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The Impact of Ageing Facilities on Oil Production in South Sudan

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ABSTRACT

The purpose of this paper is to discuss the impacts that ageing facilities and infrastructure have on oil and gas production in South Sudan and assessing life extension in order to ensure the technical and operational integrity of these ageing facilities. Strategies companies plan to use to rein in costs and mitigate risk in the years ahead. Oil and gas operators are now being driven to now operate beyond their originally conceived design life and field life. Asset life extension (ALE) beyond these thresholds presents unique safety and business risk challenges for the oil and gas industry. With aging equipment and facilities, operators face increasing challenges in maintaining equipment reliability and integrity as well as operational safety. Aging factors do not only involve hardware but also human and organizational factors. Factors include corrosion, erosion, fatigue, equipment obsolescence, normalization of deviance (accepting degraded conditions as being normal), changes in codes and standards and lack of data to forecast future risks. With aging equipment and facilities, operators face increasing challenges in maintaining equipment reliability and integrity as well as operational safety. In South Sudan, much of this infrastructure is rapidly ageing, thus increasing the risk of failure. A large number of facilities and parts of the infrastructure of the oil and gas reservoirs nationwide are approaching or have exceeded their original design life. Subsequent disruptions hamstring operations and impede opportunities for growth, with the impact of these interruptions felt in the country's economy. Furthermore, a lack of infrastructure project oversight and expertise, compounded by insufficient funding is pushing the already fragile drilling systems beyond their limits. The ageing of the South Sudan's oil and gas (O&G) installations can lead to many incidents. Such installations are over 20 years old (life cycle) and still in operation. To deal with this O&G crucial problem, the South Sudanese authorities have to launch a rehabilitation and modernization schedule of these installations. The objective of this is to highlight the effects of obsolete equipment and infrastructure that is degraded physically and functionally including the human factors and organizational issues. This documentation on ageing mechanisms will provide the assessment of the implications of ageing facilities in the oil production sector in South Sudan and it aims to examine the business implications of infrastructure failures.

Keywords: Ageing oil and gas production facilities, Maintenance, Extension of petroleum production facility service life span, maintenance management, asset life extension, integrity management, safety critical element, oil and gas producers.

INTRODUCTION

Ageing facilities is equipment for which there is evidence or likelihood of significant deterioration and damage taking place since new, or for which there is insufficient information and knowledge available to know the extent to which this possibility exists. The significance of deterioration and damage relates to the potential effect on the equipment's functionality, availability, reliability and safety. Just because an item of equipment is old does not necessarily mean that it is significantly deteriorating and damaged. All types of equipment can be susceptible to ageing mechanisms. Ageing is not about how old your equipment is; it is about its condition, and how that is changing over time. (Wintle et al. 2006). Ageing is the effect whereby a component suffers some form of material deterioration and damage (usually, but not necessarily, associated with time in service) with an increasing likelihood of failure over the lifetime. (Horrocks et al. 2010; De Rademaeker et al., 2014). Many of South Sudan's oil & gas installations are in the life extension stage, as they have passed their original design life. There will be a time when an installed facility has to be closed down permanently as per the original design life. Oil and gas facilities range from both upstream and downstream assets to include oil rigging structures, onshore tank farm facilities, Pipelines, Line Pipes, Oil Gathering poles, Well heads, Service Rigs, Horse Power (Engines) and Generators/Electricity stations. Metallic equipment and constructions in oil, gas, and refinery plants contact crude oils, natural gas, petroleum products and fuels, solvents, water, atmosphere, and soil. All processes with participation of aggressive substances occur in metallic equipment at temperatures from –196 °C to +1400 °C and pressures from vacuum to 1000 bar. Oil, gas and refinery units represent a high hazard industry with media which are flammable, explosive, toxic to human health or harmful to the environment. The combination of numerous factors makes oil, gas and refinery equipment very vulnerable to a variety of corrosion phenomena that can lead to serious accidents.

