REMOTELY – MONITORED ANTI-PIPELINE VANDALIZATION DETECTION EXPERT SYSTEM

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ABSTRACT

Vandalizing and bunkering of pipelines transporting crude oil and its refined products from one point to another across Nigeria has become a menace on the increase especially in the oil rich Niger Delta region with over 400,000 barrels of crude oil lost daily. Distractions caused by prevalent banditry, aftermaths of COVID-19 pandemic, herdsmen attacks and pervading economic woes as inflation continues unabated for decades now have prevented both security operatives and government from effectively checkmating pipeline vandalisations. Enactment of anti-pipeline vandalisation laws and the grossly inadequate activities of law enforcement agents and security operatives, had failed woefully. Consequently, lots of lives had been lost as a result of clashes of interest and increased use of sophisticated weapons by the nefarious men of the underworld responsible for pipeline vandalisation. It has becoming more intimidating for law enforcement agents to combat these vandals. This study developed and recommended adoption and use of embedded remotely monitored anti-pipeline vandalisation system. A prototype which was built using C language to code functions into its micro-controller sensors demonstrates capability of using Artificial Intelligence (AI) technologies to remotely monitor, detect and report pipeline vandalisation activities with little or no loss of lives. The prototype when tested, successfully monitored, detected and reported pipeline vandalisation within 15M radius of the control base. This implies that during implementation the range or radius only needs to be scaled up to desired distance around the control base(s).

Keyword: Crude Oil, Pipeline, Prototype, Sensor, Remote, Vandalisation, Control Base.

Introduction

Pipeline system as a medium of transportation is usually attributed to very sensitive products such as crude oil, natural gas and industrial chemicals. When left unattended to, unimaginable catastrophes such as terrorist attacks, pipeline vandalisation, and theft or diversion of the pipeline content do occur. Pipeline vandalisation is responsible for significant drop in Nigeria's oil production distribution in Nigeria from 2.2 million barrels per day (bpd) to less than 1.1 bpd (Mmeje, Bello & Mohammed, 2017). This in turn increased the cost of needed gas for electricity generation. The cost of all goods and services that are dependent directly or indirectly on electricity had become unbearable to many producers and investors. Besides, one militant group known as the Niger Delta Avengers who had already destroyed facilities belonging to international oil companies, was reported to have vowed to reduce the country's production to zero (Okere, 2016). Consequently, more investors abandon the country for more investment-conducive environments; a development that has in turn worsened Nigerian economy and increased unemployment rate.

The economic losses associated with oil pipeline vandalism becomes more vivid when quantify in monetary terms the value of lost products and pipelines' repair costs. This has amounted to billions of Naira over the years (Onoja, 2013). For instance, one time Managing Director of Pipelines and Products Marketing Company (PPMC), Prince Haruna Momoh recently revealed that "between 2009 and December 2012 alone, the Nigerian National Petroleum Corporation, NNPC alone lost about ₦165 Billion to products theft and repairs of vandalized pipelines" (Ugwuanyi, 2013). Combined as of 2013 report, Nigeria has lost as much as ₦1.011 trillion to oil theft. A report issued by NEITI in July 2013 indicates that Nigeria lost a whooping sum of 10.9 billon US Dollars to oil theft and vandalism in the period of 2009 to 2011 alone.

These translate to huge economic loss with far reaching implications for Nigeria's economic growth and development, and by extension national security. Current spate of unemployment and resultant kidnapping and banditry for the purpose of ransom payments are partly resultant from poor management of pipeline security issues.

Vidal (2011), Ogbeni (2012) and Ugwuanyi (2013) who differently conducted studies on the impact of pipeline vandalisation on the growth of Nigeria's economy, also concluded that this nefarious acts of vandalism do result in wanton destruction of lives, properties and financial stability of the country. Thus the need for implementing adequate security systems for pipeline management cannot be overemphasized.

