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ABSTRACT:
Depot facilities are industrial equipments used for the storage of oil, gas and petrochemical products etc., and from which these products are usually transported to end users or for furtherstorages. In the maintenance and sustainability of keeping fuel delivery systems in safe checks, there are needs to derive standard programs to achieving these objectives. Maintenance is a combination of technical and administrative activities to keep a machine or equipment in its functional state. Machines or equipment with poor maintenance will result in dysfunction thatmight likely result to defective products which affect the quality of the products. These involve reliability of the machines and equipments, the manpower and the equipment perform to a standard level of quality assurance.
In this research work, the failure mode and effect analysis (FMEA) result indicate that six potential causes of failure were identified; three causes are critical and high risk priority number (RPN), these are; mechanical damage and cases of sabotage, spillage, potential fire/explosion. The above critical failures should be reduced and taking preventive action and corrective action to eliminate or reduce the failure. The result indicates that the equipment with the highest RPN 300 is pipe, which is that of mechanical damage and sabotage. But after implementing preventive and corrective action, the RPN has reduced to 160.

Keywords: Flow, pump, efficiency and reliability

1.0 INTRODUCTION

Maintenance of equipment's and machines is a combination of technical and administrative activities to keep them is safe and effective functional state. The pipeline system experiences unexpected failure from corrosion, external interference and operational error related incidences which led to downtime and less of product through spillages. Again, poor maintenance of production facilities can result in poor end-product quality and customer dissatisfaction lost production runs, cost inefficiencies, and sometimes, unavailability of the facility for future use (Bagshaw, 2017). Unfortunately, most organization’s facilities in Nigeria, for example the refineries, lack quality maintenance due to relatively high cost of maintenance cost, lack of wiliness, manpower and efficiency etc., and these results in frequent breakdown and stoppages with many losses in the process systems, Zhigao (2012).
The main objective of this study was to establish an enhanced operational reliability of the machine, tools and equipments and to preserve the value of the plant assets facilities.

2.0 BACKGROUND LITERATURES

Maintenance approaches can broadly be categorized as either corrective maintenance (CM) or preventive maintenance (PM). In corrective maintenance, maintenance activity is undertaken after the equipment has failed. CM is sometimes regarded as all actions performed after a failure in order to restore an item to a specified condition (Wang, 2002). In the review of the literature's, several authors are been depicted as presented in Table 1.

Table 1 Summarized version of reviewed investigations

Author(s)	**Investigation and Tank farm capacity**	**Research Benefits/Product storage**	**Remarks**
Argyropoulos *et al.*, 2012	The roof has the ability to rise and fall on the stored-fuel surface, in order to prevent the large volumes emittance of fuel-vapours.	The tank can be used for storage of fuel-oils, asphalt, vacuum /atmospheric residue etc. Using insulation, steam or heating coil in the tanks is necessary at keeping its content in liquid state.	The tank can also be used to store other products like jet fuel, diesel and gasoline. And can prevent the dissemination of the oil leakage to the surrounding.
Jian *et al.*, 2022	An Integrated framework of safety performance evaluation for oil and gas production plants: Application to a petroleum transportation station.	High integral framework to identify measures to prevent leakages and improve on safety standard.	Advanced safety management of tank farms need urgent attention, to prevent hazards/catastrophic accidents.
Idris *et al.*, 2022	Two-scenarios was established, the estimated risks are associated to petroleum tank farm activity, e.g., leakage at dispenser area due to poor safeguarding systems.	The risk associated with the highest risk hazard was reduced to an acceptable level.	Prior identification of hazards are minimized during the study activities by using the FMEA method sheet

Table 2 shows a comparison of corrective and preventive maintenance approaches in terms of their advantages and disadvantages (Moghaddam, 2011).

Table 2 Comparison of maintenance approaches

Approach	Advantages	Disadvantages
Corrective maintenance	No over maintenance (low cost policy). No condition related cost. Requires minimal management. Useful on small non-integrated plant.	High production downtime. Large spare inventory. High cost repairs. Crisis management needed. Overtime labor.
Preventive maintenance	Enabled management control. Reduced downtime. Control over spare parts and costs. Reduced unexpected failure. Fewer catastrophic failures.	Over maintenance. Unscheduled breakdown.

