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Assessing the Capacity of Libyan Local Authorities in Managing Environmental Pollution for Sustainable Development

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ABSTRACT

After a prolonged period of political instability, rapid urbanization, inadequate infrastructure, and a lack of institutional capacity, environmental pollution in Libya increased. Responsibility for regulating air, water, and soil pollution rests largely with local authorities, and particularly the Ministry of Environment; however, the institutional context demonstrates structural constraints preventing the regulation of pollution. This study, is concerned with the functioning of the Ministry as a key institution within the environmental pollution management system in Libya, specifically exploring the roles of institutional capacity, regulatory compliance, inter-agency collaboration, training and capacity building, and community education and engagement. A quantitative research methodology was utilized through a structured Likert-scale questionnaire that was completed by 350 staff of the Ministry. Statistical analysis (descriptive statistics, correlational tests, and multiple regression analyses) was attempt to test the relationship between the five independent variables and pollution management effectiveness. In conclusion, all five factors contributed in some way, however the salient contribution was training and capacity building; suggesting that well trained and qualified regulatory staff to conduct, monitoring, enforcement, and engage with the community is of paramount importance. Additionally, weak coordination, lack of funding, outdated performance monitoring system, and minimal public participation will continue to hinder this progress. Several recommendations are made in the study that will provide a strong evidence base for institutional development, regulatory compliance, and collaborative governance practices. Improvements in these areas will allow Libya to move towards enhancing environmental sustainability and meeting the global development agenda.

Keywords: Environmental Governance, Pollution Management, Local Authorities, Institutional Capacity, Sustainable Development.

INTRODUCTION

Air pollution is among the global issues that are a threat to the ecological system, human health, and the economy, particularly in the Global South, where rapid population growth, inappropriate infrastructure, and political instability exacerbate the situation [1]. In Libya, such difficulties are even more evident because of the continued violence, the shattered government, and the shortage of resources that do not allow for effective environmental management [2]. Managing environmental pollution is very challenging, especially in countries faced with much pollution. The pollution may come from the air, land, river, or sea. Generally, different countries will use different technologies or methods to manage pollution. Sustainability in oil spills, untreated wastewater, and solid waste has been polluting the environment and putting people at risk [3]. Political instability, scarcity of resources, and fragmentation in governance exacerbate the challenges associated with environmental management.

Ongoing instability interferes with data collection, diminishes the efficiency of monitoring, and obstructs the enforcement of environmental regulations in Libya.

Environmental pollution in Libya originates from different sources such as, industrial emissions, uncontrolled waste disposal, sewage disposal, and oil-related operations [4]. These issues will affect public health, the level of environmental quality, and the ecological system. According to the Ministry's numerous reports, waste management in Libya's bigger cities, water pollution, and air pollution are all at high levels. The coordination of the numerous institutions executing the environmental protection mandates has become problematic due to fragmented governance. In cases of pollution, the Ministry of Environment is frequently limited due to a lack of resources, monitoring systems experience and enforcement capabilities. The Ministry's ability to obtain pollution monitoring equipment for field inspections or to produce environmental reports is hampered by weak institutional capacity [5]. The Ministry's capacity to support the creation of monitoring systems and enforcement initiatives is hampered by a lack of funding.

Institutional capacity is essential to environmental governance. Significant financial resources are needed to purchase sophisticated pollution monitoring equipment, air quality monitoring systems and field inspection tools [6]. The financial resources available in Libya are insufficient to support ongoing data analysis, monitoring and enforcement initiatives. Funding limitations make it hard for the Ministry to implement environmental policies. Consequently, poor environmental monitoring mechanisms, ineffective reporting tools and inadequate staffing levels have been caused by a lack of both technical and financial resources.

For past reductions in the level of pollution, enforcement of regulations was critical. Enforcement comes from enforcement mechanisms related to regulations, including inspections of facilities, fines, and regulations assuring compliance. Enforcement is important because, absent the enforcement mechanism, you may think you have pollution control through monitoring methods, but in reality, there are no violations since the violations go undetected. Enforcement is also a factor related to many other things, including the number of inspectors, the amount of fines that have to be paid, and the political will of those in the jurisdiction. In fact, many local governments, especially in oil extraction, take little concern about fines since inspections are not close to adequate for making it an issue. Weak enforcement has resulted in pollution issues in the country. Making the inspections and fines consistent for purposes of enforcement related to environmental regulations is really the key way to reduce pollution [7].

To effectively manage the multiple representations of the environment, agencies and layers of government will need to work together. Water service pollution, especially, necessitates coordination across many government levels, including the Ministry of Environment and the Ministry of Water Resources, municipalities, and other government bodies. In Libya, agency coordination is weak due to political fragmentation, overlapping agency mandates, and weak communication [8]. Uncoordinated governance of the environment causes declines in environmental issue response, delays timely decisions, and weakens pollution governance capacity, especially as uncoordinating multiple agencies may disrupt any required inter-agency process toward policy implementation. Libya's environmental governance capacity is again complicated, further associated with inter-agency inefficiency behaviours, lack of common goals, and limitations associated with sharing data.