Several efforts have been made to address this menace. The international sponsors (and some local sponsors some of who are highly placed in our society), of the vandalisation of oil pipelines, and not just their boys or representatives, must be apprehended and be brought to book in other to deter further vandalism (Bello, 2020).

Series of efforts by the Federal Government to engage in a dialogue, in a bid to stop the destruction of oil facilities, have failed so far. Corruption is partly responsible for the dismal failure of the Federal Government to curb this menace. Thus passage of Petroleum Industry Bill (PIB) has been recommended to the Government in order to attract the requisite foreign direct investment into the oil and gas industry. Despite these noble efforts, pipeline vandalisation and related atrocities continue to worsen in the country. Thus, the need for a more pragmatic and more technical approach to resolve this problem.

The use of sensor technology in remote sensing, communication and security systems has gained popularity in recent decades. This is not unconnected with the remarkable success that are associated with this technology. It has been successfully deployed in car tracking devices, security alarm systems, computerized closed circuit television (CCTV), Cyberphysical systems, community policing and vigilance systems and especially and more recently in artificial intelligent systems functional in autonomous systems and Internet of Things, IoT.

Implementation has been found in pattern recognition mobile devices, metal detector systems and doors, contactless keys for cars, ignition system and building apartments and remote diagnosing medical systems. In the table 1 below, classification of sensors based on 1) area of detection, 2) specification and 3) area of application is given by Yu Gu (2018).

Table 1: Classification of Sensors (Yu Gu, 2018)

Classification by broad area of detection	Classification by specifications	Classification by specifications	Classification by area of application
Electric sensors	Photoelectric	Accuracy	Consumer products
Magnetic	Magnetoelectric	Sensitivity	Military applications
Electromagnetic	Thermoelectric	Stability	Healthy
Acoustic	Photoconductive	Response time	Energy
Chemical	Thermomagnetic	Hysteresis	Manufacturing
Optical	Electrochemical	Frequency response	Transportation
Temperature	Magnitostrictive	Resolution	Automotive
Mechanical	Photomagnetic	Linearity	Avionic
Radiation	Thermoelastic	Operating temperature	Space
Biological	Photoelastic	Construction materials	Scientific

It is the candid opinion of the researcher that application of remote sensing could in an inestimable way provide the needed solution to petroleum (energy) pipeline vandalisation and insecurity problems with reduced cost and loss of lives and properties.

Related Work

For over a decade now, the usefulness of sensor tech and networks in remote monitoring systems had been on the rise especially when integrated into networked Remote Telemetry Units (RTUs). RTUs systems have been used to manage devices from remote locations (Carberrry M. 2021). It is a primary component of Remote Monitoring System (RMS). An RTU can be programmed to monitor diverse equipments or activities and one RTU can be used to monitor a number of activities. When in operation, it sends signals to a master station control center. The master station in turn will take specified actions based on programmed instructions. Such could be: automatically sending pings to other RTUs to obtain extra corroborative information, shutting down a system, sending alert signals and notifications (which might be in form of images and location coordinates, text messages, or email) to the right recipients such as security operatives (Erickson, 2021). An RMS could have several RTUs.

Howard et al (2004) carried out a study on real-time remote monitoring of water quality with specific considerations to current applications and advancements in sensor, telemetry and computing technologies. They concluded that increased use and continuing advancements of real-time remote monitoring (RTRM) and sensing technologies will become a progressively more important tool for evaluating water quality.

One of the many International Oil Companies (IOCs) operating in the Niger Delta region in a bid to protect its vast array of oil pipelines and other oil facilities scattered in the Niger Delta, in January 2005, introduced the use of micro wireless sensor network (WSN) which was supposed to help her to detect drop in pressure once an oil pipeline is ruptured by vandals and alert her on the exact location of the vandalisation. Despite this latest effort to combat pipeline vandalism, pipeline vandalism and subsequent crude oil theft has been on the increase as a result of obvious collaboration and collusion of security officers with oil thieves who are supposed to race to the scene of vandalisation, make arrest of the vandals and bring them to face the law.

