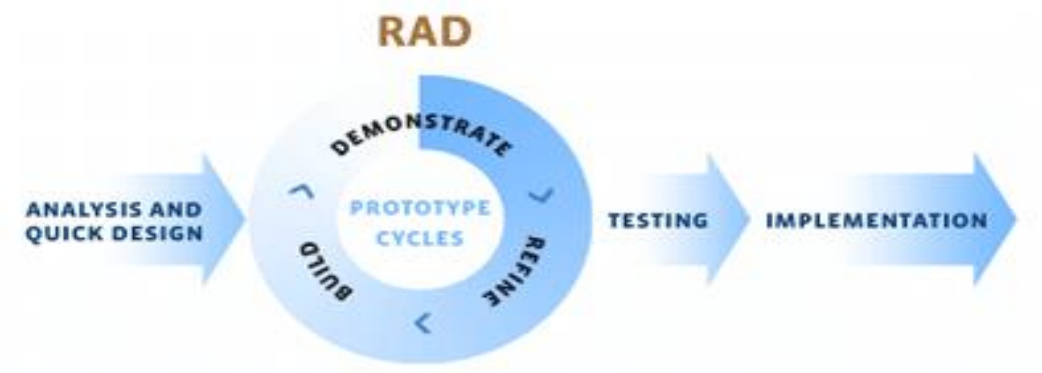

Figure 1. Development of Information System of Environmental Pollution Monitoring with RAD Method [13]

RAD is a system development method for designing applications in a short time. There are several stages or application development cycles with the RAD method. The stages are as follows:

1. Requirement Planning: Users and analysts conduct meetings to identify the objectives of the system and information needs to achieve the goals. At this stage, the most important thing is the involvement of both parties.
2. System Design: At this stage, the activity of the users involved determines the achievement of objectives. The process of design, repair, and improvement are carried out during this stage if there is still a mismatch between the user and the analyst. A user can immediately comment

when there is a discrepancy in the design, and be actively involved in designing the system by referring to the documentation of user needs made in the previous stage. The output of this stage is software specifications that include system organization in general, data structures and others.

3. Implementation: This is the stage where the programmer develops the design of the program that has been approved by both the user and the analyst. Before being applied to an organization, a program testing isdone at first to check whether there is an error or not. At this stage, the user usually gives a response to the system that has been made and gives approval for it.

3.2. The use of software in system design

The software used to compose information system of environmental pollution monitoring in this study was opensource software. The software used to develop the program and to display spatial and non-spatial model were as follows:

1. Quantum GIS Valmiera, for spatial data processing
2. The software that is running on the server (server-side), such as MySQL spatial, serves as a database system that stores both the spatial data as well as the non-spatial data; Apache and PHP, are software that acts as a web server.
3. The software that is running on the client (client-side), such as Internet Browser (Microsoft Internet Explorer, Mozilla Firefox, Opera, and others), are used to access the application
4. OpenLayers 2.2, for displaying the layers of spatial data on the system
5. GML, for making web-based spatial data (polygon, polyline, point)

3.3. Research data

The data used in this study include primary and secondary data. Primary data obtained through field surveys, while secondary data obtained from the Geospatial Information Agency. The type of data is spatial and non-spatial data. The primary spatial data is the coordinate locations of environmental pollution; while the secondary spatial data is the map of Surakarta City (scale 1:50,000). The non-spatial primary data includes description and documentation of contamination sites. Detailed information on the used data can be seen in Table 1.

Table 1. Research Data

No	Data	Data Type	Structure of data	Source
1	Administration map of Surakarta, scale 1:50.000	Secondary data	Spatial	Geospatial Information Agency
2	Coordinates of pollution sites	Primary data	Spatial	Survey
3	Documentation of pollution	Primary data	Non spatial	Survey
4	Description of pollution sites	Primary data	Non spatial	Survey

Source: Author, 2018

The Surakarta administration map data as shown in Table 1 includes regional administrative data and regional boundary data. Coordinate data for pollution sources are obtained from users who report pollution events in the field accompanied by documentary evidence and a brief narrative of pollution events. Data of pollution reports that enters the system will be validated and checked in the field, so that the environmental pollution complaint is 100% valid before entering the follow-up stage.

3.4. Stages of the Research

The implementation of this research is divided into 3 stages, namely: the preparation of system procedures, system testing, and system implementation. The order about the stages of implementation of the research in detail can be seen in Figure 2.