The unified Sudan began producing oil in the late 1990s, and as a result, the country tripled its per capita income within a decade. The southern region overwhelmingly voted for secession in 2005 in accordance to the Comprehensive Peace Agreement (CPA), and in July 2011, South Sudan became an independent nation-state separate from Sudan, with Juba and Khartoum as their respective capitals. South Sudan's oil sectors play a vital role in the economy. In South Sudan, the administrative structure in the Oil and gas sector consist of the Ministry of Petroleum and Mining which is responsible for managing South Sudan's petroleum sector, the National Petroleum and Gas Corporation (NPGC) which is the main policymaking and supervisory body, and it reports directly to the president and national legislative assembly. It participates in all segments of the hydrocarbon sector and approves petroleum agreements on the government's behalf. The Nile Petroleum Corporation (Nilepet) is South Sudan's national oil company. Nilepet oversees operations in the petroleum sector, and because of its limited technical expertise and financial resources, it holds minority stakes in production-sharing contracts with foreign oil companies. South Sudan's Transitional Constitution, the 2012 Petroleum Act, and the 2013 Petroleum Revenue Management Act define the regulatory framework governing the hydrocarbon sector.

In South Sudan, the outbreaks of civil war and political instability have undermined its ability to increase output to peak production capacity. Low investor confidence and the poor security situation pose serious obstacles to the government's ability to boost crude oil production, and they may need to rely on privately negotiated deals with smaller companies. Damaged infrastructure and shut-in fields stemming from conflict have lowered overall production levels, and efforts to repair infrastructure or restart production have been delayed. In 2018, combined production from both South Sudan and Sudan fell to less than half of the peak production levels of 2010; the unified Sudan produced about 486,000 b/d. Neither country will likely be able to substantially increase production without significantly improving the security situation or increasing foreign investment. A key question for South Sudan going forward is whether the oil production can be increased and extended beyond the projections presented in the South Sudan Development

Plan (2011). The most direct way to achieve this would be to increase the recovery rate from existing fields. Most of the oil and gas facilities currently under operation were set up in the late 1990s after the signing of the EPSAs by the government of the then unified Sudan. Today, little is known about the conditions of the infrastructure being used in oil and gas production in South Sudan. The government of South Sudan, which does not yet have strong and experienced institutions, does not have monitoring, audit and review arrangements in place.

Table 1: South Sudan Oil fields and operators

LOCATION	MAIN FIELDS	BLEND	OPERATOR
BLOCK 1, 2, 4	Unity, Toma, Munga, Heglig, Bamboo, Diffra, Neem	Nile	GPOC
BLOCK 3, 7	Paloch, Adar-Yale	Dar	DPOC
BLOCK 5A	Mala, Thar Jath	Nile	SPOC