This obvious economic sabotage and corruption has compounded the menace of pipeline vandalism and crude oil theft which has left the Nigerian Federal Government aghast on how to tackle the problem.

Jingran et al (2009) designed a program to achieve the remote monitoring information system. The system acquires some detailed physiological data of the far-away patients using human-monitoring sensor chips and the Internet of Things, automatically generate electronic medical records, which is saved into the database. Besides, with the support of information platform, this system can feed back the corresponding diagnosis, medical programs and proposals after analyzing the data. The System, which relying on a Zigbee Wireless Sensor Network technology, has achieved real-time transmission of physical information. And the intelligence of the system in data professing and information releasing has been largely developed by the applications of databases and both wireless and wire line networking. The system has many application scenarios, such as family health care, which improves people's daily health care standard and the level of health monitoring intelligence. Meanwhile, it promotes applications of the Internet of things in health care.

Clement (2013) reviewed the strong role remote sensing plays within the agricultural sector and concluded that remotely provided information is urgently needed for various decision makers. He further obsered that requests for objective information will increase in the future, as a result of the expected changes in the agricultural sector and only (satellite) remote sensing—combined with sophisticated modeling tools—can provide such information in a timely manner, over large areas, in sufficient spatial detail and with reasonable costs.

Ezeh, Chukwuemekwa, Ojiaku and Ekeanyawu (2014) worked on Pipeline Vandalisation

Detection Alert system with SMS and recommended that alert received via mobile device in form of SMS – Short message service can serve as a trigger to move security operatives to action. However, consideration is not given to cases where the members of the community who are expected to send the SMS are either beneficiaries cooperating with the looting or are highly intimidated and threatened with genocide by the perpetrators and their sponsors.

Research Methodology

Development of Petroleum Products Pipeline Vandalisation Surveillance and Monitoring System.

The model adopted for the development of Petroleum Products pipeline vandalisation surveillance and monitoring system is the Linear Sequential Model or the Classic Life Cycle (Pressman, 2002; Sommerville, 2003). Figures 1 to 7 show the steps that were followed to develop the software system.

The model views the process of software development in five stages. The activities in one stage will be completed before moving to the other. Phases involved in the Waterfall Model are:

Requirement Analysis and Definition; System and Software Design; Implementation and testing; System testing; Maintenance

Research Design.

Figure 1 shows the diagram of an embedded prototype system developed by the researcher to determine when a petroleum pipeline is being vandalized.

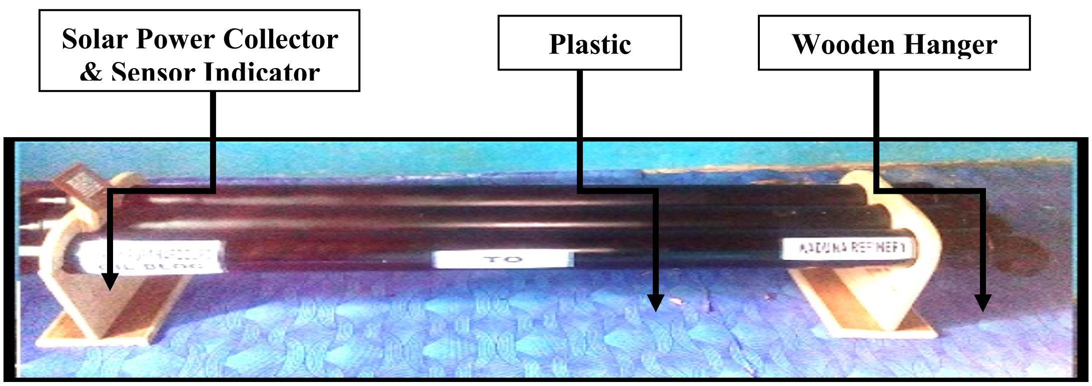

Figure 1: Diagram of Prototype Pipeline System

System Components and Description

Solar power collector and sensor indicator

This charges up the inner internal battery of the transmitter, so that the battery will not run down, thereby ensuring continuous power supply.

