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# **Status of Environmental Impact Assessment Projects in Nepal**

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## **Abstract**

Since the enforcement of Environment Protection Act (EPA) and Environment Protection Regulation (EPR), a total of 237 Environmental Impact Assessment (EIA) projects have been approved. Status of those projects is still largely unknown. Based on desktop study and field verification, this study describes the status of EIA projects in terms of sector, administrative boundary, year and progress. Study showed that, in Nepal maximum number of EIA are related to water resources and energy sector followed by road and forest while minimum number is from mining sector. Kathmandu has highest number of projects while five districts namely; Dolpa, Jumla, Rautahat, Saptari, Sarlahi and Syangja have none projects. Last 3 years (2013-2015) were particularly impressive in terms of approved EIA numbers. Out of 237 projects, 36 projects are not started yet, 70 projects are in pre-phase, 24 are in post phase, 67 projects are completed and 40 projects have no data. Study concludes that Nepal is still very much relying on water resources for its development and development is still capital centered.

**Keywords:** Environment Impact Assessment, development, sector

## **1. Introduction**

Acting as a bridge between economic prosperity and environmental sustainability, Environmental Impact Assessment (hereafter called EIA) is considered an integral part of the development projects for which impacts and mitigations are not known or proven. EIA is "the process of identifying, predicting, evaluating and mitigating the biophysical, socio-cultural and other relevant effects of development proposals prior to major decisions being taken and commitments made" (IAIA, 1999). Based on environmental studies and public comments on the likely environmental impacts, EIAs require decision makers to account for environmental values in their decisions (Holder, 2004).

In Nepal, the need of EIA first came into surface during the mid-1980s, when sixth five-year plan (1980-1985) provisioned of EIA for major infrastructure projects (Upreti, 2008). However, prior to mid-1990s, the requirement of EIA was sector specific and was mandatory only for government projects (Bhatt & Khanal, 2009). In the process of internalizing the provision of EIA and Initial Environment Examination (hereafter called IEE), it was made mandatory to prescribed projects after the enforcement of Environment Protection Act (hereafter called EPA) of 1996 and the Environment Protection Regulations (hereafter called EPR) of 1997. The act and regulations endowed the concerned ministries to approve the IEE reports whereas in case of EIA reports, approval shall be done by Ministry of Population and Environment (hereafter called MoPE).

After enforcement of the EPA and EPR up to the end of February 2016, a total of 237 EIA projects have been approved by MoPE, status of which were largely unknown or unexplored. There is not a single research but one which shed light on status of EIA projects per sector, per year and per progress. Upreti in 2008 attempted to cover this gap by enlisting 72 projects which were approved by the end of October 2007 (Upreti, 2008). Status study not only helps to trace the progress of projects but also tells the trend, development orientation and spatial distribution of development projects.

Studying the status of IEE projects and drawing the gaps in EIA approach is beyond the scope of this paper. This work only focuses on studying the status of 237 EIA projects which were

approved up to the end of February 2016. Status not only confined in terms of progress, but includes also yearly, sectorial and spatially distribution of EIA.

## 2. Methodology

This study is mainly based on desktop study. All the EIA reports available from MoPE and Department of Environment (hereafter called DoEnv) were studied to study the proposed time scale, concerned agency, project location and approval date. Proponent detailed address was taken from the report and necessary arrangements were made to contact the proponent. Also, all the available monitoring reports from MoPE, DoEnv and the concerned ministries were studied to enrich the implementation status. Based on the available EIA reports concerned ministries, departments, central level offices and project contact offices were visited to collect the monitoring reports, feedbacks, information exchange and study the progress.

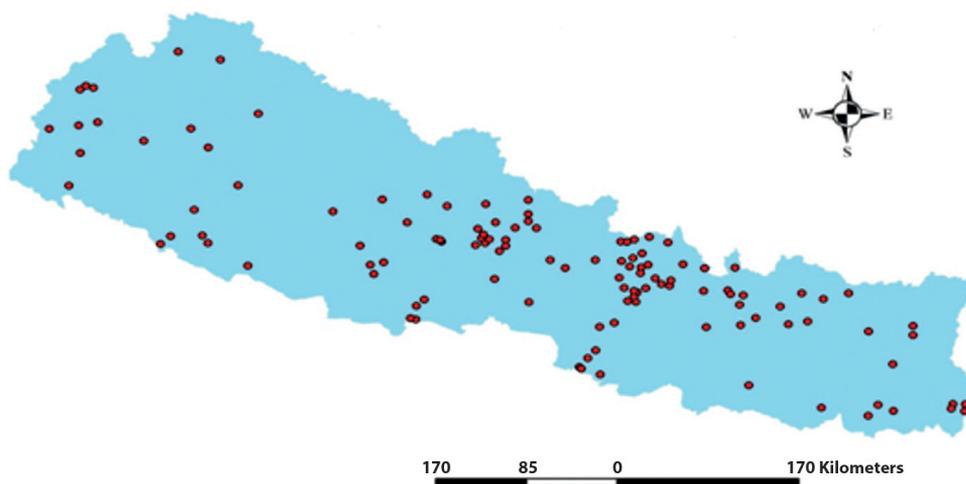
ArcMap 9.0 was used to prepare all the maps. Since the coordinates, given in the EIA reports were in different datums and different formats, all the coordinates point were extracted based on the project location (VDC level). Based on the VDC boundary, centroid points were extracted and those were considered the project location within that particular VDC. For the line projects, arbitrary lines were drawn just to show the districts it covered.

## 3. Results and Discussions

### 3.1 Sectorial EIA Projects

EPR, 1997 categorize the EIA projects in 11 different sectors. Out of 237 EIA projects approved by MoPE (Fig. 1) this article differentiates the EIA projects in 11 sectors based on concerned governmental agencies and work scope of the EIA project. Spatial distribution of EIA projects indicate the concentration of major projects in Central Nepal followed by Eastern Nepal whereas there is least number of EIA projects in West Nepal. Dissect the map vertically and there emerges the clear picture of major focus of work on Hilly and Mountain areas, which is mainly due to hydropower related projects.

Figure 1: EIA Projects approved (till 2016 Feb.) in Nepal



Based on 11 sectors differentiated by EPR, sectorial maps were prepared (Fig.2). Forest sector (Fig. 2a) covers maximum of the districts mainly concentrated in Western Nepal excluding Western mountains. This is mainly due to projects related to collection of Resin in Hills and processing of resins in southern plains (Terai). There are 20 EIA projects approved related to forest sector (Fig.3). Industrial sector (Fig. 2b) are spatially distributed in Terai region and districts adjoined to Kathmandu (Dhading, Chitwan and Makwanpur). There are 16 EIA projects related to this sector (Fig. 3). Only 3 projects related to mining sector (Fig. 2c) are approved since the enforcement of EPA and EPR which are in Arghakhanchi, Makwanpur and Rupandehi. A total of 22 projects are related to road sector (Fig. 3) mainly focused in Eastern and Central Nepal. None but two (Bhurigaun-Telpani-Surkhet road and Hilsa-Simikot road) are located in Western Nepal (Fig. 2d). All but one project (Makwanpur) related to building and urban planning are centered in Kathmandu valley (8 in Kathmandu and 7 in Lalitpur). Inference from EIA projects show that water resources and energy is the sector which is most sought after in Nepal. 118 projects related to this sector have been approved till 2016 February (Fig. 3). For the sake of convenience, this study divided water resources and energy sector into 3 sub-sectors; hydro-electricity, transmission line and irrigation. Hydro-electric projects are centered in Mountains and Hills which is logical given the water resources and topographical slope required for generating electricity (Fig. 2f1). kaski, Rasuwa, Lamjung, Solukhumbu and Sindhupalchok are the top 5 districts which shows the great hydro-electric potential (14,13,8,8 and 7 number of projects respectively). Transmission line projects (Fig. 2f2) follows the same trend as that of hydro-electric except that there is no projects in Eastern Nepal notably Solukhumbu which have 8 hydro-electric project. Interestingly, irrigation related projects are only located in western Terai (Fig. 2f3). 5 major irrigation projects have been approved so far. Fattepur irrigation in Banke, Sikta irrigation in Banke, Mahakali irrigation in Kailali and Kanchanpur, Babai irrigation and Babai river siphon in Bardiya and Badkapath irrigation in Dang. As Eastern Nepal received more precipitation than west, it might be the case that western Terai needs more irrigation.

10 projects related to tourism sector covers 6 districts (Fig 2g). Of the 10 projects, 3 are airport related, 4 are hotel and hospitality related and 3 are ecotourism related. There are 5 projects related to drinking water sector, out of which 2 are in Kathmandu and 1 each in Kavrepalanchowk, Sindhupalchok, Kaski and Surkhet (Fig 2h). 6 number of waste management related projects are approved covering 5 districts (Fig 2i). It's interesting to note that except for Kathmandu, other metropolitan or sub-metropolitan cities which have highest population density, doesn't have drinking water and waste management related EIA project. One might be compelled to think, if these two requirements haven't still made mandatory criteria for declaring metropolitan cities. There are 4 agriculture related EIA projects (Fig 2j), all but one are agro-chemicals or pesticides related. One is related to manufacture of animal feed. As expected, all projects are located in Terai, which is agriculture pocket area. For an agriculture country, this number might seem discouraging, but as proposed by EPR, for this sector, almost all work can be done through IEE. Health sector has 17 EIA projects approved so far covering 10 districts. Distribution of hospitals related EIA shows that locations are chosen either based on population (Kathmandu and Pokhara) or accessibility (Terai region). There is not a single project in hills (except Pokhara) and mountains. Out of these 17 projects, almost half of them (7 in number) are based in Kathmandu valley (Fig 2k).

**Figure 2: EIA status (Sectorial) in Nepal: (a) Forest (b) Industrial (c) Mining (d) Road (e) Building and Urban Planning (f) Hydro-electricity (f) 2 Transmission Line (f) 3 Irrigation (g) Tourism (h) Drinking water (i) Waste management (j) Agriculture and (k) Health. The numbers in the maps indicate number of projects in district. Lines drawn (d and f2) are arbitrary lines to indicate districts covered.**

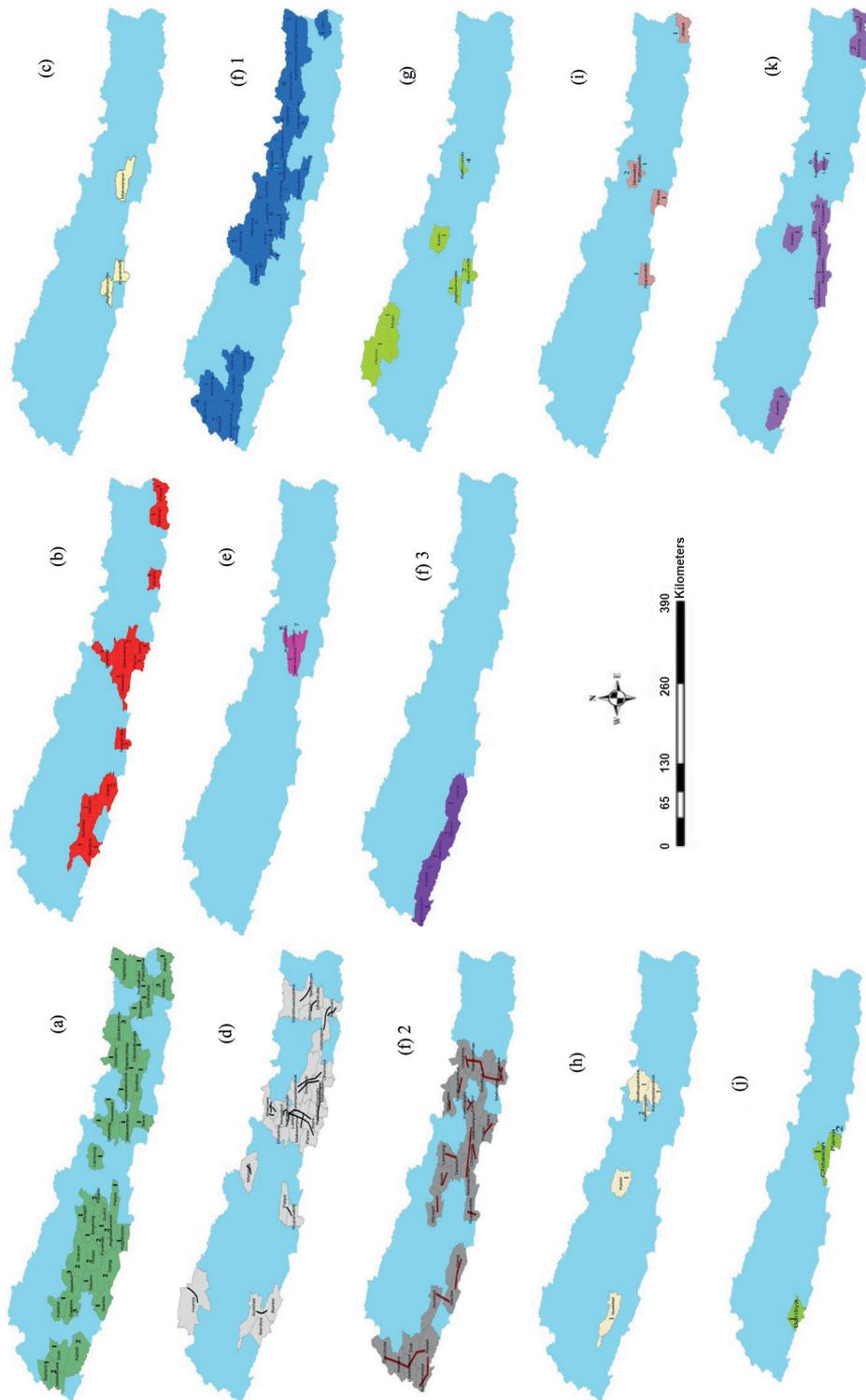
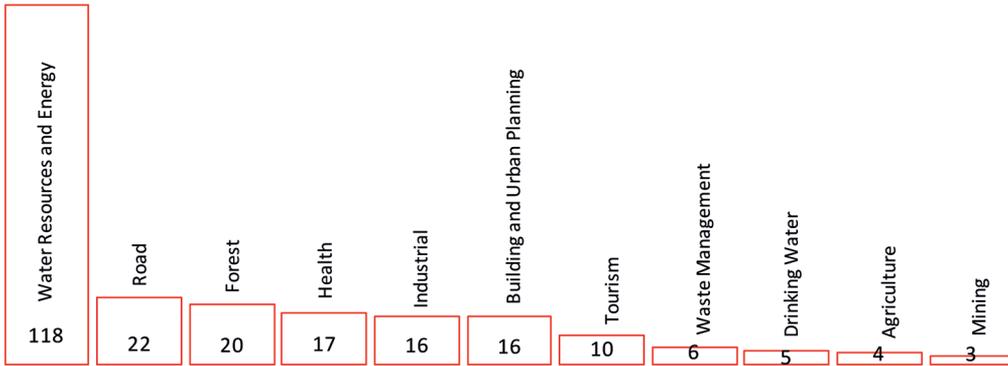


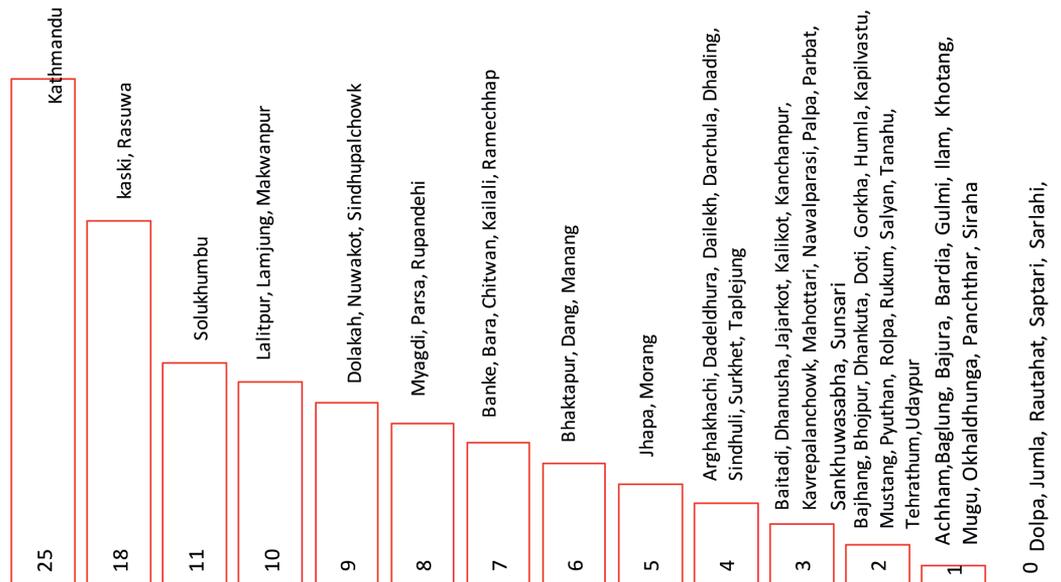
Figure 3: Number of Sectorial EIA in Nepal



### 3.2 Number of EIA projects (District)

25 projects are located in Kathmandu, maximum of which are housing projects and hospitals. As seen from Figure 3, maximum numbers of EIA projects are from water resources, which is why districts like Kaski, Rasuwa, Solukhumbu, Lamjung, Dolakha, Sindhupalchowk, Myagdi, Manang and Ramechhap has higher number of projects (Fig 4). Many district made their way into the list because of the forest related projects, mainly resin collection which covers more than one district. 6 districts namely: Dolpa, Jumla, Rautahat, Saptari, Sarlahi and Syangja has none EIA projects.