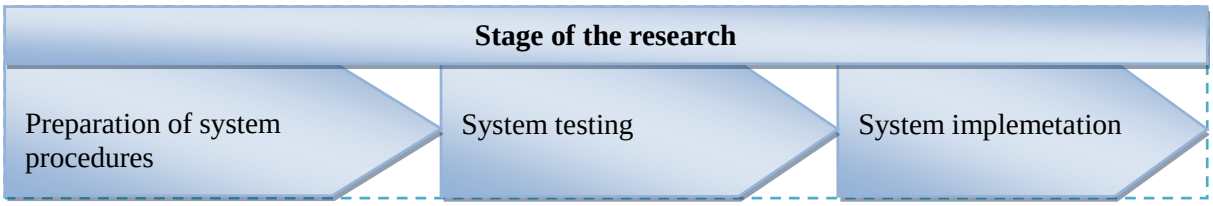

Figure 2. Stages of the Research
Source: Author, 2018

3.4.1. Preparation of System Procedures. The system to be built is expected to be implemented in environmental pollution monitoring activities. The information contained in the system includes coordinates and location of pollution, documentation of pollution events, and chronological descriptions of the events. In order to the system procedures to be in accordance with the needs of users, the system is designed by holding FGD (Focus Group Discussion) activities together with stakeholders such as the Department of Environment in Surakarta (DLH), NGOs, and community.

3.4.2. System Development. There are several steps that must be done in developing an environmental pollution information system. The stages include:

1. Inventory of equipment and information needs related to the monitoring of environmental pollution (user requirements).
2. System Analysis is the system design stage based on the analysis of system requirements in the previous stage. At this stage, a system design that will be used to support environmental pollution monitoring is produced.
3. Spatial database design is the stage of making a spatial database scheme that is in accordance with the analysis that has been made.
4. Designing the system interface. At this stage, an interface design is made according to user needs.
5. Workshop on system design with users.The system analysis and the resulting design need to be adjusted to users. If all the designs are approved by users, the next stage will be carried out. However, if there still need a change in the design, adjustments will be made with the user in this workshop session.
6. The process of coding in applications. At this stage, the design that has been made is then implemented in programming scripts to produce the application as it has been designed.

3.4.3. System Testing

1. A system operational manual making.
2. System socialization that has been made.
3. System testing, which involves users
4. Evaluation of the system with users. After the user tries the application, then an evaluation session is carried out for the improvement in the application.

3.4.4. System Implementation

1. Stage of server and infrastructure preparation.
2. Socialization stage to stakeholders.
3. Stage of system utilization

4. Research Results

4.1. System procedure preparation

The preparation of system procedures in this study was carried out through a Forum Discussion Group (FGD) with Department of Environment of Surakarta City. The system procedures compiled include system procedures for admin, field officers, and users. The details are as follows:

1. System procedure for admin
   a. Admin log in to the system
   b. Admin looks and list of user requests
   c. Admin checks the completeness of registration documents and activates the registration of users and field officers. At this stage, the username and password of the user and field officer will be sent by the system via email and phone number
   d. The admin selects a list of complaints about environmental pollution from users and continues those information to field officers
   e. The admin receives and prints the verification report from the field officer
   f. The admin reviews the results of the report and gives a follow-up decision based on the verification report from the field officer
   g. Admin provides notification of follow-up results from complaints of environmental pollution to users
   h. Admin closes complaints of environmental pollution
2. System procedure for field officers
   a. Field officers log in to the system
   b. Field officers see a list of complaints that must be surveyed or checked
   c. Field officers verify complaints to the field
   d. Field officers report the results of field checks and print reports
   e. Field officers close the list of complaints that have been surveyed
3. System procedures for users
   a. Users register online
   b. Users fill out the registration form and upload the documents or files needed during registration (copy of ID card, and user's photograph and his ID card)
   c. Users log in to the system
   d. Users report pollution events with the documentation of evidence in the field
   e. The user prints the report
   f. Users receive follow-up notifications from the admin regarding their complaints

4.2. System architecture

System architecture in this research is divided into a user architecture, a web server, and database. The architecture of the system is presented in Figure 3. Spatial database stored in the database can be visualized on OpenLayers (JavaScript framework) after changed into GML format using PHP [13].