Training courses are a critical aspect of effective pollution management. We have a chance to improve and develop both our technical and management skills during the training courses so that they may manage pollution issues, comply with regulations, and promote working with stakeholders. The Ministry in Libya struggles to deliver effective regular training courses -- because they are limited due to funding and capacity restrictions. This process takes away from professional or staff capacity to respond to pollution issues such as oil spills or waste management. Structured training courses to enhance competencies and assist the agency with pollution reduction initiatives are needed [9]. Research conducted in the MENA region also highlights that ongoing training improved environmental outcomes for the agency and has produced several important implications and lessons for improvements to training courses in Libya.

Through a variety of strategies, including awareness campaigns, participatory programs and feedback mechanisms, the public and stakeholders actively participate in pollution control programs, which is why community engagement is so important to environmental governance. According to a study [10], Libya has low levels of public cooperation due to a lack of comprehensive awareness campaigns and participatory programs. The Ministry's capacity to successfully promote environmentally responsible practices is hampered by the low level of community involvement. Additionally the lack of resources makes it difficult to carry out extensive awareness campaigns and there are still few participatory projects like recycling programs and community clean-ups.

Involving the community promotes the adoption of sustainable practices to lower pollution and cultivates a sense of shared responsibility. Pollution reduction efforts in Libya are hampered by a lack of public awareness brought on by poor waste management and disregard for environmental regulations. Community engagement is one strategy to address this lack of awareness, as it can help ensure compliance with environmental regulations and generate substantial support for environmental awareness initiatives. Without community support through

awareness campaigns and policies, the Ministry finds it difficult to carry out efficient pollution management plans. Pollution levels can be decreased by involving and winning over the community since greater community involvement raises public awareness, compliance and involvement in environmental initiatives.

Political unpredictability, a lack of funding, weak enforcement capabilities, low community awareness and poor institutional coordination make managing pollution in Libya extremely difficult. An extensive assessment of the Ministry of Environment's performance in combating environmental pollution is required to address these issues. The purpose of this study is to evaluate how Libya's Ministry of Environment's pollution management effectiveness is affected by institutional capacity, regulatory enforcement, inter-agency coordination, training programs and community engagement. The study attempts to shed light on the internal variables that affect pollution management initiatives in Libya's conflict-affected environment by employing a quantitative employee-focused methodology. It provides an empirical evaluation of the Ministry's internal capabilities and attempts to close a research gap in quantitative studies about pollution management in Libya.

LITERATURE REVIEW

In order to achieve better environmental management outcomes, the literature repeatedly emphasizes the critical roles that institutional capacity, regulatory enforcement, cross-agency coordination, training initiatives and community involvement play. In many developing contexts, research shows that inadequate institutional capacity gaps in enforcement, poor coordination, inadequate training and low community involvement, result in less effective pollution management [11]. In order to improve pollution control outcomes, studies on environmental governance emphasize the significance of efficient enforcement and coordination, as well as the support of strong community participation and training programs. Case studies like port pollution management related to MARPOL show how enforcement and coordination directly affect effectiveness, how training improves technical competence and how community engagement strengthens compliance and support [12].

Horizontal coordination is vital to improving environmental effectiveness based on the evidence provided from studies in watershed environmental management. It has also been found that improving environmental outcomes requires involvement from the local community. In addition, the studies continued to emphasize the importance of institutional capacity in achieving sustainable pollution control. As strategies to minimize pollution, both improvement of institutional capacity, enhancement of community engagement, and building coordination were offered as options [13]. Reviews of regulatory frameworks show coordination mechanisms significantly impact outcomes, which is consistent with other evidence. Furthermore, improving environmental governing systems has been shown to require both training and capacity-building [14]. Research on the effectiveness of environmental enforcement has shown that weak capacity, ineffective enforcement, and insufficient interagency coordination negatively impact pollution control. They stress the importance of building institutional capacity, enhancing coordination, increasing training programs, and promoting community engagement to advance environmental compliance and improve pollution monitoring systems. Quantitative research on regulatory quality and institutional coordination demonstrates that institutional capacity has a strong effect on effectiveness. These studies also show that training programs, coordination, and enforcement all have a significant effect on the environment. In addition, the research demonstrates the importance of community engagement to improve compliance and acceptance of environmental policies [15].

