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A Chemical-Based Pipeline Maintenance Decision Support System

W. Anyoku[1*], E.O. Nwachukwu[2], B.O. Eke[3]

[1,2,3]Dept. of Computer Science, Faculty of Science, University of Portharcourt, Rivers State, Nigeria

Corresponding Author: wanyoku@gmail.com, Tel.: +2348033535544

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Abstract- Pipeline Corrosion Management System is the process of analyzing corrosion status in a crude pipeline by extracting data from a Linear Polarization Resistance (Probe) to monitor corrosion behavior. Petroleum pipelines are prone to corrosion due to the sea water injection into the wells to increased pressure required to force crude from the reservoir. Petroleum pipelines maintenance therefore becomes very necessary so that imminent growth of bacteria and corrosion are eliminated. Many researchers has done tremendous work in detection and treatment corrosion caused mainly by microbial growth but these systems does not recommend appropriate chemicals and quantities for treatment of different types of corrosion discovered. Hence to solve these problems stated we develop a Chemical-Based Pipeline Maintenance Decision Support System. This system offers an online management technique which reads the Probe, extracts corrosion details and proffer chemical treatment if corrosion is found. An Object Oriented Analysis and Design (OOAD) methodology was adopted, while we used PHP programming language at the front end, and MySQL relational database at the backend to achieve this goal. Our findings reveal that corrosion inhibitors and biocides are good treatments for corrosion and bacteria growths in oil pipelines. The Linear Probe is faster for pipeline corrosion detection, treatment and recommendation when compared to the existing Coupon method. This system will give confidence to pipeline operator when handling corrosion detection and treatment and make them deliver their work timely and less expensive.

Keywords— Pipeline, Decision Support System, Microbes, Corrosion, Biocides, Inhibitors

I. INTRODUCTION

Technology has crept into almost every aspect of human endeavour of which petroleum pipeline maintenance is not an exception. There exist diverse ways through which oil pipeline may be sabotaged and they include vandalism, corrosion, bacteria growth in the internal side of the pipe, etc. As any of these damages happens to oil pipeline, the pipeline operator usually makes frantic effort to recover the situation. In this process, a lot of money and time are wasted as-well-as human and material resources. Damages to pipeline has done more harm than good to the environment including plants, rivers and the animals found in the water.

Pipelines could be damaged as a result of vandalism or corrosion due to microbial growth has caused a lot of financial wastes in the recovery process. These damages to pipelines has done so much harm than good to the environment including plants, rivers and animals found in water.

Pipeline petroleum transportation system in Nigeria would have been very efficient and cost saving despite opposed difficulties which include: pipeline vandalism and damages/leakages caused by material defects as a result of corrosion and ageing of pipeline. Thousands of tubs (containers0 of oil wastes into the environment in this process. Federal Environmental Protection Agency(FEPA) has been trying to manage this surge. In this study, we implored and demonstrated the application of if-then-else rules of Expert Support System to detect and treat corrosion caused mainly by microbial growth. We developed a Decision Support System that will help detect and recommend appropriate chemicals and quantities appropriate for treatment of different types of corrosion discovered.

Activities in the oil and gas production remain typically categorized into downstream, mid-stream and the upstream which includes all undertakings involving the, discovery, extraction and exploration of oil and gas as-well-as their treatment, transportation and conveyance to designated export terminals or otherwise to processing plants . The undertakings involved in the upstream include oil prospecting, drilling, production and oil exploration. The mid-stream-segments consist of all undertakings involving storing of crude-petroleum, delivery of crude-petroleum to refineries, jetties and for exportations . The downstream sector encompasses all undertakings from conveyance to processing plants,[1]. The undertaking includes refining of crude-oil to form white petroleum goods and its transformation into petro-chemical goods. The complete petroleum-goods coming from the refineries include “liquefied petroleum gas (cooking gas), premium motor spirit (PMS), dual purpose kerosene (DPK) (aviation fuel and household kerosene), automotive gas oil (AGO) (diesel), low and high pure fuel oil, waxes (three grades), base oils, asphalt and sulphur. The downstream-segment setups likewise encompass the importation of white as-well-as additional finished goods, storing of white-products in depots, its conveyance and supply through pipelines or by using long distance trucks, marketing, pump-supply to buyers and customers using cars and cans as-well-as retailing in gallons, bottles, and quarts. This paper is organized as follows, Section I contains the introduction of petroleum pipeline corrosion, vandalisation, and their causes , Section II contain the related work of petroleum pipeline corrosion and decision support, Section III explain the methodology used, Architecture of the proposed system and its component, Section IV describes results and discussion, Section V concludes research work with future scope, Section VI contain the references.