2.1 Preventive Maintenance

Preventive maintenance (PM) involves identifying potential areas of failure as to avoid breakdown which might be costlier. This is followed through by inspection, service and replacement of parts before they fail. Banjoko (2009) stated that PM 'involves the regular or periodic check and servicing of the machines, tools and other facilities used in the production process so as to delay or prevent the breakdown or the total failure of the facilities'. Furthermore, the problem undertaking in a preventive maintenance is to have a stand-by facility, which might increase the cost of asset, but a safer heaven. Again, stopping the machines for routine maintenance will cut down on its operating time, bearing in mind that the operation mode and plant-specific variables have a direct impact on the normal operating life of machine (Mobley, 2013). While PM might not be the optimum maintenance strategic option, it does have several advantages over that of the breakdown maintenance strategy. Undertaking PM of machines and equipment's will ensure that the functional state of the machine or equipment is maximized as in the design specification.

2.2 Corrective Maintenance

Corrective maintenance (CM) involves the replacement or repair of equipment after it fails. In response to equipment failure, CM tasks identify the failure (it may be an equipment component or equipment item) and rectify the failure so that the equipment can be reinstated and the facility production restored. CM tasks are prioritized so that the high-priority tasks that may be safety related or affecting production are addressed first. CM is in general low cost because it can generally be performed with a fewer number of resources and maintenance infrastructure, including tools, technologies and expertise. The consequence, however, is that it is inefficient and in the long term it can be very expensive because failures generally result in catastrophic events, which means there is more damage that needs to be repaired and hence the manufacturing mean time to repairs (MTTRs) are longer. CM also does not focus on the root cause of the equipment failure and therefore compute mean time between failures (MTBF) will be much lower than with proactive maintenance. In other words, there will be many repeat failures. The depicted picture presented in Figures 1 and 2 are sourced from (Argyropoulos et al., 2012), and Ahmad, (2012).

Figure 1: Fixed roof tank


Figure 2: Floating roof tank

3.0 MATERIALS AND METHODS

3.1 Materials: Process data from the NNPCL Maiduguri depot was collected**,** discussion with the field engineers and summary of questioner comments from the operator were obtained. In addition, the data obtained are depicted in Tables 3 – 5.

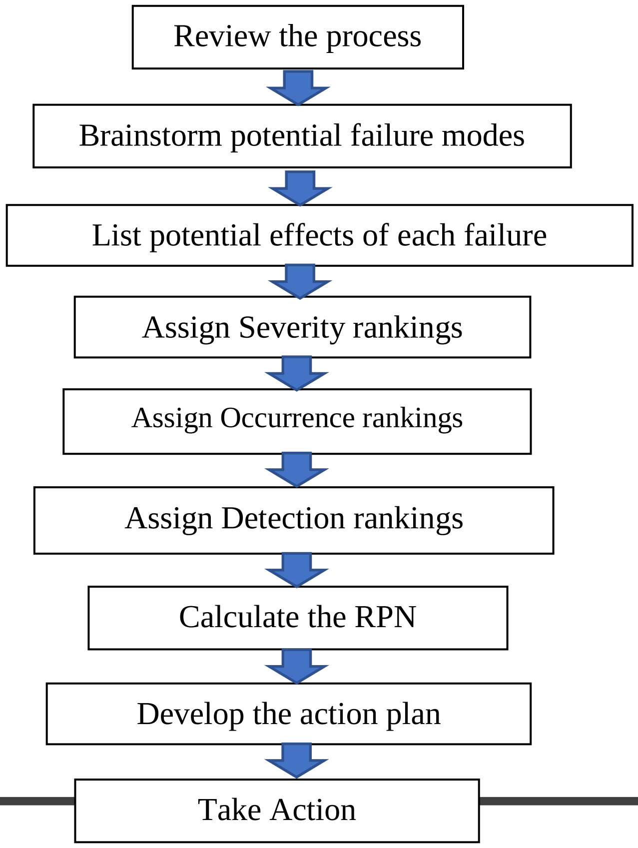
3.2 Methodology: two methods were used as risk assessment tools to evaluate the various potential hazards in petroleum tank farm. They are:

a) HAZOP (Hazards and Operability Study) for temperature and level parameters are respectively detailed in Tables 2 and 3.
b) FMEA (Failure Mode Effect Analysis)
c) After this practice, priority of failures due to their disaster effects should be ranked by a Risk Priority Number (RPN). RPN is priority potential level of failure which shows that the higher RPN value then the higher risk received. Value of S, O and D obtained through discussion process with the chief engineer, engine crew and port engineer where they have more than ten years' experiences working on board.
Furthermore, The Value of S, O and D calculate obtained in the worksheet using calculation as below:

$$RPN = S \times O \times D \quad (1)$$

Where:
RPN = Risk Priority Number
S = Severity
O = Occurrence
D = Detectability
Here, FMEA will be carried out on some of the major components relating to the storage tank unit.

The method adopted for FMEA is as shown in Figure 3.0.



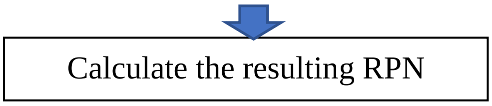


Figure 3: An FMEA block diagram

Table 3 represent the qualitative scale for severity index criteria in classifying the depot delivery systems and its auxiliaries.

Table 3 Qualitative scale for severity index

Rating	Effect	Criteria
1	No	No effect, No loss recorded.
2	Very slight	Very slight effect on equipment or performance.
3	Slight	Slight effect on equipment or system performance.
4	Minor	Minor effect on equipment or system performance.
5	Moderate	Moderate effect on equipment or system performance.
6	Significant	Equipment performance degraded, but operable and safe. Partial failure, but operable.
7	Major	Equipment performance severity affected but functional and safe. System impaired.
8	Extreme	Equipment inoperable but safe. System inoperable.
9	Serious	Potential hazardous effect. Able to stop equipment without mishap-time dependent failure.
10	Hazardous	Hazardous effect. Safety related-sudden failure.

Table 4 represent the qualitative scale for occurrence index criteria in classifying the depot delivery systems and its auxiliaries.

Table 4 Qualitative scale for occurrence index

Rating	Effect	Criteria
1	Almost never	Failure unlikely. History shows no failure.
2	Remote	Rare number of failures likely. One occurrence every twelve to fifteen years.
3	Very slight	Very few failures likely. One occurrence every twelve to fifteen years.
4	Slight	Few failures likely. One occurrence every eight to eleven years.
5	Low	Occasional number of failures likely. One occurrence every four to seven years.
6	Medium	Medium number of failure likely. One occurrence every two to three years.
7	Moderate high	Moderately high number of failures likely. One occurrence per year.
8	High	High number of failures likely. One occurrence every six months to one year.
9	Very high	Very high number of failures likely. One occurrence every

		three months.
10	Almost certain	Failure almost certain. Histories of failures exist from previous or similar designs. One occurrence per month.

Table 5 represent the qualitative scale for detectability index criteria in classifying the depot delivery systems and its auxiliaries.

Table 5 Qualitative scale for detectability index

Rating	Effect	Likelihood of detection (criteria)
1	Almost certain	Control will detect potential cause and subsequent failure mode.
2	Very high	Very high chance the control will detect potential cause and subsequent failure mode.
3	High	High chance the control will detect potential cause and subsequent failure mode.
4	Moderate high	Moderately high chance the control will detect potential cause and subsequent failure mode.
5	Moderate	Moderate chance the control will detect potential cause and subsequent failure mode.
6	Low	Low chance the control will detect potential cause and subsequent failure mode.
7	Very low	Very low chance the control will detect potential cause and subsequent failure mode.
8	Remote	Remote chance the control will detect potential cause and subsequent failure mode.
9	Very remote	Very remote chance the control will detect potential cause and subsequent failure mode.
10	Absolute uncertainty	Control cannot detect potential cause and subsequent failure mode.

4.0 RESULTS AND DISCUSSIONS

4.1 Results

Table 6 is the results carried out on some selected product tanks, storage capacity and roofing types.