Plastic Pipes

The plastic pipes represent the vulnerable oil pipelines for transporting petroleum products.

Wooden Hanger

The wooden hanger serves as support/stands for both the plastic pipes and solar collector and sensor indicator.

Drilling Machine

It represents any tool or object that might be used to bore hole into or break the pipelines.

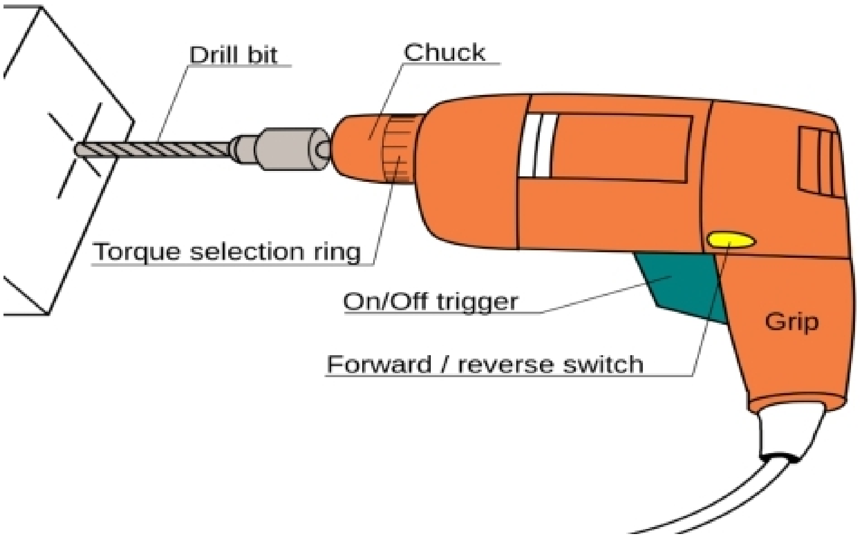

Figure 2: The Drilling Machine (mechanicalenotes.com, 2021)

Battery

It powers the drilling machine that was used to 'vandalise' or tamper with the multilayered plastic pipes.

Figure 3: 75Amps Car Battery (Courtesy: exideindustries.com, 2021)

Circuit Description and Operations

In this project, a wireless safety tamper alert system was built. It consists of two major sections - the transmitter section and the receiver section. The model gives an alert with a light indicator to the rescue team for immediate action. The supporting circuit uses a transmitter and a receiver. The receiver receives information from insulated copper cable sensors wrapped around the pipeline and processed by standard integrated circuit CD4081 or CD4089 and gates, a multiplexer BPS4036 and other discreet electronic components. The processed information is is displayed by the receiver. Alarm is concurrently triggered which indicates that the pipelines are being vandalized at that instant.