Source: Company websites and presentations, RYSTAD Energy, Africa Oil & Power

Midstream infrastructure

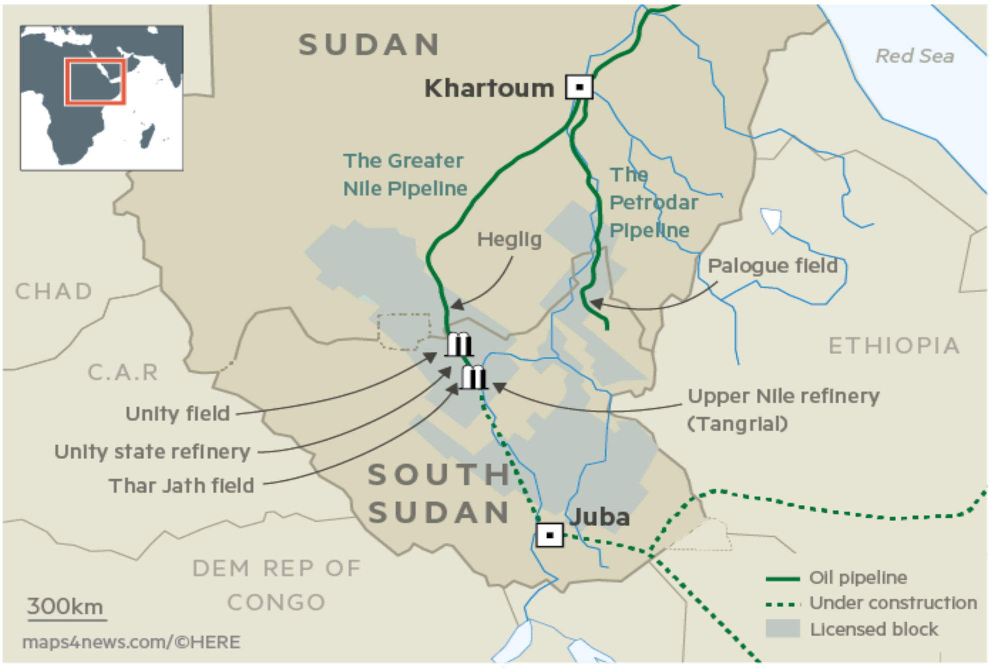

Fig 1: Map Showing the Main Pipeline Infrastructure in Sudan and South Sudan.
Source: maps4news.com

South Sudan uses previously established infrastructure that was set up before it attained independence. This however, comes at a cost to the young nation. According to a Business Monitor Intelligence (BMI) Research report, South Sudan currently pays Sudan U.S. $24.50/barrel, which consists of a U.S. $9.50/barrel transit fee and a U.S. $15/barrel fee to cover the cost of debt repayment shared between the two countries. Sudan has two main export pipelines that travel north across the country to the Bashayer Marine Terminal, located about 15 miles south of Port Sudan. Most of Sudan's storage facilities for crude oil and refined products are also located at the Bashayer Marine Terminal. The Bashayer Marine Terminal has a storage facility with a capacity of 2.5 million b/d and an export/import facility with a handling capacity of 1.2 million b/d. The Greater Nile Petroleum Operating Company (GNPOC) operates the terminal. South Sudan currently does not have any significant storage capacity.18 South Sudan exports all of its crude oil via pipeline through Sudan. The Petrodar (PDOC) pipeline transports crude oil from Palogue and Adar Yale oil fields (Blocks 3E and 7E) in the Melut Basin to the Bashayer Marine Terminal in Port Sudan. The pipeline has several heating units to facilitate the movement of the Dar blend crude oil along the pipeline. The GNPOC pipeline transports Nile blend crude oil from the Heglig oil fields (Blocks 2 and 4) in Sudan and the Thar Jath and Mala oil fields (Block 1 and 5A) in South Sudan to the Bashayer Marine Terminal in Port Sudan for export and to two refineries in El-Obeid and Khartoum for refining and distribution to the domestic market. In September 2014, ownership of the pipeline and facilities was fully transferred to a local Sudanese pipeline operator, Petrolines for Crude Oil Ltd. (PETCO).

Table 2: Crude oil pipelines in Sudan and South Sudan

Operator	Start of Pipeline	Destination	Crude Oil Blend Type	Approx. length (miles)	Design Capacity (Thousand B/D)
Main Crude Oil Pipelines					
DPOC	Block 3 and 7	Bashayer Terminal 2, Port Sudan	Dar	850 miles	500
GNPOC	Heglig Facilities	Bashayer Terminal 1, Port Sudan	Nile	1000 miles	450
SPOC	Block 5A	Connects to Heglig facilities	Nile	60 miles	200
CNPC	Block 6	Khartoum Refinery	Fula	450	200
Proposed Crude Oil Pipelines					
--	South Sudan	Lamu (Kenya)	--	--	450
--	South Sudan	Djibouti via Ethiopia	--	--	--

Source: Company websites, Middle East Economic Survey

Refining and refined oil products

South Sudan has no domestic refining capacity so it must rely on imported petroleum products to meet domestic demand. The South Sudanese government has sought to accelerate the development of two refineries in Bentiu and Tangrial; however, the poor security environment has impeded the development of downstream infrastructure.

Aspects of Ageing Facilities.