Table 6: Show some selected product tanks, storage capacity and roofing type

Tank number	Products	Tank ccapacity (m^3)	Tank type
203	Premium Motor Spirit	5587	Floating tank
204	Premium Motor Spirit	5587	Floating tank
205	Premium Motor Spirit	9775	Floating tank
206	Premium Motor Spirit	9775	Floating tank
201	Dual Purpose Kerosene	9800	Floating tank
202	Dual Purpose Kerosene	5587	Floating tank
101	Automotive Gas Oil	8160	Fixed tank
102	Automotive Gas Oil	9530	Fixed tank
103	SLOP	155	Fixed tank
104	SLOP	155	Fixed tank
105	SLOP	155	Fixed tank
106	SLOP	155	Fixed tank

Table 7 listed the fuel delivery equipment prone to failure, their function and causes of failure, failure mode and effect of the failure. This table also indicates the severity, occurrences, detectability and RPN value for each of the equipment. The purpose of this worksheet is to identify and eliminate potential product and process failures. Table 8 includes new amounts of severity/ detection/ occurrence based on expert engineering team estimations, after implementing preventive and/or corrective actions to decrease the significance (severity) and occurrence, and increasing the detection level of each failure.

Table 7 shows the FMEA for fuel delivery equipment's worksheet

S/No	Item	Function	Potential Failure mode	Potential Effects of failure	Potential Causes of failure	S	O	D	RPN	Action taken
1.	Pipe	Transport of petroleum Products	Pipe leak, rupture/burst.	Product release/ spillage, possible fire/Explosion	Mechanical damage and cases of sabotage	10	6	5	300	Tighten the fittings, Seal the joints.
2.	Pump	fuel transfer	Operation fail	Engine stop	Engine fail to Run	7	5	3	105	Old gasket and seals should be replaced by new ones.
3.	Storage Tank	Product Storage	Product overflow	Product spill, potential fire/ explosion**.**	Corrosion	5	2	7	70	Do not overflow fuel tanks; fill to only 90% capacity to reduce the chance of spills.
4.	Strainer	To protect downstream pipeline equipment by removing solids from flowing fluid.	Fluid leaks/ spills from top of the strainer.	Cut O-ring, strainer filled with debris	Spillage, potential fire/explosion.	7	4	6	168	Make sure all the parts of the housing are tightened.
5.	Control valve	To regulate, direct and control flow.	Failed to operate (open/close), valve leak	Product spill, pumping stopped	Valve seized, control system problem	6	6	2	72	Weekly inspection should be employed.
6.	Flange joint	To connect Pipes, valves, pumps and other equipment to form a pipework system	Product leak/ spill.	Flange face leak, loose flange bolts, ruptured gasket, operating at pressures higher than recommended	Spillage, potential fire/explosion.	7	6	6	252	Replaced the gasket and washers with a new one.

Table 8 Revised Failure Mode Effect Analysis (FMEA) and Corrective Action plan

S/No	Item	Function	Potential Failure mode	Potential Effects of failure	Potential Causes of failure	S	O	D	RPN
1.	Pipe	Transport of petroleum Products	Pipe leak, rupture/burst.	Product release/ spillage, possible fire/ Explosion	Mechanical damage and cases of sabotage	8	5	4	160
2.	Pump	fuel transfer	Operation fail	Engine stop	Engine fail to Run	6	4	3	60
3.	Storage Tank	Product Storage	Product overflow	Product spill, potential fire/ explosion**.**	Corrosion	4	2	7	56
4.	Strainer	To protect downstream pipeline equipment by removing solids from a flowing fluid.	Fluid leaks/ spills from the top of the strainer	Cut O-ring, strainer filled with debris.	Spillage, potential fire/explosion.	5	6	1	30
5.	Control valve	To regulate, direct and control flow.	Failed to operate (open/close), valve leak	Product spill, pumping stopped	Valve seized, control sys tem problem	6	5	4	120
6.	Flange joint	To connect Pipes, valves, pumps and other equipment to form a pipework system	Product leak/ spill.	Flange face leak, loose flange bolts, ruptured gasket, operating at pressures higher than recommended	Spillage, potential fire/explosion.	5	5	2	50