Research focused on developing countries indicates that limits on institutional capacity reduce the effectiveness of poor enforcement and coordination, making pollution conditions worse. The results indicate that it is essential to support pollution enforcement actions by increasing enforcement, developing better coordination, and improving training and engagement programs [16]. Research from Tunisia indicates that when communities are involved, capacity and effectiveness are still better, although training is limited, and capacity is weak [16]. To effectively mitigate pollution issues, the studies suggest expanding training programs, improving coordination, strengthening enforcement and improving community engagement [16]. Training increases institutional capacity and institutional effectiveness in pollution management [14] according to studies of environmental management training programs. Comprehensive training programs improve environmental governance systems and regions continue to experience gaps in consistent enforcement and consistent coordination with low levels of public engagement in pollution and environmental issues [14]. Effective inter-agency coordination improves pollution management effectiveness from comparative analysis globally. It also highlights that it is important to improve institutional capacity and training to increase public engagement in regulatory enforcement [13].

The body of literature addressing environmental management in several contexts, including Libya, Egypt, Tunisia, and others, has made it evident that there is a clear gap in knowledge. Libya's Ministry of Environment has not engaged in any quantitative research that has focused on its employees, even though studies based on empirical research have produced valuable insights into environmental management. In Libya, many studies focused on environmental problems or applied qualitative or mixed methods, instead of focusing on the internal

workings of their particular ministry. Previous research has established that Libya's institutional capacity is poor, including problems of enforcement, coordination, low training levels, and poor levels of awareness among citizens. However, the previous studies have not quantified the impact of these challenges on the effectiveness of pollution management as perceived by employees [11].

The comparative regional investigations in Egypt and Tunisia uncover similar issues, such as insufficient institutional capacity, ineffective enforcement, limited coordination, and low community engagement. The studies similarly do not evaluate these issues through the lens of ministry staff nor use quantitative methods to measure the specific elements that impact pollution management effectiveness [12]. The global research similarly enhances the importance of institutional capacity, coordination, engagement, resources, and enforcement; however, these studies do not examine the internal ministry processes, or in the case of Libya, a country affected by conflict. The literature provides substantial evidence on the importance of institutional capacity, regulatory enforcement, inter-agency coordination, community engagement, and training programs. However, there is a major gap in research using a quantitative staff-based study examining Libya's Ministry of Environment. This study aims to fulfill this gap in knowledge by providing data-driven insight into Libyan staff perceptions and the relationship to pollution management effectiveness [15].

METHODOLOGY

To purposefully evaluate the impact of institutional capacity, regulatory enforcement, inter-agency coordination, training programs and community engagement, on the success of pollution management in the Ministry of Environment in Libya, a thorough and rigorous process was established for this investigation. data collection focused on collecting objective, reliable and quantifiable data from members of the ministry/staff. The design of the study, the study population sampling strategy, the construct validity and reliability of the research instrument, the data collection methods used and the data analysis strategies used in the study are presented in detail.

Due to the fact the quantitative research design was utilized in this research, relationships among variables could be determined using statistical analysis and numerical data. In regard to evaluating attitudes, perceptions, and organizational customs objectively, quantitative research design was especially suited to bring a lens for viewing the elements of ministry workers and how they affect pollution practices. Quantitive research also provides consistency of data collection and the ability to use statistical analysis to understand relationships and predict outcomes.

The research centered on employees engaged in environmental assessment, pollution monitoring, inspection administrative coordination, environmental reporting, and operational support from various Ministry of Environment divisions. The purposive sampling strategy employed effectively captured the diversity of roles within the Ministry by including roles such as officers, supervisors, technician, administrative staff, and inspectors in the field. Effectively covering the range of employees provides the study with strong perspectives from those with the experience of working on all facets of pollution activities. Because of having a population of thousands, a methodical sampling strategy was implemented to gather a manageable yet representative sample. Adequate statistical samples were achieved using a scientific methodology set out by Krejcie and Morgan, shown in Table 1.

To ensure that the sample included representatives from all the major functional areas in order to achieve trustworthy results, the sample size selected was revised to the assumed population of ministry employees. The use of this sampling strategy facilitated the accurate and generalizable results of the study. The study employed a simple random sampling technique whereby each employee had an equal chance of being included to minimize bias and fairly represent the group staff distribution and size.

Table 1. Krejcie and Morgan Sample Size Calculation

Population Size	Confidence Level	Margin of Error	Required Sample Size	Planned Distribution
1,200	95%	5%	291	350

The research utilized a structured questionnaire as the main data collection tool. The questionnaire was purposely created to examine a range of topics, such as community participation training programs, interagency coordination, institutional capacity, regulatory enforcement, as well as pollution management impact. Using a Likert scale, respondents identified their level of agreement with statements in each section of the instrument. The questionnaire was specifically designed to capture employee perceptions of internal barriers operating constraints, training types, coordination arrangements, and community participation that affect pollution management outcomes.