Figure 4: Approved EIA projects per district

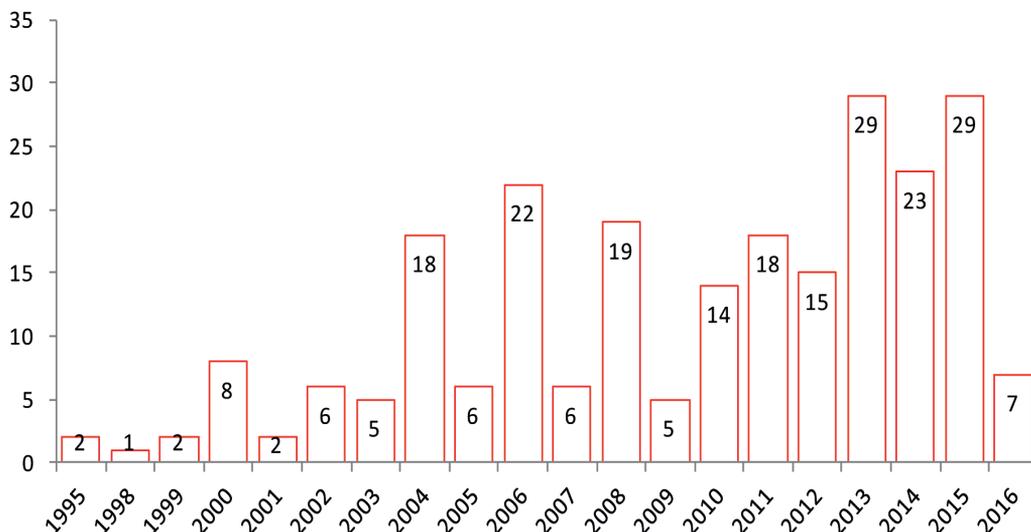


### 3.3 Approved EIA projects (Year)

Before EPA and EPR, 2 projects which had detailed environment assessment (harvesting leafy biomass of *Taxus baccata* and Upper Bhotekoshi Hydropower) are included in this study. After

the administration of EPA/EPR in 1997, 11 projects were approved in first 3 years. Year 2004, 2006 and 2008 had 18, 22 and 19 projects approved respectively (Fig 5). Last 3 years (2013-2015) were particularly impressive in terms of approved number of EIA projects. Last 3 years collectively had 81 number of EIA projects which got environment clearance.

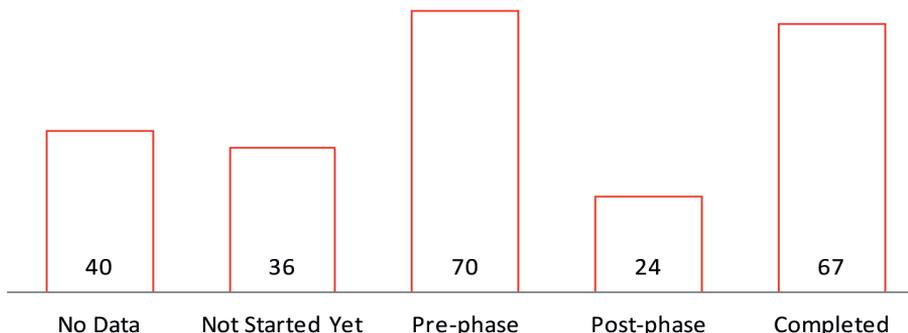
**Figure 5: Approved EIA projects per year**



### 3.4 Status of EIA Projects

Statuses of EIA projects were largely unexplored or unknown in Nepal. There are 3 main reasons behind this (i) lack of information from proponent (ii) lack of law enforcement from concerned ministries (iii) lack of coordination and information sharing among government agencies and (iv) lack of institutional memory. Statuses of some projects are completely unknown, either the projects are terminated or there is no institutional memory.

**Figure 6: Progress status of EIA Projects**

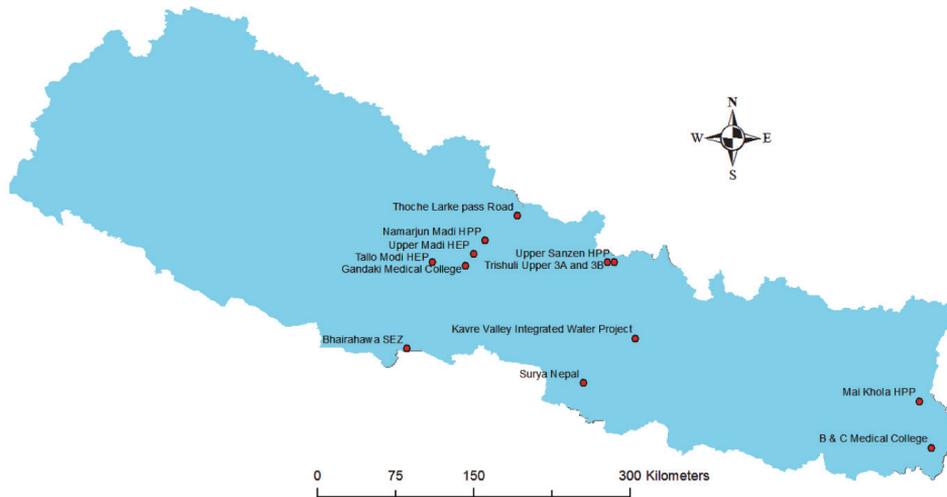


The study couldn't trace the progress of 40 EIA projects (Fig 6). 36 projects are not yet started. 70 projects are in the pre-phase stage and 24 are in post-phase stage (Pre-phase  $\leq$  50 percent progress and post-phase  $\geq$  50 percent progress). Out of 237 projects, 67 are completed so far.

### 3.5 Monitored and Examined EIA Projects

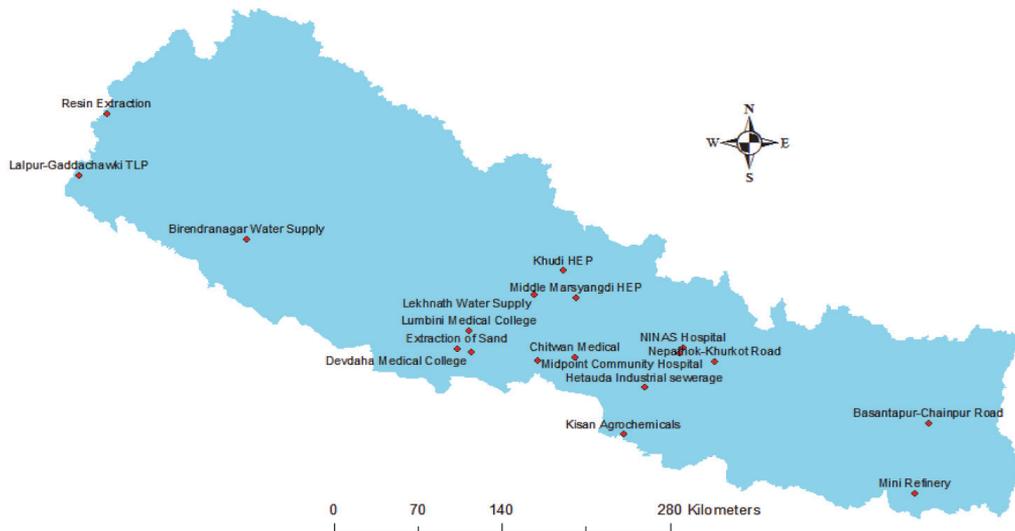
To check whether projects are complying with environmental standards and going according to the approved environment management plan, EIA projects are monitored on the need basis. Since its establishment in 2013, DoEnv has been monitoring the EIA projects and submitting its recommendations, suggestions and measurements to be taken. So far, DoEnv has monitored 12 projects, most of which are hydropower related (Fig 7).

Figure 7: Projects monitored by Department of Environment



EPA and EPR provisioned for EIA Examination which states that, after the project has been in operation for at least two years, MoPE may conduct an examination (sometimes called audit) to determine whether or not the compliance conditions have been fulfilled. So far, DoEnv has examined 18 EIA projects covering varied sectors (Fig 8).

Figure 8: Projects examined by Department of Environment



#### **4. Conclusion and Recommendations**

With the enforcement of EPA and EPR in 1997, opportunity for the involvement of stakeholders in the process has increased, which certainly increased the credibility of the EIA. However, due to lack of accredited system for experts and consulting firms, the benefits of EIA tools have been largely diluted. With the wider acceptance of EIA tools, the number of EIA projects shows generally the increasing trends, particularly last 3-4 years. Spatially, Western Nepal is still deprived of EIA projects. It seems either the tourism and hydropower potential of this region is still largely unexplored or largely neglected. Southern plains (mainly Terai) which is easily accessible and topographically suitable has very few EIA projects comparing to Northern parts (Mountains) which is remote. This shows that, Nepal is still very much relying for its development on hydropower projects. Industrial and Mining EIA are quite a few. Analyzing the number of EIA projects per district, it can be safely said that, development is still centered round the capital. Kathmandu tops this list with 25 projects. The progress report of EIA projects is not as per expectation, as only 28% of the projects (67 out of 237) are completed so far.

Based on the study findings and observations, following recommendations have been made;

**Make proponent responsible:** Tracing the environment monitoring report tells that, proponent show their back once the EIA is approved. Generally, it is proponent's responsibility to inform the concerned agencies regarding the milestones in projects. Proponents should be made responsible for informing back to MoPE.

**Ownership of EIA report:** EIA reports are prepared by consultants. Many proponents (especially government agencies) don't even know the content which resulted in entire omission or negligence of the EIA findings and recommendation. Agencies must own the report and act accordingly.

**Accredit the experts:** MoPE should start the process of accrediting the experts and consulting firms to prepare the EIA report. Thriving "copy and paste" method is reducing the quality of EIA report. In some reports, even the year of EIA preparation and coordinates were found to be taken from other project.

#### **Acknowledgement**

The author is thankful to staffs of MoPE and DoENV. Special thanks to Mr. Prakash Sigdel and Mr. Bhupendra Sharma, environment inspector, DoENV for their contribution to the original report.

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## **Environmental Impact Assessment: Provision, Process and Problems in Nepal**

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### **Abstract:**

Environmental Impact Assessment is a legal provision under the Environment Protection Act, 2053 and Environment Protection Rules, 2054 in order to keep the balance between development and environment. EIA follows a process according to EPA and EPR. Ministry of Population and Environment is responsible for approving EIA. Delay in the approval of EIA report and ensuring the compliance of mitigation measures to the environmental impacts are the major problems associated with EIA process. Preparation of quality report with the incorporation of suggestions from the multidisciplinary review team of the MoPE and timely approval as well as monitoring and environmental examination will guarantee the objective of EIA.

**Key words:** Ministry of Population and Environment, Department of Environment, Monitoring, Environmental Examination

### **1. Introduction**

Environmental Impact assessment (EIA) is both a planning tool and a mechanism for decision making (NCSIP, 1994). EIA is one of the proven tools of facilitation to achieve the goal of environmentally and socially sound and sustainable development. USA was the first country to assign mandatory status to EIA under its National Environmental Policy Act (NEPA) of 1969. Since then (1970s), the concept of Environmental Impact has spread throughout other countries (Gilpin, 1995, Groom et al., 2006).

In the past EIAs were conducted for individual development proposals, usually at the initiative of bilateral and multilateral donors according to their own policies. National Conservation Strategy, 1987 recognized the urgent need of the adoption of EIA. In 1982, Nepal established the Environmental Impact Study project (EISP) under the Ministry of Forests and Soil Conservation to initiate the activities for the formulation of necessary policies and laws and create public awareness on the environmental matters (Uprety, 2003). It also carried out EA of some projects. National EIA Guidelines, 1993, EIA Guidelines for the Forestry Sector, 1995 and EIA Guidelines for the Industry Sector, 1995 were also the important steps in the development of EIA system in Nepal

This paper elaborates the EIA legal provisions and processes associated with this in Nepal. Present issues and problems associated with it have been pointed and possible solutions to overcome the problems have been recommended.

### **2. Methodology**

Literature review and subjective analysis of the collected information has been carried out. Environment Protection Act, 2053 (1997) and Environment Protection Rules, 2054 (1997) are the major source of reviewing EIA provision and process. Personal experience is also a source of knowledge for this topic.

### **3. Results and Discussion**

#### **3.1 EIA Provision and Process**

Environment Protection Act (EPA), 2053 (1997) has made the provision of carrying out Initial Environmental Examination (IEE) and Environmental Impact Assessment of the proposal

prepared to carry out development work, physical activity that may bring change in the existing environmental conditions or any plan, project or program which changes the land uses. It defines EIA as a report on detailed study and evaluation (analytical study or evaluation in case of IEE) to be prepared to ascertain as to whether, in implementing a proposal, the proposal does have significant adverse impacts on the environment or not, whether such impacts could be avoided or mitigated by any means or not. IEE and/or EIA are the project level environmental assessment (EA). Therefore, the term environmental assessment can be used to represent both IEE and EIA. EIA is also simply used to tell both these IEE and EIA.

Fifth amendment of EPR (published in Nepal Gazette of 2073 Magh 17 i. e. January 30, 2017) has made the provision of supplementary EIA. This is the EIA carried out again if there is any partial change in the physical infrastructure, design or outline, replacement or change of structure, addition of forest area or project capacity of the EIA approved proposal.

### **3.1.1 Screening**

It is the first step of EA process and helps in determining whether or not a proposal requires an EA (Uprety, 2003). Major Benefits of screening are time and money saving, immediately identifying the potential environmental impacts at generic level and establishing the need for required level of EAs (Khadka, 1996). Environmental Protection Rule (EPR), 2054 (1997), Schedule-1 (Pertaining to Rule 3) includes proposals requiring Initial Environmental Examination (IEE) and Schedule-2 (Pertaining to Rule 3) includes proposals requiring Environmental Impact Assessment (EIA). In general small scale project proposals require IEE and large scale project proposals require EIA.

### **3.1.2 Scoping and Terms of Reference**

Scoping is a procedure for determining the extent of and the approach to an EIA. It involves the involvement of relevant authorities, interested parties and affected groups, identification of relevant or significant issues to be examined, identification and selection of alternatives and determination of the ToR for further study. ToR provides guidance to the proponent and/or consultant for the preparation of EA report of the desired quality. EPR 1997 requires approval of ToR before carrying out EAs.

ToR should be prepared by the proponent in the format of Schedule 3 of EPR 1997, and submit to the concerned agency for approval before carrying out IEE. Scoping document is not required for IEE but required for EIA. Hence, ToR can be submitted after the submission of Scoping or can be submitted together in case of EIA. Schedule 4 of EPR 1997 mentions the format of ToR for EIA.

For the scoping purpose 15 days' public notice is published in the national daily newspaper by the proponent and comments and suggestions received are incorporated in the scoping report. Scoping and ToR reports are submitted to MoPE through the concerned Ministry. MoPE determines the Scoping and approves the ToR.

### **3.1.3 Report Preparation**

IEE and EIA reports are prepared based on the approved ToR. EPR 1997 includes Schedule 5 and 6 to provide guidance to the proponent for the preparation of IEE and EIA reports respectively. Field study is carried out to gather the baseline information. In case of IEE, after preparation of the draft IEE report, 15 days' public notice is published in national daily newspaper in order to gather the public opinion regarding the implementation of the project. Comments and suggestions received from the stakeholders are also incorporated in the report.

In case of EIA, proponents need to carry out the public hearing in the project affected area to gather the public view and incorporate in the reports. Similarly, recommendations of the local bodies are also necessary to incorporate in the report.

### **3.1.4 Report Approval**

After the preparation of reports, these are submitted to concerned ministry in certain numbers. IEE reports are approved by the concerned ministry (for example, IEE of hospital by the Ministry of Health) and EIA reports by the Ministry of Population and Environment (MoPE). In case of EIA after getting the EIA reports by the concerned ministry, these should be send to MoPE with their opinion within 21 days. Then, MoPE publishes the public notice in national daily newspaper to get the public opinion within 30 days. In addition to that, MoPE forms a review committee to comment and suggest on EIA report. After incorporating the comments and suggestions of the committee, if the project will not have the significant environmental impacts, then MoPE should approve the report within 60 days. It may take 30 more days to approve if not approved within 60 days. Although there is a provision of approving the reports within certain time frame, there is a public concern in delay of the report approval.

### **3.1.5 Monitoring and Evaluation**

Environmental Monitoring is one of the most important components of an EIA. It is essential for ensuring that impacts do not exceed the established legal standards, checking the implementation of mitigation measures in the manner described in the EIA report and providing early warnings of potential environmental damage (HMG/IUCN 1993). Monitoring also provides inputs for Environmental Auditing (Khadka, 1996; Uprety 2003).

Implementation of the mitigation and enhancement measures proposed in the approved reports are monitored by the concerned ministry. While carrying out the monitoring and evaluation, if the environmental impacts are found more than the predicted in the reports, concerned ministry may direct the proponent to reduce and avoid such impacts. That direction should be informed to MoPE. This provision helps to make the mitigation measures implemented.

### **3.1.6 Environmental Examination**

Two years after the implementation of a proposal requiring an EIA, MoPE, shall carry out an environmental examination of the environmental impact of the implementation of the proposal and the measures adopted for reducing such impact etc. and maintain updated records thereof. This right of MoPE has been transferred to Department of Environment (DoEnv) under the MoPE. Therefore, DoEnv is involved in this process.

### **3.1.7 Special Provision**

Fourth amendment of EPR (published in Nepal Gazette of 2073 Baisakh 13 B S i. e. April 25, 2016) has made the special provision of the time duration required for scoping, report preparation and approval of the proposals related to national pride projects; projects related to national disaster or natural hazard management; or plan, project or program designated by GoN for immediate implementation. It has reduced the time duration for the scoping public notice (7 days), concerned ministry's opinion (5 days), MoPE's public notice publication (7 days), providing view and suggestion (10 days) and the approval of the report (20 days) for such projects. With these special provisions, it has been expected to reduce the delay in the EIA approval process.

### 3.2 Major Stakeholders

Major stakeholders involved in IEE and EIA processes are:

- Proponent
- Consultancy/Consultant
- Donor agencies
- Project affected community, family or individual
- Local bodies
- Schools, hospitals, health posts and concerned individuals or institutions of the area
- Government Agencies related to proposal
- Concerned Ministry related to proposal
- Ministry of Population and Environment
- Department of Environment

### 3.3 Issues and Problems

Some of the issues and problems associated with the EA are as below.

- Proponents think EA as an economic burden and project delaying agent. They simply take it as following the legal measures and getting approval from the concerned agencies.
- EA process is not considered during the project planning. It is done after the planning of project even during the implementation and after implementation of the project.
- Lack of sufficient baseline study before the implementation of the project making it difficult to evaluate the impacts of project implementation.
- Mitigation measures for the environmental impacts proposed in the EA reports are not implemented effectively.
- EA reports are prepared through consultancy service and therefore project proponents may be unknown about the mitigation measures proposed in those reports.
- Lack of monitoring by the concerned ministry regarding the implementation of mitigation measures proposed in the approved report.
- Inadequate field study.
- Quality of the reports.
- Delay in the approval of the reports.
- Effectiveness of environmental examination.
- No recruitment of environmental professional by the ministries approving the IEE/EIA reports.
- No database of the approved IEE and EIA reports and difficulty of finding these reports during environmental monitoring and environmental examination.
- Preference of IEE rather than EIA by the proponents considering the time and cost factor.