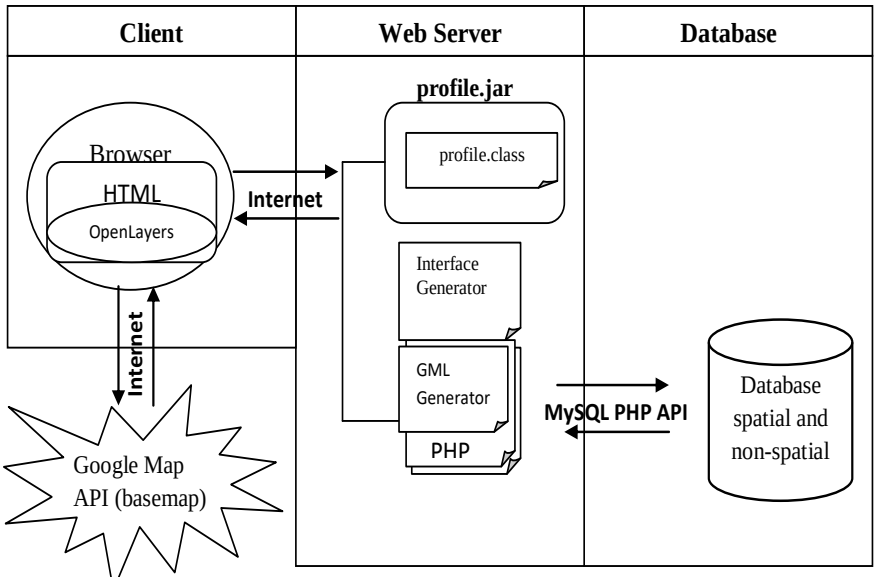

Figure 3. System Architecture [13]

Based on Figure 3, it is known that the system architecture consists of a database, web servers, and clients. The database in this system consists of spatial and non-spatial data. The spatial database includes the administrative map data, pollution coordinates, and Surakarta administrative boundaries, while non-spatial data includes data on pollution events (documentation and description). The web server consists of various PHP and GML files. On the client page, there is a web browser, HTML file, OpenLayers and also Google Map API.

4.3. Application design

The design of the main page (interface) includes spatial and non-spatial representations, menu, navigation tools, and geographic analysis. It is generally divided into 8 main parts, namely: (1) header, footer, and application title, (2) main menu, (3) legend, (4) map navigation menu (map tools), (5) layer control tab and data tracking, (6) control layer, (7) space for map (map space), and (8) panel for showing the coordinates of pointer. The application design can be seen in Figure 4, Figure 5, Figure 6, and Figure 7.

Figure 4. Application Home Page
Source: Author, 2018

Figure 4 shows the front page of the information system application. There are several menus that can be accessed by all users including the menu of river maps, downloads, web links, contacts, memberships, and logins. The river map menu contains spatial information about the point of pollution, documentation of pollution, and its description. The download menu shows data or file information that can be downloaded by users. While the link menu contains information, links related to the information systems. Further, the contact menu provides information of address and contact of the system maker and manager. The membership menu contains information and registration forms for new members or users. The login menu contains information on user access to the system.