To construct the questionnaires, a structured format provided consistency of responses that made possible the use of statistical analysis. Content validity was used to show us that the questionnaires measured the variables of

interest. A panel of experts in public administration, environmental management, and research methodology provided input on the relevance, applicability, and clarity of the questions in the Libyan context of environmental governance. Using the panel of experts input, questions were moderated or removed that were not closely aligned with the research questions. The validation process was worthwhile because the input from the panel of experts ensured the questions were clearer and reflected key aspects of the research.

Reliability of the tool was assessed using Cronbach's alpha measure of internal consistency in test exercise. Cronbach's alpha is a commonly used statistical method in determining whether the items on a scale produce consistent response patterns. Results from the reliability tests demonstrated that all constructs (institutional capacity, regulatory enforcement coordination, training, community participation, and effectiveness) received reliable scores; thus suggesting that the tool could be used in a scientific inquiry, to validly measure constructs, across different participants. Moreover, the reliability scores were above thresholds that are considered acceptable and demonstrated the stability and internal consistency of the questionnaire items (See Table 2).

Table 2. Summary of Questionnaire Items

Variable	Sub-Variable	Number of Items	Source
Institutional Capacity	Financial Resources	9	[17], [18]
Regulatory Enforcement	Inspection Frequency	9	[19], [7]
Inter-Agency Coordination	Communication Channels	9	[20], [21]
Training Programs	Training Frequency	9	[9]
Community Engagement	Awareness Campaigns	9	[22], [23]
Pollution Management Effectiveness	-	9	[24], [7]

One approach employed in the data collection process involved creating a structured web form to administer a questionnaire to employees. The use of a questionnaire in this way resulted in certain advantages such as accessibility for the employees and the option to complete the questionnaire (respond to items) when it was convenient for them personally. Furthermore, administrating data collections is is easier when the data collection occurs online with less direct interaction, administrative ease, and if the process leads participants to be more honest in their replies. For example, participants were informed of the project's purpose and confidentiality, and asked to be honest, prior to requesting them to fill out the questionnaire. Participants were free to withdraw from the study at any time and participation was voluntary.

The research team emphasized accuracy, neutrality, and respondent comfort during data collection. After all valid responses were returned, the data was prepared for analysis. Statistical analysis software was utilized in this study. Descriptive statistics were used to summarize the employee demographics of gender, age, department, years of service, and position in the Ministry. These descriptive results helped us understand the composition of the sample and identify trends in the population. The researchers used descriptive statistics, such as mean and standard deviation, to examine trends for each of the variables.

For the purpose of establishing the association between independent predictors and pollution management effectiveness, the researchers employed inferential statistics. The researchers undertook correlation analysis to determine the direction and strength of the relationships between institutional capacity, enforcement coordination, training, community participation, and pollution management outcomes. Regression analysis was also employed to ascertain the most influential factors contributing to pollution management success. By using regression analysis, the researchers were able to quantify the relative influence of each of the predictors on pollution management success and identify the percentage of ministry internal conditions that influence environmental performance in Libya.

The research addressed limitations related to data availability, lack of political certainty, and limited resources at the Ministry of Environment. The latter two barriers made it challenging for some employees to be involved in some capacity—many were involved in field work and unable to provide comprehensive data. Beyond these limitations, the research provided a robust means of examining the determinants of organizational influences on pollution management efforts.

To begin with, the primary elements of the methodology overall systematized process centered on choosing the proper population, and a quantitative study design. In addition, it also provided the appropriate sample size, a legitimate and reliable instrument, adequate procedures for collecting data, and appropriate statistical approaches for data analysis. Overall, the systemized approach to the problem ensured that the result was an accurate reflection of the opinions of the staff and provided in-depth understanding of the state of the Ministry of Environment with respect to pollution management in Libya.

RESULTS AND DISCUSSION

The results of a survey that was carried out to assess the influence of different factors on the efficiency of Libya's Ministry of Environment's pollution management will be presented and examined in this section. The survey takes into account a number of factors, including training programs, community engagement, interagency coordination, institutional capacity, and regulatory enforcement.

Demographic Profile of Respondents

This section presents the demographic survey results. There were a total of 350 respondents from different locations in Libya. The assessed components of the demographic are gender, age, year of service at the ministry, role, department, and location. Tables 3 to 8 illustrate the survey results, whereas Figure 1 to 6 shows the 3D pie charts representing the results from Tables 3 to 8.