## 4. Conclusion and Recommendations

EIA is a tool for achieving sustainable development. Considering the environmental concerns of the development works, Nepal has made the provision of carrying out IEE and EIA through EPA and EPR in 1997. MoPE approves the EIA and concerned ministries related to the project proposals approve IEE following the processes according to EPA and EPR. Quality report, time duration for

the approval of the reports and implementation of the mitigation measures proposed in the reports are the major issues associated with this process.

Based on the issues and problems above, following recommendations have been made.

- Recruitment of Environment Inspector by each Ministry approving IEE including MoPE responsible for approving EIA.
- Regular Monitoring to check the compliance of the commitments of the approved reports.
- EA should be integrated during the economic assessment of the project.
- Provision of license to the professionals involved in EA study and report preparation.
- Making the consultancy service accountable to their reports.
- Compulsory provision of the Environmental Inspector in the review committee of the draft IEE and EIA reports.
- EA system should be result oriented rather than process oriented.
- Database of the approved IEE and EIA reports should be established.
- Provision of punishment mechanism even after the environmental examination if the proposed mitigation measures are not found implemented.

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## Environmental Auditing in Nepal: Status and Challenges

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### Abstract

Environmental auditing has been an integral part of development projects. Environmental auditing has been implemented to check on existing practices, evaluating the current activities from environmental point of view. Although this is done basically to check whether the parameters mentioned in approved project documents complies with the real practices or not, it has much broader scope lying ahead. Environmental auditing outcomes have been goodwill to many organizations. In Nepal, the concept of environmental auditing is new and environmental auditing of very few organizations have been executed. Authority of environmental auditing is provided by law and department of environment is only competent authority to carry out environmental auditing. Till date, environmental auditing of 16 development projects have been completed by department of environment and many problems and challenges have been faced in short duration. Majority of the project parameters (49.5%) have not been complied and this have been a point to be improved. There are different reasons to non-compliance of the parameters and these reasons should be managed to get better results in future.

**Keywords:** Environmental auditing, Environmental Impact Assessment, Department of Environment, Environment Protection Rule

### 1. Introduction

Environmental auditing is essentially an environmental management tool for measuring the effect of certain activities on the environment against set criteria or standard. Environmental auditing is carried out when a development is already in place, and is used to check on existing practices, assessing the environmental effects of current activities (SOAS, 2014). Environmental auditing therefore provides a ‘snap-shot’ of looking at what is happening at that point in time in an organization (SOAS, 2014). It was also regarded as an activity used for avoiding prosecution or civil lawsuits under the increasing pressure from environmental legislation.

Environmental audit is currently at a crucial stage in its development as a discipline (Maltby, 1995). What has yet to be formed is a consensus among practitioners, clients, legislators and users of environmental information about the purpose of the audit, and consequently about the form that it should take (Maltby, 1995).

Environmental auditing began in the early 1970s when a handful of industrial companies, working independently and on their own initiatives, developed environmental auditing programs as internal management tools to help review and evaluate the status of the company’s operating units. It enabled managers to check compliance with (i) local environmental laws & regulations (ii) National environmental laws & regulations (iii) Corporate Policies. (SOAS, 2014)

Environmental auditing originated in the United States in the 1970s as a way of checking whether a company was complying with the multitude of new environmental laws and regulations (Jamtsho, 2005).

Environmental concern rarely formed as integral part of development plans, particularly in third world countries (Augustine et. al. 2013). Environmental issues are now at the vanguard of international and domestic as well as local government’s agenda (Augustine et. al. 2013).

Environmental auditing is not a particularly new discipline; however its popularity as a means of assessing environmental performance has recently increased dramatically (Welford, 2002; Augustine et. al. 2013). Environmental audit is a periodic, systematic, documented object review by regulated entities of facility operations and practices to assure meeting environmental requirements (EPA, 1997). It is the post project assessment of actual environmental impacts, the accuracy of impact prediction, effectiveness of impact mitigation / benefit enhancement measures and functioning of monitoring mechanism (Manandhar, 2013). As per Environmental Protection Regulation (EPR), 1997 environmental audit is carried out once for each project after two years of commencement of project operation. Previously, it was the authority of Ministry of Population and Environment (MoPE) but ministry has delegated the authority to Department of Environment.

Till date, EIA of 263 projects have been approved by the Ministry of Population and Environment (MoPE). The projects are classified in 12 sectors in accordance with Environment Protection Rules, 2054. The projects have separate threshold level according to their type and nature. So, the audit measures are also different for the projects under observation.

## 2. Methodology

Checklists, Key informant interviews and Focal Group Discussion are also found to be used in audit (Gani, 2013). Primary and secondary information were collected and analyzed in the study. Primary data were collected by the audit team and secondary data were collected via previous audit reports in the Department of Environment. The audit team visited the project to be audited and collected necessary information. Checklists were prepared in accordance with the approved Environmental Impact Assessment (EIA) report and the project was analyzed in accordance with the parameters complied by the project.

## 3. Results and discussion

Environmental auditing of 16 projects has been completed by Department of Environment. The number of projects to be audited is determined in approved annual program endorsed by ministry of population and environment. So, 6 projects were audited in FY 2070/71. Similarly, 5 and 6 projects were audited by FY 2071/72 and 2072/73 respectively. Out of total 11 sectors listed in EPR, sector with maximum no. of audited project was health sector. Environmental auditing of 6 projects from health sectors haven been completed. Figure 1 indicate that no any environmental auditing from Residential, Renewable Energy, Tourism, SWM sector and Agriculture sector have been done. This is because very few EIA reports from these sectors have been approved from Ministry of Population and Environment.

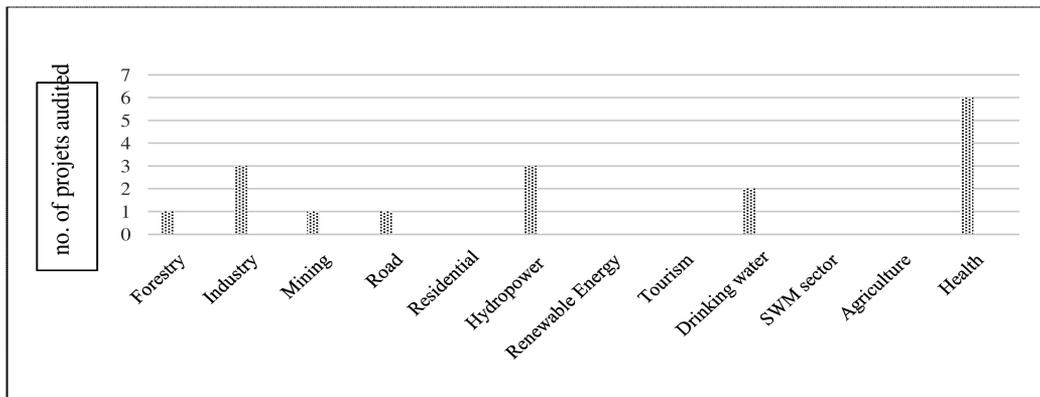


Figure 1: Sector wise status of Environmental auditing in Nepal

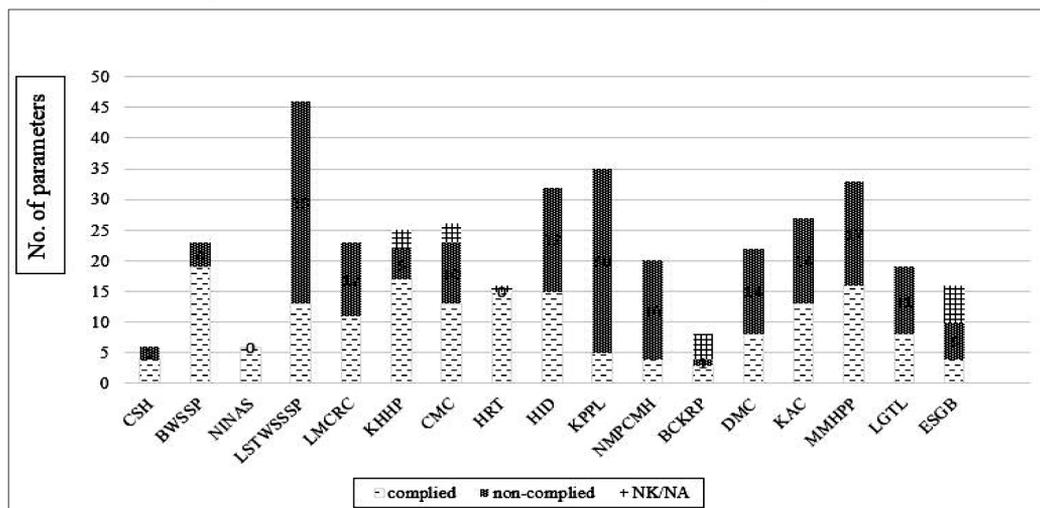


Figure 2: Status of compliance of parameters in audited projects by DoEnv

Moreover, projects to be audited is determined by the availability of the approved EIA report in the ministry and time duration of the project commencement. According to Environment Protection Rules, 1997, “two years after the commencement of service, distribution and production relating to the implementation of a proposal requiring an environmental impact assessment, the Ministry, shall carry out an environmental examination of the environmental impact of the implementation of the proposal and the measures adopted for reducing such impact etc. and maintain updated records thereof”. So, to know whether a project has completed two year time duration providing service and production is being a very difficult task. Similarly, not all the sectors listed in Environmental Protection Rules have been eligible to carry out EIA. So, to do environmental auditing of all the sectors has not been possible.

Similarly, a total of 388 parameters have been considered and audited by audit team (Figure 2). Out of these, 174 (44.8%) parameters were found complied whereas 192(49.5%) parameters were not found complied. Similarly, status of 22 (5.7%) parameters were not known. This shows the fact that majority of the parameters were not complied by the concerned stakeholders. There may be various reasons for that. Lack of knowledge on environmental issues, lack of relevant equipment to fulfill environmental provision, lack of financial resources are some of the reasons of non-compliance of environmental parameters mentioned in approved EIA reports.

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Annex 1: Individual project and its compliance status

| S.N.              | Name of the project   | Total Parameters listed in EIA report | Compliance (C) | Non-Compliance (NC) | NK/NA |
|-------------------|---|---------------------------------------|----------------|---------------------|-------|
| <b>FY 2070/71</b> |   |                                       |                |                     |       |
| 1.                | Civil Hospital  | 6                                     | 4              | 2                   | -     |
| 2.                | Birendranagar Water supply and Sanitation Project   | 23                                    | 19             | 4                   | -     |
| 3.                | National Institute of Neurological and Allie Sciences   | 6                                     | 6              | 0                   | -     |
| 4.                | Lekhnath Town Small Water Supply & Sanitation Project   | 51                                    | 13             | 33                  | 5     |
| 5.                | Lumbini Medical College and Research Centre Pvt. Ltd.   | 23                                    | 11             | 12                  | -     |
| 6.                | Khudi Hydropower Project  | 25                                    | 17             | 5                   | 3     |
| <b>FY 2071/72</b> |   |                                       |                |                     |       |
| 1.                | Chitwan School of Medical Sciences  | 26                                    | 13             | 10                  | 3     |
| 2.                | Hetauda Industrial Area, Sewerage & Drainage , WWTP   | 32                                    | 15             | 17                  | -     |
| 3.                | Mini Refinery (Petroleum Products Manufacturing Industry)   | 35                                    | 5              | 30                  | -     |
| 4.                | Proposed Nepal Mid-point Community Memorial Hospital  | 20                                    | 4              | 16                  | -     |
| 5.                | Collection of Khote sallo in Baitadi district (Shree Himal Rosin & Terpentine Prasodhan Pvt. Ltd) | 16                                    | 15             | 0                   | 1     |

| S.N.              | Name of the project  | Total Parameters listed in EIA report | Compliance (C) | Non-Compliance (NC) | NK/NA |
|-------------------|--|---------------------------------------|----------------|---------------------|-------|
| <b>FY 2072/73</b> |  |                                       |                |                     |       |
| 1.                | Basantapur-Chainpur-Khandbari Road Project   | 8                                     | 3              | 1                   | 4     |
| 2.                | Devdaha Medical College and Research Institute   | 22                                    | 8              | 14                  | -     |
| 3.                | Kishan Agro-chemicals  | 27                                    | 13             | 14                  | -     |
| 4.                | Middle Marsyangdi Hydro-power Project  | 33                                    | 16             | 17                  | -     |
| 5.                | Lalpur- Gaddachowki 132 KV Transmission Line Project   | 19                                    | 8              | 11                  |       |
| 6.                | Sustainable extraction of boulders, aggregate and sand from Tinau, danab, kanchan & Rohini rivers (Rupandehi ) | 16                                    | 4              | 6                   | 6     |

## **Heavy Metals in Fine Particle Size Fractions from Roadside Dust of Kathmandu Metropolitan City: A Potential Urban Environmental Problem**

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### **Abstract**

Heavy metals in fine particle size fractions from roadside dust of Kathmandu Metropolitan City are increasingly becoming an urban environmental issue of health concern. A total of 33 roadside dust samples were collected from 11 sites including control that represented different domain activities across the city. Four heavy metals (Cd, Cu, Pb and Zn) were analyzed for their concentrations in dust of the fractionated three fine particle sizes (150-75, 75-38 and <38  $\mu\text{m}$ ) using Atomic Absorption Spectrophotometer. Fractionation of dust revealed that size fraction of 75-38  $\mu\text{m}$  showed comparatively higher portion of dust in all sampling sites. Metal concentrations indicated that roadside dust contained elevated levels of heavy metals and varied across the city compared to control site. It was found that the concentration of metals in all the three particle size fractions and sampling sites was found to be increased with decrease in their sizes indicating the preferential partitioning of metals in the finest particle size. Further, the results revealed that all particle size fractions from all the sampling sites under investigation were found to have the metal abundance order as  $\text{Zn} > \text{Cu} > \text{Pb} > \text{Cd}$ . The correlation analysis showed the contribution of anthropogenic sources, traffic and industrial emissions, to metal levels in roadside dust in Kathmandu.

**Keywords:** Kathmandu Metropolitan City; Roadside dust; Heavy metals; Particle size fraction, Pollution

### **1. Introduction**

Dust deposited along roadsides so called roadside dust is contaminated by organic matters and heavy metals such as Cd, Pb, Zn, Ni, Cr, Co, Ag, Cu etc. Since metals are non-biodegradable, they remain as persistent environmental contaminants. As a result, they tend to accumulate and increase harmful effects in living organisms (Faiz et al., 2009; Kacálková et al., 2009). Traffic and domestic emissions, construction and demolition activities, weathering of building and pavement surface, atmospheric deposits etc., are anthropogenic sources of heavy metals in urban roadside dust (Lu et al., 2009; Morton-Bermea et al., 2009). It was reported that 5–10% of the allergenicity in California was due to atmospheric total suspended particulate matter attributed by paved road dust emissions (Miguel et al., 1999). Heavy metals, such as Cd and Pb, are non-essential that can be toxic even at trace levels, and biologically essential elements, such as Cu and Zn, which might cause toxic effects at elevated concentrations. Therefore, a high priority has been set on such pollutants for health risk and environment assessment programs (Government of Canada, 2001).

Kathmandu is becoming one of the most polluted cities in the country due to high population density and rapid increase in vehicle quantities (movements) for the past decades. Due to the massive earthquake that hit Kathmandu, Nepal in April 2015, construction and demolition activities across the city are contributing additionally significant emissions of dust in the atmosphere. These

anthropogenic activities have increased the risks for amplifying the exposure of the large urban population to toxic metals via inhalation, ingestion, and dermal contact. However, only limited attention has been given in order to control the inorganic contaminants in roadside dust. Besides, there are very limited literatures in this pertinent area of study with reference to Kathmandu. Hence, the main objective undertaken for the present study was to evaluate the characteristics of four metals; Cd, Cu, Pb and Zn with respect to three fine particle size fractions (150-75  $\mu\text{m}$ , 75-38  $\mu\text{m}$  and <38  $\mu\text{m}$ ) in roadside dusts for characterizing different urban environment in Kathmandu Metropolitan City.

## 2. Methodology

### 2.1 Study area, sample collection and processing

Kathmandu valley that comprises Kathmandu, Lalitpur and Bhaktapur districts of Nepal has a population of more than 2.5 million. Among the three districts, Kathmandu is the only city in the country with the Mahanagar (Metropolitan city) municipal status. The city is densely populated with 20,288 inhabitants per square kilometer. For the present study, ten major locations *viz.*, Balkhu, Sitapaila, Balaju, Gausala, New Baneshwor, Putalisadak, Tripureshwor, Lazimpat, Kalimati, Naikap, and Shivpuri (control) across the city area were selected for dust collection in order to compare the levels of metal contaminations for characterizing the different urban environment. The sampling locations for road dust measurements were based on different domain activities such as traffic load, population density, commercial and other anthropogenic activities. A brief description of the selected locations under investigation is given in Table 1.