Material degradation, obsolescence, and organizational issues are the three aspects of ageing. **Material Degradation** is a broad term encompassing some of the major reasons for ageing. The degradation can be associated with physical, operational and environmental factors. Also, major unfavorable maintenance practices can lead to material degradation. Material Degradation includes:

Corrosion **–** this is the loss of material due to electro-chemical reaction with the environment. Corrosion can be internal or external. Most of the internal corrosion problems are due to the corrosive contents of the produced well fluids, such as dissolved gases e.g. – CO_2 and H_2S. The constitution of the well fluids changes with time and old fields tend to be sourer, leading to an increasing rate of corrosion. External corrosion can be due to offshore environments, with sea water in the air. Corrosion under cladding or coating (e.g. PFP, insulation) is a significant issue and difficult to detect. Corrosion of exposed steel work is an increasing problem of ageing installations, particularly if maintenance (repainting) is poor.

Ageing of topside equipment includes the whole range of equipment placed on the topsides of any installations include wearing out of moving or rotating equipment due to friction, and erosion due to the removal of material from the fluid flow. This effect of degradation includes:- Wearing out of moving or rotating equipment due to friction particularly;- Erosion due to removal of material from fluid flow, particularly if the fluid contains solid particles, prior to separation on valve seats and other high velocity areas in the process.

***Environmentally assisted cracking*:** This is cracking due to electrochemical reaction of material with the environment, which includes stress corrosion cracking (SCC) and hydrogen embrittlement. The extent and rate of these processes are age related.

***General fatigue failures of welds and material*:** The structure is the primary mechanism of any installation whether fixed or floating, above or below water, which provides a supporting framework within a band of tolerance of movements that ensures the equipment and personnel continue to function properly & safely. Structures are subjected to changing loads and susceptibilities (e.g. – Increasing loads due to the marine growth) causing fatigue (it is caused due to the development of cracks under cyclical stresses). There will be general fatigue due to failure of welds and materials due to repeated cyclic stresses and vibration fatigue caused due to high cycle low amplitude cyclic stresses due to poor fixing, resonance such as in small bore piping attachments.

***Accumulated damage*:** There may be substantial accumulated damages such as dents and gouges primarily due to the impact from objects dropped from the platform or attendant vessels or as a result of maintenance.

***Scour*:** Scour is the erosion of loose seabed material directly around offshore structures. This can increase the height of the structure subjected to hydrodynamic loading.

***Increased structural load*:** Changes in effective water depth can increase both hydrodynamic loading on the structure and the probability of the deck being inundated during extreme weather conditions; effective water depth can be increase due to – settlement, subsidence, vertical movements of the tectonic plates.

***Blockages*:** Blockages of pipe work, valves, heat exchanger tubes, pressure relief systems, etc., due to build-up of corrosion products, fouling and scaling, etc.

Obsolescence: Due to prolonged use, the equipment gradually becomes out-of-date and this signifies ageing. Equipment becomes out of date or back logged and this represents a form of ageing. For example – the corrosion management system may no longer be suitable for current product chemistry, backlogs can develop in planned maintenance & inspection and the plans themselves may need to review or revise to reflect the state ageing equipment. In addition to outdated technology, obsolescence includes new needs, where one need gives rise to another. For example, to extract oil from reservoirs located further away from the facility and existing wells, new tie-ins and new types of wells are needed. This in turn results in a need for a new technology. An assessment of the extent and accuracy of available knowledge, and the adequacy of that knowledge to make sound judgments, is an essential part of the life extension process.

