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Aims and Scope

Journal of Hydropower and Civil Engineering envisage to publishes best of reviews and researches within the broad field of civil engineering which include construction management, geotechnical engineering, transportation engineering, concrete technology, and very importantly the water engineering

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Contents

Quality management and its impact on product quality in manufacturing sectors in Ethiopia, Africa

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ABSTRACT

This research document was intended to detect the impacts of quality management elements on product quality in manufacturing sectors. The research identified nine QM elements; - EMI, CUB, COI, HRM, QUP, PRM, SUM and QUT that impact PRQ. Self-administered structural questionnaires were prepared and distributed to 73 manufacturing sectors in Ethiopia, 57(78.2%) papers were filled and returned back. The questions were loaded in SPSS v20 and descriptive statistic, correlation and regression analysis were conducted for data analysis purpose. The result of this paper confirmed that 9 predictor variables accounted for 78.1% of the variation in PRQ. The outcome of the result confirmed that COI, QUT, PRM, QUP, EMI, CBU and SUM positively and to grate extent impacts Product quality of manufacturing sectors. While LED and HRM have no contribution for product quality in this sectors.

Keywords: Quality Management, Product Quality, predictor variable, impact, hypothesis

INTRODUCTION

It is usual for the firm to be competent in the market to continue in their position. In a competitive market the only way for the firm to be successful is to keep the customers satisfied with their products by improving their product quality [1]. For the firm to be competent in the market and satisfy customer need product quality plays a vital role. According to [2] Quality management practice is a driver and source of National as well as international competition. It has systematic impacts on firm's product quality and performance [3]. According to [4] Quality Management factors are classified in to 'soft' and 'hard' factor. The study of [5] relates soft factors in to people based aspect and hard factors in to technical aspects of quality management. This paper investigates and focused on soft factors that affect (impact) product quality in manufacturing sectors in Ethiopia, East Africa. Product Quality According to [6] is the whole thing that are obtained in market to get consideration, purchased or consumed that can satisfy the desires or needs of customers. Products are purchased by consumers because they can meet certain needs or provide certain benefits. It is the structure of manufactured article well matched with eight dimensions (scope) includes: - performance, features, conformance, reliability, durability, serviceability, aesthetics, and customer-perceived quality. According to different research work and scholars product quality is affected by quality management practice.

Quality Management System (QMS) is defined by [21] as a management system to direct (manage) and control (monitor) a firm with regard to quality. The aim of QMS is to setup a frame work of reference points to ensure that whenever a process is performed, the same information, methods, skills and controls are used and applied in a consistent manner. Moreover, for making the firm's performance stronger QMS offer quality requirement plan and management.

According to [3] Quality management practices or soft factor including leadership, human resource (HRM) management, quality planning (QUP), customer focus (CUB), process management (PRM), supplier management (SUM), quality tools (QUT), continuous improvement (COI) and learning have consistent impacts on firm's performance and Product Quality.

According to the investigation of [7, 8] leadership, strategic planning, customer focus, information and analysis, people management and process management, human resource management and continuous improvement have direct effects on product quality.Leadership in the Manufacturing Sectors will improve product quality performance by giving support for employee development, by establishing multipoint communication, by using information effectively and efficiently. Additionally leader participate employees in decision making and empower worker in the organization [9]. According to [10] top leadership commitment is the most vital factors for the success of product quality performance. According to [11] Customer Focus (CF) helps the firm to improve product quality in determining customer expectation, requirement and performance. It is used to investigate present and future customer performance by developing procedure to acquire (to get) information. It is the level to which the organization unceasingly fulfills client expectation and needs [12]. Human Resource Management has an undeviating positive interaction with product quality and organizational performance [7, 11, 13]. It is centered on human resource practice and adapted to clients plan and direction which seeking excellence by using competency and talents in the firm work force.

According to [13, 14] Process Management related with evaluating the organized system companies used to control its product and it incorporate production and distribution requirements, and it manages provider performance. According to Supplier Management principle improving supplier interactions increases the performance of both dealer and consumer [3, 15]. For consistent (effective) supply management dealers would be selected based on the quality of supplied product and service [16]. According to [17] establishing procedures for dealer assessment, choice, association and organization will realize the intended objectives these interns improve firm product quality and performance. Continuous improvement plays a vital role for any organizations; it highlights the current audit process, management reviews of organizational performance and

improvement process depending on the result [18]. The improvement in the firm should be precisely planned and carried out based on real by using systematic documentation. For the success of continuous improvement in the organization, there should be top management commitment and support, a structure that support all the activities in the organization, team work encouragement, effective communication system, employees reward and recognition. According to [9] employee involvement describe confirming employees are motivated and perform their jobs as per the required standards. To confirm employee's loyalty to the organization, motivation and to improve work performance, the firm should provide effective training to their employees. Employee relations are important to promote teamwork and workforce management in the organization. Employee training is positively related to operational performance, employee performance, innovation performance, customer results, market and financial performance.

Employee involvement in quality management system execution process or activity will improve product and organizational performance. Quality planning aims at achieving consistent and persistent firm's excellence through integrating quality into firm's strategic plans [11]. It is used to Cascade strategic objectives all over the firm. Quality planning integrate Customer requirements, Dealer competence and needs of other participant during policy making, objective and developing plans of the organization. Similarly, according to [19, 20] Quality Tools help employees to identify variations within processes outputs and its sources, and systematically thoroughly results in enhancing performance of product quality and or process.

Theoretical model and hypothesis development Theoretical model

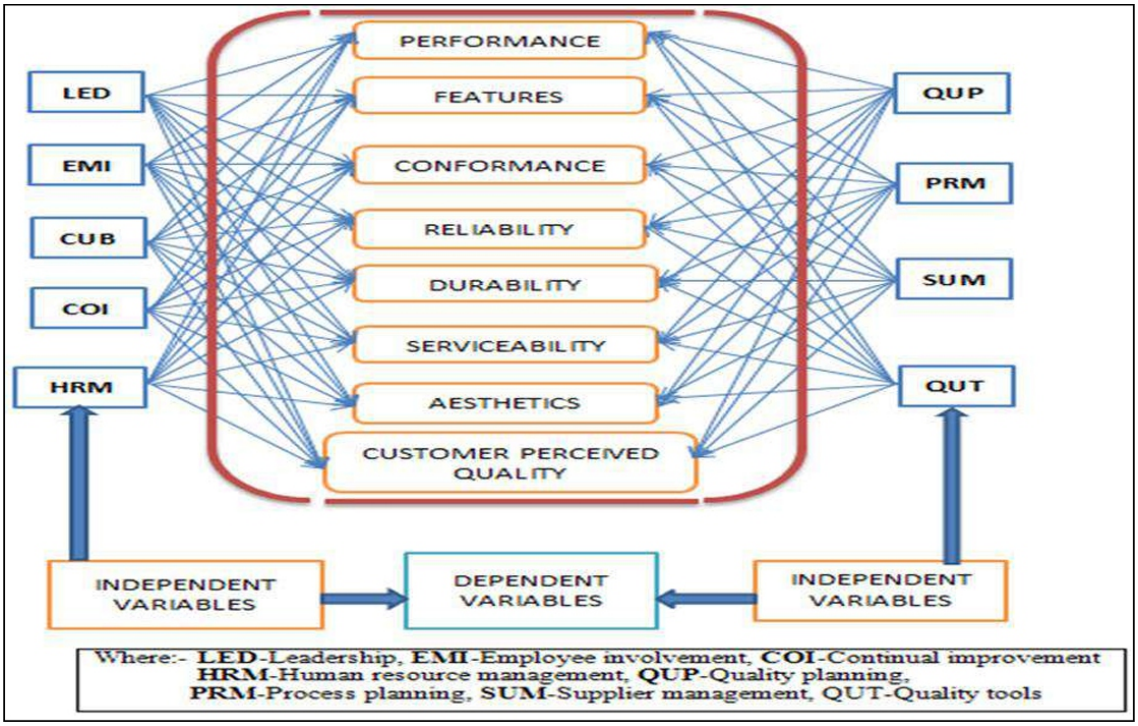

Fig 1: Theoretical model constructed by the researcher

Hypothesis development

The following nine research hypotheses were hypothesized based on the theoretical model to test the effects of predictor variables on product quality in manufacturing sector.

H1: Leader Ship has a positive effect on product quality
H2: Continual Improvement has a positive effect on product quality
H3: Human Resource Management has a positive effect on product quality
H4: Quality Tools have a positive effect on product quality
H5:-Process Management has a positive effect on product quality
H6: Quality Planning has a positive effect on product quality
H7: Employee Involvement has a positive effect on product quality
H8: Customer Focused has a positive effect on product quality
H9: Supplier Management has a positive effect on product quality

Research methodology

A. Research design, target population and response rate

This research work used both descriptive and inferential statistic for analyzing the data. The researcher was distributed self-administered structured questionnaire to the respondent. Totally 73 questionnaires were prepared and randomly distributed to:- Metal Product Manufacturing 20 (27.39%), Furniture Manufacturing 16 (21.920%), Paint Manufacturing 8 (10.95%), Pulp and Paper Manufacturing 8 (10.95%), Plastic Manufacturing 11 (15.06%) and Building (construction) material manufacturing 10(13.69%) in Ethiopia. All quality control managers, supervisors and managers from the selected sectors were participated for filling and responding the questionnaires. From the distributed 73 papers 78.02% of the papers were filled and returned.

B. Data Collection and Analysis Instrument

The survey questionnaire was used as the main primary data gathering instrument in this research study. The questionnaire used a 5 point Likert scale sorted starting from 1 = strongly disagree to 5 = strongly agree having 44 items under nine predictor (EMI, CUB, COI, HRM, QUP, PRM, SUM and QUT) variables and 32 items under eight dependent variables (PE, FE, CO, RE, DU, SE, CPQ and AE). Correlation Strength Interval and Mean Measuring Scale were developed for descriptive and Pearson's Correlation analysis as shown in table 1. Data was analyzed using mean, standard deviation, correlation and regression analysis methods.

Table 1: Correlation strength interval and mean measuring scale

Correlation Strength Interval	Value	Strength of relationship	Mean Measuring Scale	Explanation	Interval
	1.0 < r < 0.5	Strong		Strongly Unhappy	1.00 < Mean < 1.80
	0.3 < r < 0.5	Moderate		Minimum Degree	1.81 < Mean < 2.60
	0.1 < r < 0.3	Weak		Moderate Degree	2.61 < Mean < 3.40
	0.0 < r < 0.1	Very Weak		High Degree	3.41 < Mean < 4.20
				Absolutely True	4.21 < Mean < 5.00

Data analysis

A. Reliability analysis

This research paper used reliability analysis to check (to test) the consistency and stability of the research questionnaires. The researcher tested the reliability of the questionnaire by using SPSS version 20.Tables 2 shows the reliability result of the questionnaire before and after some of the questionnaires were removed. As per the result of the analysis the value of Cronbach's alpha (α) was fall from 0.611 to 0.895, which indicated higher reliability of the questionnaire.

Table 2: Reliability analysis result

Explanation		After [before]	Cronbach's Alpha	
			Before item is deleted	After item is deleted
Independent Variables (Quality Management)	Continual Improvement (COI)	8[9]	0.746	0.750
	Human Resource Management (HRM)	4[7]	0.803	0.893
	Quality Tools (QUT)	3[6]	0.772	0.895
	Process Management (PRM)	6[7]	0.736	0.756
	Leadership (LED)	5[7]	0.506	0.680
	Quality planning (QUP)	4[5]	0.608	0.620
	Employee Involvement (EMI)	6[8]	0.560	0.674
	Customer Focused (CUB)	4[7]	0.752	0.845
	Supplier Management (SUM)	4[5]	0.584	0.678
Dependent Variables (Product Quality)	Performance (PE)	5[5]	0.664	0.664
	Feature (FE)	4[6]	0.584	0.674
	Conformance (CO)	4[7]	0.644	0.810
	Reliability (RE)	6[8]	0.748	0.812
	Durability (DU)	3[7]	0.455	0.611
	Serviceability (SE)	4[5]	0.811	0.846
	Aesthetics (AE)	3[6]	0.338	0.619
	Customer perceived quality (CPQ)	3[4]	0.534	0.628

B. Descriptive analysis

Table 3 indicates the descriptive analysis result of the respondents showing the execution practice of the predictor variables (EMI, CUB, COI, HRM, QUP, PRM, SUM and QUT) in the firm. And the result investigated the causes for poor performance (practice) of these variables. The result in table 3 revealed that:-

1. COI are poorly practiced due to: lack of internal and external audits, lack of effectiveness in continuous improvement process, lack of up to date continues improvement program review, lack of emphasis to continuous improvement from all departments, lack of immediate corrective action with respect to nonconformity and area of improvement and lack of continuous monitoring of the process and product.