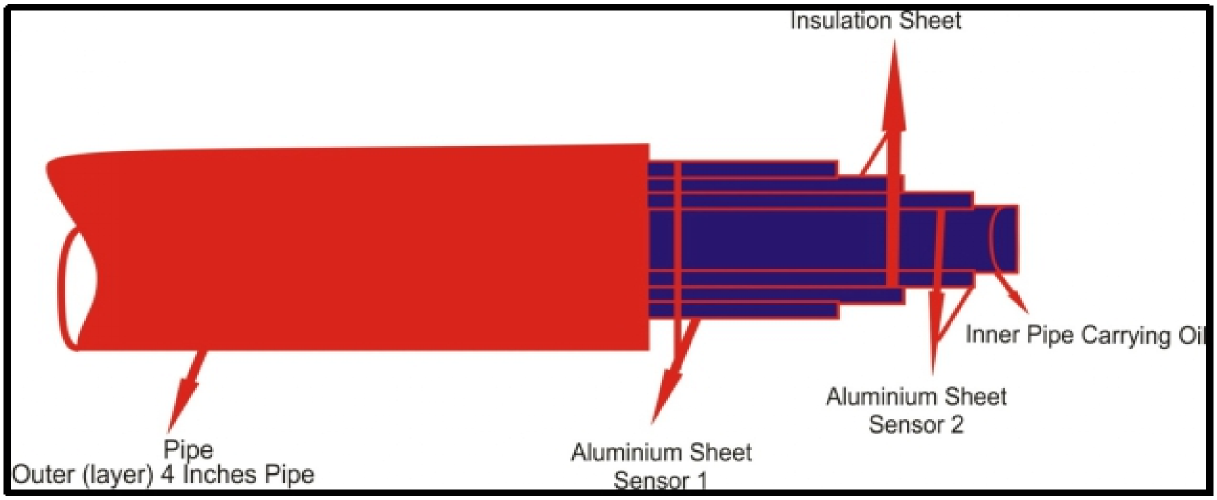

Figure 4: The Internal Structure of the Multilayered Prototype Plastic Pipes (the Pipeline)

As shown in figure 4 above, the pipe to which the sensor and the transmitter are connected has four layers: the outermost layer(without a sensor) is followed by an aluminum sheet with sensor-1 layer. Next to this is third layer, the insulation sheet. Finally we have the next-to-the innermost aluminum sheet sensor-2 layer which surrounds innermost pipe that carries the oil (figure 4). The sensor circuits are embedded in the third and fourth innermost layers. To prevent false-triggering, the outermost layer has no sensor attached in case of accidental and non-deliberate impact on the pipeline, However, the circuits have a 32kHz crystal each integrated to crank out a tone and also to sense any deliberate pressure or metal touch on the second and third layers.

Other Control Circuit Components Used and Their Sizes

KEYS:

R – Resistors

C – Capacitors

T – Transistors

D – Diode

L – Light Emitting Diode (LED)

Resistors (all ¼-watt, ± 5% Carbon)

R1 = 100 Ω

R2 = 330 KΩ

R3 – R5, R10, R25 – R27 = 2.7KΩ

R6, R 18 = 47KΩ

R7 = 33KΩ

R8 = 100KΩ

R9, R 24 = 22KΩ

R11, R 19, R28 = 1KΩ

R12, R 21 = 15KΩ

R13 = 470KΩ

R14, R 16 = 1MΩ

R15, R 22, R23 = 10KΩ

R17 = 8.2KΩ

R20 = 4.7KΩ

R29 = 4.7Ω

R30 = 100Ω

R31 = 27KΩ

CAPACITOR

C1, C3, C8 = 0.001µF (Ceramic Disc)	C12 = 220µF/25V (Electrolytic)
C2 = 0.022µF (Ceramic Disc)	C14, C18 = 0.04µF (Ceramic Disc)
C4 = 100pF (Ceramic Disc)	C 15 = 22µF/25V (Electrolytic)
C5, C13 = 0.02µF (Ceramic Disc)	C 16 = 100µF/16V (Electrolytic)
C6, C7 = 3.3pF (Ceramic Disc)	VC1, VC2 = 100pF (trimmer)
C9 – C11, C17 = 0.002µF (Ceramic Disc)	

SEMICONDUCTORS

T1, T 2, T6, T8, T9 = BC148	T5, T 7 = BC158
T3 = BF194	T10 = BEL187
T4 = BF195	D 1 = 1N4446

MISCELLANEOUS	LED
L.S. = 8 Ω speaker	AERIAL = 2
X 1 = O/P transformer	L 1 – L 4 = coil

Transmitter Section

This transmitter section is designed around oscillator transistor (BF194B) T2 followed by two transistors (BC148) T1 and T3. Transistor T2 generates special radio frequency determined by trimmer (variable capacitor) and coil. Transistor T1 is used as pulse generator. The output from transistor T3 is given to emitter of transistor T2 in order to get radio frequency from its collector. Trimmer VC1 is used to adjust the transmitter frequency. The transmitter circuit has a solar collector which enables continual power supply to the circuit.