Organizational Issues: Usually both the work force and the installation platform are ageing simultaneously and therefore the transfer of information may not function properly. The workforce, the team dedicated or allotted for particular installation, age and change, therefore level of knowledge and preparedness particularly in the event of emergency or crisis, have to be regularly tested and refreshed especially for their influence on or participation in any proposed management system. Arrangements for maintaining a trained and competent workforce with an awareness of equipment ageing and its effects is an issue to be addressed. Much of the current workforce is acknowledged to be approaching retirement and the succession needs to be part of life extension planning. Loss of corporate knowledge with retiring staff is also an issue. The teams that are ageing are more than just operational teams or design teams that support as well as undertake new builds. On account of very limited new people entering in teams, succession of knowledge is hindered. Also the teams represent a significant proportion of organisational memory. Usually both the work force and the installation platform are ageing simultaneously and therefore the transfer of information mechanism may not function properly. Any degradation or problem on the installation if not managed in a good way, may pass on a message of corporate negligence to the staff working offshore which will in some way affect their acceptance of any new integrity management scheme. Thus extension planning can help to ensure that the organizational issues and knowledge are up to date and hence they are not hampering any progress. Also the success of management scheme developed to manage life extension should be in accordance with abilities, skills and aptitude of the workforce who are intended to implement them.

Ageing accelerating factors (+ ageing) include:

Age and in-service time**:** These factors have been considered one the alternative of the other one as they refer to the duration of plant operations, thus the real age of the system should be subtracted by the shut-down periods. The factors are respectively defined as the ratio "age/designed age" and "in-service time/designed in-service time".

Shut-downs**:** This factor is the ratio "no. unexpected shutdowns/no. total shutdowns". It is evident that numerous shut-downs accelerate the ageing of the installation, on the basis of the experience if the number of unexpected stops is more than 2/3 of the total it can reasonably be assumed that the system is out of control. The range 0÷0.7 can be assumed.

Accidents/incidents and anomalies (failures): This factor includes only mechanical failures and is quantitatively given by the failure rate. The range of variability is 0÷1.

Identified damages**:** This factor refers to the damage of components, which are detected by inspections and do not compromise their function. It is related to the percentage of damaged components and the entity of the defects, these sub-factors contribute in line. Defects are classified as light and severe, respectively, depending on if they comprise the stability of operations or they need to be repaired.

Deterioration mechanisms**:** This factor is related to the damage's detection capability of the main mechanisms (by inspection), the damage propagation velocity, the level of variability and knowledge of the phenomenon. The level of variability of the mechanism refers about the dependence on variables that can be controlled (e.g. operating parameters, chemical composition of fluid streams, etc.) or not (e.g. external pollution, contamination of inputs, etc.). The level of knowledge of the mechanism relates to its comprehension and, thus, the availability of technique to achieve its control. The contribution of each sub-factor of Table 3 is not in line, this time the final factor is given by the product of each parameter.

Impact of ageing facilities

Oil and gas industry is a strategic sector in South Sudan, dominated by foreign Oil Companies that have merged into consortiums. Its installations are complex and dangerous. The ageing of installations increases risks that are translated through potential dangers associated with such installations. As highlighted earlier, materials fatigue and corrosion are the major mechanisms of ageing of infrastructure facilities. Historically, leaks caused by equipment's corrosion of Gas Liquefaction Plant have been the main source tragedy with heavy consequences in terms of deaths, injuries and material losses worth billions of dollars. It is worthy to note that the ageing of this plant equipment is the main cause of the persistent explosions which were previously occurred in the oil fields in the country.

***Impact on safety*:** Generally, safety is a fundamental principle in any engineering design. It is primarily concerned with sudden catastrophic incident that could result in serious injury or death. Older structures are more prone to accidents, especially fires, and more dangerous for workers. Therefore, in considering any maintenance planning, the criticality of the structure with regards to safety is considered very important in assessing any defect. The effect of aging facilities can be felt in the following factors; chemical/radiation exposure, lightning and ventilation, ergonomics, noise/vibration pollution, material handling and storage, outdoor operations and accommodation facilities.

***Impact on assets*:** According to Ratnayake and Markeset, an asset is defined as any physical core, acquired (i.e. the organization has either the possession or the custody of the asset) elements of significant value to the organization, which provides and request service for the organization. Hence, an asset forms the basis of entity of any organization. It is important to note that, a defects that will have an adverse effect on the asset may have a direct impact on the entire objective of the organization.