2. LED are inadequately practiced due to: lack of support from top management for long term quality improvement process, lack of setting clear future strategic direction, lack of encouragement from top

management, lack of communication and lack of ensuring the required resource to all the department.

3. EMI are inadequately exercised due to: lack of participation from all department in quality management program, lack of motivation, communication, and involvement of employees in quality management program, employees unaccountability for their own performance, lack of employees clear job description for quality management program, lack of team work and lack of employees opportunity to improve their competency, knowledge and experience.

4. CUB are inadequately carried out due to: lack of employees awareness about customers need, lack of striving to meet customers need and expectation, lack of idea about market orientation.

5. HRM are insufficiently practiced due to: lack of consideration for physical and ergonomic factors to quality management personnel, lack of periodic training for quality management system personnel and lack of improving employee's skill and experience.

6. QUP are poorly practiced due to: lack of communicating and supporting mission statement through the company, lack of reviewing short and long term planning process goals and lack of planning customer requirement, suppliers capability and need of other stakeholders

7. PRM are inadequately exercised due to: lack of using effective quality manual, lack of recording organizational activities and their result to provide evidence, lack of maintenance procedures for different process of the firm and lack of reliability of the process.

8. SUM are poorly practiced due to: lack of treating the materials provided from the customer and suppliers equally, lack of supplier involvement in new product development process.

9. QUT are poorly exercised due to: lack of structured and comprehensive quality control planning process, lack of using statistical quality control for equipment and process on shop floor level and lack of using statistical techniques for reducing variance in the process.

Table 3: Summary of descriptive analysis result

Predictor variable	Mean	Std Dev	Rank	Interpretation
Continual Improvement(COI)	4.0022	.42514	1	Absolutely true
Human Resource Management(HRM)	3.9518	.73546	2	High degree
Quality Tools(QUT)	3.8421	.67551	3	High degree
Process Management(PRM)	3.8041	1.05939	4	High degree
Leadership(LED)	3.4737	.69897	5	High degree
Quality planning(QUP)	3.4123	0.8844	6	High degree
Employee Involvement(EMI)	3.3275	.74476	7	Moderate degree
Customer Focused(CUB)	3.2895	.81292	8	Moderate degree
Supplier Management(SUM)	2.9561	.94092	9	Moderate degree

C. Correlation analysis

The study used to examine the strength of the relationship between LED, EMI, CUB, COI, HRM, QUP, PRM, SUM and QUT) and Product Quality (PRQ). The result in table 5 revealed that EMI, COI and PRM have strong positive impact on Product quality while LED, CUB, HRM, QUP, SUM and QUP have

moderate positive impact on Product Quality.

D. Regression analysis

This research paper used regression analysis for evaluating the appropriateness of the model and to investigate fundamental relationship between predictor variables (LED, EMI, CUB, COI, HRM, QUP, PRM, SUM and QUT) and Product Quality (PRQ).

The result in Table 4 indicated that the identified nine predictor variable (LED, EMI, CUB, COI, HRM, QUP, PRM, SUM and QUT) accounted for 71.8% of the variation in product quality and the rest 28.2% are unidentified variables by this research work. The result of model 2 indicated in Table 4 revealed that the importance of the model by the value of F-statistics ($p = 0.000$), and $F = 13.296$ which indicated that there were strong relationship between Product quality and Quality Management (LED, EMI, CUB, COI, HRM, QUP, PRM, SUM and QUT) in the case the case manufacturing sectors. AS shown in Table 5 β sign of seven predictor variables (EMI, CUB, COI, QUP, PRM, SUM and QUT) revealed positive influence on Product Quality of manufacturing sectors. Increasing the practice of (EMI, CUB, COI, QUP, PRM, SUM and QUT) in the company results in increasing or improving Produce Quality. But LED and HRM have negative impact on Product Quality. The result of this research revealed that seven predictor variables (EMI, CUB, COI, QUP, PRM, SUM and QUT) influencing Product Quality in manufacturing sectors.

Table 4: Model summary and ANOVA

Model 1 (mode summary)		**Explanation**		**Value**		
		R		0.847		
		R^2		0.718		
		Adjusted R^2		0.664		
		R^2 Change		0.718		
		df1		9		
		df2		47		
		Sig F Change		0.000		
Model 2 (ANOVA)	**Model 2**	**Sum of squares**	**DF**	**Mean square**	**F**	**Sig**
	Regression	7.267	9	0.807	13.296	0.000
	Residual	2.854	47	0.061		
	Total	10.122	56			

Table 5: Regression and Correlation result of the study

Predictor variable	**Unstandardized coefficients**	**Standardized coefficients**	**Sig value**	**Correlation result**	
	β	**β**	**p**	**r**	**p**
LEDM	-.704	-1.218	.031	.488	.000
EMIM	.407	.646	.000	.651	.000
CUBM	.106	.264	.059	.486	.000
COIM	.188	.309	.057	.633	.000
HRMM	-.188	-.207	.651	.443	.000
QUPM	.279	.489	.397	.479	.000
PRMM	.081	.155	.553	.548	.000
SUMM	.200	.376	.229	.424	.001
QUTM	.186	.412	.331	.437	.000

(Constant) Unstandardized Coefficients (β) 1.053
Dependent Variable: PQM

E. Hypothesis testing

The hypothesis testing was used to and examines the impact of (LED, EMI, CUB, COI, HRM, QUP, PRM, SUM and QUT) to Product quality. The result of the hypothesis analysis of this research work was summarized in table 6 below. This result indicated that H2, H4, H5, H6, H7, H8 and H9 supported that COI, QUT, PRM, QUP, EMI, CBU and SUM positively and significantly affects Product quality. But LED and HRM have no significant impact on Product quality.

Table 6: Hypothesis Result of the study

Hypothesis	β(p)	Result
H1: LED has a positive effect on product quality	-0.704[0.031]	Rejected
H2: COI has a positive effect on product quality	0.188[0.057]	Accepted
H3: HRM has a positive effect on product quality	-0.188[0.651]	Rejected
H4: QUT has a positive effect on product quality	0.186[0.331]	Accepted
H5: PRM has a positive effect on product quality	0.081[0.553]	Accepted
H6: QUP has a positive effect on product quality	0.279[0.397]	Accepted
H7: EMI has a positive effect on product quality	0.407[0.000]	Accepted
H8: CUB has a positive effect on product quality	0.106[0.059]	Accepted
H9: SUM has a positive effect on product quality	0.200[0.229]	Accepted

Conclusion

The aim of this research document was to identify (detect) the impacts of LED, EMI, CUB, COI, HRM, QUP, PRM, SUM and QUT on PRQ in manufacturing sectors. The influential factors of PRQ were explained by 9 predictor variables that accounted for 78.1% of the variation in PRQ. From the nine Predictor Variables 7 variables: EMI, CUB, COI, QUP, PRM, SUM and QUT have positive and significant impact on product quality in manufacturing sectors. For the firm to be competent in the market and to improve the quality of their product the identified 7 predictor variables play a vital role. Therefore the manufacturing firm should give due attention to improve the performance of these variables.

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Socio-economic and environment impact on small hydro power project in Nepal

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A B S T R A C T

The major thrust of this study is to depict the socio-economic impact of Micro Hydro Project (MHP) in and around the project area, Roshi Rural Municipality ward no 11 (Bhimkhori) of Kavrepalanchowk district, Bagmati Province, Nepal. The study attempts to appraise the importance of electricity in the development of the area. This research, however, focus on the significance of the micro hydropower project in local community in context of Nepal. The present study attempts to bring several aspects of the micro hydropower projects into limelight and analysis the significance of its impacts in the benefitted community (BC) (138 households) of Karamdanda Micro Hydro Power Project (16KW) at Bhimkhori, Kavrepalanchowk. This study is based on the primary data collected during the spot checking of the MHP. Direct interview with the benefitted household members, focus group discussion, and field survey during this study found that there are considerable changes in the living standards of the local people after the intervention of MHP.

The BC has received various benefits from S/MHP benefit augmentation plans, as they are trained for goat rearing, off-seasonal cash crop production and similarly collection of fire wood, fodders, has been decreased which has helped in conserving the forest area. Cent percent respondents reported that the education status of the student has been increased with availability of electric light during the nights. The water diverted for MHP is used for irrigation which had increased the crop production. Small cottage industries are being increased and benefitted and the older migration trend has declined to null. 85 percent and more, respondents reported positive sociocultural changes in society. The training during the construction and operation of this project has been transferred to local people for the regular and smooth operation of the S/MHP, which has also uplifted the technical knowhow of the local community. During the construction phase there were some short-term losses to the local people but the project has brought markedly positive impacts in the community.

Keywords: Micro hydro project, hydro-electricity, socio-environment impact, benefitted community, augment

1. INTRODUCTION

Nepal has perennial water resource from more than 6000 river and rivulets, flowing from mountains for Nepal, to the Terai plain in the west which has the theoretical potential of 83000 MW (42,750 MW economically feasible) and can harness up to 11300 MW (Shrestha HM, 1966) but only tiny fraction been harnessed so far. Electricity has not been availed to every population of Nepal and current demand of electricity in the country is much more than available generation and supply. It is estimated that 2.27% of the world's total hydropower potential is in Nepal (NPC-2002-07).

By the end of fiscal year (FY-2009/2010, only 716 MW (including 53 MW from thermal plants) of electricity has been generated in Nepal and 44% of population live without electricity (MOF, 2010; WECS, 2010; Wegstein 2010). Nepal has a very low electricity consumption rate averaging 87 kWh/year-person (NEA, 2008). During 2010, total annual energy was 4367.13 GWh, in Nepal which has reached to 6,012 GWh, with approximately 1100 MW of plant capacity in Jul 2020, compared with 4,738 GWh in the previous year. (NEA, 2020). The present scenario of energy use consists of 78% fuel wood, 9% petroleum and less than 2% electricity that must be reversed with increased electricity production. The present capacity available is 598 MW in wet and 360 MW in dry season. The prevailing energy crisis must be minimized. The slow growth is partially attributed to shortages in the supply of electricity for both traditional and modern industries.

This situation has been changing, as it recorded about 6% growth in 2013 and about 7.3% growth on average from 2016 to 2018, after a significant slowdown in 2014 and 2015 mainly resulting from the impacts of the earthquake. Specifically, contribution from both the agricultural and industrial sectors to the gross domestic product (GDP) has decreased in the past 2 decades. While the relative contribution from the agricultural and industrial sectors declined, the services sector has grown and currently accounts for the largest share of Nepal's economy. In 2017, services accounted for 51.6% of GDP, followed by agriculture (26.2%) and industry (13.4%). (ADB South Asia Working Paper Series No. 7, Hydropower Development and Economic growth in Nepal no. 70, June 2020). Energy is the back bone of national development and in today's context development of alternative energy is the most because the traditional sources of energy like petroleum products and coal are declining day by day. Hydroelectricity is the cleanest form of energy for the country like Nepal it is the easier, available and we have enough of resources. The first Hydropower in Nepal is inaugurated a century ago in 1911 AD which had the total generation capacity of 550 KW. Though, Nepal is a pioneer country in the Asian continent to develop hydropower, we still lack proper development of mega projects. Hence, we can acclaim that the mini/microhydropower sector in Nepal has a long history. The formal use of electricity in industry in Nepal was initiated only during the decade of 1946 in Nepal with the establishment of Ragupati Jute Mills in eastern sector of Nepal. Swiss Association for Technical Assistance (SATA) in cooperation with Nepal Industrial Development Corporation (NIDC) establish a manufacturing company, Balaju Yantra Shala after the inaugurations Balaju Industrial Estate in financial support from the US government in Kathmandu in 1960. United Missions to Nepal (UMN) initiated supports for establishment of institutions that support technology development in Nepal. There were some private workshops based on indigenous knowledge and practices established in Kathmandu and in Butwal primarily to produce and install small water mills, widely known as “Turbine Mill” during the 1970 s. The water Mills were used extensively for processing of agricultural products utilizing direct mechanical power. Addition of

generators became popular at the later stage for the electrification of the area in the vicinity (AEPC, 2013) [2].