**Table 1. Description of sampling locations in Kathmandu Metropolitan city.**

| Site No. | Name of locations | Site description   |
|----------|-------------------|--|
| 1        | Balkhu,           | Heavy traffic, commercial area, densely populated and Ring-road junction                     |
| 2        | Sitapaila         | Heavy traffic load, commercial area, residential, densely populated and Ring-road junction   |
| 3        | Balaju            | Heavy traffic load, commercial, industrial, densely populated and Ring-road junction         |
| 4        | Gausala           | Religious area, heavy traffic load, residential and densely populated and Ring-road junction |
| 5        | New Baneshwor     | Heavy traffic, business complexes, institutions, densely populated and residential area      |
| 6        | Putalisadak       | Traffic load, commercial area, institutions, hospitals, residential and densely populated    |
| 7        | Tripureshwor      | Heavy traffic load, commercial area, hospital, residential and densely populated             |
| 8        | Lazimpat          | Traffic load, commercial area, hotels, residential and densely populated                     |
| 9        | Kalimati          | Traffic load, residential and commercial area, densely populated and market area             |

|    |                    |  |
|----|--------------------|--|
| 10 | Naikap             | Entry to Ring-road and core area of Kathmandu city, Heavy traffic, commercial area and densely populated |
| 11 | Shivpuri (control) | Low traffic load, sparse residential and undisturbed area  |

A total of 33 roadside dust samples (three samples from each location at an interval of 100 m from both sides of roadway) including control were collected during dry season (November 2016) to avoid rain washing out the heavy metals. At each sampling point, approximately 250-500 g of dust particles from an area of 1 x 1 m<sup>2</sup> was collected from the pavement edges with a clean plastic dustpan and a brush. The collected samples were directly transferred to self-sealing polyethylene bags for transport to the laboratory for further analysis. Sampling sites were not selected adjacent to site-specific pollution sources such as industries, gasoline stations, parking lots etc. The selected control site is the area without evidence of past and current anthropogenic activities and no signals of disturbances were observed during the sampling.

## 2.2 Fractionation of dust samples

All the collected samples were dried in a hot air-oven for 24 hr at 105 °C to drive out moisture and sieved through a 2 mm sieve to remove tiny pebbles and other unwanted materials. Then, 100 g of the oven dried bulk samples from each sampling location was passed through a stack of three metal free sieves of different particle sizes (150 µm, 75 µm and 38 µm) to collect dust particles of altogether four different fractions *viz.*, >150 µm, 150-75 µm, 75-38 µm and <38 µm. While percent distribution of dust in each of the four particle fractions were calculated, metals were determined only in dust of fine particle sizes of 150-75 µm, 75-38 µm and <38 µm respectively as these particle sizes are easily re-suspended, transported and can be inhaled through the nose or mouth during breathing (Ferreira-Baptista and De Miguel 2005). The experiment was carried out in triplicate.

## 2.3 Determination of heavy metals (Cd, Cu, Pb and Zn)

For determination of heavy metal concentrations, accurately 0.5 g of dried dust sample of each particle size fraction was digested in 20 ml of freshly prepared aqua-regia (v/v 1:3 HNO<sub>3</sub>:HCl) according to Abdel-Latif and Saleh (2012). The content of the beaker was heated to 100°C, and the temperature was gradually increased to 250°C, and left at this temperature for 30 min. The beaker was cooled and the sample solution was filtered using Whatman filter paper (42). Clear solution was transferred into 50-ml volumetric flask, and the volume was made up to the mark with double-distilled water. Samples were stored in acid (HNO<sub>3</sub>) washed polyethylene bottles at 4°C until analysis. The same process was carried out for all the samples under investigation.

All the standard solutions (1000 ppm) for Cd, Cu, Pb and Zn were certified and obtained from Merck, Germany. These solutions were diluted carefully to the required concentrations with double-distilled water and used for calibration. The content of 4 elements (Cd, Cu, Pb and Zn) was determined by Atomic Absorption Spectrophotometer (Model 2380, Perkin Elmer, Inc., Norwalk, CT, USA) using air-acetylene flame. The instrumental parameters were those recommended by the manufacturer. Reagent blanks, standard samples and duplicate samples were analyzed simultaneously in the experiments to provide quality control. The analytical precision, measured as relative standard deviation, was routinely 3–5%.

## 2.4 Statistical analysis

All statistical analyses and data processing in this study were performed on an IBM-PC computer. Descriptive statistics such as mean, percentage and standard deviation were performed after multi-element analysis. The Pearson's correlation coefficients ( $r$ ) among metals were calculated by  $p < 0.05$ .

## 3. Results and discussion

### 3.1 Distribution of dust in particle size fractions

Dust particle size is considered as one of the important dust properties. Table 2 shows mean percent distribution of dust in three different particle size fractions from different sampling sites.

**Table 2. Distribution of dust (%) in three particle size fractions (Mean  $\pm$  SD; n=3)**

| Sampling locations | Particle size fractions |                      |                     |                   |
|--------------------|-------------------------|----------------------|---------------------|-------------------|
|                    | >150 $\mu\text{m}$      | 150-75 $\mu\text{m}$ | 75-38 $\mu\text{m}$ | <38 $\mu\text{m}$ |
| Balkhu,            | 46.9 $\pm$ 4.1          | 21.7 $\pm$ 4.2       | 28.9 $\pm$ 6.9      | 2.1 $\pm$ 0.3     |
| Sitapaila          | 51.1 $\pm$ 6.6          | 20.1 $\pm$ 5.0       | 26.5 $\pm$ 7.9      | 1.9 $\pm$ 1.1     |
| Balaju             | 56.0 $\pm$ 7.9          | 18.4 $\pm$ 2.9       | 22.4 $\pm$ 4.9      | 2.9 $\pm$ 0.9     |
| Gausala            | 47.0 $\pm$ 7.3          | 23.8 $\pm$ 3.7       | 26.1 $\pm$ 5.6      | 2.4 $\pm$ 1.7     |
| New Baneshwor      | 45.9 $\pm$ 5.2          | 24.4 $\pm$ 7.8       | 25.3 $\pm$ 5.3      | 1.7 $\pm$ 1.2     |
| Putalisadak        | 57.4 $\pm$ 8.4          | 19.6 $\pm$ 2.2       | 21.0 $\pm$ 7.1      | 1.8 $\pm$ 0.8     |
| Tripureshwar       | 43.0 $\pm$ 6.9          | 25.9 $\pm$ 4.9       | 27.7 $\pm$ 8.0      | 2.2 $\pm$ 0.7     |
| Lazimpat           | 52.9 $\pm$ 5.9          | 20.7 $\pm$ 2.6       | 22.9 $\pm$ 7.5      | 2.7 $\pm$ 1.4     |
| Kalimati           | 47.6 $\pm$ 4.4          | 19.9 $\pm$ 3.8       | 29.5 $\pm$ 6.9      | 2.3 $\pm$ 1.2     |
| Naikap             | 48.8 $\pm$ 8.3          | 17.5 $\pm$ 4.2       | 31.1 $\pm$ 8.9      | 2.0 $\pm$ 1.6     |
| Shivpuri (control) | 58.3 $\pm$ 6.8          | 11.4 $\pm$ 2.7       | 15.7 $\pm$ 2.9      | 3.9 $\pm$ 2.1     |

Fractionation of bulk dust into different particle size fractions revealed that >150  $\mu\text{m}$  particle size was found the main domain fraction in all the sampling sites and the amount of dust association in this particle size varied from 43.0 (Tripureshwar) to 57.4% (Putalisadak) except control (Shivpuri, 58.3%). Among the three fine particle size fractions under investigation, 75-38  $\mu\text{m}$  particle size showed comparatively higher and <38  $\mu\text{m}$  lowest association of dust and the similar pattern was observed in all the sampling sites. The distribution of dust in 150-75  $\mu\text{m}$ , 75-38  $\mu\text{m}$  and <38  $\mu\text{m}$  particle size fractions was found to vary from 17.5 (Naikap) to 25.9% (Tripureshwar), 21.0 (Putalisadak) to 31.1% (Naikap) and 1.7 (New Baneshwor) to 2.9% (Balaju) respectively. The control (Shivpuri) also showed similar pattern of dust particle size distribution. The composition of dust may vary depending on various factors such as climate, human activities, soils and rocks of the surrounding areas etc., (Amato et al., 2010). The dust particle with a smaller size is often considered risky for environment and human health (Homolya, 1999). Now if this is the case, the percent contribution of all the three fine particle sizes (150-75  $\mu\text{m}$ , 75-38  $\mu\text{m}$  and <38  $\mu\text{m}$ ) upon grouping at each sampling location would range from approximately 43 (Putalisadak) to 56% (Tripureshwar) in roadside dust with potential risk for environment and human health.

It is generally accepted that deposition of atmospheric aerosol and displaced urban soil are the two main sources of roadside dust and consequently of the trace elements found therein (Ferreira-Baptista and DeMiguel, 2005; Han et al., 2007). Dust particle smaller than 150  $\mu\text{m}$

move in suspension and the finest among them may remain airborne for prolonged periods of time (Charlesworth et al., 2011).

### 3.2 Heavy metal concentrations in fine particle size fractions

Concentrations of four heavy metals (Cd, Cu, Pb and Zn) were determined in three different particle size fractions (150-75  $\mu\text{m}$ , 75-38  $\mu\text{m}$  and <38  $\mu\text{m}$ ) of roadside dust collected from 11 sites. Table 3 shows mean concentrations of metals in roadside dust from different sampling locations.

It was found that all the three particle size fractions from dust of all the sampling locations showed concentration of metals higher than those in control site of similar fractions. In all the sampling sites and the metals under investigation, the metal concentrations were found to increase with decrease in particle sizes and ranked by their abundance in the order as Zn > Cu > Pb > Cd. Evidently, the metals embedded into the finest particle size fraction (<38  $\mu\text{m}$ ) from all the sites were found to be significantly higher than the other two fractions under the present study. The results are in agreement with many studies (Acosta et al., 2011; Abdel-Latif and Saleh, 2012; Ewen et al., 2009) which also showed significant levels of metals in smaller particle size fraction. Preferential partitioning of metals to fine particle size fractions may be attributed to the increase in the specific area with the decrease of particle size (Ljung et al., 2006) and concomitant increase in the proportion of reactive substrates (Sutherland, 2003) with negative charges associated with these fine particles (Acosta et al., 2011). The dust particle with a smaller size is considered a major environmental and health hazard (Homolya, 1999) because of its large surface area to retain large amounts of metals (Wang, Wong, Leharne, & Fisher, 1998).

**Table 3. Heavy metal concentrations (mg/kg) in particle size fractions from roadside dust of different sampling locations across Kathmandu Metropolitan City (Mean  $\pm$  SD; n = 3)**

| Sampling locations | Particle size fraction ( $\mu\text{m}$ ) | Cd              | Cu               | Pb              | Zn               |
|--------------------|--|-----------------|------------------|-----------------|------------------|
| Balkhu             | 150-75                                   | 0.62 $\pm$ 0.03 | 56.2 $\pm$ 4.2   | 32.9 $\pm$ 4.4  | 123.6 $\pm$ 4.8  |
|                    | 75-38                                    | 0.73 $\pm$ 0.06 | 81.2 $\pm$ 4.8   | 48.5 $\pm$ 5.0  | 148.9 $\pm$ 18.1 |
|                    | <38                                      | 0.92 $\pm$ 0.08 | 107.1 $\pm$ 8.8  | 77.4 $\pm$ 6.4  | 198.4 $\pm$ 19.2 |
| Sitapaila          | 150-75                                   | 0.57 $\pm$ 0.06 | 79.3 $\pm$ 6.7   | 44.4 $\pm$ 7.0  | 112.8 $\pm$ 5.5  |
|                    | 75-38                                    | 0.76 $\pm$ 0.09 | 110.7 $\pm$ 7.8  | 64.6 $\pm$ 5.6  | 176.5 $\pm$ 7.9  |
|                    | <38                                      | 0.95 $\pm$ 0.14 | 179.4 $\pm$ 11.9 | 89.6 $\pm$ 9.2  | 205.2 $\pm$ 7.2  |
| Balaju             | 150-75                                   | 0.88 $\pm$ 0.06 | 132.6 $\pm$ 4.4  | 50.3 $\pm$ 3.2  | 140.5 $\pm$ 7.0  |
|                    | 75-38                                    | 0.95 $\pm$ 0.05 | 178.9 $\pm$ 5.8  | 70.4 $\pm$ 10.2 | 198.2 $\pm$ 12.8 |
|                    | <38                                      | 1.07 $\pm$ 0.12 | 199.9 $\pm$ 6.1  | 97.8 $\pm$ 8.6  | 224.7 $\pm$ 7.9  |
| Gausala            | 150-75                                   | 0.62 $\pm$ 0.01 | 79.9 $\pm$ 8.8   | 67.8 $\pm$ 9.0  | 134.4 $\pm$ 6.8  |
|                    | 75-38                                    | 0.80 $\pm$ 0.06 | 110.7 $\pm$ 9.8  | 88.8 $\pm$ 5.2  | 178.9 $\pm$ 9.2  |
|                    | <38                                      | 0.97 $\pm$ 0.12 | 148.6 $\pm$ 10.2 | 106.4 $\pm$ 3.2 | 220.1 $\pm$ 15.4 |
| New Baneshwor      | 150-75                                   | 0.60 $\pm$ 0.10 | 53.3 $\pm$ 8.2   | 33.3 $\pm$ 9.6  | 129.0 $\pm$ 9.1  |
|                    | 75-38                                    | 0.88 $\pm$ 0.08 | 99.0 $\pm$ 5.8   | 79.7 $\pm$ 6.2  | 167.4 $\pm$ 15.4 |
|                    | <38                                      | 1.11 $\pm$ 0.09 | 131.5 $\pm$ 9.7  | 111.6 $\pm$ 7.2 | 222.8 $\pm$ 16.8 |

|                       |        |             |              |              |              |
|-----------------------|--------|-------------|--------------|--------------|--------------|
| Putalisadak           | 150-75 | 0.69 ± 0.02 | 62.8 ± 9.4   | 28.4 ± 7.8   | 116.6 ± 2.8  |
|                       | 75-38  | 0.76 ± 0.06 | 116.4 ± 13.6 | 36.2 ± 9.0   | 138.3 ± 14.2 |
|                       | <38    | 1.02 ± 0.13 | 167.0 ± 14.6 | 68.0 ± 4.7   | 250.6 ± 18.4 |
| Tripureshwor          | 150-75 | 0.61 ± 0.01 | 65.6 ± 6.1   | 33.2 ± 8.5   | 82.9 ± 2.7   |
|                       | 75-38  | 0.77 ± 0.10 | 82.5 ± 2.6   | 54.9 ± 2.8   | 107.2 ± 4.4  |
|                       | <38    | 0.99 ± 0.08 | 119.2 ± 7.4  | 85.6 ± 13.2  | 140.8 ± 7.1  |
| Lazimpat              | 150-75 | 0.58 ± 0.06 | 78.4 ± 10.2  | 25.6 ± 7.2   | 98.0 ± 3.4   |
|                       | 75-38  | 0.61 ± 0.11 | 98.8 ± 6.4   | 39.9 ± 12.2  | 126.8 ± 2.1  |
|                       | <38    | 0.91 ± 0.16 | 122.4 ± 12.6 | 64.9 ± 6.2   | 210.4 ± 7.6  |
| Kalimati              | 150-75 | 0.54 ± 0.08 | 58.4 ± 3.2   | 41.5 ± 5.4   | 99.8 ± 5.2   |
|                       | 75-38  | 0.66 ± 0.10 | 78.5 ± 6.4   | 54.7 ± 6.2   | 120.4 ± 8.8  |
|                       | <38    | 0.87 ± 0.08 | 132.4 ± 12.5 | 75.9 ± 8.9   | 185.5 ± 14.1 |
| Naikap                | 150-75 | 0.79 ± 0.08 | 72.3 ± 6.2   | 61.8 ± 8.4   | 88.4 ± 4.4   |
|                       | 75-38  | 0.92 ± 0.11 | 108.4 ± 8.5  | 94.8 ± 12.9  | 150.7 ± 8.2  |
|                       | <38    | 1.75 ± 0.14 | 188.9 ± 15.5 | 176.2 ± 13.8 | 231.4 ± 15.7 |
| Shivpuri<br>(control) | 150-75 | 0.27 ± 0.04 | 28.4 ± 2.0   | 10.5 ± 4.0   | 57.9 ± 5.2   |
|                       | 75-38  | 0.34 ± 0.07 | 46.5 ± 2.7   | 29.2 ± 5.4   | 73.7 ± 6.9   |
|                       | <38    | 0.42 ± 0.10 | 64.7 ± 7.9   | 37.3 ± 5.9   | 98.8 ± 9.5   |

For Zn among the sampling sites, Balaju showed 140.5 and 198.2 mg/kg as the highest levels for 150-75 and 75-38  $\mu$ m particle size fractions respectively while Putalisadak showed 250.6 mg/kg as the highest level for <38  $\mu$ m particle size. On the contrary, all the fractions showed the lowest levels of Zn in dust of Tripureshwor site. As for Pb, it was found that the dust from Gausala site recorded 67.8 mg/kg as the highest concentration for 150-75  $\mu$ m fraction while dust from Naikap site recorded 94.8 and 176.2 mg/kg as the highest concentration for 75-38 and <38  $\mu$ m fractions respectively. In case of Cu, 150-75  $\mu$ m, 75-38  $\mu$ m and <38  $\mu$ m particle size fractions measured 132.6, 178.9 and 199.9 mg/kg respectively as the highest levels in dust samples from Balaju site alone. Cadmium exhibited the lowest levels in dust of all the sampling sites analyzed compared to other metals in consistent with the findings of Elik (2003), who also concluded that the street dust generally contained lower levels of Cd than the other metals. It was found that Balaju site recorded 0.88 and 0.95 mg/kg of Cd in dust of 150-75 and 75-38  $\mu$ m fractions respectively as the highest level while Naikap recorded 1.75 mg/kg as the highest level for <38  $\mu$ m fraction.

The potential sources of metal contamination in roadside dust may be industrial activities, traffic emission, automobiles and other anthropogenic activities. Pb from leaded gasoline, Cu, Zn and Cd from car components, tyre abrasion, lubricants, leakage of oil products, industrial and incinerator emissions are the main sources of contamination (Markus and McBratney, 1996). Besides, Cu is also associated with inorganic fertilizers in agricultural areas, and Zn from recreational, domestic, and commercial sources. Lead and Zn are not only present in brake pads and tyre rubber but also in fuels either as a natural component (Pb) or as an additive (Zn). After phasing out leaded gasoline in Nepal, vehicular Pb emissions could be produced mainly from wear rather than fuel combustion (Fujiwara et al., 2011).

For all the three fine particle size fractions (150-75  $\mu\text{m}$ , 75-38  $\mu\text{m}$  and <38  $\mu\text{m}$ ), moderate to high correlation coefficient was found between Pb and each of Zn, Cd, and Cu implying that these elements have somewhat similar sources; i.e. traffic emissions, industrial and other anthropogenic activities. This finding was confirmed by correlation coefficient values shown in Table 4. Further, it has been demonstrated that the most common heavy metals released from vehicles on road are cadmium, lead, copper, nickel and zinc (Elik, 2003; Han et al., 2007).