***Impact on the environment*:** Of recent, many events have occurred that solicited for environmental concern. One example of such an event is Macandor well blowout in in the Gulf of Mexico. This event has cost BP a huge sum of dollars as a result of environmental impact the event has caused. It is therefore not arguable that, the impact industrial organization has on the quality of social and ecological environment of the future generations. Environmental and social concerns are expressed as health, safety and environment (HSE) in industrial asset operation. Many holds the notion that, defects or failure of civil structures in process plants may have negligible or no serious impact on the environment. Nevertheless, there are instance where the structures carries critical equipment such as tank, column, vessel etc. In this case, if the supporting structure failed, there is every tendency for the equipment to be affected and this may eventually leak of containment that may litter the environment.

***Impact on production*:** Companies nowadays are faced with challenges of increasing demands in terms of quality and quantity of products and services, responsiveness and costs reducing. To deal with these demands, company must have a reliable production system, well maintained by an efficient and inexpensive maintenance system. A performance and well-organized maintenance service contributes to the production system consistency, it will extend the life of industrial equipment and thus the best overall performance of the plant. Ageing facilities have a negative impact on production levels as they tend to cause disruptions and stoppage from time to time thus companies do not meet the targeted production amount per day.

Impact on Reputation: This is public information regarding a company' trustworthiness. A company's reputation reflects the information that third parties have on how trustworthy his behaviour has been in the past. It thus be seen as a rating in which a stakeholder state if the entity meets the expectations of the stakeholder. By using ageing infrastructure, Companies also risk a negative impact on their brands, which can affect current and future business opportunities.

***Impact on cost*:** The main objective of any business entity is to generate revenue that can be used to sustain its function and services. Convincing executives and regulators to make proactive investments in infrastructure can be challenging. But when companies fail to take such approach, they increase the likelihood of facing emergencies and the resultant high costs of repairing failed infrastructure.

***Impact on Cyber-Security*:** Cybersecurity threats constantly evolve, with hackers working to exploit systems old and new. Whereas at least the new systems have recent threats in mind during their development, outdated systems may not be equipped to handle newer issues. Technology continues to develop at a rapid pace, and hackers are adapting. The oil and gas industry needs to adapt as well, requiring frequent updates of its control system software and infrastructure.

***Impact on Plant Shutdown*:** If a plant has to shut down for some reason, there should be a protocol in place to ensure all technology and systems can be secured even without a human presence. Utility interruptions and plant shutdowns, in addition to health issues like spills, can require the evacuation of the premises. In such a scenario, the industry should equip its security infrastructure to withstand secure remote access or automated security. Ageing infrastructure may not be compatible with the latest remote shut down technology.

***Aging electrical component*:** Facilities are designed typically with a life span of 20–25 years. However, it is becoming common for facilities, to be operated beyond its life span. While assets are designed for 20–25 years, equipment age differently and suffer from different age-related failure mechanisms. Other than aging, electrical, control and instrumentation equipment suffer from obsolescence. This is primarily due to unavailability of components and end of hardware/software support. Aging generators/ electrical components lead to power shortages which can interrupt oil production and thus have an impact on the barrel per day target that is set. As South Sudan's largest oilfields age, the power required to keep them operating can rise dramatically even as the amount of petroleum they produce drops.

Recommendations

Oil and gas producers in South Sudan are often driven to continue operations beyond its design facility and are required to operate safely. Studies shows that effective inspection and maintenance are important in ensuring asset integrity and reliability. Ageing Infrastructure, (if not managed properly or upgraded) can result in catastrophes. Therefore, oil and gas production, refineries and petrochemical plants should manage their units safely. For this, they have to make efforts to control technological processes and organize corrosion management strategies in order to diminish accident risks to a minimum. Risks communication strategies that are associated with industrial installations because of ageing problem should be developed to help in decision making allowances on control of ageing and assessing the achieved progress either in ageing control or in installations' modernization in order to address ageing problem.