Table 9 Potential cause of failures ranked 1 to 6 in decrease order of criticality

S/No.	Potential Causes of Failures	RPN
1	Mechanical damage and cases of sabotage	300
2	Spillage, potential fire/explosion.	252
3	Spillage, potential fire/explosion.	168
4	Engine fail to Run	105
5	Valve seized, control system problem	72
6	Corrosion	70

Table 9 shows that the highest RPN is 300 which potential cause of failure is mechanical damage and cases of sabotage. This has potential failures mode of Pipe leak, Rupture/burst from table 8. Another high pressure in the top load, spillage, and potential fire/explosion related failure which has high probability with RPN of 252, this potential failure mode of filter blocked as seen in Figure 4 and a correspondence review was found at Dey, (2013).

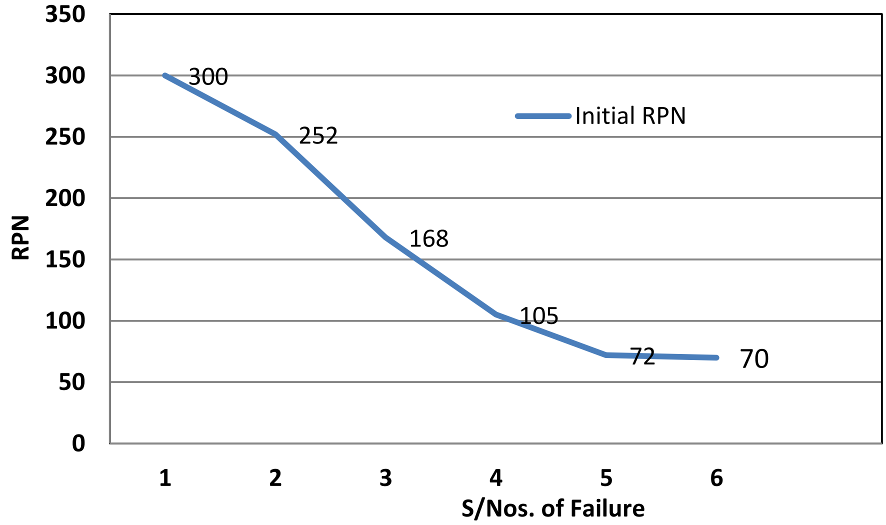


Figure 4 Graphical representation of potential failure cause at initial FMEA

Figure 4 depicts a profile of potential failure caused at the initial FMEA. Where at failure 1, the RPN was 300 and at 6 the RPN was 70. This shows that the response was higher at the initial cause level 1 when compared with that of level 6. The following figures 8 to 12 shows a clear pictures of the tank facilities accessed in the refinery depot **(**NNPCL deport Maiduguri, Borno State).

Figure 5 Transport pipelines
Figure 6 Flow pump

Figure 5 is the transport pipelines in the depot plant, while figure 6 pipe is a hallow tube with round cross section for the conveyance of product.it is necessary for the oil and gas industry to function. While figure 6 is a flow pump as a device used to move fluids by mechanical action from one place to the other. Without pumps, an oil depot or refineries cannot operate.
Figure 7 is a storage tank used store large quantities of petroleum products. The tanks are cylindrical and large with various capacities. They are constructed with stainless steel to resist corrosion. Figure 8 control valve is use to regulate, direct and control the flow of petroleum products.it also ensure pressure management in the supply network ASME. (2010).

Figure 7 Storage Tank

Figure 8 Control valve

Figure 9 Strainer

Figure 10 Flange joint

Figure 9 is a strainer used to capture solid particles and other solid contaminants within a liquid and stop them from continuing through the system. It helps to present potential damage to other parts of the system. While figure 10 Flange joint are one of the efficient components in a method to connect pipes, along with forging connection in a piping system. It regularly permits workers with inspection points which are easy to modify and clean the system Narain, (2017).