**Table 4. Correlation coefficient between metals in three different particle size fractions**

|    | 150-75 $\mu\text{m}$ |       |        |       | 75-38 $\mu\text{m}$ |       |        |       | <38 $\mu\text{m}$ |       |        |       |
|----|----------------------|-------|--------|-------|---------------------|-------|--------|-------|-------------------|-------|--------|-------|
|    | Pb                   | Cd    | Cu     | Zn    | Pb                  | Cd    | Cu     | Zn    | Pb                | Cd    | Cu     | Zn    |
| Pb | 1.000                |       |        |       | 1.000               |       |        |       | 1.000             |       |        |       |
| Cd | 0.762*               | 1.000 |        |       | 0.746*              | 1.000 |        |       | 0.797*            | 1.000 |        |       |
| Cu | 0.749*               | 0.345 | 1.000  |       | 0.756*              | 0.432 | 1.000  |       | 0.789*            | 0.416 | 1.000  |       |
| Zn | 0.543                | 0.587 | 0.798* | 1.000 | 0.598               | 0.576 | 0.778* | 1.000 | 0.578             | 0.511 | 0.876* | 1.000 |

Significance level: \* $p < 0.05$

#### 4. Conclusion

The present study was focused on determination of Cd, Cu, Pb and Zn in three fine particle size fractions (150-75  $\mu\text{m}$ , 75-38  $\mu\text{m}$  and <38  $\mu\text{m}$ ) from roadside dust for characterizing different urban environment in Kathmandu Metropolitan City. Fractionation of bulk dust revealed that size fraction of 75-38  $\mu\text{m}$  among the three fractions showed comparatively higher dust association in all the sampling sites. Results suggested that roadside dust contained elevated levels of metals in all the three particle size fractions across the city compared to control site. The levels of metals were found to increase with decrease in their sizes having metal abundance order as  $\text{Zn} > \text{Cu} > \text{Pb} > \text{Cd}$ . Interestingly, similar characteristics were obtained in all the fractions and sampling sites. This indicates the preferential partitioning of metals for the finest particle sizes and is markedly affected by the land use, associated with the metal sources. Putalisadak and Balaju sites showed highest levels for Zn and Cd respectively in dust of <38  $\mu\text{m}$  size fraction while Naikap site showed both Pb and Cu as domain in the same particle size. Correlation analysis among metals revealed similar sources of contamination.

The dust particle with a smaller size is considered a major environmental and health hazard because they are easily transported and inhaled. Hence, we conclude from the present study that a monitoring plan is necessary to evaluate the evolution of metal concentration in dust in order to develop the proper measures for reducing the risk of inhalation and ingestion of dust for humans and environment of the city.

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## **Status of Gaseous Air Pollutants in Kathmandu Valley, Nepal**

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### **Abstract**

The study was conducted to understand the status of gaseous pollutants in Kathmandu Valley. The weekly concentration of pollutants; Nitrogen oxides (NO<sub>x</sub>), Nitrogen dioxide (NO<sub>2</sub>), Sulfur dioxide (SO<sub>2</sub>) and Ozone (O<sub>3</sub>) in ambient air and inhalation level of traffic police were monitored at 13 sites representing urban, sub-urban and rural environment of Kathmandu Valley during winter (February-March) and monsoon (July-September) seasons by using Ogawa passive sampler. The mean ambient concentration of NO<sub>2</sub>, SO<sub>2</sub> exceeded the 24 hrs NAAQS while O<sub>3</sub> exceeded the 8 hrs NAAQS value. Seasonal variation was observed with higher NO<sub>2</sub> and NO<sub>x</sub> concentration during winter and that of SO<sub>2</sub> and O<sub>3</sub> in the monsoon season. Within the microenvironment, urban area had highest pollutant concentration. While observing the pollutants inhalation level of the traffic police, exposure to NO<sub>2</sub> and NO<sub>x</sub> was higher during winter and that of SO<sub>2</sub> and O<sub>3</sub> was higher during monsoon. The association between ambient concentration and exposure of traffic police to gaseous pollutants was found significant. About 93% of traffic police reported at least one health problem associated with air pollution.

**Keywords:** Ambient concentration, gaseous pollutants, passive sampling, personal exposure

### **1. Introduction**

The insufficient knowledge on air pollution sources (Gurung & Bell, 2013) and its bowl shaped topography that restricts the movement of air (Panday & Prinn., 2009) is worsening the air quality of the Kathmandu Valley (WHO, 2014). Among pollutant types, gaseous pollutants are of great concern as it reacts in impressive rate to form aerosol or other secondary pollutants and its period of sink is longer than particulate matter. Exposure to gaseous pollutants exert irritant inflammatory effect on the respiratory organs (Kampa & Castanas, 2008; Uysal & Schapira, 2003) especially (esp.) of outdoor urban workers (traffic police, parking warden or vendors) spending majority of time outdoors (Violante et al., 2006).

Few periodic studies on gaseous pollutants; O<sub>3</sub> (Pudasainee et al., 2006 and Pudasainee et al., 2010), NO<sub>2</sub> and SO<sub>2</sub> (Kondo et al., 2005, Bhanju et al. 2012) do provide some information on the seasonal and micro environmental variation on ambient concentration of gaseous pollutants. But, further studies are still required to understand the present situation of this growing city. The study was conducted with objectives 1) to assess the seasonal variation of ambient air pollutants in terms of criteria gaseous pollutants (NO<sub>2</sub>, NO<sub>x</sub>, SO<sub>2</sub> and O<sub>3</sub>) in Kathmandu Valley and 2) to assess the personal exposure among traffic police in terms of predictive symptoms.

### **2. Methodology**

#### **2.1 Study Area**

Kathmandu Valley lies between latitude 27°32'13" and 27°49'10" N and longitudes 85°11'31" and 85°31'38" E covering the area of 340 km<sup>2</sup> (Figure 1). The Valley basin is at the average elevation of 1350 m above mean sea level surrounded by mountains ranging from 2000 to 2800 m. Rainfall is concentrated in three summer months (June to August) as it receive 90% of its annual rainfall (Panday & Prinn, 2009). The average temperature varies from 28–30°C in summer and 10.1°C in winter season. Wind is ordinarily light throughout the year, but there is a strong wind

in and around the month of May and June. Wind direction is easterly and southwesterly throughout the year (Sapkota, 2004).

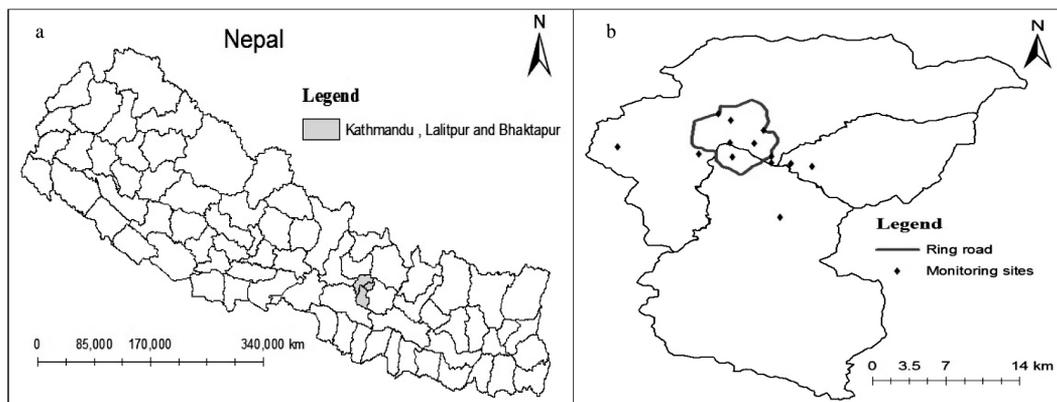


Figure 1: Map of Nepal (a) and monitoring sites within Valley (b) *Monitoring sites*

Thirteen monitoring sites around Kathmandu Valley were selected by purposive sampling which were categorized into three micro environments; Urban, Sub-urban (area located at the urban outskirts) and Rural sites. The urban sites were further divided into on-road urban site (junction of busy road) and urban background (urban residential area far from busy traffic) (Table 1). The field study was conducted during winter (23<sup>rd</sup> February to 4<sup>th</sup> April 2014) and monsoon (27<sup>th</sup> July to 21<sup>st</sup> September 2014) seasons. The sampling in urban background, sub urban and rural sites were conducted only during monsoon season, so the season-wise comparison was studied for on-road urban sites only.

**Table 1: Monitoring sites with their geographical location**

<sup>1</sup> Monitoring sites in winter, <sup>2</sup> Monitoring sites in monsoon, \* Personal exposure and Questionnaire survey

| S.N. | Station                     | Type             | Lat.        | Long.      | Elev.(m) |
|------|-----------------------------|------------------|-------------|------------|----------|
| 1    | Koteshwor <sup>12*</sup>    | On Road Urban    | 27°40'43" N | 85°20'58"E | 1317     |
| 2    | Balaju <sup>12*</sup>       | On Road Urban    | 27°43'54" N | 85°18'16"E | 1304     |
| 3    | Pulchowk <sup>12*</sup>     | On Road Urban    | 27°40'48" N | 85°19'02"E | 1319     |
| 4    | Tripureshwor <sup>12*</sup> | On Road Urban    | 27°41'38" N | 85°18'51"E | 1298     |
| 5    | Gaushala <sup>12*</sup>     | On Road Urban    | 27°42'28" N | 85°20'36"E | 1334     |
| 6    | Baneshwor <sup>2</sup>      | Urban background | 27°41'36" N | 85°20'06"E | 1316     |
| 7    | Lokanthali <sup>2</sup>     | Urban background | 27°40'14" N | 85°21'02"E | 1304     |
| 8    | Lainchaur <sup>2</sup>      | Urban background | 27°43'10" N | 85°18'55"E | 1320     |
| 9    | Dadhikot <sup>2</sup>       | Urban background | 27°40'03" N | 85°23'04"E | 1312     |

|    |                       |           |             |            |      |
|----|-----------------------|-----------|-------------|------------|------|
| 10 | Thankot <sup>2</sup>  | Rural     | 27°41'21" N | 85°13'05"E | 1491 |
| 11 | Godawari <sup>2</sup> | Rural     | 27°36'37" N | 85°21'25"E | 1443 |
| 12 | Kirtipur <sup>2</sup> | Sub Urban | 27°40'54"N  | 85°17'16"E | 1328 |
| 13 | Balkot <sup>2</sup>   | Sub Urban | 27°40'14"N  | 85°21'59"E | 1302 |

## **2.2 Sampling Techniques**

### **2.2.1 Ambient concentration**

Ogawa passive samplers loaded with corresponding absorbent pads of pollutant were used for sampling of gaseous pollutants. The loaded samplers were kept on the junction of the road for the on-road urban sites whereas for the remaining sites they were kept on the outer wall of the house. The exposure height was maintained at 2.5 meters. After a week long exposure, the exposed pads were then transferred to the shipping vials (PS-118) for the laboratory analysis. The analysis was carried out in the laboratory of Department of Environmental Health at University of Massachusetts, Amherst. The standard procedures provided by the Ogawa and Co. were followed for laboratory analysis.

### **2.2.2 Personal (traffic police) exposure**

The exposure level to gaseous pollutants of the traffic police were observed for a week using Ogawa passive samplers. Each traffic police were provided with loaded Ogawa samplers. The samplers were attached on their uniform near shirt collar within the head airway region. The samplers were exposed 24 hours (hrs) a day, i.e., the air sampled included both outdoor and the indoor environment.

Six traffic police from each on-road urban sites were involved in the study. The involved traffic police were randomly selected constable, head constable and Quick Response Traffic (QRT) officers including both male and female and both smokers and non-smokers. The traffic police who were past smoker were considered as non-smoker.

## **2.3 Questionnaire survey**

The questionnaire survey was carried out to know the health status of the involved traffic police. The semi-structured questionnaire included self-reported chronic and acute health symptoms experienced at work which includes; headache, coughing, runny nose, shortness of breath, sneezing, coughing, eye irritation tightness of chest, anxiety and sleeping disorder. About 45 questionnaires were filled that provided health condition of individual traffic police.

## **2.4 Statistical analysis**

All the data were analyzed and presented in the form of table and graph by using the Microsoft Excel 7.0 and SPSS 16.0. The T-test was conducted for the seasonal variation of pollutants while chi-square test was carried out for identifying the association between the pollutant concentration and health effect at 95% confidence level. Pearson correlation was analyzed to study relationship among ambient concentration and personal exposure of traffic police.

### 3. Result and Discussion

#### 3.1 Ambient concentration of gaseous pollutants

##### 3.1.1 Nitrogen dioxide

The mean weekly NO<sub>2</sub> concentration level of the Kathmandu Valley ranged from 47.5±15.1 µg/m<sup>3</sup> (monsoon) to 103.9±7.0 µg/m<sup>3</sup> (winter) which exceeded the National Ambient Air Quality Standard (NAAQS) 24hrs value; 80 µg/m<sup>3</sup> (Figure 2d). Among study sites, Pulchowk (on-road urban) had highest concentrations during both seasons; 123.5µg/m<sup>3</sup> (winter) and 184.4µg/m<sup>3</sup> (monsoon) (Table 2). Compared to previous studies (Kondo et al., 2005; Byanju et al., 2012), the concentration level of pollutants have increased especially on-road urban sites.

The mean NO<sub>2</sub> concentrations of micro environment were 66.12±18.65 µg/m<sup>3</sup> (urban), 6.05±0.6 µg/m<sup>3</sup> (rural) and 4.9±0.7 µg/m<sup>3</sup> (sub urban) (Figure 2a). The three out of five on-road urban sites have higher concentration during winter season than summer (Figure 2d). However, T-test shows no significant seasonal variation of NO<sub>2</sub> concentration (p=0.3 at 0.05 level).

The emission from the vehicle exhaust is the major cause for NO<sub>2</sub> production as it emits nitric oxide (NO) which further reacts with O<sub>2</sub> in the atmosphere to produce NO<sub>2</sub>. This reaction occurs rapidly due to which the area with high vehicle flow (like on-road urban sites) have higher concentration of NO<sub>2</sub> than other micro-environment (Simkhada et al., 2005). The control of emitting sources is required as mean NO<sub>2</sub> concentration exceeded standards.

In contrast to other on-road urban sites, the lower concentration of NO<sub>2</sub> at Gaushala and Pulchowk (Table 2) in winter season could be due to the loss of NO due to the O<sub>3</sub> formation. Additionally, the weather was clear with no rain at those sites during the field survey in monsoon season (DHM, 2014).

**Table 2: Weekly ambient concentration of gaseous pollutants**

| Station      | Site type                   | Season  | NO <sub>2</sub> (µg/m <sup>3</sup> ) | NOx (µg/m <sup>3</sup> ) | SO <sub>2</sub> (µg/m <sup>3</sup> ) | O <sub>3</sub> (µg/m <sup>3</sup> ) |
|--------------|-----------------------------|---------|--------------------------------------|--------------------------|--------------------------------------|-------------------------------------|
| Balaju       | Urban<br>(Road Side)        | Winter  | 116.0                                | 232.2                    | -                                    | 6.1                                 |
| Gaushala     |                             |         | 85.6                                 | 275.3                    | 7.0                                  | 9.3                                 |
| Koteshwor    |                             |         | 101.0                                | 239.3                    | 0.0                                  | 30.3                                |
| Tripureshwor |                             |         | 93.6                                 | 185.6                    | -                                    | 10.0                                |
| Pulchowk     |                             |         | 123.5                                | 0.0                      | 6.5                                  | 14.4                                |
| Balaju       | Urban<br>(Urban background) | Monsoon | 88.0                                 | 150.5                    | 32.5                                 | 9.6                                 |
| Gaushala     |                             |         | 115.1                                | -                        | -                                    | 11.8                                |
| Koteshwor    |                             |         | 58.2                                 | -                        | 12.8                                 | 17.8                                |
| Tripureshwor |                             |         | 64.4                                 | 187.1                    | 0.0                                  | 17.4                                |
| Pulchowk     |                             |         | 184.4                                | -                        | 31.1                                 | 26.4                                |
| Baneshwor    |                             |         | 31.8                                 | 67.7                     | 1.2                                  | 14.1                                |
| Dadhikot     |                             |         | 24.7                                 | 51.1                     | -                                    | 5.1                                 |
| Lainchaur    |                             |         | 17.1                                 | 40.4                     | 0.3                                  | 20.1                                |

|            |           |         |      |       |     |      |
|------------|-----------|---------|------|-------|-----|------|
| Lokanthali |           |         | 11.9 | -     | -   | 13.2 |
| Kirtipur   | Sub-Urban | Monsoon | 4.2  | 115.2 | 4.3 | 14.0 |
| Balkot     |           |         | 5.6  | 10.7  | 0.0 | 13.6 |
| Thankot    | Rural     |         | 6.7  | 7.9   | 5.0 | 23.5 |
| Godavari   |           |         | 5.4  | 8.3   | 0.0 | 6.9  |

### 3.1.2 Nitrogen oxides

The weekly mean concentration of  $\text{NO}_x$  ranged from  $49.1 \pm 19.3 \mu\text{g}/\text{m}^3$  (monsoon) to  $186.5 \pm 54.5 \mu\text{g}/\text{m}^3$  (winter). The concentration of  $\text{NO}_x$  was highest in Gaushala ( $275.3 \mu\text{g}/\text{m}^3$ ) which is on-road urban site where major source of pollutants is exhaust from vehicles.

Within micro environment, the weekly mean concentration of  $\text{NO}_x$  was highest in the sub urban ( $62.8 \pm 52.1 \mu\text{g}/\text{m}^3$ ) site followed by the urban ( $55.1 \pm 23.3 \mu\text{g}/\text{m}^3$ ) and rural site ( $8.1 \pm 0.2 \mu\text{g}/\text{m}^3$ ) during monsoon season. The rural sites have very less traffic leading to lower concentration than two urban sites. Vehicular emission as major contributor of  $\text{NO}_x$  concentration is also mentioned by previous researchers (Kondo et al., 2005).