Table 3. Survey results of gender

Gender	Frequency
Male	350
Female	0

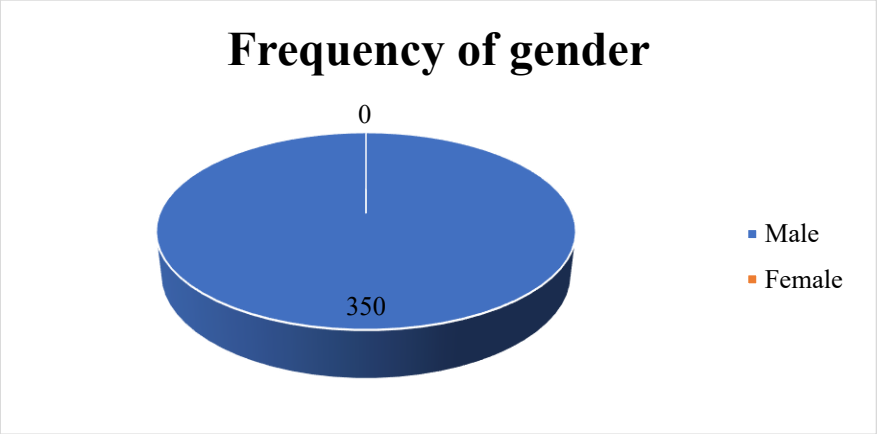

Figure 01. Gender survey results

Table 4. Age survey results

Age	Frequency
20-29	113
30-39	195
40-49	32
50 and above	10

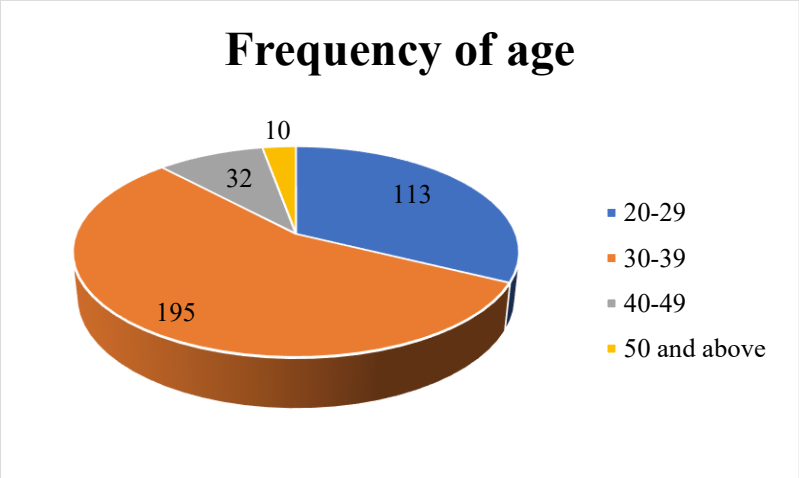

Figure 2. Age survey results

Table 5. Department survey results

Department	Frequency
policy	81
environment monitoring	188
enforcement	43
public outreach	38