II. RELATED WORK

Pipeline leakage is a demand from both governmental and environmental associations that companies need to comply with . Owing to high -accuracy on detecting leakage, it is essential to set measures that will accomplish a leading performance. Their research defines a methodology for setting-up instrumentations systems to accomplish with the legal prerequisite for keeping high reliability during normal and fail operations conditions. To realize the defined state, their research suggests an approved model acting as Expert-systems: everyone witnessing and diagnosing pipeline-leakage in real-time. Their proposed system also validates the operations with regards to the business rules applied to it. A set of techniques is applied in directive to make it possible for their system to execute its function: fuzzy logic, neural-network, genetic-algorithm and statistical-analysis were applied in developing their system[2].

Biocide Injection in the treatment of Internal corrosion of oil pipelines performed lab experiments on a sample of Sump Tank discharge from Mobil facility to check or investigate the effect of biocide injection in the treatment of internal corrosion of oil pipelines[3].

Investigating the effect of biocide injection in the management of internal-corrosion of oil-pipelines . This result illustrates that biocide might be applied in avoidance of internal-corrosion of oil-pipeline as it inhibits hydrogen-sulphide formation from metabolism of-the bacteria. This knowledge was demonstrated by rule-based-mechanisms[4] .

Expert system for corrosion protection of concrete structures is a user-friendly computer interface using suitable software . The expert system consist of four features: a knowledge base, inference engine, a working memory and a predictive modeling power. It helps the user to find remedies for Corrosion-related issues of the concrete structure in building. The user can input the defects seen and the expert system will return the possible cause and remedies for the problem found -as the output - from the knowledge base of the Expert System[5].

Pipeline networks are the indispensable part of our modern life. Proactive observing and recurrent checkup are precarious for upholding pipeline wellbeing such that safe and efficient functionalities of pipelines can be persisted for a lengthier period. Initial pipeline monitoring systems were built with a wired network. The crucial use of a wired-network is to connect and communicate with sensors scattered through the pipelines . This technique has some problems like network failure tolerance, physical security in large scale, and difficulty in locating and accessing [6].

The model optimizes the cost of pipeline operations by reducing subjectivity in selecting a specific inspection method, identifying and prioritizing the right pipeline segment for inspection and maintenance, deriving budget allocation, providing guidance to deploy the right mix labor for inspection and maintenance, planning emergency preparation, and deriving logical insurance plan.

Decision support system for inspection and maintenance which uses A Case study of oil pipelines The model optimizes the cost of pipeline operations by reducing subjectivity in selecting a specific inspection method, identifying and prioritizing the right pipeline segment for inspection and maintenance, deriving budget allocation, providing guidance to deploy the right mix labour for inspection and maintenance, planning emergency preparation, and deriving logical insurance plan [7].

Condition-based maintenance decision support system for oil and gas pipeline, Their model selects rehabilitation/repair alternatives for oil and gas pipelines based on their condition during their service life. These alternatives are then used to calculate the cash flow throughout the service life of these infrastructures. The model, which uses Monte Carlo simulation and fuzzy approach to address the uncertainties in the estimation of the maintenance operation costs and the economic parameters, calculates the Equivalent Uniform Annual Worth of the identified alternatives. The optimum maintenance programmes consist of the alternatives that have the lowest life cycle cost of oil and gas pipelines [8].

Analytic Hierarchy Process as a Decision Support System in the Petroleum Pipeline Industry, he looks at Analytic Hierarchy Process (AHP) as a tool used in petroleum pipe industry to help in decision making [9].

Decision Support Systems, such as PARMS-PLANNING support long-term planning and budget settings in relation to pipeline replacement decisions [10].