4.2 Discussion of Results

Based on FMEA worksheet on the Table 7 with the existence of cause and effect on the fuel delivery system also be able to use as supporting equipment to identify failure arise on the component. FMEA is a proactive analytical tool to assist engineers in order to define, identify and eliminate potential failures, constraints, inaccuracies or other systems, design and/or operations. From table 7, it can be seen that the highest RPN value is that of mechanical damage and sabotage related effects to the pipe at 300. This is attributed to the high product volumes lost, high failure rates and the lack of failure detection facilities on the pipe. The second item with high RPN is flange joint, the third items with high RPN is the strainer. Table 8 is the revised failure mode effect analysis (FMEA) and corrective action plan. Based on the RPN values, priority of attention is given to mechanical damage and sabotage, spillage, potential fire/explosion, these components on the fuel delivery system are potentially dangerous to start from the pollution of the deport environment to the occurrence of fire. Whereas storage tank, pump and control valve related incidences will be given least attention, as found at Han, (2010) and Simonoff, (2010).
An effort was implemented to lower the RPN which was done by a proper packing design and also by carefully controlling the distributor of the liquid at different levels, after the implementing the maintenance action. FMEA revised table was developed and changed to table 8, as shown, which indicates that the RPN value of the discussed fuel delivery equipment's, has reduced and this makes it less risky than before implementing maintenance actions. as it can be seen in table 8 new amounts of severity/ detection/ occurrence based on expert engineering team estimations, after implementing preventive and/or corrective actions to decrease the significance (severity) and occurrence, and increasing the detection level of each failure Tina, (2018).
More accurate and reality-based revised values result in much more appropriate and reality-based prioritizing failures. Revised severity/detection/occurrence values must be assigned by exact calculations based on available technical and statistical methodologies. Figure 11 illustrates trade-off between RPN rates before and after implementing FMEA process.

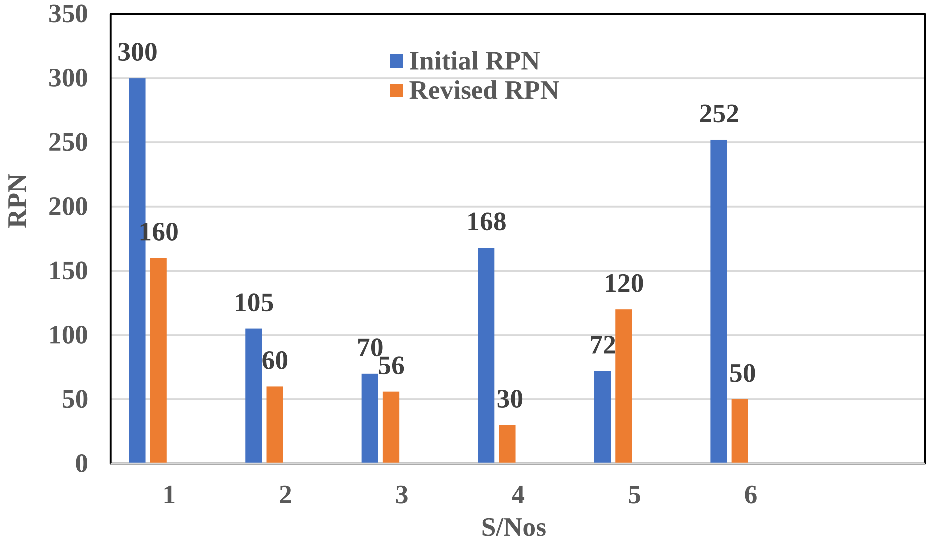


Figure 11 Initial FMEA versus revised FMEA

As shown in figure 11, after implementing preventive and corrective actions on described failures, RPN of malfunctions will change and this leads us in focusing on the most hazardous failures, due to limitations of the process.