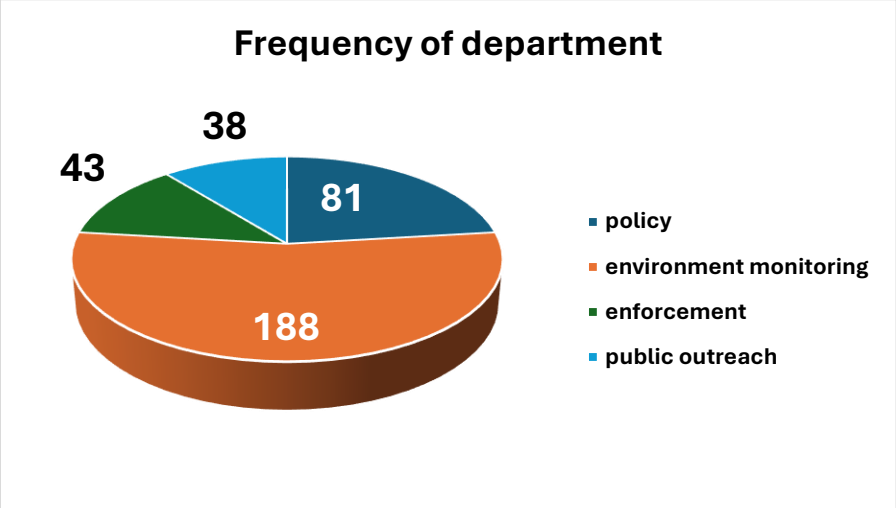

Figure 03. Department survey results

Table 06. Location survey results

Location	Frequency
Tripoli	125
Benghazi	102
Mistrata	112
Sabha	11

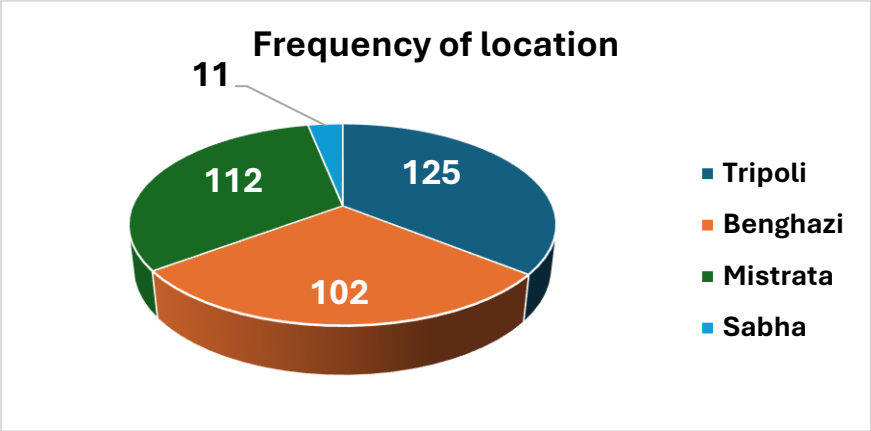

Figure 4. Location survey results

Table 7. Year of service at ministry survey results

Year of service at ministry	Frequency
Less than 1 year	32
1 - 5 year	112
6 - 10 year	188
over 10 years	18

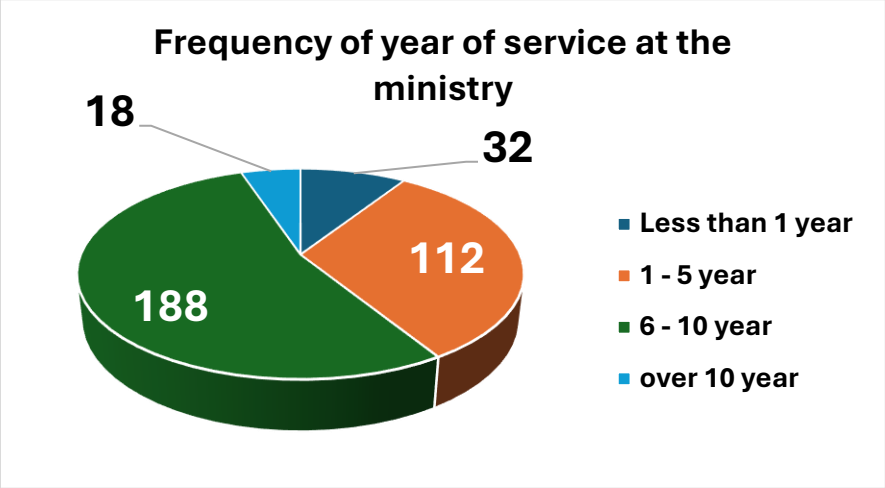

Figure 05. Year of service at the ministry survey results

Table 8. Role survey results

Role	Frequency
Administrative staff	87
Technical personnel	140
Environmental scientists	119
Policymaker	4

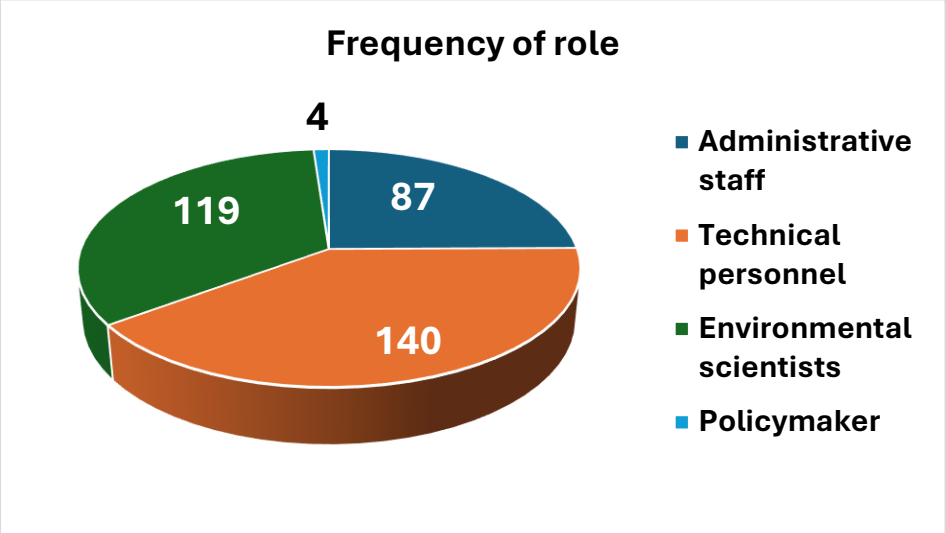

Figure 06. Role survey results

Based on Table 3, the survey recorded 350 male participants, representing 100% of the respondents, with a mean value of 1.0. Table 4 shows that the age group 30–39 recorded the highest frequency at 55.7%, while the lowest was the 50 and above group at 2.9%, with an overall mean of 1.826. In Table 5, the environmental monitoring department had the highest participation at 53.7% (188 respondents), while public outreach had the lowest at 10.9%, producing an overall mean of 2.1.