III. METHODOLOGY

The methodologies we adopted in designing a proposed a chemical-based pipeline maintenance decision support system are: object orientated analysis and design, prototyping and experimentation . Experimentation is used to confirm the efficiency of new system over existing ones. The proposed system is a chemical-based pipeline maintenance decision support system. We simulated an a chemical-based pipeline maintenance decision support system in PHP programming language. The proposed system is a computer-based Pipeline flow error detection and correction expert system. It is an improvement of the existing human pipeline flow error detecting. and correction system. It uses an online capability of reading the Pipeline status and extracting corrosion data with the aid of a Linear Polarization Resistance and Data-Logger. This proposed system is fast, reliable, cost effective and informative in nature. In the design of the-proposed system, we shall use Hypertext Preprocessor, JavaScript, CSS3 and HTML5 as-well-as MySQL relational database to develop the expert-system that will enable Pipeline Operators easily identify the corrosion problem and use the inference engine to query the knowledge base to know the exact chemical and the quantities that can be injected on the pipeline to stop the corrosion. We shall design a database that will store different types of pipeline corrosion and bacteria problems and possible chemical treatment.

The program will work in a way that allows the user to select the location of the pipeline and type of corrosion, it will automatically display the chemical and the quantity of chemical required to solve the corrosion problem. We shall design this application in a way that the age of the pipeline can be known in order to inform the user whether corrosion is about to attack the pipe. This will act like a preventive measure since the lifespan of pipelines is about 70years.

Figure 1 is the architecture of the proposed system and it shows the skeletal structure of the main application including the location and point of insertion of the expert system that is clearly introduced in the proposed system. The expert system is expected to handle corrosion analysis and bottle test of in the system. This is handled by gathering the expert knowledge into the knowledge base from where the inference engine is used to infer decisions on the options to take both during the corrosion analysis and the bottle test. Based on the knowledge provided by the knowledge base, decision can easily be inferred from the options offered to the system before proceeding to final decision.

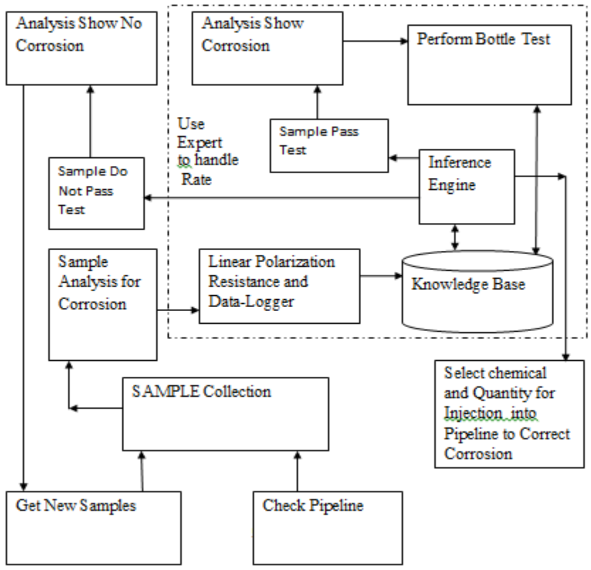

Figure 1. Architecture of the proposed system.

Components of the Proposed System

Proposed system is the Expert System which contains: User, Interface, Inference Engine and the Knowledge base. These are already explained in the definition of terms in Chapter One.

User Module:

The User is the key player who coordinates in the consultation and development sections of the Expert System, interfacing with the Expert System using the Knowledgebase and the Inference Engine. He is the computer operator who accesses the application through a computer-system as long as he/she is registered.

Interface Module:

User Interface is the process of interaction between the user and the expert system , this could be through other application or directly by dialogue boxes. Expert systems contain a language processor for friendly, problem-oriented communication between the user and the computer . This communication can best be carried out in a natural language. Due to technological constraints, most existing systems use the question-and-answer approach to interact with the user. Sometimes it is supplemented by menus, electronic forms, and graphics. Some of the user interface features in this work include:

1. Home page: This is the page that the user sees as he logs in.
2. Check Pipeline: This is the page that does the data extraction from the LPR
3. Pipe Age: Pipe age also finds the pipeline age and advice on the pipeline.
4. Login: Is the page that enables users to login to the application.
5. MySQL/Knowledgebase: The stack of the chemicals in an orderly manner to be selected or retrieved when needed is in the database.