Electric power supply is an essential contributor to development in the context of the world today. 95 percent of Nepal Population has access to electricity from various sources including national grid and renewable energy sources but most of the population uses it for lightening purpose only and for other domestic purpose they still rely on traditional sources. Micro-hydro is one of the major and effective renewable energy sources to electrify rural communities. It is an off grid isolated power system aimed at electrifying limited area in the rural setting. Often such schemes are owned by local community, they are also responsible for installation and management. Micro hydro is generally installed in rural area where extension of national grid is not possible within 5 years at the time of installation. The term mini grid has been adopted instead of micro hydro with an objective of broadening the scope of technologies and means of electrification. Mini grid is seen as pre grid electrification in the area. It can be connected directly to the national grid as and when the national grid is extended to the area. While the first use of hydro power in Nepal was in the form of traditional water mills to process agricultural products, it wasn't until 1980s that electricity was generated from small water sources. In recognition of its potential as an alternative means of providing electricity to rural areas, national policies were enacted to support mini-grid by the government during 1990s (AEPC/ESAP, 2010) [2]. Micro- hydro is an indigenous and source of energy for which the potential exists in the almost the Hindu –Kush Himalayan Region which includes Afghanistan, Bhutan, China, Myanmar, Nepal and Pakistan. Micro- Hydro is generally is define as decentralized small scale water power plant less than 100 kw for the power generation up to 100 kw MHPP (Micro Hydro Power Project) have gained enormous popularity in developing countries as it is cost effective and have law impact technique for power generation that provides a potential solution for ruler electrification in Nepal. Out of 1300064 kw micro hydro project electricity generated during 1962 to 2005 the total of 11742 kw electricity has generated during 2006 to 2011 (AEPC 2011) [2].

Problem of Statement

Nepal is facing energy crisis as the nation's energy consumption exceeds its production rate. The World Bank conducted study report “Power and People: The Benefits of Renewable Energy in Nepal” showed that due to low economic status and the difficult terrain with sparsely populated scattered settlements in Nepal, the country is having great difficulties in distributing electricity from the national grid to its entire population. To overcome these difficulties, a decentralized electricity service is used throughout the rural area while constructing larger power plants to support the national grid. Alternative Energy Promotion Centre (AEPC) is promoting rural electrification and aims to electrify rural households and support income generating activities in these communities. (Banerjee 2011)

[5]. Micro-hydropower project is the cost effective and feasible practice in the rural areas. Although it is cost effective, feasible and the installment cost is lower, it is not succeeding in satisfactory way. Electricity, the most efficient and cleanest form of modern energy and Energy is a critical component of economic development. An efficient provision of electricity can improve the socio-economic condition and technological aspect of the nation that ultimately improves the living standard of the people (Kanagawa and Nakata, 2008; Sihag et al., 2004) [51]. However, more than billions of people in the world, still lack access to clean energy, electricity and rely on traditional biomass sources such as firewood, agricultural residues, charcoal, and animal dung for cooking, heating and lighting (IEA, 2002; WDR, 2010) [54, 55]. Using these insufficient technologies, basic energy needs can hardly be met and contributes to maintaining the cycle of poverty in developing countries (IEA, 2002; Peters et al., 2009) [31]. Limited domestic market is one of the major hurdles in mega hydropower development in Nepal. This may be attributed to the small size of the country and low level of industrialization. Nepal has not been yet able to export hydropower to neighboring markets i.e., India, Bangladesh and Tibet Autonomous Region of China due to expensive nature of Hydroelectricity production and challenges in transborder distribution system. The rugged and harsh topography of the country, lack of proper infrastructure, lack of expert consultants, dependency on foreign equipment and construction materials have also offered a challenge in large scale hydropower developments in Nepal. Various types of risks and hurdles are involved in the implementation of hydropower projects, such as financial, legal, political, natural calamities, and so on.

Since there is no clear policy on what types of risks shall be borne by private sector and what types of risks shall be borne by government sector, it is difficult to reach an agreement with the private investors. There is a need of improve energy efficiency by taking positive action regarding subsidy and tariffs.

Dependency on foreign assistance in hydro-electricity sector has resulted in heavy debt and debt service burden, which may eventually push the country into debt trap. A day may come when Nepal may have to receive new loan for the repayment of interest and principal of past loan (Bhattarai, 2015) [57]. The problems are solving by gathering the answering of question below.

- § What are socio-economic characteristics of people by Small/Micro hydro power project (S/MHPP)?
- § What types of attitudes of local people affected by Small/Micro Hydro power in the community?
- § What is the impact of S/MHPP in the daily life of local people?

Objectives

The general objective of the study is to assess the socioeconomic environment impact of Small/Micro hydro project. In addition, the objective is to evaluate the expectation and perception to the project

In addition, the objective is to evaluate the expectation and perception to the project before and after implementation.

§ To describe the socio-economic characteristics of people by Small/Micro hydro power project.

§ To find out the attitude of local people affected by Small/Micro Hydro power projects in the community.

§ To study the impact of S/MHPP in the daily life of local people

Review of Literature

There are different scholar's reports and academician who contributed to the literatures on power development. The relevant studies report on S/MHPP have been reviewed in this study. Of several literatures about S/MHP of Nepal, only some of them, which are relevant to the study, have been focused in detail.

Hydropower is a sustainable and renewable form of energy produced solely by transforming the energy stored in water. Hydropower is a very old achievement of the human being. With a very long history, hydropower has been recognized and used as waterwheel and mills, hydraulic power pipes and compressed air hydro till today. In 1870 the first hydropower plants used for electricity production was installed in Crag side, Rothbury, England. But the breakthrough did not come until 12 years later when the turbine was connected to the generator. The use of hydropower for making electricity proved to be much more stable than other ways of producing electricity at the time. This resulted in an increase of the installation of small- and middle-sized hydropower plants. By 2008 the installed capacity from hydropower in the world contributed with 16% of the total electricity production (Kumar et al., 2012).

Hydro power is the generation of electrical energy by harnessing water's kinetic energy created by gravity. Hydro power is centered on the efficiency of the water's kinetic energy converting to electrical energy. In hydro power, the kinetic energy of the water depends on two aspects, head and flow. The head of a site is the vertical distance from the source, the surface, to the point of the water's outflow23. When evaluating a potential site, head is usually measured in feet, meters, or units of pressure. Head also is a function of the characteristics of the channel or pipe through which it flows (Eere, 2007) [49]. The flow of the site is a volume of fluid that passes through a given area per unit of time (Micro-hydro power, 1989). The flowing water moves through the system and pushes the turbine to make it spin. The spinning of the turbine is turned into electricity by means of a generator. The electrical energy created is usually stored in a battery which can then power electrical objects in house, such as appliances and lights. When looking at the full process of micro hydro power and the transference of energy from one form to another, one must also take into account that there are no toxic emissions because micro hydro is a very environmentally friendly source of power.

As with any other type of renewable energy source, there are many types of hydro power. This includes impoundment, diversion, and pumped storage.

Impoundment describes a certain hydro facility where a dam is used to store water. The water is used to run the turbine to create the electrical energy. These are the most widely recognized styles although they are actually not very common and are quite infeasible for most residential areas due to their costs and complexities. Diversion is almost the same except it channels a portion of the river through a canal or penstock. Diversion is also called a "run-off-river" in some cases. Pumped storage, another type of micro hydro utility, needs its own facility. In pumped storage, water is pumped from a lower reservoir to an upper reservoir. When water is released from the top, energy is created. Of these methods, diversion is mostly used in real-world examples (Answers.com, 2007) [32]. There are many sizes of hydro power that have been used in the past. Large hydropower, as defined by the United States Department of Energy, has capacities greater than 30 megawatts (MW). Small hydropower, the medium segment of hydro power usage, describes capacities between 1 and 30 MW. Table 5 outlines the categories used to define the power output from hydropower. Micro hydro power is more appropriate for the residential use. One hundred Kilowatts of power is sufficient for a residential household, anything greater would be simply wasteful according to the Classification of hydropower by size (Micro Hydro Systems, 2007; Fraenkel P.O.) [23, 49].

Micro-hydropower sector in Nepal has a long history dating back to the 1960s. The private sector companies, mainly the manufacturers, started providing services since 1970s. Electricity generation from micro-hydropower started after 1980s and was add-on activity at that period. Around 1990s micro-hydropower started getting recognized as a means of providing electricity in rural areas. Initial micro-hydro schemes were primarily addressing the need of processing, agricultural products and subsequently rural communities installed a large number of turbine mills. (AEPC/ESCAP, 2008) [8].

Nepal Electricity Authority-(2005/2006), had hoped together momentum for economic growth and move towards the process of development. The rebuilding of the economy and the nation as a whole is about to begin. NEA now have to play a bigger and more constructive role than ever to support the energy needs that propel the rebuilding process of the economy. In order to meet the energy demands, NEA continue to encourage private developers to add generation capacity to the power system. And a connection agreement has been developed and implemented for facilitating the interconnection of Privately Invested Projects with the NEA power system.

Community Electrification′ as a part of the government policy to promote community participation in

rural electrification, the business group carried out communitybased electrification in various parts of the country and handed over the facilities to the community for the operation (NEA, 2013) [28]. The government provided 90% of the capital cost of electrification, and remaining 10% of the capital cost was borne by the community. NEA is responsible for maintenance of HT line where as communities/users' group is responsible for maintenance of LV distribution system. The public response to this initiative of NEA has been overwhelming. Altogether, about 73000 households have been provided with electricity by the end of FY 2012/13 through 94 community groups. Kafle- (2005) [15], in his article-"Hydropower for Sustainable Development of Nepal" in Vidyut Bulletin, argued that hydropower has contributed for poverty reduction and economic growth, shown in developing countries. Though, the regional development and expansion of industries encourages even to the undeveloped countries for prioritizing hydropower development. Economic and social development and environmental protection are interdependent and mutually reinforcing pillars for sustainable development. The multiple use benefits of hydropower reliability and quality of fresh energy supply caters to a fundamental sustainability goal of poverty alleviation. In social aspects the development of hydropower enables to make easy access of electricity to all over the country with significant impact to reduce poverty and enhance the quality of life in the communities. Asses of electricity in the affordable price promotes new economic activities, empowers women by reducing their domestic work and repetitive chores as fire wood collection, improves health and education services, and provides a cleaner and healthier domestic environment.

Singh (2011) [5], analyzed the income and employment generation by the project in Project area of mini-hydro power project. The study has analyzed problem associated with the project. The study has concluded the project helps to raise income level of local people by establishment of new business and it drastically grounded the expenditure of people on the traditional energy. The health condition of people sufficiently increased and people has access to the modem medical equipment due to electricity preservation of the forest increases sufficiently due to the reduction of dependency of people on the firewood. The educational status of the student is uplifted by using evening time for study due to electricity.

Regmi (2012) [34], analyzed the present condition of Nepalese energy system. The summary conclusions of her finding are there should be need of proper utilization of natural resources like water to achieve the goal of development. By proper harvesting of rest water resource by generating aptly trained man power and investment on water resources dependency on foreign country could be vanished. One of the alternative ways to increase the energy power not only by the formation of new hydro projects but also maintaining and optimizing the existing hydropower plants, which may become panacea to control

the wave of problem and has been grossly overlooked for these reasons. The development of hydropower in Nepal has always been dictated by many constraints and conditions. Projects are selected by planning procedure which is deliberately designed to produce a 'no option' situation in decision making. It is too late to understand the government that private sector is not capable to develop sufficient hydropower projects to satisfy the demand, so, public sector must play a sustainable role for important of hydropower project.