Receiver Section

The receiver section is further divided into two main sections i.e. RF amplifier section and bell trigger section. An aerial is used to receive the transmitted frequency from the transmitter which is further amplified by amplifier and trigger circuit. The whole receiver circuit utilizes seven transistors with a pre-programmed IC CD4089.

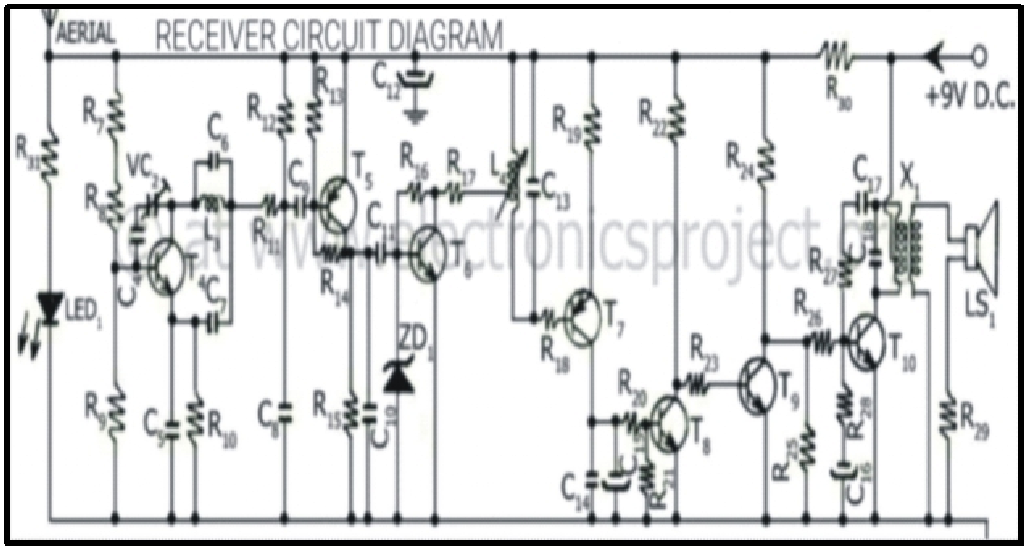

Figure 5: Receiver's Circuit Diagram (Adapted from Pradeep, 2020)