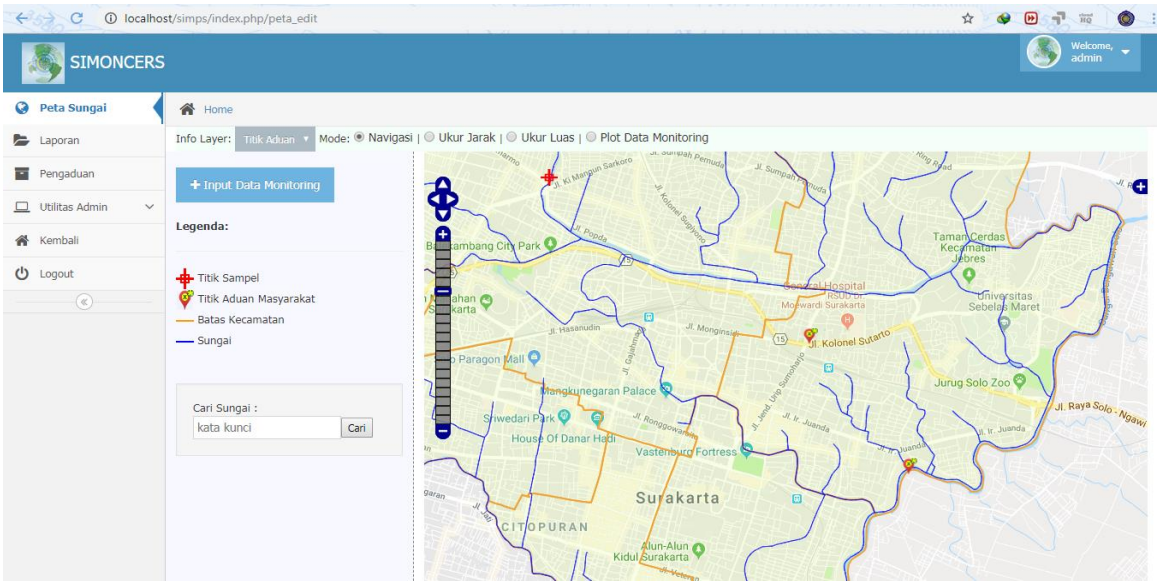

Figure 5. Web GIS Display on the Application
Source: Author, 2018

Figure 5 shows the GIS Web view on information systems. This page contains some information, such as view maps with the basic Google MAP API, legend maps, wind direction, zoom in and zoom out maps, data search, map navigation, tools for measuring distance and area, plot map coordinates, and the forms to input environmental pollution data.

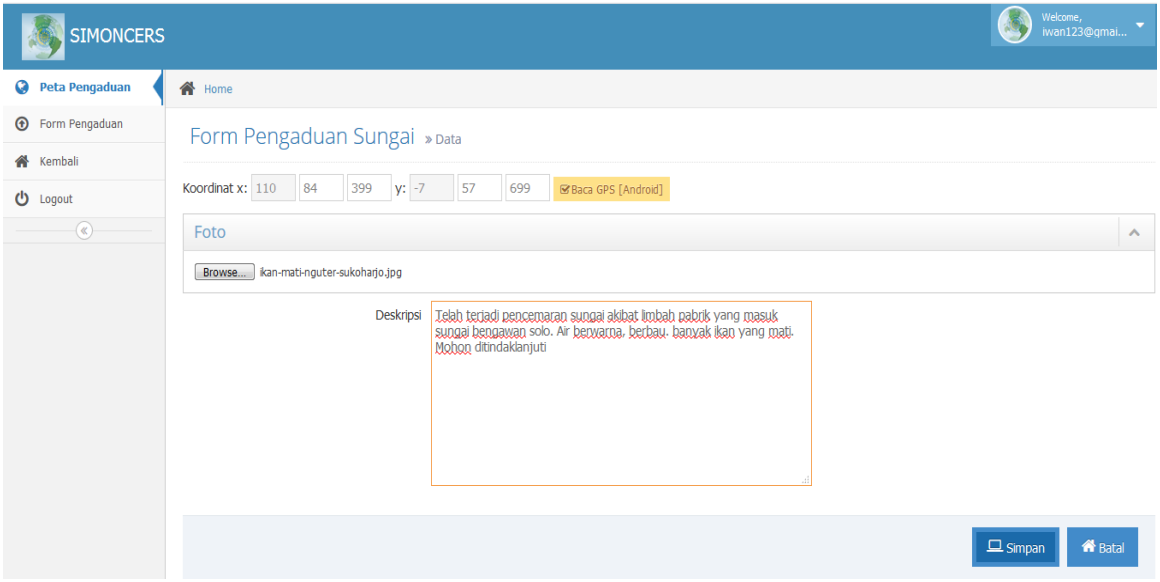

Figure 6. Form Page of Environmental Pollution Complaint on User Application
Source: Author, 2018

Figure 6 presents the page of the complaint form for environmental pollution from users. Reports of environmental pollution via Android phones and tablets will automatically record the coordinates of the location of the pollution. If reporting is done through a notebook or personal computer, then the coordinate data can be searched through the plot coordinate menu which is available in the system. Next, the user uploads a photo of the pollution event and describes the chronology of the event. After all forms are filled, user can report the pollution incident by pressing the save menu on the system.