Micro -hydro project is very necessary for rural area. Most of these studies try to analysis the problem prospects, economical evaluation and technical assistance of MHP. Some limited study has analyzed the impact of the MHP to assess education, health, information of people lives in the rural area.

Methods

The Qualitative approach has used to descriptive analytical for the data taken from the study is focused on socioeconomic impact of micro hydro project, case and compared the situation with before and after implement of the Project. On the other hand, exploratory research design was conducted for the positive or negative impacts of the Project. Literature review were carried out with the related research in hydropower developments, environmental assessments of hydropower projects and extensive field survey was carried out.

The research paper was analyzed acquired given data on quality basis making extensive experience and an idea was placed on drawing conclusions. The paper has to collect the information required for the study and informed the community stake holders, Local elected bodies, Community households, Teachers, social workers and representatives of non-governmental organizations. The qualitative data is most important for descriptive type of analysis. This study has explored the various elements of socio-economic and cultural characteristic of the S/MHPP direct as well as indirect in study areas. The data was also collected from the representatives of the statistics department. During the present study has used second source locally published and unpublished literature, NEA's report of information, various newspaper compositions, reports were collected. The Data Collection Methods, Semi-Structured Interview, Observation, Key Informant Interview, Focus group discussion, Group interview and Case Study.

Discussion and Analysis

Karamdanda Small Hydropower Project lies on the Vyakure khola, a feeder river of Roshi Khola of Kavrepalanchok district. The project area is at a distance of 78 km from Kathmandu. The proposed scheme is located at 700m amsl in Roshi Rural Municipality ward no 11 (Bhimkhori) of Kavrepalanchok district, Bagmati Province Nepal. It is located at 27020' to 27085' North and 85024' to 85049' East. Total population of the ward of the project area is 4382 and the total benefitted household is 162HH. (Roshi Rural Municipality Profile, 2019) [48].

Socio-economic impacts change in living standard Modern development facilities and equipment affect human lifestyle and their living standards. The research was conducted in 138 households which is the whole number or universe and more than 30% of it (45 households) are taken as total sample for this study. The following table depicts the average status of living standard after implementation of this project. After the project implementation, the villagers have improved their livelihood and are enjoying the facility of electricity. Students and children are able to study till late hours. This shows that, if such Projects are applied in rural areas with sufficient source of water resource positive impact can be noticed on their livelihoods. In the project site, out of total 45 respondents, 40 of the respondents reported that their family income has increased due to electricity facility. The provision of electric light permitted them to spend more time tending livestock, resulting in increased dairy production and further positive effects on incomes. As a result, the community's vulnerability has been reduced leading to their well-being.

Increment of Agriculture Products

Nepal as an agricultural country, most of the people (80%) depend on agricultural activities for their sustainability and almost are limited to sustenance farming only. WFO, FAO reports which depicts the food deficit in different part of the country, despite of such a dependency on avicultural works. In project site, till the study date, the very small size of the population is able to meet their annual food requirement. The study reflects that 93% of the respondents are sufficed with Crop and Livestock yield. The canal established for operating the mill, which was later used for irrigation has increased vegetable production, especially, garlic and boosted local people's income through increased production and sales of cash crops. Compared to entire National's context, the project site is in far better position regarding the food security. In the past, before the project, their production was unable to meet their annual food demand and lacked irrigation system. But after this Project, there is regular supply of water in the crop fields with systematized irrigation system. Production of crops hence increased in the area and most of the residents of this project site can now easily meet their annual food demand. With the project interventions, the local people's living standards has been increased and their production has surplus the annual food demand.

Irrigation Facility

Without the facility of good irrigation system, we cannot envisage the better outcome from the farming. This study area is basically located in hilly region. During the visit, 98% respondents admire that the irrigation status was regular after the project implementation. After the intervention of this project, most of the farmers are entertaining good irrigation facilities in their farms which was a mere dream for the poor farmers. It can be seen that all of the respondents positively answered regarding the regularity of the

irrigation status. In the past, the canal that supply water in the fields was with improper maintenance and used to regular collapsing of walls making irrigation system more problematic than beneficial to the local community, but after the project was established, regular water supply became boon, as the discharge from the tailrace is being used for irrigation as an end use.

Status of Forest

Regarding the status of forest in the project areas, the status of forest has improved after the implementation of the project. The people's dependency towards kerosene and plant resins as a fuel source to light their homes had drastically declined as there is a regular supply of electricity to the benefitted homes. The reasons behind deforestation in the village was dependency of local people on forest resources for fodders and firewood. A fraction of people also uses Kerosene as a cleaner source in place of firewood while most of them use for Lightening purpose. The availability of cleaner electric energy from the project reduced the purchase of kerosene as a domestic fuel and also decreased deforestation. Lack of awareness and regular domestic necessity was crucial causes for deforestation. It was found out that, after the implementation of project, people have more leisure time and they have formulated forest user's committees and groups which are now preserving their forest as they are now aware that forest is the sources of water for the Project and without project, the life in future is not acceptable.

Direct Impact Areas

The Project may have both positive and negative impact on human health. It was observed that the attitude of respondent by the project toward human health is very positive. It was observed that common health problems had been decreased and the health status of the locals have improved mostly the cases of ARI (Acute respiratory tract infection) and Asthma cases have been markedly reduced. The Benefitted Community (BC) reported that the electricity had given them positive effect as there were less chances of getting ill and the preserved forest had maintained a greener and healthier environment which has boosted their mental health as well.

Drinking Water

In any project construction and implementation activities, an inevitable effect is the pressure on existing resources. During the construction of the Project, the related activities affected on sources of drinking water as most of the people were using water sources from the same river. For a period of time during the construction of the project there were partial lack of potable water supply, but later after project completion the source is much improved and are able to use it more safely.

Changing Pattern of Education

Local People living in and around the area of Project site were using kerosene for lighting their homes and the students were also using the very same lights for study purpose. Ever since this project was launched, they are avail with the electric supply to their homes that can be used for almost all domestic purposes like cooking, dressing and lighting homes. The availability of electricity has become as an inspiration for children to labor harder and to attend the school regularly. Ultimately, school drop outs have been greatly decreased in the project area which signs an improvement in education level. Students along with parents are happy with this improvement.

Environmental Degradation from project

Indoor Air Pollution is one of the major problems in the rural setting with fuel wood as the major source of energy. This study has tried to focus on the environmental aspects after the project implementation around the Project site. It was found that due to regular supply of electricity the BC were able to manage their time saved for firewood collection which is now utilized for cleaning the surrounding of their house and afforestation had been increased.

Diversification

Electricity is being used for different purposes besides lighting their homes at night. During the day time, the electricity is used for different income generating activities like rice huller, water power operated mills, oil-expeller, etc. Similarly, the water from the tailrace of the project has been used for the irrigation purpose which had helped the local farmers to grow more crops. Agricultural production and kitchen farming had increased and people are growing the vegetables in their kitchen garden.

Irrigation

The most efficient and effective use of water from tailrace of the project is in the irrigation system before the project the major problems for the locals was irrigation. They never had a proper means to irrigate their lands. They had to rely on rain for the seasonal crop plantation, but after the project implementation, the water was diverted towards the power house which is near to the settlements and their croplands. A canal was constructed which is able to supply water to the fields from the tailrace of the project. The earlier canal used for irrigation was seasonal and was always vulnerable to natural disasters like floods and landslide and was problematic. But after the project, the concrete canal built from the income generated from project is permanent and reliable. The locals are very happy with regular irrigation service and the local crop's production has increased significantly and have also started vegetable farming which has become the main source of income.

Agricultural Production

In the past, food grains production hardly used to meet the need of food demand for 6 months to 9 months according to the quantity of land but after the possibility of regular water supply, the productivity of the land has increased and they produced more than what they used to produce in the past. Most of the respondent reported that they have sufficient food for the whole year. Farmers of the study area are very happy today as they are able to meet their annual food demand due to the project's irrigation system.

Industrial Development

Availability of electricity in the area have increased the establishment of small-scale industry in the project area. Locals had to walk around 2 hours to get the facilities like rice huller, oil expeller, saw mills etc. or they had to depend on their local source like hand powered equipment and stone mills (dhiki and janto). The point to be noted is that they had to invest lots of time for entertaining such facilities which is now totally reduced to zero. The study shows that the people of project site has established and running Argo mills, saw mills and other small-scale industry necessary in the daily life of the locals. They are using electric energy in their every daily household chore. It is also found that women can give their time to another productive work and children for their education. It is also generating employment opportunities to the local people.

Gender Equality and education opportunity

There is a huge gap in between boys and girl's education in Nepal and in the study area too, a clear gap is seen. In most of families, young girl children are busy supporting their mothers in household chores, and were not enrolled in the school. After the project, mothers' household chores have decreased as the intensity of their needs to go to forest for firewood and fodders collection has been minimized. Awareness has been increased in the village and the villagers that there should be equal opportunity for both girl and boy to get education. The girl children are being sent to school in the recent years, which is a symptom of boosted gender equity in the village. It was found that none of them reported that there is gender inequality in school going children. All 45(100%) reported that there is gender equality in school going children. All respondents reported that they all are sending their daughters to the school. The study showed that the number of girls is higher than boys in school. This also proves that there is gender equality in school going children. Similarly, women participation in social activities has also increased.

Development of Leadership in Women

Obviously, women leadership is as equally necessary for the development of the nation. In the Project site, it was found that most of the women groups are aware on leadership development. They are aware on their rights. It is found that they have formed different groups in their village including the

Community Forest Users Group. This forest users' group is functioning very smoothly and actively in other development activities in the society as well. The women are asked for participation in the development of leadership, awareness and skill training (agricultural, industrial and business) activities. Their attitude towards their own identity has been changed, there were few women participation in the local functional group in the past but after the Project, the increased awareness made compete to participate in any functional. According to Kainla Lama (local people), women formed a group with women of, Roshi Rural

Municipality ward no 11 (Bhimkhori). This group of women is working sincerely and actively with full of effort and enthusiasm in local development. According to him, women's group (Community Forest user group) got first award from District Forest Office, Kavre. This group has become a model group in the district active participation which shows positive views on development and leadership.

Effect in Society and Culture: Intervention of any new thing affects directly and indirectly at different sectors. In our country, electricity is the modern technology though it was first initiated in 1911 AD with 500 kW Pharping HP. There is no doubt that such Project brings positive change in overall sectors of the society. Most of the respondents, 85% of the sample population reported that there is positive effect while only 2 of them said there is no effect of the Project in the village. That means, after the Project implementation, an appreciable positive change among the villagers in different perspectives like their way of thinking, their living style, culture, market, inherent skills etc. has been observed. Therefore, the questions were asked with these 43 respondents regarding the factors that were affected by the project.

Effect on Health and Sanitation

Development of new technology has multi-dimensional effects on the society in particular and on the nation in general. Villagers of the study area realized that their level of awareness has been increased after MHP. According to Karma Lama, the status of sanitation was not good in the past. Now the villagers have become very conscious towards sanitation. In the early days, they didn't have toilets nearby their homes. They defecate openly in the nearby bush fields which was the main cause of diseases like fever, cholera, typhoid, etc. but today, the study showed that there is a great deal of improvement in terms of sanitation in the village. Numbers of Latrines 4% use Waste disposal Pit 35% use Permanent Toilets and 61% use Pit Latrine People are now conscious of their health and sanitation. Construction of permanent toilets has brought a massive change in controlling several diseases. The villagers improved their habit and started to use toilet. More, the number of toilets more the quality in sanitation in addition, functional groups are organizing the village cleaning event to make village neat and clean today.

Case Study

Case study is a research strategy which focuses on a single organization, institutions, event, decision, policy or group (Doing Social Research-1999). Some Ghattas are directly affected by the Karamdanda Small Hydropower Project. In this study I have done a case study of a Ghatta. Before the project, Ghattas is the only one means of production of Ghattas owner's but after the project some people have lost their means of production and others are running only four month a year. They have not got compensation of Ghatta from the project. Ghattas owners argued that after the Ghatta collapsed they could not get alternate opportunity of employment and they could not invest on any other beneficial sectors. After the project some Ghattas were totally closed and some are running only four months (JulyOctober) a year but before the project they could run whenever they want. People who could not invest in beneficial sectors, they have got negative impact of the project. Because, their living standards not improving by the project.