### 3.1.3 Ozone

The weekly mean concentration of ozone was elevated in monsoon season ( $16.6 \pm 6.5 \mu\text{g}/\text{m}^3$ ) than in winter season ( $14.0 \pm 9.6 \mu\text{g}/\text{m}^3$ ). The concentration of  $\text{O}_3$  was highest at Koteshwor ( $30.3 \mu\text{g}/\text{m}^3$ ) during winter and Pulchowk ( $26.4 \mu\text{g}/\text{m}^3$ ) during monsoon. The  $\text{O}_3$  concentration level has increased compared to previous studies (Pudaisainee et al., 2006; Pudaisainee et al., 2010). Nevertheless, concentration of  $\text{O}_3$  is still below NAAQS and WHO guideline (figure 2e). The high concentration of  $\text{O}_3$  in Koteshwor and Pulchowk might be due to its surrounding environment where very large emission of NO occurs due to traffic intensity. The NO are consumed to release  $\text{NO}_2$  which plays key role in production of  $\text{O}_3$  (Bernard et al., 2001).

The concentration of  $\text{O}_3$  highly relies on the meteorological factors like solar intensity and atmospheric temperature. These factors plays key role in causing seasonal variation of  $\text{O}_3$  concentration. Increase in the solar intensity and temperature increases the  $\text{O}_3$  concentration (Pudaisainee et al., 2006). The high value of temperature and length of visible light could be the reason for high concentration of the  $\text{O}_3$  in monsoon (DHM, 2014; Weather Channel, 2012). This favorable meteorological condition favors the active photochemical production mechanism of  $\text{O}_3$  on increasing precursor's concentration (Pudaisainee et al., 2006). However, the paired sample t-test didn't show any significant difference between the concentrations of  $\text{O}_3$  in two seasons ( $p=0.5$ ) at 0.05 level.

While comparing three studied micro-environments, mean concentration of  $\text{O}_3$  was highest in rural site ( $14.9 \pm 8.05 \mu\text{g}/\text{m}^3$ ) followed by urban site ( $14.7 \pm 2.04 \mu\text{g}/\text{m}^3$ ) and sub-urban sites ( $13.5 \pm 0.5 \mu\text{g}/\text{m}^3$ ) (figure 2c).  $\text{VOC}_s$  and  $\text{NO}_x$  are the major precursor of  $\text{O}_3$ . Though less  $\text{NO}_x$  concentration, high  $\text{O}_3$  concentration in the rural site might be due to the high  $\text{VOC}_s$  concentration. Besides anthropogenic emission of  $\text{VOC}_s$ , biogenic  $\text{VOC}_s$  concentration is at peak during summer season (Bernard et al., 2001).

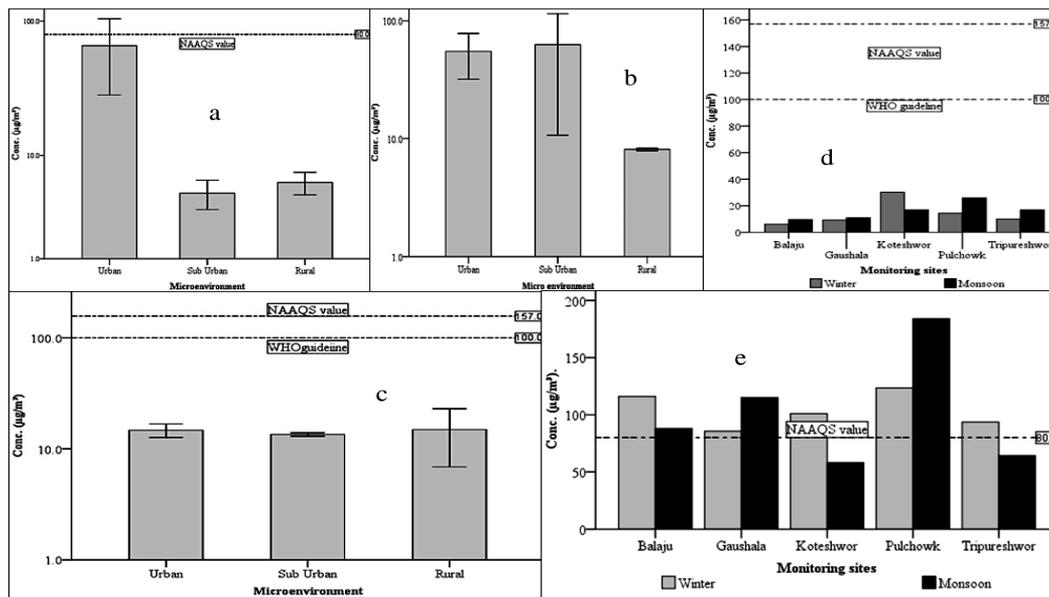


Figure 2: Concentration of a) NO<sub>2</sub>, b) NO<sub>x</sub> and c) O<sub>3</sub> at three microenvironment during monsoon \*log scale; Error bar:S.E. ; Seasonal variation of d) NO<sub>2</sub> and e) O<sub>3</sub> concentration

### 3.1.4 Sulfur dioxide

The weekly mean SO<sub>2</sub> level was elevated during monsoon (25.4±11 µg/m<sup>3</sup>) than in winter season (6.7±0.4 µg/m<sup>3</sup>). Missing data of three sites of winter season possibly attributed in less concentration than monsoon season. The concentration of SO<sub>2</sub> was lower than NAAQS value (70µg/m<sup>3</sup>) and WHO guideline (20µg/m<sup>3</sup>) (figure 3). Higher value of SO<sub>2</sub> were obtained in this study than those reported by previous study ( Silwal et al., Kondo et al., 2005; Byanju et al., 2012). The Gaushala and Balaju had highest value during winter and monsoon month respectively. Exhaust from vehicles, generators and the burning activities near the study sites contributed in high value of SO<sub>2</sub> in these two sites. In case of Balaju, Balaju Industrial State nearby the study site could be the reason for the higher concentration of SO<sub>2</sub>. Byanju et al., (2012) mentioned about the higher concentration of SO<sub>2</sub> in Balaju because of industrial area.

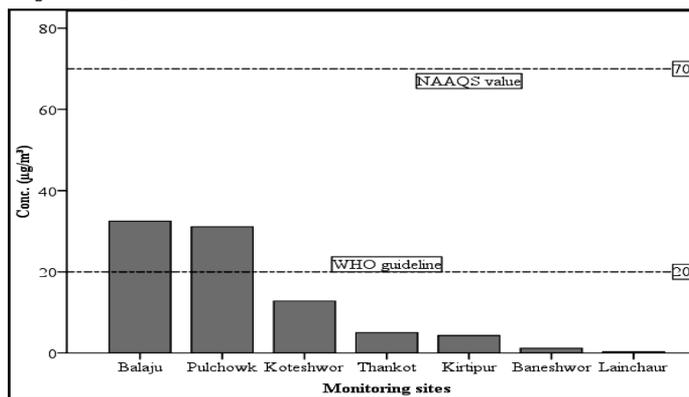


Figure 3: Ambient concentration of the SO<sub>2</sub> during monsoon

Besides season and sources, meteorological parameter such as: rainfall, specific humidity, temperature, wind speed and wind direction shows significant variation in pollutants concentration (Pudasainee et al. 2010; Byanju, 2012)

### 3.2 Personal exposure to gaseous pollutants

The traffic police exposure to mean concentration of NO<sub>2</sub> was highest at Koteshwor (108.3±13.2 µg/m<sup>3</sup>) and lowest at Pulchowk (68.0±7.3 µg/m<sup>3</sup>) during winter season (Table 4). In monsoon, the personal exposure was highest at Gaushala. While observing the seasonal data of NO<sub>2</sub>, significant difference was observed between two seasons exposure level (p= 0.03 at 0.05 level). The concentration was higher during winter season than in the monsoon season. Precipitation was the major reason for the reduction of exposure in monsoon season.

The personal exposure of Traffic police to mean concentration of NO<sub>x</sub> was highest at Gaushala (381.8±23.2 µg/m<sup>3</sup>). The personal exposure of Balaju and Koteshwor traffic police had the mean concentration less during monsoon season while Gaushala and Pulchowk had comparably higher in the monsoon season (Table 3). The vehicle emission is the major source for the NO<sub>x</sub> concentration. Besides these, habitual action like cigarette smoking could increase the concentration of NO<sub>x</sub> (NIH, 2012). The 40% of the traffic police involved in the study were smokers. Moreover these traffic police shared common room where other traffic police were smokers.

**Table 3: Personal exposure of traffic police to different pollutants**

| Season  | Stations  | Mean NO <sub>2</sub> conc. (µg/m <sup>3</sup> ) | Mean NO <sub>x</sub> conc. (µg/m <sup>3</sup> ) | Mean SO <sub>2</sub> conc. (µg/m <sup>3</sup> ) | Mean O <sub>3</sub> conc. (µg/m <sup>3</sup> ) |
|---------|-----------|---|---|---|--|
| Winter  | Balaju    | 72.3±4.1  | 235.1±24.1                                      | 7.2± 1.5  | 10.0±1.9                                       |
|         | Gaushala  | 92.0±6.0  | 277.3±40.5                                      | 8.8± 3.0  | 9.1±2.6  |
|         | Koteshwor | 108.3±13.2                                      | 305.9±38.9                                      | 7.9± 0.7  | 24.8±4.5                                       |
|         | Pulchowk  | 68.0±7.3  | 65.2±3.5  | 4.8± 1.6  | 19.5±2.6                                       |
| Monsoon | Balaju    | 49.8±3.1  | 78.0  | 10.8± 2.5                                       | 14.3±0.7                                       |
|         | Gaushala  | 55.0±2.1  | 381.8±23.2                                      | 0.8± 0.1  | 13.7±0.6                                       |
|         | Koteshwor | 35.5±1.2  | 269.9±7.1                                       | 8.2± 1.9  | 11.4±0.5                                       |
|         | Pulchowk  | 37.4±1.3  | 72.4±9.5  | 23.4± 5.9                                       | 23.4±0.8                                       |

The weekly exposure of traffic police to concentration of SO<sub>2</sub> was higher in the monsoon season than in winter season except Koteshwor. The exposure level of Pulchowk traffic police during monsoon season (23.4± 5.9 µg/m<sup>3</sup>) (Table 3) exceeded the WHO guideline value. The duty of the traffic police near the sources of the pollutants might have increased the concentration level.

The weekly exposure to concentration of O<sub>3</sub> was higher in monsoon season than in the winter season. Same condition was observed in the ambient concentration of the ozone. Hence, this can be explained by the high photochemical production of the ozone during monsoon season favored by the meteorological factors and ozone precursors (Pudasainee et al., 2006).

The variability in the data and their habitual action could be the reason for the observed insignificant paired t-test value for NO<sub>x</sub>, SO<sub>2</sub> and O<sub>3</sub>. Further, individual data may vary because of their varying duty and their habitual action. Some of the traffic police involved were new in

monsoon season. Although the stations were similar, their habitual action may vary. Moreover, their duties and activities may vary greatly between the two seasons.

### 3.3 Ambient concentration and personal exposure

The personal exposure to mean concentration of the gaseous pollutant was found relatively less than the ambient concentration. On average, 4 out of the 6 traffic police have concentration less than of ambient value. Traffic police are exposed to about 87% of ambient concentration of the gaseous pollutants. Significant correlation was observed between ambient concentration and personal exposure ( $p=0.01$ ) at 0.05 level. Hence, traffic police are highly prone to health effect cause by gaseous pollutants.

### 3.4 Health status of traffic police

The health symptoms observed in the smoker traffic police (40%) and non smoker traffic police (60%) revealed that smoker had higher prevalence of the symptoms like headache (53%), cough (71%), sneezing (82%), shortness of breath (24%) and runny nose (53%) than the non-smoker. The ninety two percent of traffic police reported at least one symptom of the health problems related to the air pollution. The high prevalence for many of reported symptoms indicated that the general health status of traffic police was poor. The symptoms like runny nose (46%,  $n=19$ ), chest pain (17%,  $n=8$ ), coughing (63%,  $n=25$ ) and eye irritation (50%,  $n=23$ ) was reported by the traffic police. These symptoms are related to the health effect caused by the gaseous pollutants (Kampa & Castanas, 2008; Uysal & Schapira, 2003). Similar studies conducted in India, Taiwan and Nigeria and had shown significantly higher prevalence of symptoms in traffic workers whom were occupationally exposed to vehicle emissions (Ingle et al. 2005; Yang et al. 2002; Moen, 2008). Hence, detail study is required to understand the potential health impact on traffic police.

## 4. Conclusion

Seasonal variation on gaseous pollutant concentration of on-road urban sites was studied. The urban micro environment had highest pollutant concentration. The concentration of most of gaseous pollutants on Pulchowk was highest though it seems relatively cleaner than other ring road areas focusing on the fact that cleaner areas not necessarily are always free of pollutants (especially gaseous). The personal exposure to  $\text{NO}_2$  was found significantly different during winter and monsoon season. The weekly exposure level of the traffic police was found significantly related to the ambient concentration of gaseous pollutants. The traffic police reporting the health problem during schedule survey was high. Hence, immediate action on control of pollution level is needed to safeguard human health.

### Acknowledgement

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## Adsorption of Ni (II) Ions from Aqueous Solution on the Activated Carbon Prepared from Lapsi Seed Stone by Phosphoric Acid Activation

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### Abstract

The use of Activated carbon prepared from Lapsi (*Choerospondias axillaris*) Seed Stone has been studied in place of costly adsorbents for the removal of Ni (II) ions from aqueous solution. The activated carbon prepared is characterized by FTIR and SEM. Batch adsorption experiments were studied to describe the effect of pH and contact time on the metal ion adsorption. The optimum pH for the adsorption of Ni (II) ions on the activated carbon is found to be 5. The adsorption data were satisfactorily described by Langmuir isotherm model and the maximum adsorption capacity calculated from Langmuir isotherm model was found to be 28.0mg/g. The results of the present study suggest that Lapsi Seed stone can be used beneficially for the removal of Ni (II) from aqueous solution.

**Keywords:** Activated carbon, Nickel, Adsorption, Adsorption isotherms, Adsorption capacity,

### 1. Introduction

Removal of toxic heavy metals from water has received considerable attention in recent years due to toxicity and carcinogenicity. Nickel, one of toxic heavy metals, is used in number of industries including batteries manufacturing, forging, electroplating, mining, metal finishing etc. Serious health problems such as damage to lungs, kidneys, gastrointestinal distress, e.g. nausea, vomiting, diarrhea, pulmonary fibrosis, renal edema, and skin dermatitis are caused because of nickel through water [Dhokpande et al; 2013]. The higher concentration of Nickel causes poisoning effects like headache, dizziness, tightness of the chest, dry cough, chest pain, shortness of breath, rapid respiration, cyanosis and extreme weakness. Nickel is known to have toxic effects at very low concentrations as well as very high concentration [Nies DH, 1980].

These harmful effects of Ni (II) ions make necessary to remove it from water before release into water bodies. The conventional methods which are commonly used for the removal of Ni(II) ions from aqueous solution are physico-chemical methods, such as chemical precipitation, chemical oxidation or reduction, electrochemical treatment, evaporative recovery, filtration, ion exchange, activated carbon adsorption, reverse osmosis and membrane technologies. In comparison to other methods, adsorption with activated carbon has received much more attention because it is convenient and economical for reducing trace quantities of heavy metals [Yetis et al; 2000].

Activated carbon which has high surface area, porous structure and functional groups has been the most popular and widely used adsorbent in water treatment technology all over the world [Babel et al; 2003]. Many researchers indicate that activated carbon is very effective in the removal of Ni (II) ions. However, the widespread use of activated carbon is restricted due to its high costs. In order to minimize the treatment costs, many attempts have been made to find the alternative inexpensive precursors for the preparation of activated carbon. At present more attention has been focused on the utilization of agricultural waste materials such as saw dust [Marquez et al; 2001], coconut shell [Sekar and Rengarag, 2004], fruit stones such as Lapsi Seed Stone (Shrestha R.M. 2015), Apricot stone [Mouni et al; 2001], Olive stone [Bohli et al ; 2012], Date stone [Muthana J.A. 2011], Peach stone (Amina et al; 2005), Lotus stalk [Hui et al; 2011] etc. for the production of activated carbon. In this study activated carbon was prepared by chemical activation with phosphoric acid. Chemical

activation involves one step in which carbonization and activation is carried out simultaneously

The present study has been addressed to the removal of Ni (II) ions from aqueous solution by using activated carbon prepared from Lapsi seed stone since the seed stones are readily available and can be used as the alternative inexpensive precursors for the preparation of activated carbon.

## **2. Materials and Methods**

### **2.1 Preparation of Activated carbon**

The precursors used in the preparation of activated carbon are seed stone of Lapsi fruits. The fruits were collected from Fruits and Vegetable Market, Kalimati, Kathmandu. The fruits are boiled for the pulp and then seed stones are exposed and collected. The seed stones were washed well with tap water and distilled water, dried at 110 °C, crushed to desired size (300µm) using a grinder crusher. The dried mass was mixed with 50% H<sub>3</sub>PO<sub>4</sub> in the ratio of 1:1 and dehydrated at 100 °C for 24 hours in hot box oven and then carbonized at 400 °C for 4 hours in a horizontal tubular furnace under flow of nitrogen (75 ml /min). The activated thus prepared was cooled well at room temperature and washed several times with warm water. The material was then dried at 110 °C, cooled and sieved to obtain the particles size 106µm. The activated carbon was represented by PALC (Phosphoric acid activated Lapsi seed stone carbon) and used for the adsorption of Ni (II) ions from aqueous solution.

### **2.2 Chemicals and Instruments**

The chemicals and reagents used are of analytical grade. Distilled water prepared in the laboratory was used to prepare stock solution of Ni (II) ions. All the working solutions were prepared by diluting the stock solutions with distilled water. Digital pH was used to measure pH value of solutions. Solutions of 0.1M NaOH and 0.1M HCl were used to adjust pH of the solutions. The adsorption experiments were carried out in Shaker (Digital VDRL Rotator RPM-S). The concentrations of Ni (II) ions were determined by Atomic Absorption Spectrophotometer (AA-VARIAN-AA240FS).

### **2.3 Adsorption Experiments**

Adsorption of Ni (II) ions was studied by batch adsorption experiments using aqueous solution of metal ions taken in 50 ml stopped conical flasks. The flasks were agitated on Digital VDRL Rotator-RPM-S at 225 rpm for identified time intervals. The effect of parameters like contact time and pH was studied by using 25 ml of Ni (II) ions of 50 mg / L at room temperature. Since pH is the critical parameter in the process, pH of the solutions was adjusted by addition of NaOH and HCl. Each experiment was carried out by suspending 0.05 g of adsorbent in 25 ml adsorbate solution taken in the conical flasks.