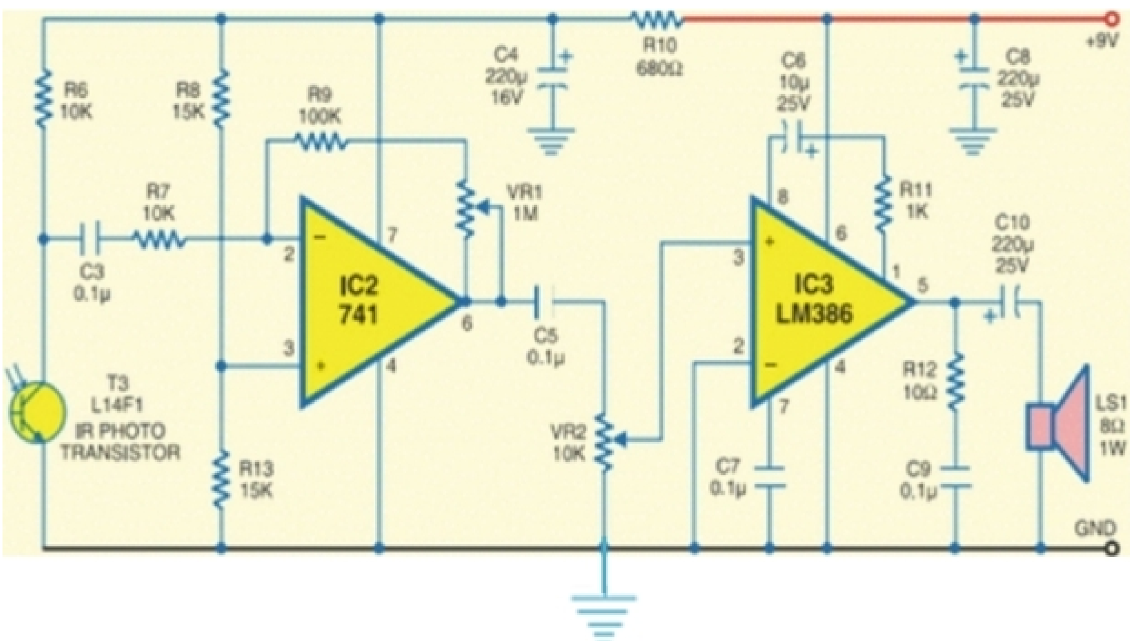

Figure 6: Transmitter Circuit Diagram (Adapted from Pradeep, 2020)

Transistor T4 gets frequency from sensor unit and further sends to tuned circuit made from capacitor C6 and coil L2. Transistors T5 is used as comparator which further send amplify voltage to capacitor C11 for filter. The filter voltage is passed through detector stage i.e. rectified and given to base of transistor T6. Transistor T6 is adjusted in amplifier mode for amplifying the signal voltage. The amplified voltage from transistor T6 is given to base of transistor T7, used in complementary mode. The positive voltage at collector of transistor T7 let transistor T8 in conducting state and T9 in non- conducting state. The positive voltage available at collector of T9 is given to base of transistor T10. Transistor T10 is used here in blocking oscillator mode which further produces bird sound combining with output transformer.

Conclusion and Recommendations

In this work, an attempt has been made to examine the phenomenon of oil pipeline explosion disaster in Nigeria with a view to situating its impacts and implications vis-a-vis Nigeria's national economy and security. This research provides insights on the way an automated surveillance and monitoring system can be used to detect, and alert security officers of an oil pipeline vandalisation incident from a remote location to oil pipelines, at the control station. A method for providing automated detection for pipeline with remote monitoring and location specification was achieved. A sensor was used to detect early intrusion of vandals into the pipeline system in order to communicate to the pipeline operators. This will trigger an alarm through the receiver so that a proactive action such as calling on the security patrol team can be initiated to mitigate loss.

To checkmate the criminality and vandalisation of oil pipelines, the research recommends stringent penalties for sponsors, supporters and perpetrators of oil pipeline vandalism in an attempt to ensure deterrence. The Nigeria National Petroleum Company (NNPC) and oil multinationals should work with local communities towards ensuring that pipelines are adequately protected in the hinterlands. Thus, there is need for the law enforcement agents to be up and doing and proactive in installing and regularly monitoring strategically located, software controlled anti-pipeline vandalisation surveillance systems in order to deter and apprehend prospective vandals.

This study recommends targeted aerial, long range but localized chemical or biological attack on the perpetrators of oil pipeline vandalisation. This can include sleeping gas rain on target location and its immediate environs. This will prevent unnecessary wastage of lives of security operatives during combat and allow for thorough interrogation to fish out their barons. Any security personnel who achieves well in this regard should be handsomely rewarded while those who betray should be executed without delay.

Recommendation for Further Studies

This research work "the design and implementation of remote-controlled anti-pipeline vandalisation monitoring system" has some limitations which includes time factors, precautions against false alarm, GPS location specifics, real time image capture for transmission, distance of coverage, real time implementation which requires government intervention and high price of materials needed for the implementation. Hence, more research should be conducted on this research topic to assess its effectiveness. We recommend that further studies should be carried out on this research topic to proffer an extensive solution to the problem of oil pipeline vandalisation.

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