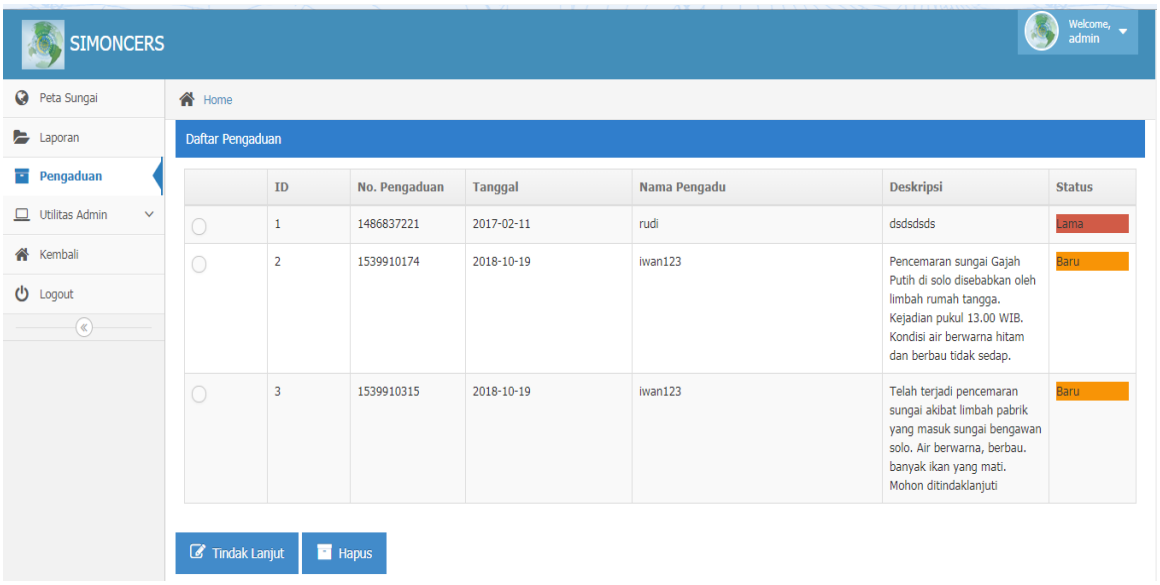

Figure 7. Page of Environmental Pollution Complaints List on Admin Application
Source: Author, 2018

Figure 7 shows a list of reports in the system admin page or web administrator. On this page, the admin can select complaints from users. There are two menu options in response to the complaints of environmental pollution from users: follow up or delete from the system. Valid pollution reports will be followed up, while the invalid reports (not in accordance with the field conditions) will be deleted from the system. The follow-up response regarding those reports is in the form of environmental policies from the authorized agency to handle the pollution.

4.4. Application prototype

At this stage, an application prototype has been built which will later be evaluated together with stakeholders. Stakeholders who will be involved in the evaluation of the system are the community, the local government of Surakarta, business actors, and NGOs. This application prototype is available and can be accessed through http://simps.kreasibundanhk.com.

5. Discussion

The use of GIS in this study combined with the decision-making system is in accordance with the Spatial Decision Support System (SDSS) criteria [14]. In this case, GIS has also been adjusted to the needs of users in order to facilitate the use by lay people. The research on the development of web-based GIS applications for environmental pollution monitoring has a fairly good progress compared to previous studies in the same study focus. Based on aspects of technology utilization reflected in the system architecture, this study shows an improvement that has been adjusted to technological developments compared to the architectures developed by other previous studies, such as the use of web-based GIS to map renewable energy after the reconstruction and rehabilitation process in Aceh Province [3], web-based GIS development for groundwater management in Karanganyar [4], use of web-based GIS for land cover monitoring in Mekong Delta, Vietnam [5], and the use of Web GIS applications to estimate land price [6]. The architecture of this system theoretically has better performance and accessibility assessed in several aspects. First, by relying on JavaScript framework, the web-based GIS of environmental pollution monitoring information system will be more independent because it does not depend on third-party applications. Second, the use of the OpenLayers framework is considered more in line with the Open Geospatial Consortium (OGC) standard as a guarantor institution for quality standards for spatial data, thus enabling better data sharing. Third, the use of Google Map API as a provider of spatial data is considered reliable and has a good and automatic level of data updates.

6. Conclusion

Based on the results and the software testing that has been done, it can be concluded that problems related to environmental pollution are the domain that involves several stakeholders so that synergistic collaboration between stakeholders is required. Furthermore, the applications developed in this study can run properly and be accessed by the admin, users, and field officers.

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