Table 6 indicates that most respondents were from Tripoli (125 respondents, 35.7%), whereas Sabha recorded the lowest frequency of 11 (3.1%). The overall mean for location was 2.0. As shown in Table 7, employees with 6–10 years of service formed the largest group at 53.7% (188 respondents), while those with more than 10 years accounted for only 5.1% (18 respondents), with an overall mean of 2.55. Table 8 shows that technical personnel formed the highest proportion at 40% (140 respondents), while policymakers were the lowest at 1.1% (4 respondents), giving an overall mean of 2.1.

Reliability and Validity Testing

The sample size for the reliability and validity test is 35, which is 10% of the total sample size, 350. This small sample size is known as a pilot test. Table 9 shows the reliability test results.

Table 09. Reliability test results

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	35	100.0
	Excluded[a]	0	.0
	Total	35	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.945	54

Notice that the Cronbach's alpha is larger than 0.7. This shows that survey results are reliable. For the validity test, there is a need to compute the sum of all the variable scores and then use the correlation function to compute the significance of 2-tail. The targeted result is ≤ 0.001. From Appendix B, the correlation matrix table, and looking at the "Sum" column and counting the number of ≤ 0.001, it is that there are 42 total significance 2-tailed, ≤ 0.001. The total number of questions is 63. Thus, this gives 42/63 = 0.67 or 67% of validity.

Descriptive Analysis of The Variables

This section presents the results after analyzing using a statistical method. To analyze the independent and dependent variables, all the 9 questions in each section of the variables are summed up and computed using the descriptive statistics function provided by SPSS. Table 10 shows the results produced by SPSS after running the descriptive statistic functions. Note that mean, standard deviation, and variance are targeted in the analysis. As seen from Table 10, the highest mean of the variable is CEA, whereas the lowest mean is REI. The mean range is from 32 to 41. The calculation of the mean is by summing the Likert scale score for each variable and then dividing by the number of items in the variable. For the standard deviation, the lowest is ICF, whereas the highest is CEA. This produces the lowest variance for ICF and the highest variance for CEA. The meaning of low and high standard deviation will be explained in the discussion section.

Table 10. Descriptive statistical results for all the variables

Descriptives

Descriptive Statistics

	N	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
ICF	350	28.00	39.00	11894.00	33.9829	2.67317	7.146
REI	350	21.00	36.00	11532.00	32.9486	4.48016	20.072
IAC	350	21.00	39.00	11804.00	33.7257	4.88424	23.856
TPT	350	14.00	43.00	13887.00	39.6771	5.06194	25.623
CEA	350	16.00	45.00	14685.00	41.9571	7.98070	63.692
PME	350	17.00	42.00	13579.00	38.7971	4.37124	19.108
Valid N (listwise)	350						

Correlation Analysis

The correlation analysis was calculated by summing all the survey results in each variable (independent variables and dependent variables). After summing up, use the correlation calculation built into SPSS to compute

the correlation. Table 11 and 12 shows the correlation results. Table 11 shows the correlation results generated by the SPSS correlation function, whereas Table 12 shows the correlation results extracted from Table 11. Note the highest and lowest scores of the correlation. From Table 11 or Table 12, it is seen that TPT (Training Program) scores the highest in correlation. The value is 0.945, which is close to 1. The lowest score of correlation is Inter-Agency Coordination, which is 0.469. This means that TPT significantly influences the PME. The score of PME is 1, which is close to 0.945.

Table 11. Correlation results computed by SPSS

Correlations

Correlations

		ICF	REI	IAC	TPT	CEA	PME
ICF	Pearson Correlation	1	.442**	.525**	.475**	.456**	.578**
	Sig. (2-tailed)		<.001	<.001	<.001	<.001	<.001
	N	350	350	350	350	350	350
REI	Pearson Correlation	.442**	1	.911**	.363**	.652**	.572**
	Sig. (2-tailed)	<.001		<.001	<.001	<.001	<.001
	N	350	350	350	350	350	350
IAC	Pearson Correlation	.525**	.911**	1	.206**	.450**	.469**
	Sig. (2-tailed)	<.001	<.001		<.001	<.001	<.001
	N	350	350	350	350	350	350
TPT	Pearson Correlation	.475**	.363**	.206**	1	.623**	.945**
	Sig. (2-tailed)	<.001	<.001	<.001		<.001	<.001
	N	350	350	350	350	350	350
CEA	Pearson Correlation	.456**	.652**	.450**	.623**	1	.644**
	Sig. (2-tailed)	<.001	<.001	<.001	<.001		<.001
	N	350	350	350	350	350	350
PME	Pearson Correlation	.578**	.572**	.469**	.945**	.644**	1
	Sig. (2-tailed)	<.001	<.001	<.001	<.001	<.001	
	N	350	350	350	350	350	350

**. Correlation is significant at the 0.01 level (2-tailed).

Lowest correlation

Highest correlation

Table 12. Correlation results extracted from Table 11

Independent variables	Correlation results with Pollution Management Effectiveness (PME)
Institutional Capacity (Financial Resources) [ICF]	0.578
Regulatory Enforcement (Inspection Frequency) [REI]	0.572
Inter-Agency Coordination (Communication Channels) [IAC]	0.469
Training Programs (Training Frequency) [TPT]	0.945
Community Engagement (Awareness Campaigns) [CEA]	0.644

Figure 7 exhibits the correlation results with pollution management effectiveness (PME) according to independent variables.