Inference Engine Module:
The "brain" of the ES is the inference engine, also known as the control structure or the rule interpreter (in rule-based ES). This component is a computer program that provides a methodology for reasoning about information in the knowledge base and on the blackboard, and for formulating conclusions . This component provides directions about how to use the system's knowledge by developing the agenda that organizes and controls the steps taken to solve problems whenever consultation takes place". It will be further elaborated in the "Rule Based Expert System".

Knowledge Base Module:
Knowledge base contains the relevant knowledge that is required for understanding, formulating, and solving problems. It includes two basic elements: (1) facts, such as the problem situation and the theory of the problem area, and (2) special heuristics or rules that direct the use of knowledge to solve specific problems in a particular domain. Inclusively, the inference engine can include general purpose problem solving and decision-making rules. Knowledge, not mere facts, is the primary raw material of expert systems.

Apache Server Module:
The information and chemicals on this application are available in the cloud through the apache server. Hence it enables the establishment of web storage files on the cloud. The proposed system described above is an Expert System. An Expert system can also be described as a knowledge-based system which is a compute program that comprises the knowledge and analytical skills of one or more experts in a specific problem domain, with a method that expertise can be gained applied and reused [11].

Rules for applied decision (Volume and Quantity)
The inference engine fetches and manipulates the ideas from the knowledge base to arrive at a goal. The rules for reasoning are stated in simple form below as: (CC is Corrosion Class, R1 is Rule 1, F1 is Fact 1, D1 is Decision 1).

Rules:
R1: IF CC is F1 THEN D1
R2: IF CC is F2 THEN D2
R3: IF CC is F3 THEN D3
R4: IF CC is F4 THEN D4

Facts: (knowledge)
F1: Low
F2: Moderate
F3: High
F4: Severe

Decisions: (Inference)
D1: 97VD129
D2: EC6838A
D3: EC6225E
D4: EC6125A

Figure 2: Decision Rules for Volume and Quantity

In this illustration, we use the following values for Volume and Quantity of chemical needed for a particular corrosion rate calculated according to laboratory standards.

The Corrosion Class Selection Rule "if then rule":

```
If(CorrosionRate<1)Then
        Remark="Low"
        Volume="Between(1-9)ppm
else if(CorrosionRate=1 $$ CorrosionRate<4.9)Then
                Remark="Moderate"
                Volume="Between(10-30)ppm
Else if(CorrosionRate=5 $$ CorrosionRate<9.9)Then
                Remark="High"
                Volume="Between(31-100)ppm
Else if(CorrosionRate=10 $$ CorrosionRate>10)Then
                Remark="Severe"
                Volume="Between(100 and above)ppm
end if
        endif
                endif
                        endif
```

Figure 3: Corrosion Class Selection Rule

Rules used for Chemical Application in detecting corrosion

```
If (Corrosion Detected = "General Attack Corrosion")Then
        Chemical ="97VD129 "
elseif(CorrosionDetected="Localized Corrosion")Then
        Chemical=" EC6125A"
elseif(CorrosionDetected="Galvanic Corrosion")Then
        Chemical="EC1509A"
elseif(CorrosionDetected="EnvironmentalCorrosion")Then
        Chemical="EC1304A"
elseif(CorrosionDetected="Flow AssistedCorrosion")Then
        Chemical="97VD130"
elseif(CorrosionDetected="Intergranular Corrosion")Then
        Chemical="EC500AC"
elseif(CorrosionDetected="MicrobialInfluencedCorrosio")Then
        Chemical="EC6838"
else
        No Corrosion Detected
endif
        endif
                endif
                        endif
```

Figure 4: Chemical Application in detecting corrosion

IV. RESULTS AND DISCUSSION

The system was able to perform the detection, treatment/maintenance of pipeline corrosion by scanning the location of pipelines, corrosion rate as well as the year the pipeline was installed. As the user logs in after registration, he/she will be taken to the page where he can select the location of the pipeline and then scan the online Linear Polarization Resistance LPR, commonly known as Probe to detect if there is corrosion or not. The corrosion detected is compared to the Corrosion rates results from coupons inserted as shown in table 1 below. The rate of corrosion is therefore monitored to know when it is low, high, moderate or severe before it will suggest chemical treatment.