The amount of Ni (II) ions adsorbed at the equilibrium,  $q_e$  (mg / g) was calculated using the equation.

$$q_e = \frac{(C_0 - C_e) * V}{M} \dots\dots\dots 1$$

Where  $C_0$  and  $C_e$  are initial and equilibrium concentration of metal ions (mg / L) respectively, M is the mass of adsorbent in gram (g) and V is the volume of the solution in liter (L).

The percentage of removed metal ions ( $R_{cm} \%$ ) in solution is calculated by using following the formula.

$$Rem(\%) = \frac{(C_o - C_e) * 100}{C_o} \dots\dots\dots 2$$

### 3. Results and Discussion

#### 3.1 Fourier Transform Infrared (FTIR) Spectroscopy

FTIR spectra of carbon prepared without activating agent (Raw carbon), dried unloaded activated carbon (PALC) and Ni (II) ions loaded activated carbon were examined to study the effect of activating agent in the formation of surface functional groups and were presented in Figures 1, 2 and 3 respectively. The FTIR spectra of unloaded activated carbon exhibit a broad band at  $3419 \text{ cm}^{-1}$  due to the presence of hydroxyl groups. The band located at  $1725 \text{ cm}^{-1}$  is ascribed to the stretching vibrations of carboxylic groups or to conjugated carbonyl groups ( $\text{C}=\text{O}$  in carboxylic and lactones groups). Asymmetric stretching vibrations of ionic carboxylic groups ( $-\text{COO}^-$ ) appeared at  $1571 \text{ cm}^{-1}$ . The FTIR of raw carbon as shown in Figure 1 has no such bands. Comparing the raw and activated carbon, the bands  $1725.0 \text{ cm}^{-1}$  and  $3419.0 \text{ cm}^{-1}$  were observed in activated carbon but they were not seen in raw carbon. The presence of these bands in activated carbon is due to the action of activating agent in functionalizing the carbon during its preparation. Similarly comparing Ni(II) unloaded activated carbon with Ni (II) ions loaded activated carbon the bands at  $3419.0 \text{ cm}^{-1}$  and  $1571 \text{ cm}^{-1}$  were shifted to higher wave numbers  $3454.32 \text{ cm}^{-1}$  and  $1587 \text{ cm}^{-1}$  respectively and whereas  $1725 \text{ cm}^{-1}$  band was disappeared in Ni (II) ions loaded activated carbon. This indicates that the functional groups were involved in the adsorption of Ni (II) ions onto the activated carbon.

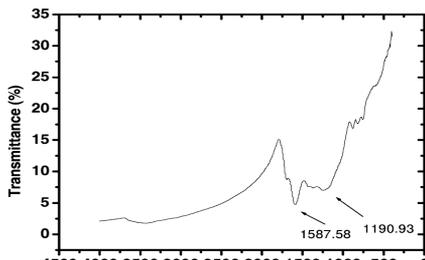


Figure 1 FTIR Spectra of Raw carbon

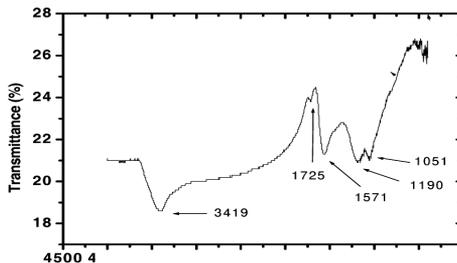


Figure 2 FTIR Spectra of Ni (II) ions unloaded PALC

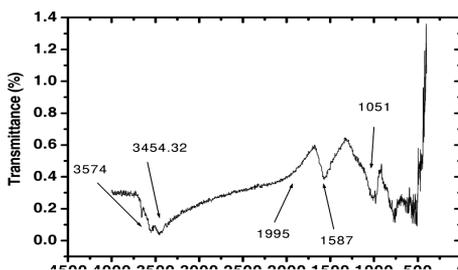


Figure 3 FTIR Spectra of Ni (II) ions loaded PALC

Figure 3 FTIR Spectra of Ni (II) ions loaded PALC

### 3.2 Scanning Electron Microscope (SEM)

Scanning Electron Microscope (SEM) of the carbons prepared without activating agent and with  $H_3PO_4$  as activating agent with 50% is presented in Figure 4. Figure 4(a) is the SEM of carbon prepared from Lapsi seed stone without any activating agent. The surface is heterogeneous and hardly any pores are visible. Figure 4 (b) is the SEM image of activated carbon prepared by using 50%  $H_3PO_4$  as an activation agent. In the SEM image (b) a number of pores with different diameters are observed. This development of porous structure may be attributed to the dehydrating effect of  $H_3PO_4$  which being a strong dehydrating agent removes oxygen and hydrogen from lignocellulosic material as water.

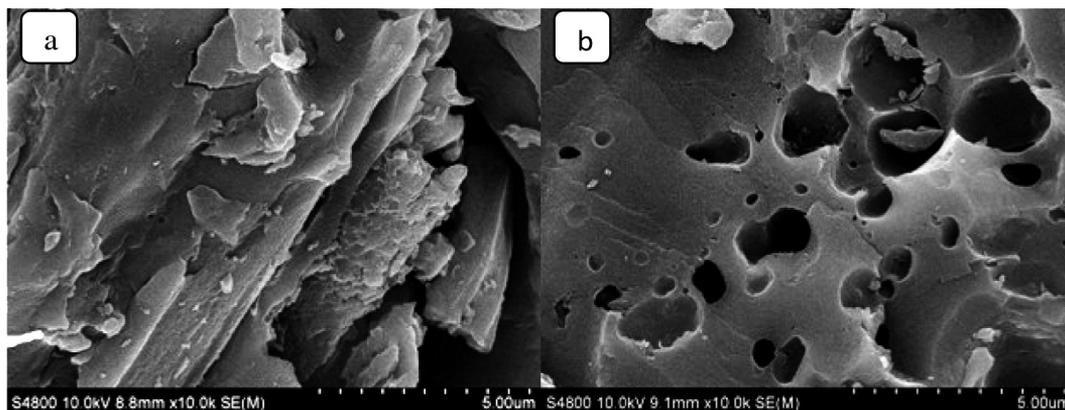


Figure 4 SEM Photographs of (a) carbon prepared without activating agent (Raw carbon) (b) activated carbon prepared using 50 %  $H_3PO_4$  [Carbonization time: 4 hr; ratio of LSSP:  $H_3PO_4$ =1:1]

### 3.3 Effect of pH

The pH of the aqueous solution plays an important role and influences the surface properties of adsorbent and therefore can affect the extent of adsorption [Li et al; 2010]. So the adsorption has been studied over a pH range of 2-7 at room temperature. The percentage removal of metal ions against pH is shown in Figure 5. The percentage removal of metal ions increases with increase in pH and attains plateau value at pH range of 6-7. The percentage of removal of Ni (II) ions is lower at low pH. This lower percentage removal of the metal ions may be due to the fact that at lower pH there is higher concentration of hydrogen ions that competes with metal ions.

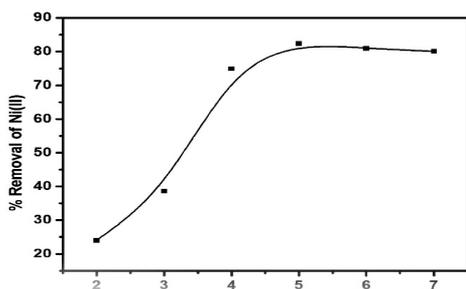


Figure 5 Effect of pH on the adsorption of Ni(II) ions.

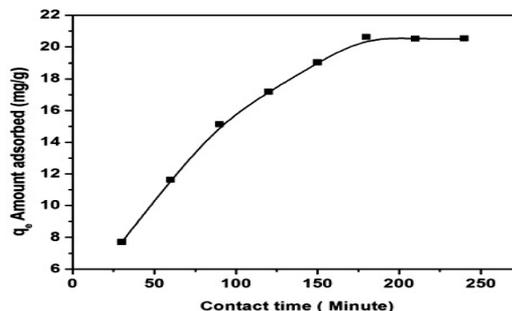


Figure 6 Effect of contact time on the adsorption of Ni (II) ions

### 3.4 Effect of Contact time

The amount of Ni (II) ions adsorbed increases with increase in time and attains a maximum value at about 180 minutes and then remains almost constant with the increase of time as shown in Figure 6. After 100 minutes amount of the metal ions adsorbed increases gradually and attains plateau value at 180 minutes. At equilibrium all the active sites will be covered by the metal ions and no further adsorption of metal ions takes place. Thus equilibrium time for adsorption of Ni (II) ions is about 3 hours.

### 3.5 Adsorption isotherms

Langmuir and Freundlich adsorption isotherms are the most important isotherms generally used to analyze the adsorptive behavior of adsorbate on adsorbent [Rao et al; 200] and [Sharma et al; 2005]. In this study both the isotherms were used to describe the relationship between amount of Ni (II) ions adsorbed and its equilibrium concentration in solution in laboratory temperature.

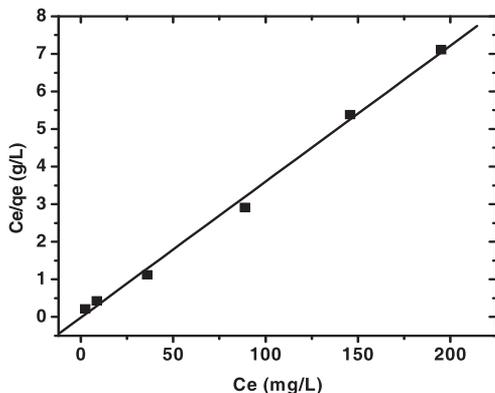
#### 3.5.1 Langmuir Adsorption isotherm

This adsorption isotherm presumes homogeneous surface adsorption with the formation of monolayer on the adsorbent surface. The linear form of Langmuir isotherm equation is given by

$$\frac{C_e}{q_e} = \frac{1}{bq_m} + \frac{C_e}{q_m} \dots \dots \dots 3$$

Where  $C_e$  is the equilibrium concentration of the adsorbate (mg/L) and  $q_e$  is the amount of the adsorbate adsorbed under equilibrium while  $q_m$  is the monolayer adsorption capacity (mg / g) and b is the Langmuir constant. The typical plot  $C_e/q_e$  vs  $C_e$  is shown in Figure 7. The plot is found to be linear one with coefficient of determination ( $R^2$ ) nearly equal to 1 indicating the validity of Langmuir adsorption isotherm

**Table 1 Adsorption capacities of Ni (II) ions by various adsorbents for comparison with that of PALC.**



**Figure 7 Langmuir adsorption isotherms of Ni (II) ions onto PALC**

| Adsorbents                    | Adsorption capacity qmax mg g-1 | References             |
|-------------------------------|---------------------------------|------------------------|
| Tea factory waste             | 15.3                            | Malkoc and Yasar, 2005 |
| AC from cotton stalk by H3PO4 | 31.5                            | Huang et al., 2010     |
| NaOH treated rice hull        | 12.3                            | Mashall et al., 1995   |
| PALC                          | 28.0                            | This study             |

#### 3.5.2 Freundlich Adsorption isotherm

The Freundlich isotherm assumes that the removal of metal ions occurs on a heterogeneous adsorbent adsorbent surface and can be applied to multilayer adsorption. The linear form of the Freundlich isotherm equation is as follows.

$$\log q_e = \log K_f + \frac{1}{n} \log C_e \dots \dots \dots 4$$

Where  $K_f$  and  $n$  are Freundlich constants related to adsorption capacity and adsorption intensity respectively. In order to test the validity of Freundlich adsorption isotherm adsorption data of PALC are tested by plotting the value of  $\log C_e$  vs  $\log q_e$  as shown in Figure 8. Table 2 shows that the value of coefficient of determination for Freundlich adsorption isotherm is found to be less than that for Langmuir isotherm. This means the adsorption follows Langmuir isotherm better than Freundlich isotherm.

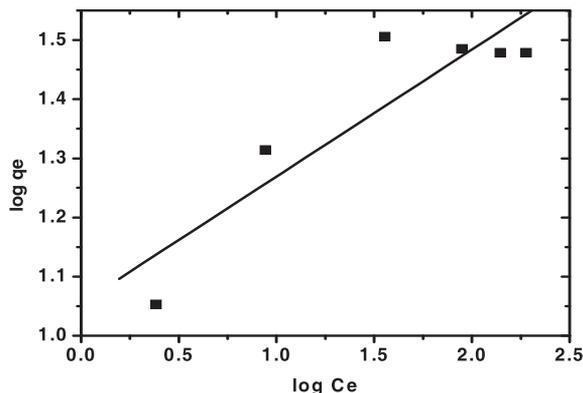


Figure 8 Freundlich adsorption isotherms of Ni (II) ions onto PALC

Table 2 Langmuir and Freundlich parameters for adsorption of Ni (II) ions onto PALC

| Heavy metal-ions | Langmuir parameters         |      | R <sup>2</sup> | Freundlich parameters |      | R <sup>2</sup> |
|------------------|-----------------------------|------|----------------|-----------------------|------|----------------|
|                  | q <sub>max</sub><br>mmole/g | b    |                | K <sub>f</sub> (mg/g) | (n)  |                |
| Ni(II)           | 0.48                        | 0.56 | 0.997          | 11.33                 | 4.65 | 0.811          |

#### 4. Conclusion

The activated carbon prepared from Lapsi seed stone by chemical activation with phosphoric acid can be used as an adsorbent for removal of Ni (II) ions from aqueous solution. The adsorption of Ni (II) ions is found to be greatly dependent on the pH of sample solution. The optimal value of pH for the adsorption of Ni (II) ions onto PALC is found to be 5. FTIR shows the presence of surface functional groups. SEM image of activated carbon exhibits pores of different diameters. Equilibrium data are described satisfactorily by Langmuir isotherm with higher value of coefficient of determination as compared to that of Freundlich isotherm, confirming the monolayer adsorption capacity of Ni (II) ions with adsorption capacity 28 mg/g. The result demonstrated that the activated carbon prepared from Lapsi seed stone by one step phosphoric acid activation is expected to be economically feasible for the removal of Ni (II) ions from aqueous solutions.

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## **A Comparative Study of Environmental Aspect in Dairy Industries of Kathmandu Valley**

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### **Abstract**

Considering environment while processing a product can help in preventing inefficient use of resources and avoiding unnecessary generation of waste, an organization can benefit from reduced operating costs, reduced waste treatment and disposal costs. In Nepal, there are cottage scales to large scales mechanized dairy industries handling various quantity of milk for producing different milk products. The key environmental issues associated with dairy processing are the high consumption of water, chemical, energy, fuel and generation of effluent streams and solid waste. Companies that consider environment into the design stage of a product will be well placed to benefit from productivity, profitability and marketing advantages of any future eco-labeling schemes.

The processing of raw milk to produce dairy products is a significant contributor to the overall pollution load produced over the life cycle of milk product followed by their consumption. Therefore in processing phase of the milk products life cycle, it is very important to consider the environmental aspect. This study has presented a comparative analysis of energy, chemical, water, wastewater and solid waste from Dairy Development Corporation (DDC), Nepal Dairy Industry and Bhaktapur Dairy Industry which are operating within the Kathmandu valley. Its findings details the reason for more resources consumption and more waste generation in comparison to each of the industries and at the same time it has suggested resource efficient cleaner production practices to the dairy industries.

**Key words:** Cleaner Production, Solid waste, Waste water

### **1. Introduction**

In Nepal, there are many small scale, some medium scale, few large scale mechanized dairies and numerous cottage type dairies handling various quantity of milk for producing different milk products, particularly pasteurized milk, ghee, ice cream, butter, cheese and yoghurt. The processing of milk to produce dairy products is a significant contributor to the overall environmental load produced over the life cycle of milk production and consumption. Therefore the application of Resource Efficient Cleaner Production (RECP) in this phase of the life cycle is important. As in many food processing industries, the key environmental issues associated with dairy processing are high consumption of water, generation of effluent streams, consumption of energy and fuel, and generation of by-products. For some sites, noise and odor may also be concerns.

In this study, the upstream process of fresh milk production and the downstream processes of wastewater treatment at dairy farms, distribution process and post-consumer packaging management are not covered.

In Nepal, as demand for professional dairy industries increased, private sector started getting involved in the dairy-processing sector from late 1970s. Today, there are many private dairies (including cooperatives) of various sizes both within and outside the Kathmandu valley. Prominent among the private dairies with modern milk processing facilities are Nepal Dairy, Bhaktapur Dairy, Himalaya Dairy, Sitaram Dairy, Anmol Dairy, Kathmandu Dairy, Adhunik Dairy etc in Kathmandu valley; Sujal Dairy in Pokhara valley, and Kamdhenu Dairy in Sunsari. However, dairy industries are still not in a position to meet the environmental compliance and are facing pressure from the community group and the government. At the present scenario, these dairy industries can be benefitted from RECP techniques which helps of reduce negative environmental impact and enhance productivity which results in increase in profitability in the long run.