To address the ageing problems of South Sudan's Oil and Gas installations, the National Authorities should commit to develop a strategic action plan which will be materialized through implementation policies and legislature that will establish the conditions of installations and equipment compliance associated with hydrocarbons activities, and establish terms and conditions of approval specific Hazards Studies of hydrocarbons. Among the policies should be directions to implement risks control instructions associated with ageing facilities (installations and equipment's). Such instructions are indeed, necessary for industrial ageing control in a sector as strategically important as Oil & Gas industry in South Sudan.

The government should have monitoring, audit and review arrangements in place as part of the HSE or related management systems. Monitoring processes should be defined and this will provide reasonable assurance that there is compliance to Asset Life Extension management policies in the country's oil and gas sector. Examples of monitoring processes are: - Active line monitoring by site-based supervisors and managers as part of routine operations; active monitoring by oil-filed based support personnel and in particular by engineering Technical Authorities; monitoring by oil-field based line management in the course of routine business/operational meetings; regular monitoring of performance against key performance indicators; reactive monitoring in the form of the investigation of incidents and other failures. Management includes planning actions for determination of corrosion risk, performance requirements of standards, recommended practices and specifications for correct selection of materials, corrosion protection, and monitoring methods. This should be carried out at the stage of design and then their realization in practice under inspection, control, and monitoring. Study of each accident with failure analysis, coordination, education, and knowledge transfer are also necessary components of corrosion management methodology.

The government management system should develop approaches focusing on particular indicators which according to the safety objectives of companies. The proposed indicators that can help in monitoring and evaluating ageing facilities are; Age Indicators which reveals the installation average age, allows the provision with information related to the installation equipment's, mainly regarding equipment's operating under pressure, overhead storage, pipes, safety instrument systems, civil engineering works such as retention pond, etc.; Implementation of Maintenance Policies indicators which allows to highlight the maintenance policy practiced within an installation, aims at not only, to helping users to detect at a timely manner, even to anticipate undesirable ageing symptoms, but equally to qualify interventions regardless of their nature. Other important indicators are indicators such as Implementation of Quality, Safety & Environment (QSE) Management System: In management terms, this indicator is a durable surveillance element which can be summing up as follows: (1) Improvement of control, modification and intervention procedures. (2) Prevention of industrial and environmental risks. Modernization Actions illustrates another industrial ageing phenomenon consequence. It relates to modernization which represents a reactive or a proactive action allowing the measuring up of an industrial installation ageing. In other words, without modernization actions, the industrial ageing problem will be intensified within time despite the other measures taken to manage it. Hence, such indicator is very important for the assessment of the industrial ageing risks.

Human factors area comprises methods and knowledge which can be used to assess and improve the interaction between people, technology and organization to realize efficient and safe operations. The factors should include organizational structure, competency or training requirements, and succession planning. Human factor is a key issue in corrosion management and diminishing corrosion accidents. The causes of human mistakes are the lack of awareness, education, knowledge and training, incorrect design, insufficient control and supervision, lack of motivation and incentives to decrease the corrosion risk, wrong operation, and element of change. Many organizations in these industries face losing valuable expertise when key personnel retire or take positions in other companies. Capturing best practices as part of the project management process, as well as training and mentoring of junior staff by senior staff, can help reduce that risk. The important role of training in control of industrial ageing is notably in ensuring success of installations inspection plans requiring a high competence and a particular diligence of involved persons in the implementation of such plans.

Ageing infrastructure will continue to affect South Sudan's Oil and Gas industries for years to come. However, those impacts may be reduced by organisational investments in time and resources to solve problems. The best solutions involve a blend of technology, project planning and due diligence. Collectively, these elements help organisations identify and resolve problems before crises occur. This proactive approach requires both a significant financial investment and a substantial culture change. Averting impending problems for cost-effective and safe repair before failures occur, rather than narrowly focusing on compliance, improves a company's ability to be agile, to seize new opportunities and to protect customers, employees, operations and the corporate image from the costly consequences of infrastructure failure.

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