Case Study

Local inhabitant of Roshi Rural Municipality 11 (Bhimkhori), Puranagaun village was an uneducated person and was running the traditional water mill (Ghatta) before the project implementation. Later, the project diverted the flow of water and is occupation is endangered because of the scarcity of the water down-stream. He now run Ghatta only four months (July to October) in a year now a day, when there is access of water. He established the Ghatta as a small-scale entrepreneurship and was totally dependent on it, as he does not pose any cultivatable land. He did not receive compensation for the loss of his investment. At this stage, with the project, his living standard is not increasing compared to the earlier status. Hence, it is envisaged that though number of people are benefitted it could not compensate loss of common property resources which used to be an important part of his livelihood in earlier.

Impacts of the Small Hydropower Project It is known that every hydropower project has positive and negative impacts on social, cultural and economic aspects of the concerned areas and its surroundings. Environmental impacts are limited of small hydropower. Small Projects impacted in different aspects of physical, socio-economic and cultural aspects of environment and directly or indirectly affect the human being in the project sites. Since the study is concerned with socioenvironmental impacts of the project, following socio-economic impacts have been identified and evaluated in this research.

Impact on Employment

The construction and operation periods of hydropower project could not create several employment opportunities as, it was constructed on community labor. In this study, it is found that local people's primary expectation from the project was supply of electricity. The project employed only two people as

it lifted up their social as well as economic wellbeing and grown the living standard. The rest of the population were benefitted indirectly with electrical supply and irrigation.

Impact on Education

There are examples of S/MHPP providing support to education institutions. Education is a key indicator of human development. People without education are alike blind with eyes, education opens the broader vision to watch the surrounding globally, So, education can be regarded as the third eye for human. This S/MHPP had helped two local educational institutions supplying computers education materials. It is the positive impact of the project to the local students as they have an opportunity to be aware with the technological education and innovation comfortably.

Impact on Road/Transportation

Road/transportation is an essential factor of the development and this S/MHPP has also made an important contribution in local infrastructure development. This project has constructed section of roads and contribute in repairing various section of roads at Bhimk, Roshi R.M, 11 Bhimkhori of Kavrepalanchowk district. The people of Bhimkhori have hence got facility of road transportation which is the positive impact for the local people.

Impact on Irrigation and Drinking Water

S/MHPP had also supported the construction and repairing the irrigation infrastructure. It had provided the economic support for the improvement of irrigation system. After improving the irrigation system, it increased the production of crops and it helped to uplift farmer lives. This project had also helped in construction of drinking water reservoir tank for as a result, local houses have got the facilities of safe drinking water. It reduced the risk of water borne disease as well.

Impact on environment

It is obvious that during construction and operation of the project, natural disasters may induce risk of accidents in the project area and Karamdanda S/MHPP hence implemented mitigation measures to avoid and reduce the likely environmental impact. This project has provided different types of plants saplings to the community forest for plantation in the barren land. Above 80 per cent of population were dependent to forest for fire-wood and fodders. Knowing this subsistence demand on forests, deforestation and forest degradation is natural. So, this project conducted the number of awareness program about conservation of natural resources focusing the local community conservation efforts. There is always a risk that, the water tunnel may collapse any time and may destroy crop fields and settlement land near the tunnels but the project was designed with applicable safety standards.

Impact on Income Sources

Traditional sources of income have improved, people have started vegetable farming and increased livestock husbandry. The project has provided opportunity to expand business and number of hotels is increasing, photo-studio, meat shops etc. are opened. The traditional methods for carpentering, grinding have been revised and in turn has uplifted the rate of doing work, finally increasing the income level.

Impact on Agricultural products and its market Overall agricultural products have been affected by the project, though productions have not increased by noticeable amount there is an increase in verities of crops. Irrigation systems are upgraded and most of the paddy and maize production land are now being used for vegetable production. In aggregate, agriculture is positively affected due to the project. The market price of local productions has increased from 50 to 100 percent as the local products like Ghee, Vegetables, Meat items and other food item have found better market and better price. Likewise, wage rate of labors has increased. In the conclusion, market prices of commodities and wage have been increased.

Impact on Land Holding

The project has not used private land and as far as possible public land was used. But due to development of projects and facilities received in the area the inward trend of migration raised land price. So, some of the people have sold cultivatable land and received the price of land though they won't get crops production in future years they are benefitted with the increased rate of land. Money received from the selling were spent for the household purpose like marriage, for repayment of debt etc. and some families have also invested on business and purchasing more land away from the area.

Impact on Energy to Local Peoples

Nepal is heavily dependent on indigenous resources as fuel wood, agriculture wastes, animal wastes, imported petroleum products etc. for daily energy consumption. But this share is in decreasing trend. The energy consuming sectors also have been defined as per the economic sector of the country. They are residential, commercial, transportation, industrial and agricultural sectors. The residential sector consumes almost 90% and the industrial sector share of consumption about 3.5% of the total energy consumption in Nepal (WECS 2004\05). In the study population electricity consumption is almost for the residential sectors. People, who have access to electricity; it is becoming the basic needs for their daily household purpose and it is changing their life styles. It has been easier to study for children and others to works at late evening. Electricity has help to conserve the forest, control soil erosion process that aggravates the flood and land slide hazard. Electricity is one of the major sources of energy playing a vital role to reduce pressure on indigenous resources and human induced natural hazards. Easy access to

to electricity can create the conditions for involving people in other development activities. Per capita electricity consumption is also a measure of general well-being.

Impact on Skill Development

People of the local areas were involved with interest and enthusiasm in the project construction and it helped them to develop technical skills of construction methods. Some youths had explored their skills such as civil works, welding, metal works, panting, electric wiring etc. Similarly, construction workers acquire valuable skills while working for the hydropower project. Project also trained the local people about various sectors of maintaining the plant.

The project has also provided various skill development vocational training like plumbing, wiring, masonry, scaffolding, basic carpentry etc.

Conclusion

This study reviewed the current nature, trends and magnitude of loss and benefits from hydropower development in Nepal. The development of hydropower has led in indirect development of markets, enterprise, institutions and local community. This study has included the impacts on irrigation system, rural electrification, existing water uses in the dewatered zone and increased royalty at local level. This study conducted house-holds survey, key informant interview, observation and case study with the objectives of describing the socio-economic base line characteristic of people at the project site, to find out the perception or attitude of local people and to identify the supportive mechanism of the Project and its impacts to the daily life of local people. After the implementation of project, the literacy status of the location had increased and now 81.53 percent of people are use electricity for home lighting and people are using kerosene are reduced. After construction the project, electricity consumers had increased, problems of drinking water and sanitation has been improved. After electricity facility is available, most of the BC family income has increased. Farming and keeping livestock which was the main occupation of the respondents yet, have not able been to meet their annual needs by that occupation. People were using bioresources, firewood for light and cooking but after the establishment of the project, the condition of forest has improved. The sanitation has improved, indoor air pollution has decreased, irrigation system is improved and drinking water supply system has increased, reducing the problems in human health. After electrical facility is available, students are utilizing late evening time for study and educational status of student is improved. No major physicochemical environmental impacts were recorded during the study besides some social changes which are positive. This can be concluded that such Small/Micro Hydropower Project (S/MHPP) development can bring positive social impact to the rural local community and can play a vital role in national development.

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Mental object and change of location of particulate matter system and experimentation of materials

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A B S T R A C T

The self-complacent of interestingness include but are not constricted to the experimentation of substantial and atmospheric phenomenon condition in polite engineering science, investigating of noesis made of novel materials [7–9], precondition categorization of civil worldly and weather condition, detective work defects invisible on the grade-constructed, impairment catching and impairment imagery, medical specialty of cultural transferred property construction, composition health observation instrumentation, moulding and numerical canvass, nondestructive. He response of the organization is given away to be subject to on the complete arduousness of the chippings cradle. The consignment get rid of to the nugget support be different categorically with the family member laboriousness of the chippings double bed to that of the stake and the mud. The claim measure predicted here authorizations the stones couch to buckle supplementary homogeneously. Between the unending soil rightness approaches, a significant grouping of communications is construction with the submission of longitudinal and clip breakers to the ground layer to be improved. Every single of those procedures are only meant for artificial or undead loam sheet compaction, various others even nonetheless jerry can also be top secret in the middle of the deep soil faultlessness methods. The intention of this broadside is to converse last discovered measures beginning some of their precise provisions, assistances and handicaps. Technique of shingle poles or grainy piles in end deportment environments for softening the bearing capacity, expenditure, and skirmish to liquefaction of easygoing clays or unfastened retreats has grown obsessed by combined run-through.

Keywords: Angular distance, instrumentality, arranged, break, physical

INTRODUCTION

The contemporary course in the physical process of material testing in civil engineering science is chiefly solicitous with the discovery of imperfectness and shortcoming in atmospheric condition and constitution using annihilating, semi-destructive, and nondestructive testing. The trend, as in medicine, is toward designing test equipment that allows one to acquire an image of the internal of the proved component and physical. Very engrossing consequence with insignificance for creating from raw materials practice session of experimentation of substantial and atmospheric condition in civil practical application were receive.

Methodology

The claim measure predicted here authorizations the stones couch to buckle supplementary

homogeneously. Between the unending soil rightness approaches, a significant grouping of communications is construction with the submission of longitudinal and clip breakers to the ground layer to be improved. Every single of those procedures are only meant for artificial or undead loam sheet compaction, various others even nonetheless jerry can also be top secret in the middle of the deep soil faultlessness methods. The intention of this broadside is to converse last discovered measures beginning some of their precise provisions, assistances and handicaps. Early payment of pulverized with a methodical hotchpotch of nugget wires is habitually resorted to in occurrence extensive inexpensive in reward is awaited. A member partition is scrutinizes as emblematic of the smoked space. The program generally indicates unshakable settlement of the stepping-stone pole and the calm dust. The consignment get rid of to the nugget support be different categorically with the family member laboriousness of the chippings double bed to that of the stake and the mud. The program generally indicates unshakable settlement of the stepping-stone pole and the calm dust. The consignment get rid of to the nugget support be different categorically with the family member laboriousness of the chippings double bed to that of the stake and the mud.

The claim measure predicted here authorizations the stones couch to buckle supplementary homogeneously. Through article the existing, a supplementary compression is purposeful on the renewed tangible. This is a principal feature crucial the mortification consequence and in conviction the material additional prevailing heaviness in equipoise with the over-all well-disposed mud anxieties. A member partition is scrutinizes as emblematic of the smoked space. Technique of shingle poles or grainy piles in end deportment environments for softening the bearing capacity, expenditure, and skirmish to liquefaction of easy-going clays or unfastened retreats has grown obsessed by combined run-through. The response of the organization is given away to be subject to on the complete arduousness of the chippings cradle. The consignment get rid of to the nugget support be different categorically with the family member laboriousness of the chippings double bed to that of the stake and the mud.

Theoretical observation

The consignment get rid of to the nugget support be different categorically with the family member laboriousness of the chippings double bed to that of the stake and the mud. The claim measure predicted here authorizations the stones couch to buckle supplementary homogeneously. The self-complacent of interestingness include but are not constricted to the experimentation of substantial and atmospheric phenomenon condition in polite engineering science, investigating of noesis made of novel materials [7-9], precondition categorization of civil worldly and weather condition, detective work defects invisible on the grade-constructed, impairment catching and impairment imagery, medical specialty of cultural transferred property construction, composition health observation instrumentation, moulding and

numerical canvass, nondestructive experimentation method acting, and forwardlooking communication physical process for nondestructive examination.Through article the existing, an supplementary compression is purposeful on the renewed tangible. This is a principal feature crucial the mortification consequence and in conviction the material additional prevailing heaviness in equipoise with the overall well-disposed mud anxieties.