Table 1 Corrosion rates comparison between coupons and Linear Polarization Resistance (LPR)

Constant	Initial	Final	Weight Loss	MPY	Den (g/cm3)	Coupon Area	Time (days)	Existing	Time (days)	Proposed
22300	33.6522	33.3401	0.3121	9.480262	2.71	3.01	90	9.480262	1	0.105336
22300	35.4361	35.1298	0.3063	6.82503	2.78	4	90	6.82503	1	0.075834
22300	33.0878	32.782	0.3058	2.21225	8.52	4.02	90	2.21225	1	0.024581
22300	34.0306	33.73	0.3006	2.922032	8.33	3.06	90	2.922032	1	0.032467
22300	34.1306	32.0582	2.0724	19.95673	8.52	3.02	90	19.95673	1	0.221741
22300	33.7935	31.6547	2.1388	22.4283	7.85	3.01	90	22.4283	1	0.249203
22300	34.2273	33.9277	0.2996	2.355251	7.86	4.01	90	2.355251	1	0.026169
22300	34.1498	33.8486	0.3012	2.356078	7.86	4.03	90	2.356078	1	0.026179
22300	33.6274	33.5068	0.1206	1.302207	8.08	2.84	90	1.302207	1	0.014469
22300	33.7946	33.6738	0.1208	1.665177	7.19	2.5	90	1.665177	1	0.018502

In figure 5 we plotted the value of existing system against proposed system.

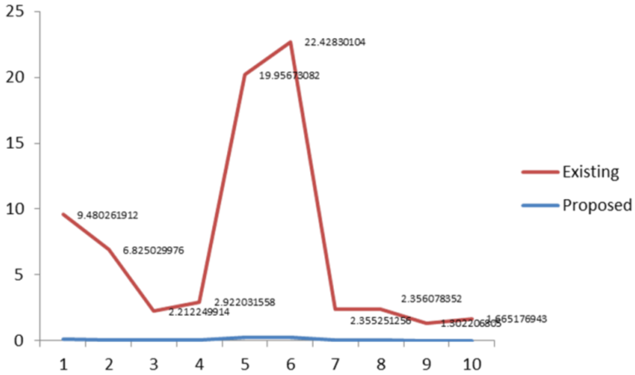

Figure 5 Comparative Corrosion Rates analysis between coupons and LPR (Existing and Proposed system)

Table 2: Corrosion Rates Analysis

Class	Corrosion rate (mpy)
Low	Less than 1
Moderate	1.0 - 4.9
High	5.0 - 9.9
Severe	Greater than 10

Analysis is drawn when standard corrosion results are compared between the corrosion detected using the Linear Probe with the corrosion derived using the manual coupon insertion method. The result of the calculations reveals the different classes of corrosion rates, for example, if the corrosion rate is Low, then MPY is less than 1, It is Moderate if the mpy is greater than 1, but less than 5. High or Severe classes are recorded for mpy greater than 5, and 10 respectively. See detailed analysis as shown in Table 2.

V. CONCLUSION AND FUTURE SCOPE

Petroleum pipelines are prone to corrosion due to the sea water injection into the wells to increased pressure required to force crude from the reservoir. Petroleum pipelines maintenance therefore becomes very necessary so that imminent growth of bacteria and corrosion are eliminated. A Chemical-Based Pipeline Maintenance Decision Support System is an automated corrosion discovery and treatment system that can scan a chemical pipeline and suggest chemical treatment, against the existing system which was done manually. We may conclude that the application has been developed using the recommended techniques. Our future plan is to bring this research to the point where it can be developed further to include an online chemical injection system.

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Authors Profile

Mr.Anyoku Winston pursed Bachelor of Science in Computer Science from University of Nigeria, Nsukka, and Master of Science in Computer Science from University of Portharcourt.