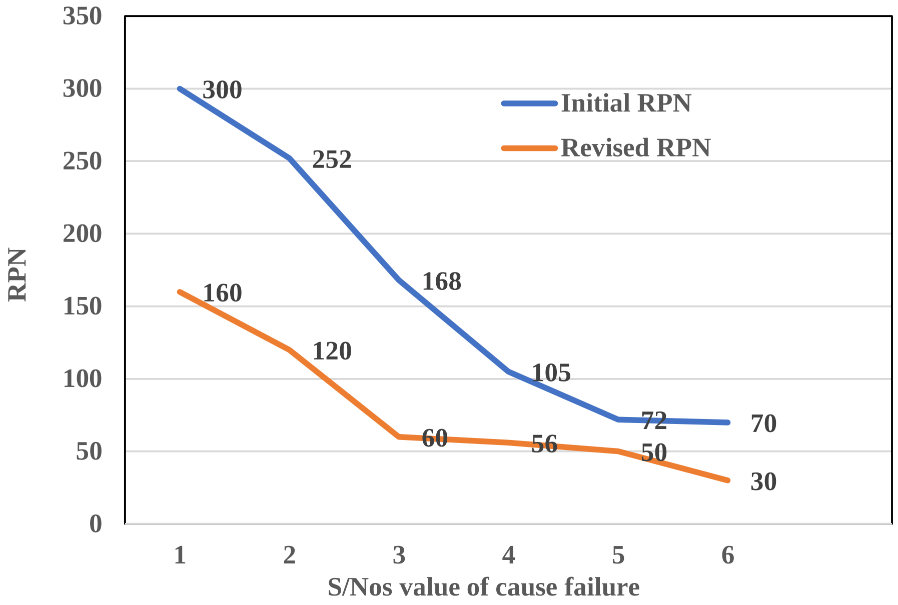


Figure 12 Profile of the Initial versus. Revised RPN

Figure 12 shows the graphical representation profile of the initial and revised RPN rates where the initial profile indicated the potential causes of failures from the most hazardous failure with the highest RPN which is 300 to the lowest RPN 70.While the profile also indicated the potential causes of failures from the highest RPN rates which is 160 to the lowest RPN 50.from the profile it can be seen that before implementing preventive and corrective actions the equipment failure are very critical, but after carrying out necessary actions the potential failures were reduced.

Table 10 Comparison of the results of this research work and the literature (Achilla, 2015).

Study	Method	Results
This research study	Failure Mode And Effect Analysis (FMEA)	The result indicates that the equipment with the highest RPN 300 is pipe, which is that of mechanical damage and sabotage. But after implementing preventive and corrective action, the RPN has reduced to 160.
(Achilla, 2015)	Failure Mode And Effect analysis (FMEA)	The result indicates that the equipment with the highest RPN 640 is pipe, which is that of mechanical damage and sabotage. Attention is given to the equipment but did not implement action in the research.

5.0 Conclusion

After carrying out this study, The FMEA result Indicate that six potential cause of failure were identified with these cause three are critical and high RPN these are; mechanical damage and cases of sabotage, Spillage, potential fire/explosion, after taking preventive and corrective actions plan for each failure the corresponding RPN were revised and the critical failures reduces and becomes lesser than before. To conclude, the result of FMEA on fuel delivery equipment in the oil depot shows that critical failure with high RPN which significantly affect and disturb the system were reduced.

The contributors of equipment failure include valve failure, worn out seals, pump failure, gasket rupture, flange joint leaks, level indicator failure, clamp failure and defective O-rings. The result indicates that the equipment with the highest RPN 300 is pipe, which is that of mechanical damage and sabotage. But after implementing preventive and corrective action, the RPN has reduced to 160, when compared with Achilla, (2015).

6.0 Recommendations

Within the limit of the experimental studies, it is recommended that this research indicates that FMEA as a possible tool to reach the better maintenance practice of the (NNPC deport Maiduguri). Other recommendations preferred are:

1. Appropriate and modern safety gadgets should be provided for staff members in the depot to improve compliance.
2. There should be regular maintenance of depot facilities to guide against fire outbreak, leakages and other hazards in the depot
3. Investigate the financial consequences arising from the pipeline system failure by developing a model that will combine all consequences of failure.
4. Determine the acceptable and tolerable risk levels for the pipeline system in a refinery depot.

Abbreviations:

FMEA	*Failure mode effect analysis*
FTA	*Failure test analysis*
HSE	*Health and safety executive*
NFPA	*National fire protection agency*
NNPCL	*Nigerian national petroleum corporation Limited*
QRA	*Qualitative risk assessment*
RPN	*Risk Priority Number*

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