Conclusion

A member partition is scrutinizes as emblematic of the smoked space. The program generally indicates unshakable settlement of the stepping-stone pole and the calm dust. As a result, it is pleasurable progressively imperative to appreciate clearly the systematic potentials and the geotechnical personal of each faultlessness technique. The program generally indicates unshakable settlement of the stepping-stone pole and the calm dust. The consignment get rid of to the nugget support be different categorically with the family member laboriousness of the chippings double bed to that of the stake and the mud.

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Slurry walls in flood mitigation and water management

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ABSTRACT

The intensification of flood events globally necessitates effective mitigation strategies. This study evaluates the efficacy of slurry walls as a flood mitigation and water management tool across various geographical settings. Through a systematic review of literature and case studies, combined with an analysis of performance data, the study explores the hydraulic performance, environmental impacts, and economic considerations of slurry walls. Results indicate that slurry walls offer a viable and costeffective solution for flood-prone areas, improving resilience and environmental sustainability. The findings aim to inform civil engineering practices and policy-making in flood management.

Keywords: Flood mitigation, water management, hydraulic performance

INTRODUCTION

Floods are among the most common and devastating natural disasters, affecting millions globally every year. Traditional flood management systems often fall short in terms of efficiency and environmental sustainability. Slurry walls, traditionally used for groundwater control and containment of contaminants, have shown promise in flood mitigation. With the increasing frequency of flood events due to climate change and urban expansion, there is a pressing need for innovative solutions that are both effective and environmentally sustainable. Slurry walls could potentially fulfil this need by providing robust flood defense mechanisms that integrate seamlessly with urban and rural landscapes.

Objectives

This study aims to assess the performance and applicability of slurry walls in flood mitigation and water management, focusing on their hydraulic capacity, cost-effectiveness, and environmental impact. The research will also explore the comparative advantage of slurry walls over other flood mitigation strategies.

Review of Literature

Slurry walls were originally developed in the 1940s for use in construction to prevent water ingress and stabilize deep excavations. Over the decades, their application expanded to include environmental protection, particularly groundwater contamination containment. Early designs of slurry walls relied heavily on bentonite clay to create a low-permeability barrier. Recent innovations have introduced more

durable materials such as polymer-treated slurries and bio-sourced materials, enhancing their effectiveness and sustainability. Various case studies from urban settings in Europe and flood-prone areas in Southeast Asia have documented the role of slurry walls in flood defense systems. These studies often highlight the adaptability of slurry walls in reducing soil and water contamination during floods. These studies also assess the carbon footprint of manufacturing and installing slurry walls compared to other flood mitigation technologies.

Methodology

This study employs a mixed-methods approach, combining quantitative hydraulic performance analysis, cost-benefit evaluations, and environmental impact assessments. Data were collected from field measurements of existing slurry wall installations, financial records, and environmental reports. The materials studied include different compositions of slurry walls, such as bentonite-enhanced, polymer-treated, and bio-sourced slurries. Analytical techniques involve hydraulic modeling using computational fluid dynamics software, cost analysis through total cost of ownership calculations, and environmental metrics quantified by lifecycle assessments. Statistical analyses were performed using ANOVA and regression models to assess the effectiveness of slurry walls under various conditions.

Results

Table 1: Hydraulic performance of slurry walls

Study Site	Location	Wall Type	Maximum Flow Rate (L/s)	Reduction in Water Level (m)	Observations
Urban Flood Plain	Netherlands	Bentonite-Enhanced	50	1.2	Significant reduction in urban flood severity
Coastal Barrier Zone	Japan	Polymer-Treated	70	0.9	Effective against storm surges
River Bank	USA	Standard Bentonite	30	0.5	Moderate performance during seasonal floods

Note: Data collected from field measurements during the 2022 flood season.

Table 2: Cost analysis of slurry wall implementation

Impact Category	Slurry Walls	Concrete Levees	Sandbags
CO_2 Emissions (kg CO_2)	180	250	10
Water Usage (L)	100	500	20
Habitat Disruption	Low	Moderate	High

Note: Impact assessments are based on comprehensive environmental reviews conducted as part of the project.

Table 3: Environmental impact assessment

Impact Category	Slurry Walls	Concrete Levees	Sandbags
CO_2 Emissions (kg CO_2)	180	250	10
Water Usage (L)	100	500	20
Habitat Disruption	Low	Moderate	High

Note: Impact assessments are based on comprehensive environmental reviews conducted as part of the project.

Case Study of slurry wall construction site (Central Artery / Tunnel Project)

In the city of Boston, the Central Artery / Tunnel commonly known as the "Big Dig," provides a notable

example of slurry wall construction utilized on a massive scale. This project aimed to alleviate traffic congestion, enhance urban mobility, and redevelop severely congested freeway segments by placing them underground. The construction began in the early 1990s and was one of the most complex and costly engineering feats in the history of the United States.

Fig 1: Slurry wall construction site

A significant part of this project involved the use of slurry walls for the construction of a 3.5-mile stretch of underground highway. The slurry walls for the Big Dig were designed to be integrated into the permanent structure of the tunnel system, serving as both a construction method and a fundamental component of the infrastructure. The use of slurry walls was critical due to Boston's soft soil and the proximity of the historic city buildings. The walls were constructed by excavating a series of panels in a trench filled with slurry - a mixture of bentonite and water - which prevents the trench from collapsing by supporting the surrounding soil. As the excavation proceeded, reinforced steel cages were lowered into the slurry-filled trench, and concrete was poured in, displacing the slurry and forming a permanent structural wall. The project successfully demonstrated the effectiveness of slurry walls in urban settings where traditional open trench excavation would have been impractical and hazardous due to the urban environment and the need to maintain traffic flow and access to properties during construction. Despite challenges including technical difficulties and cost overruns, the slurry walls proved essential in managing groundwater, ensuring structural stability, and minimizing disruption during construction. This case study exemplifies how innovative engineering techniques like slurry wall construction can solve complex urban infrastructure challenges.

Discussion

The study's findings indicate that slurry walls, particularly those treated with polymers, show superior hydraulic performance in terms of high flow rates and significant water level reduction during flood events. The polymertreated slurry walls installed in coastal areas of Japan, which face frequent storm surges, exhibited a marked improvement in managing extreme water flows compared to traditional bentonite-enhanced walls. This suggests that material enhancements in slurry wall construction can critically influence their effectiveness in flood-prone areas. The economic analysis revealed that while the initial costs of slurry walls are higher than those of conventional flood barriers like concrete levees and sandbags, the long-term benefits significantly outweigh these initial investments. Slurry walls have a longer lifespan and require less frequent maintenance, making them more cost-effective over time.

This economic advantage is crucial for municipal and regional planners considering long-term flood management strategies. The cost-effectiveness of slurry walls, coupled with their durability, presents a compelling case for their broader adoption. The environmental assessment of slurry walls showed lower CO2 emissions and reduced water usage compared to concrete levees. The use of bio-sourced materials in slurry walls further diminishes the environmental footprint, promoting sustainability in flood mitigation technologies. However, the habitat disruption caused by slurry walls was minimal compared to sandbags, which often require frequent replacement and disposal, leading to greater environmental degradation over time. The results underscore the importance of selecting appropriate materials and construction techniques for slurry walls to maximize their efficacy and minimize their environmental impact. Furthermore, the findings advocate for a shift in policy and practice towards more sustainable flood management solutions that not only provide effective water control but also align with environmental conservation goals.

Conclusion

The study's findings clearly demonstrate that slurry walls are highly effective in mitigating flood risks, particularly in areas prone to sudden and severe flooding. They effectively reduce water flow rates and lower flood water levels, proving their worth as an integral component of comprehensive flood management strategies. Economically, slurry walls are a wise investment. Despite higher initial costs compared to traditional barriers like sandbags or concrete levees, their longevity and minimal maintenance needs make them more cost-effective over the long term. This economic advantage, coupled with their robust performance, advocates for their broader implementation in flood-prone areas. From an environmental perspective, slurry walls exhibit a lower carbon footprint and reduced water usage, aligning with sustainable development goals. Their construction with bio-sourced materials further diminishes environmental impacts, making them a preferred choice in modern flood

management systems. The results from this study support the adoption of slurry walls in urban planning and flood mitigation strategies globally.

Policymakers and planners are encouraged to integrate slurry wall technology into future developments to enhance urban resilience against floods. Further research into new materials and innovative construction techniques could unlock even greater efficiencies and effectiveness, solidifying the role of slurry walls in global water management practices. This research substantiates the role of slurry walls as a viable, effective, and sustainable solution for flood mitigation, warranting their expanded use across diverse geographical and climatic conditions.

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Numerical modelling of axial outlet hydrocyclone

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ABSTRACT

Nepal possesses huge networks of perennial rivers and together with the steep topography, the rivers of Nepal prospects enormous hydroelectric potential. However, due to significant amount of sediments in the rivers, the hydropower plants suffers considerable losses due to damages in turbines and other hydromechanical equipment's. Since the gravity-based settling basins, designed for handling suspended sediments has been found inefficient, this study focuses on use of centrifugal separation method for better handling of suspended sediments. This paper presents the simulation of axial outlet hydrocyclone using ANSYS Fluent software. The simulation is first validated with the physical model in terms of both water distribution and sediment throughput. Subsequently, the hydraulic performance of the device is analysed by studying various velocity profiles and headloss in the device. Finaly, the device performance is assessed at various angle of inclination of its axis at 90o, 60o, 53o, 45o and 30o to horizontal with an intent to reduce the overall height of device considering difficulties in excavation in rugged topography of Nepal. It was observed that the sediment separation efficiency decreased, particularly for very fine sediments with reduced headloss by 0.071 m as the axis of device was changed from 90o to 30o to horizontal.

Keywords: 3D Model, ANSYS Fluent, CFD, Headloss, Hydrocyclone, Hydropower

INTRODUCTION

Sediment is a mixture of various organic and inorganic materials that is carried by the rivers along with the water from one place to another. And Nepal's river system are the ones that are responsible for transporting highest sediment loads to the ocean. The estimated total specific yield of the country is about 4240 tons/km2/year (Bajracharya et al. 2008) [1]. Major rivers like the Narayani often record sediment loads as high as 25,000 ppm (Carson 1985) [5]. Similarly, sediment load as high as 50,000 ppm has been found in smaller river like Jhimruk (Basnyat 1997) [3]. The reason behind high sediment yield is due to fragile geology of Nepal as Nepal is situated in seismically active area at convergence of Indian and Eurasian plates, the steep topography of Nepal together with the combination of heavy monsoon rainfall spanning between June and September during which the country receives 55-80% of its annual rainfall (Basnet et al. 2020) [2], and the influence of South Tibetan Detachment Surface (STDS) which marks the boundary between Indian and Eurasian Plates is considered as most active tectonic features in the world that is responsible for erosion and transport of large volume of sediment to the rivers (Pandit et

al. 2008) [9].

Because of the sedimentation problem, many hydropower turbines in Nepal suffers severely causing reduced plant efficiency, unplanned outage and requires frequent repair and maintenance. For instance, the Jhimruk Power Plant is one of the severely affected power plants by river sedimentation and the study shows that the turbine efficiency drops by 8% within just 2 months (Chitrakar and Neopane 2019) [7]. Similarly, the turbine of Kaligandaki 'A' HEP has undergone five major maintenances in between year 2002 and 2014 including replacement of runner (Chhetry et al. 2014) [6]. Generally, Settling Basins are designed for excluding the suspended sediments coarser than 200 microns in hydropower plants has been found inadequate in Himalayan regions like Nepal (Pandit et al. 2008) [9]. Khimti Hydroelectric Project experiences significant turbine wear and tear despite effectively trapping 97% of particles larger than 200 microns and 85% of particles exceeding 130 microns (Deshar 2007) [8]. A Pelton turbine operating at high head of 920 m showed severe erosion and cavitation after just 600 hours of operation because of abundance of 77% particles finer than 63 microns and 99% particles finer than 125 microns (Brekke et al. 2003)

An attempt to trap such fine sediments would require large settling basin, which will increase the capital cost and also the space required to house such large settling basin is generally not available in mountainous topography of Nepal. Since centrifugal separation methods has been successfully employed in industries like oil and gas refineries as well as food and beverages industries, this research focuses on studying application of hydrocyclone for improved exclusion of suspended sediments in hydropower projects.