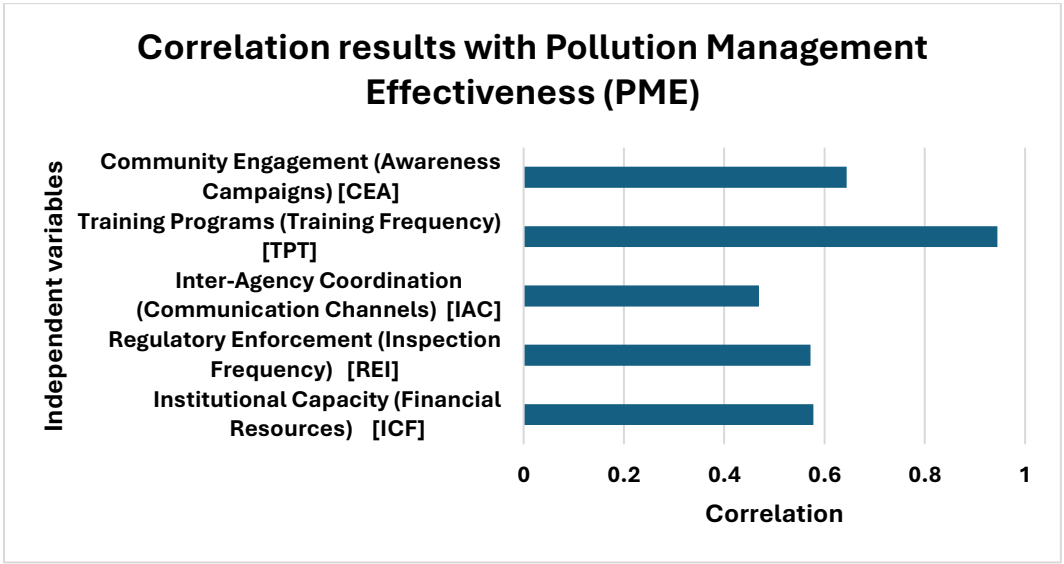

Figure 7. The plot for Table 12

The statistical results confirm that training programs (TPT) and community engagement (CEA) are the most significant drivers of pollution management effectiveness in Libya's Ministry of Environment, with correlations of 0.945 and 0.644, respectively. Institutional capacity (ICF) and regulatory enforcement (REI) have moderate impacts ($r = 0.578$ and 0.572), while inter-agency coordination (IAC) is the least influential ($r = 0.469$). These results are consistent with literature identifying training and engagement as key themes in the MENA region [9][22] but are specific to Libya's context, where political instability and limited resources directly affected the priorities of employees. The results inform the research questions, support the hypotheses H1–H5, and provide a basis for policy recommendations to improve sustainable pollution management.

All the survey participants were male. They were young, aged from 30 to 39. Most of them were also affiliated with the environmental monitoring department. Additionally, most of the participants appeared to be from Tripoli and were in technical positions. The total participants was 350. They completed a questionnaire that had 5 independent variables to measure the dependent variable. Statistical analyses (i.e., both correlation and regression methods) were used to analyze the responses from the questionnaire. The results illustrated that training makes a significant contribution to the effectiveness of the management of pollution.

CONCLUSION

The study's findings provide a comprehensive understanding of how institutional capacity (financial resources), regulatory enforcement (inspection frequency), inter-agency coordination (communication channels), training programs (training frequency), and community engagement (awareness campaigns) influence the pollution management effectiveness (PME) of Libya's Ministry of Environment, based on employee perceptions. The Ministry's primary strength lies in the potential of training programs and community engagement to enhance pollution management effectiveness. Employees prioritize practical skill development and public awareness, reflecting a proactive approach to pollution prevention in Libya's resource-constrained and conflict-affected context. Weaknesses include inadequate inter-agency coordination, hindered by bureaucratic and political challenges, and moderate impacts of institutional capacity and regulatory enforcement, limited by funding shortages and logistical constraints. The findings highlight training programs and community engagement as key drivers of the Ministry's effectiveness, offering a pathway to address pollution through skill development and public participation. By quantifying employee perceptions, this study fills a critical gap in Libya-specific research, providing evidence-based insights to inform policy and practice. The recommendations for enhanced training, robust campaigns, and improved systems aim to strengthen the Ministry's capacity to manage pollution sustainably. Future research should build on these findings through longitudinal and comparative studies to ensure Libya's environmental strategies evolve with emerging challenges, contributing to a cleaner, healthier future for its citizens.

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