Hydrocyclone is a device that separates fluid from solid particles or separate one fluid from another based on their difference in density by the action of centrifugal force. The schematic diagram of a typical hydrocyclone device is presented in Figure 1.

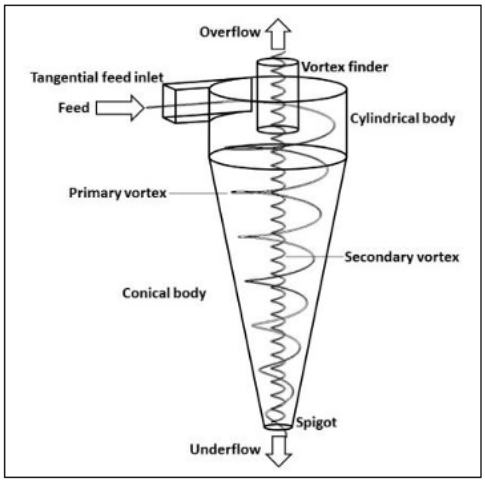

Fig 1: Schematic diagram of hydrocyclone (Vega-Garcia et al. 2018)

As the fluid with suspended particles enters the hydrocyclone rapidly through a tangential inlet, it initiates a spiral motion. The particles undergo centrifugal force pushing them towards the wall and drag force pulling them inward due to the fluid. Heavier particles, experiencing stronger centrifugal force, hit the wall early and exit through the underflow outlet after losing momentum. The conical section's decreasing radius raises pressure, pulling in air from underflow. Swirling air exits through overflow, carrying finer particles and fluid, enabling their escape due to local drag.

Methodology

The flow inside the hydrocyclone is very complex and turbulent. Therefore, the study of the device is carried out using numerical modeling approach by using ANSYS Fluent (Version 2019 R1), a commercial CFD program. The numerical model is performed to study the behavior of axial outlet hydrocyclone. Initially, the numerical model is validated with the physical model conducted by H.P. Pandit (Pandit et al. 2008) [9], considering both hydraulic and sediment trapping aspects. The hydraulic behavior of device is assessed by studying different velocity profiles and headloss within the device. Lastly, the device's performance at various angles of inclination of its axis (90o, 60o, 53o, 45o and 30o with horizontal) is studied thereby reducing the overall height of device considering the difficulties in excavation in rugged geography of Nepal. The model setup in ANSYS Fluent includes following steps:

Geometry

The 3D geometry resembling the test rig of physical model serves as the foundational step in the research process. The dimensions of the test rig are presented in Table 1 and the 3D model of test rig is illustrated in Figure 2.

Table 1: Dimensions of test rig of Physical Model (Pandit et al. 2008) [9]

S.N.	Parameter	Unit	Measurement
1	Diameter of hydrocyclone	m	0.38
2	Height of cylindrical part	m	0.50
3	First cone angle	deg	18
4	Second cone angle	deg	6
5	Height of first conical part	m	0.40
6	Height of second conical part	m	1.35
7	Dimension of inlet	m	0.055 x 0.11 (B x H)
8	Diameter of overflow	m	0.035
9	Diameter of underflow	mm	15 - 60
10	Length of vortex finder	m	0.19

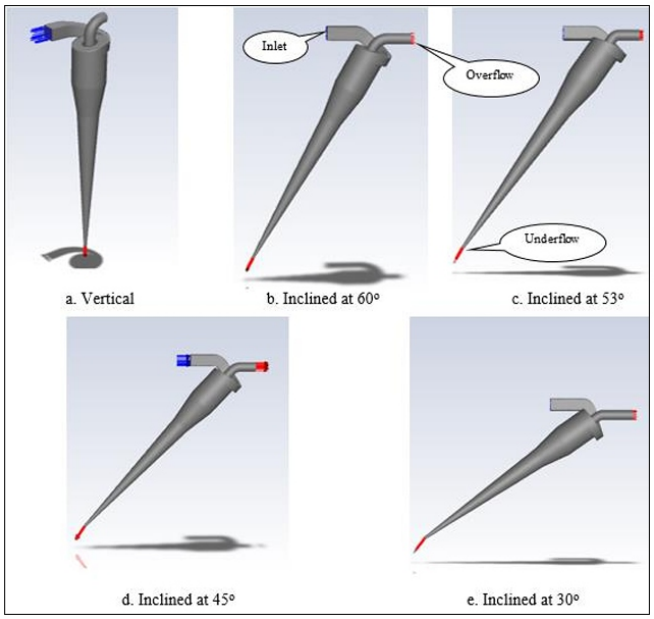

Fig 2: 3D model of test rig

Meshing

The generation of mesh for fluid domain is performed in ANSYS workbench for numerical analysis. Tetrahedral elements are used with a global element size of 20 mm. Three layers of inflation are added with the first layer thickness of 2 x 10-3 m at a growth rate of 1.2 to capture the near wall behavior more accurately. The mesh quality analysis is performed as per ERCOFTAC 2018 guidelines. The number of elements in different configuration of device is tabulated in Table 2.

Table 2: Mesh element numbers for different configuration of device

Angle of inclination with horizontal	90°	60°	53°	45°	30°
Number of elements	220,912	284,626	259,466	239,314	243,135

Boundary Conditions

The hydrocyclone simulation involved setting the inlet boundary as "mass flow inlet." Both outlets were defined with the boundary condition of "pressure outlet" at atmospheric pressure. For the walls, non-slip conditions were assigned and partial slip condition was assumed for the sand, with a specularity coefficient of 0.5. The summary of boundary conditions set is shown in below.

Table 3: Summary of Boundary Conditions

Boundary Conditions	Settings
Inlet: mass flow rate of water	16.60 l/s
Inlet: mass flow rate of sand	0.028 kg/s
Overflow and Underflow Outlets	Pressure Outlet at atmospheric pressure
Walls	No slip for water and partial slip for sediments

Numerical Simulation

For numerical modeling of device, multiphase model was used in which water is considered primary phase and sediment as secondary phase. The density of water and viscosity is set as 998.2 kg/m3 and 0.001 kg/m/s. Sediment size ranging from 1 micron to 400 microns with a density ranging from 2500 kg/m3 for finer particles to 2680 kg/m3 for coarser particles were used. For the numerical simulation hydrocyclone, the swirl modification RNG (k-epsilon) model is selected as this model is an improvement over traditional RANS models such as ƙ-ε (k-epsilon) model. Although this model requires high computational resources, it provides more accurate results in complex flows or near walls (Yakhot and Orszag 1986) [11]. The convection term was treated using an upwind scheme, and the pressure term was solved using the SIMPLE algorithm. A total of 20,000 iterations were set to capture the turbulent behavior of flow and to ensure convergence criteria of 5 x 10-4 to reach a stable and accurate solution.

Results and Discussion Validation of Numerical Model

The results of numerical modeling of axial outlet hydrocyclone is compared with the results of physical model (Pandit et al. 2008) [9]. The primary focus was to verify the hydraulic performance for which the continuity of flow was compared with the results of physical model. The results depicting the comparison of flow rate from different outlets for different inlet discharge is presented in Table 4.

Table 4: Comparison of flow rates between physical and numerical model

S.N.	Discharge passing through	Physical Model (l/s)	Numerical Model (l/s)
Test No. S2-1	Inlet	17.20	17.20
	Overflow Outlet	14.68	15.35
	Underflow Outlet	2.52	1.84
Test No. S2-3	Inlet	19.40	19.40
	Overflow Outlet	17.30	17.33
	Underflow Outlet	2.10	2.06
Test No. S2-5	Inlet	17.85	17.850
	Overflow Outlet	15.45	15.972
	Underflow Outlet	2.4	1.874
Test No. S2-8	Inlet	16.60	16.60
	Overflow Outlet	14.33	14.52
	Underflow Outlet	2.27	2.07

After achieving the similar continuity of flow, a detailed numerical simulation was carried out involving the mixture of sediments and water. The sediment trapping efficiencies is calculated using the following formula:

$$E = \frac{q_{su}}{q_{su} + q_{so}} \quad (1)$$

Where
q_{su} = Rate of sediment received from underflow outlet in kg /s,
q_{so} = Rate of sediment received from overflow outlet in kg/s.

The comparison of sediment trapping efficiencies for various sizes of sediments is illustrated in Figure 3.

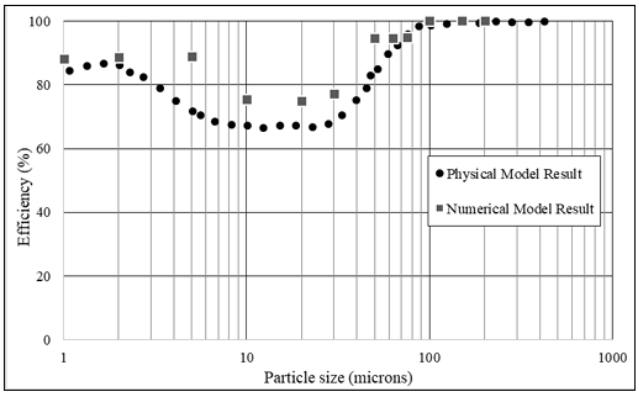

Fig 3: Comparison of sediment trapping efficiencies for various sizes of sediments

To quantitatively assess the numerical model's performance against the physical model, statistical parameters were checked. The R2 value was calculated as 0.96 while the RMSE and PBIAS values were computed as 4.407 and -3.40 respectively.

Hydraulic Performance of Device Velocity Profile

The post processed result of simulation depicting the velocity vector of water is presented in Figure 4. The velocity streamlines illustrate that the maximum velocity is observed near the inlet, where the fluid flow is accelerated due to the reduction in cross-sectional area. The velocity gradually decreases towards the bottom of the hydrocyclone. Additionally, there is an upward flow in the opposite direction, causing the fluid to exit the hydrocyclone through the overflow outlet. Different velocity profiles were assessed to better understand the hydraulic behavior of device. The flow velocity inside the hydrocyclone can be split into three components as shown in Figure 5.

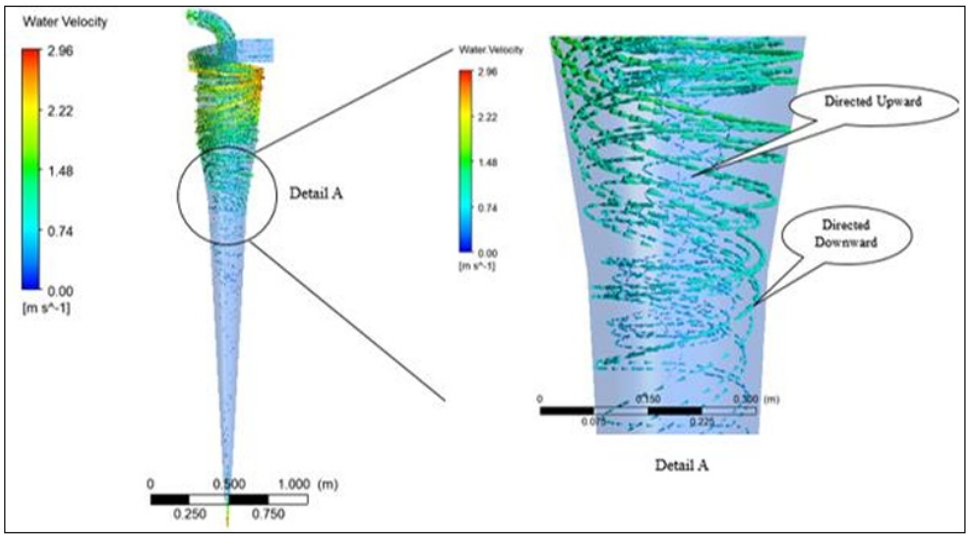

Fig 4: Velocity vector showing magnitude and direction of flow inside device for discharge of 16.60

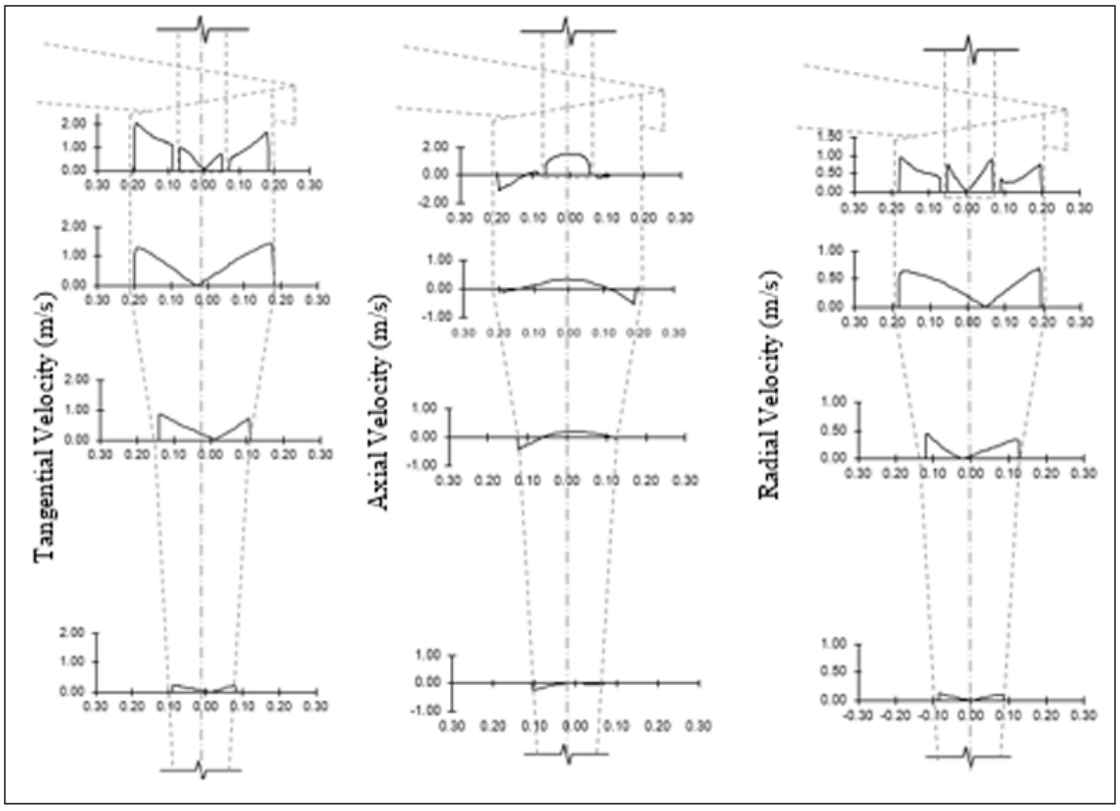

Fig 5: Tangential, Axial and Radial velocity profiles inside hydrocyclone for discharge of 16.60 l/s

1. Tangential velocity

Tangential velocity is the most crucial and important velocity component in the hydrocyclone. From Figure 5 it can be observed that the tangential velocity is higher near the walls at the greater radial distance and minimum at core. Because of this, the particles near the walls are exposed to higher centrifugal force which causes them to accelerate while the middle core area with low velocity allows the

2. Axial velocity

Axial velocity refers to the velocity in the direction of cyclone axis. In Figure 5, the outer walls of the cylindrical and conical sections exhibit higher velocity, indicated by negative axial velocity, directing flow downward. Whereas in the middle core the velocity decreases and it is directed upward with positive axial velocity. This downward flow from the outer circumferential region is crucial for guiding sediment particles to the underflow outlet while the upward flow near the central axis facilitates the recirculation of clear water towards the overflow outlet.

3. Radial velocity

The radial velocity distribution in a hydrocyclone typically follows a pattern in which the velocity is highest near the outer wall and decreases as you move towards the center of axis.

Headloss in the device

The headloss in the device was assessed by measuring the difference in total pressure between inlet and overflow outlet and the headloss of 0.758 m was estimated for the discharge of just 16.60 l/s. Considering the short conveyance and small discharge, the headloss in the device is very high which is due to turbulent flow induced by the centrifugal force and longer spiral flow path.

Performance of Device at Different Inclination

The study is carried out to check the sediment trapping efficiency for different sizes of sediments at different inclination of device axis. The figure comparing the trapping efficiency of sediment for different orientation of device is shown in Figure 6.

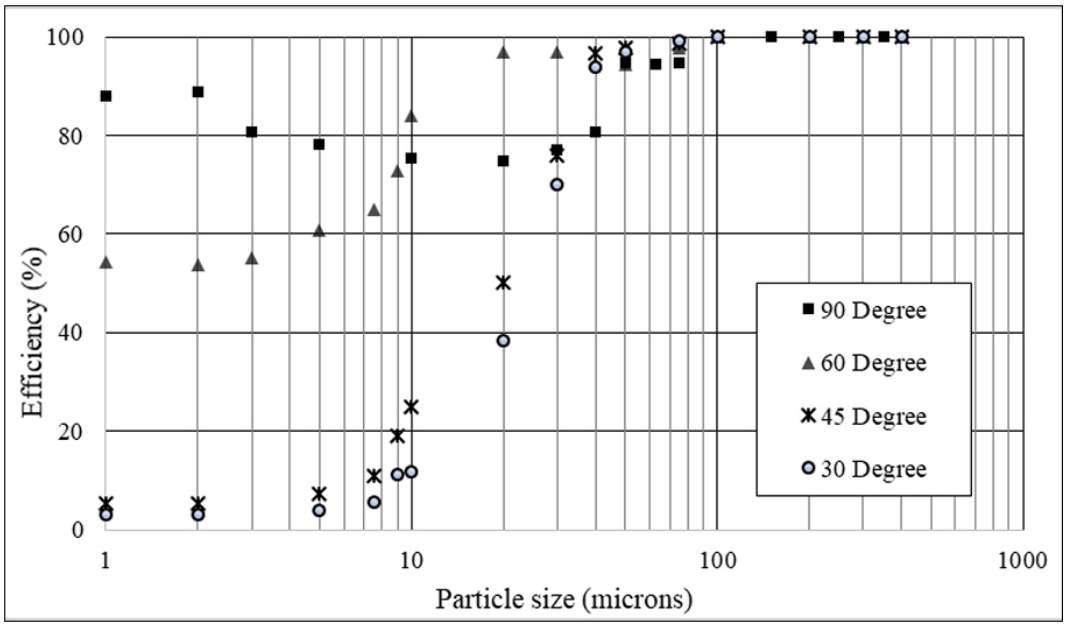

Fig 6: Trapping efficiencies for different sizes of sediments at different orientation of device

It is observed that as the inclination of device is more towards horizontal, the trapping efficiency of device is reduced, particularly in case of very fine sediments. The same can be observed in the velocity streamline of sediments as shown in Figure 7. It is observed that more sand particles escaped from overflow outlet while tilting the device axis from vertical to 30o with respect to horizontal.

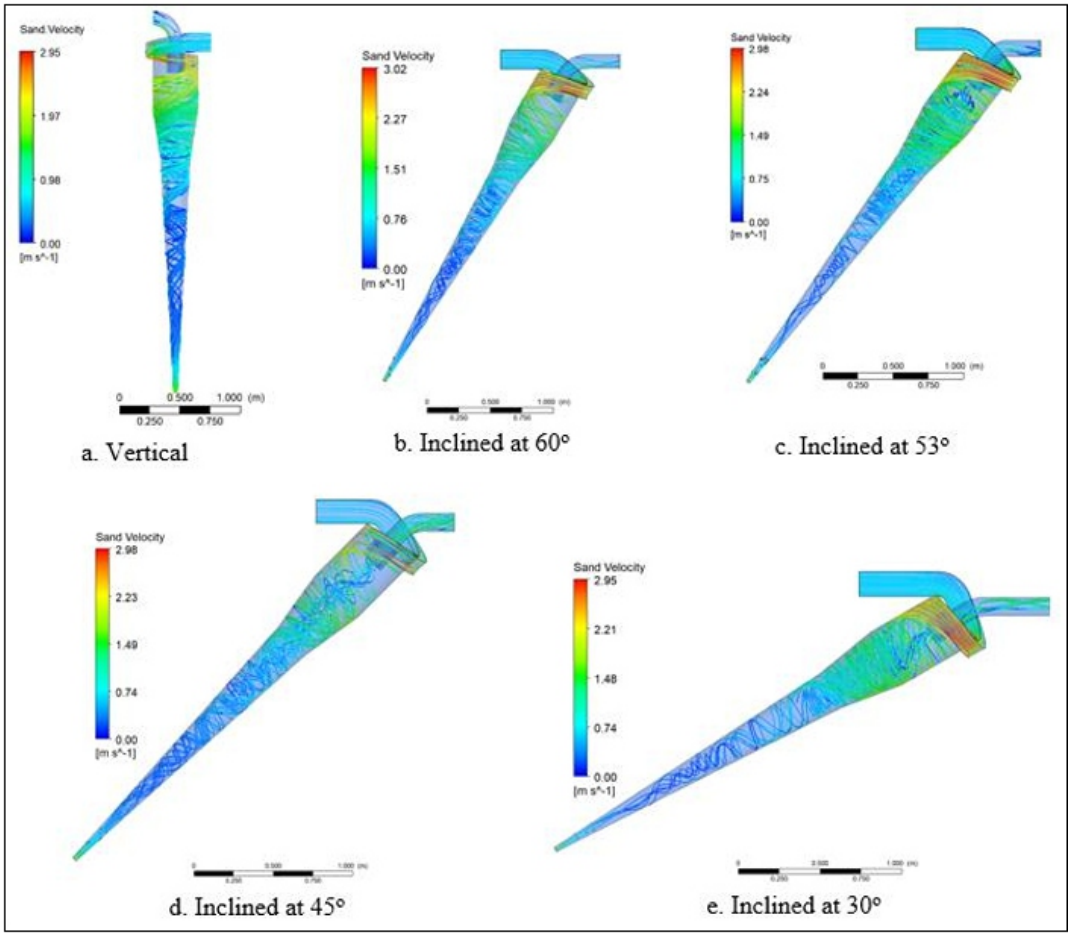

Fig 7: Velocity streamline of sediment for different inclination of device

The headloss in the device at different orientation of its axis is shown in Table 5. It is observed that as the device is inclined from 90o to 30o towards horizontal, the headloss in the device is reduced by around 0.071 m. This decrease in headloss is desirable, however it comes with the cost of reduced trapping efficiency, particularly for very fine sediments.

Table 5: Headloss in device at different inclination of device for discharge of 16.60 l/s

Angle of inclination with horizontal	90°	60°	53°	45°	30°
Headloss (m)	0.758	0.709	0.702	0.695	0.687

Conclusion

In this study, the comprehensive study and analysis of axial outlet hydrocyclone has been carried out. The numerical model was first validated with the physical model. The output of numerical model closely

matched with the physical model exhibiting similar water distribution and sediment throughput. The model results were compared both visually and quantitatively. The quantitative assessment involved the utilization of various statistical tools such as Coefficient of Determination (R2), Root Mean Square Error (RMSE) and Percentage Bias (PBIAS), and whose values were determined to be 0.96, 4.407 and -3.40 respectively. Furthermore, a fish hook effect can be observed in Figure 3, which further validates the capability of model to accurately capture the distinct behavior of hydrocyclone device. Further the device's hydraulic performance was studied by analyzing various velocity profiles and headloss within the device. The tangential velocity, vital for sediment separation, increases from the central axis to the walls due to centrifugal force. Axial velocity moves downward near the outer wall and upward near the core, while radial velocity peaks at the outer wall and decreases towards the center. The observed velocity profiles matched with the typical velocity profiles inside the hydrocyclone device. A headloss of approximately 0.76 m was observed for a discharge of just 16.60 l/s. Lastly the device's performance was assessed under different angle of inclination of its axis at 60o, 53o, 45o, and 30o with horizontal. The results showed that while adjusting the device's axis from vertical to 30o to horizontal, a reduction in headloss was observed by 0.071 m. This decline in headloss is desirable, however it comes at the cost of lowered sediment separation efficiency, especially for very fine sediments.

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