## **2. Methodology**

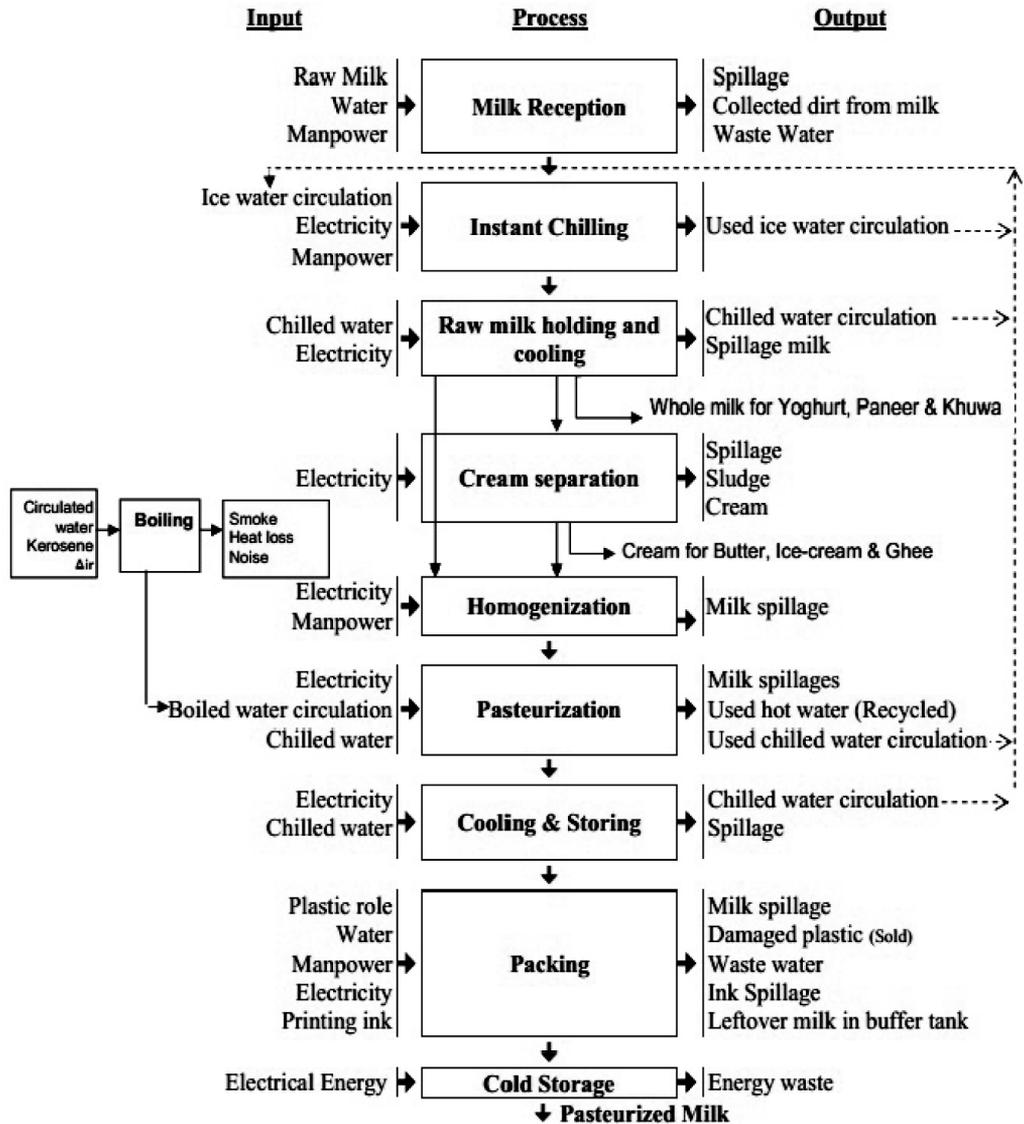
Collection of relevant books and reports, and its review was conducted. Additionally, assessment questionnaire was prepared to collect information on current industrial practices, certification, knowledge on RECP, uses of energy, water and chemicals, and amount of solid waste and waste water generation. Industrial visit was arranged to Dairy Development Corporation (DDC), Nepal Dairy Industry and Bhaktapur Dairy Industry that are within Kathmandu Valley and are of different production scale from large to small respectively. Due to constraint of time period and methodologies used, the study was limited to these three industries. These three industries were selected on the basis of their popularity in the local market and their willingness to participate in this study.

Also, successful case studies in other countries were reviewed about the economical and environmental benefits of the implementation of the RECP approaches in dairy industries. These provide the research with a clear understanding about the RECP benefits, limitations and problems when implemented in dairy industry. Proper coordination and co-operation from the production, maintenance, administration, finance and quality control department made this research fruitful and easy.

Most of the information received was as per documentation and book keeping records of the industries, from the account and finance section. For some of the information out of record, the information provided during the interviews was based on the best estimates and memory of the management personnel and facility engineers or related experts.

## **3. Results and discussion**

It should be noted that the research does not present name of the individual industry. Where necessary, these industries have been identified as A, B and C. The intention of doing so is to maintain confidentiality and not to reveal any confidential information or discuss technical details relating to the companies. In general, the process flow chart of the dairy industries for production of dairy items such as; milk, yoghurt, paneer, khuwa, butter, ice-cream, and ghee is given below;



Source: (PACE Nepal, 2012)

Figure 1: Process Flow Chart of Dairy Industries

### 3.1 General Description

From the study of three industries it was found that their annual production capacity altogether is 61,320,000 L whereas, actual annual production is 59,274,175 L. These dairy industries yet do not have QMS ISO 9001-2008 and EMS ISO 14001-2004 certification. The technical persons are aware of the importance of certification and its application but the management teams are not aware of it. None of these industries has an aspiration to get

similar certification at present. In total 578 persons are involved in these industries. Among the industries visited, it was found that, large scale industries are operating in three shifts, medium scale industries in two shift and small scale industries are operating in single shift.

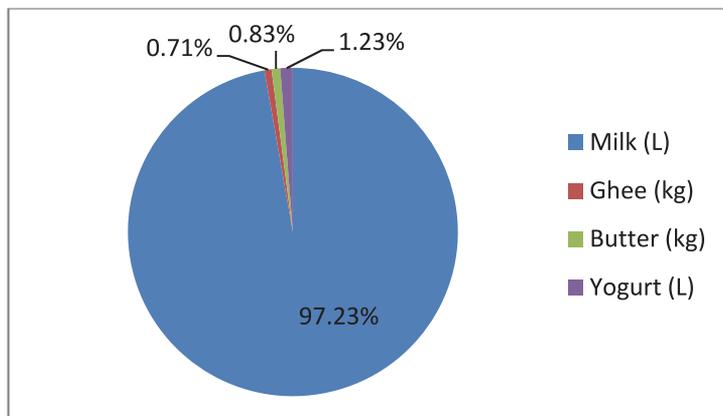


Figure 2: Distribution of Dairy Products

Industries A, B and C have not developed or implemented Environmental Policy and Occupational Health and Safety (OHSAS) Policy. But they have tried to reduce energy bills by the use of CFL or LED bulbs for lightning, replacing old motors with new high efficiency motors at the time of break down and use of fuel efficient boilers and generators. In case of OHSAS Policy, these industries are operating through compliance with the Labor Law of Nepal.

A, B and C dairy industries have conducted Environmental Impact Assessment (EIA) / Initial Environmental Examination (IEE) but none of the industries has wastewater treatment plant. These industries have been allowed to operate in Kathmandu Valley only after conducting EIA/IEE study and implementing mitigation measures as stated in the approved EIA/IEE report. However, these industries have allocated land for constructing wastewater treatment plant and have a plan to construct in near future.

Due to factors such as deteriorating market situation, unstable political situation in the country, out-migration of labor force and irregular power supply, Nepalese dairy entrepreneurs are not willing to invest in new technology and new products. Similarly, the owners of dairy industries are paying less attention to changing market needs and research and development.

Many food processors that undertake RECP projects find that significant environmental improvement and cost savings can be derived from simple modification to housekeeping procedures and maintenance programs. Table 1 below presents a checklist of some of the RECP procedures and programs. They are generic ideas that apply to the dairy manufacturing process as a whole.

Table 1: General Good Housekeeping Ideas

1. Keep work areas tidy and uncluttered to avoid accidents.
2. Maintain good inventory control to avoid waste of raw ingredients.
3. Ensure that employees are aware of the environmental aspects of the company's operations and their personal responsibilities.
4. Train staff in good cleaning practices.
5. Schedule regular maintenance activities to avoid breakdowns.
6. Optimize and standardize equipment settings for each shift.
7. Identify and mark all valves and equipment settings to reduce the risk that they will be set incorrectly by inexperienced staff.
8. Improve start-up and shut-down procedures.
9. Segregate waste for reuse and recycling.
10. Install drip pans or trays to collect drips and spills.

(United Nations Environment Programme (UNEP), 1999)

### 3.2 Energy and Fuel

Energy is an area where substantial savings can be made almost immediately with no capital investment, through simple housekeeping and plant optimization efforts. Substantial saving are possible through improved housekeeping and fine tuning of existing processes and additional savings are possible through the use of more energy-efficient equipment and heat recovery systems.

The total annual electricity consumption by the three industries is 1,703,891.403 kWh. The specific electricity consumption of the three industries collectively is 0.055 kWh per liter of milk production. The specific electricity consumption of industry A, B and C are presented in Figure 3 below:

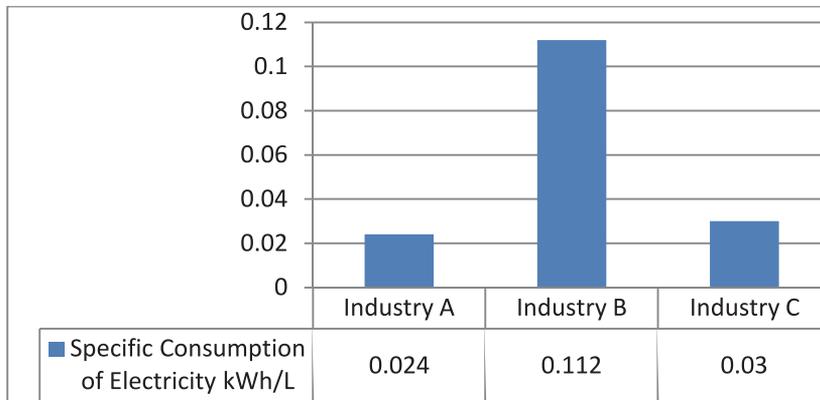


Figure 3: Specific Consumption of Electricity

Industry A seems to be more efficient in terms of energy use in comparison to industry B and industry C, which is mainly due to the installation of Time of Day (TOD) meter and better efficiency of motor loading and capacitor banks.

Diesel is mainly used for operating boiler. It is also used to operate generator at the time of load-shedding. The three industries collectively have 910 KVA capacity generators in place. The total annual consumption of diesel by the three industries is 495,360 liters. Industry B was found using kerosene to operate boiler, the annual consumption being 73,000 liters. The specific fuel consumption in three industries is collectively 0.0167 liter per liter of milk production. The specific fuel consumption of industry A, B and C are presented in Figure 4 below:

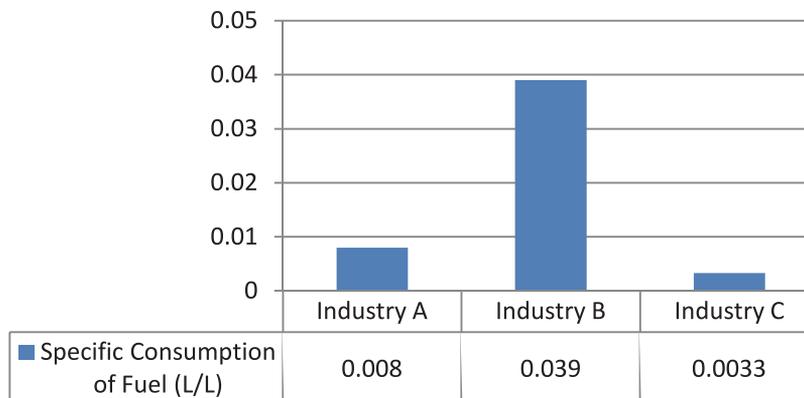


Figure 4: Specific Consumption of Fuel

Industry A and industry C are located inside the industrial area where, electricity is continuously supplied from 9 am to 5 pm. Hence their diesel requirement for running generator is low as compared to industry B. Industry C operating in single shift mainly runs from 9 am to 5 pm. Hence its fuel requirement is the lowest. Whereas, difference between industry A and industry B is because industry A has highly efficient automatic boiler and generator.

LP gas is used in laboratory only for performing sample test. The total annual consumption of LP gas by the three dairy industries is 647.52 kg. The specific LP gas consumption by the three industries is 0.023 kg per m<sup>3</sup> of milk production. The specific LP gas consumption of industry A, B and C are presented in Figure 5 below:

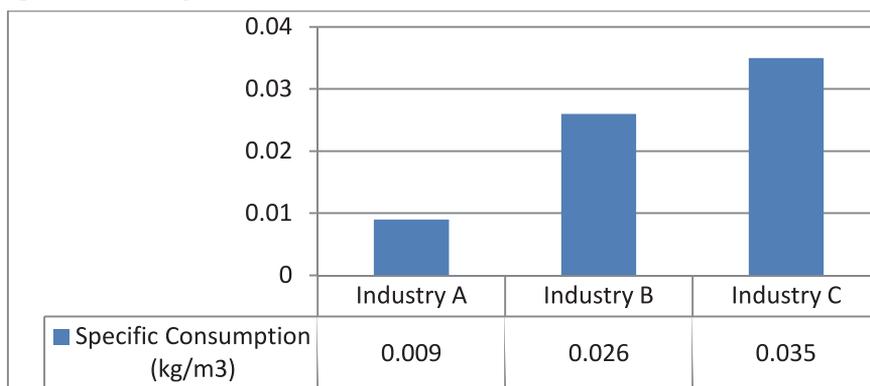


Figure 5: Specific Consumption of LP Gas

Efficiency in LP gas mainly depends upon the number of tanker that delivers the milk every day. In case of industry A, large tankers deliver milk to the industry from chilling centers and hence the number of lab test is less. Whereas in case of industry C, milk is collected from the communities and hence number of lab tests is more. Table 2 presents a checklist of RECP options in saving energy and fuels. They are generic ideas that apply to the dairy manufacturing process as a whole.

Table 2: Energy and Fuel Saving Options

- |   |
|---|
| <ol style="list-style-type: none"><li>1. Implement switch-off awareness programs to turn off or power down lights and equipment when not in use.</li><li>2. Improvement in motor loading.</li><li>3. Improvement in insulation of the cold pipelines, storage room walls and ceiling.</li><li>4. Replacement of old and rewound motors by energy efficient motors. Favor more energy and fuel efficient equipment.</li><li>5. Improve maintenance to optimize energy and fuel efficiency of equipment.</li><li>6. Improvement in the efficiency of capacitor banks.</li><li>7. Maintain optimal combustion efficiencies on steam and hot water boilers.</li><li>8. Eliminate steam leaks and condensate recovery.</li></ol> |
|---|

(United Nations Environment Programme (UNEP), 1999) and (PACE Nepal, 2012)

### 3.3 Water

Water is used extensively in dairy processing. So water saving offers very common RECP opportunity in these industries. In the dairy processing industry, water is used principally for cleaning equipment and work areas to maintain hygienic conditions, and accounts for a large proportion of total water use. Rates of water consumption can vary considerably, depending on the scale of the plant, its age, type of processes (batch or continuous) and the ease with which equipment can be cleaned, as well as operator practices.

The source of water in these industries is mainly groundwater from deep boring. Industry A and industry B also use water from water tanker when groundwater is not enough. The quality of groundwater used has been tested by industry A and industry B but not by industry C. The quantity of water used also depends on the operating practice adopted by an industry. More consumption of water means high volume of wastewater leading to high investment in wastewater treatment facility. The total water consumed by the three industries is 12,075 m<sup>3</sup> per annum. The specific consumption of water by the three industries is 0.83 liter per liter of milk processing. The specific water consumption of industry A, B and C are presented in Figure 6 below:

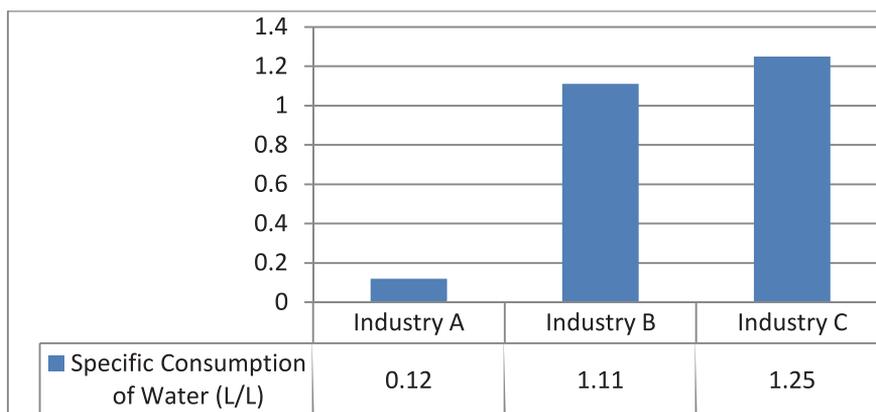


Figure 6: Specific Consumption of Water

Here, industry A has very less specific water consumption in comparison to industry B and industry C since industry A is operating with continuous processes whereas industry B and industry C with batch process. In industry A and industry B automated cleaning-in-place (CIP) systems is used but industry C is operating in manual cleaning process. Industry A has highly motivated maintenance team, who can immediately tackle any kind of leakage and is using high pressure water flow controller for manual cleaning processes. This practice makes industry A quite different in comparison to industry B and industry C. Table 3 presents a checklist of RECP options in reducing quantity of water uses. They are generic ideas that apply to the dairy manufacturing process as a whole.

Table 3: Water Saving Options

1. Use continuous rather than batch processes to reduce the frequency of cleaning.
2. Use automated CIP systems for cleaning to control and optimizes water use.
3. Install fixtures that restrict or control the flow of water for manual cleaning processes.
4. Use high pressure rather than high volume for cleaning surfaces.
5. Reuse relatively clean wastewaters (such as those from final rinses) for other cleaning steps or in non-critical applications.
6. Recirculate water used in non-critical applications.
7. Install meters on high-use equipment to monitor consumption.
8. Use compressed air instead of water where appropriate.
9. Report and fix leaks promptly.

(United Nations Environment Programme (UNEP), 1999)

### 3.4 Wastewater

Most water consumed within dairy plants ultimately becomes effluent. Among the three industries visited, none of them had water treatment plant and the effluent is directly discharged to municipal sewerage systems. The organic load discharged into the effluent stream varies, depending on cleaning practices and type of process (batch or continuous) used, since batch processes require a greater frequency of cleaning. Effluent standard of dairy industries as stated by Government of

Nepal is presented in Table 4 below:

Table 4: Effluent Standard of Dairy Industries

| SN | Characteristics                 | Tolerance Limit |
|----|---------------------------------|-----------------|
| 1  | pH                              | 5.5 – 8.5       |
| 2  | TSS, mg/l, max                  | 150             |
| 3  | BOD (5 days at 20o C) Mg/L, Max | 100             |
| 4  | Oil and grease, mg/L, Max       | 10              |
| 5  | COD, mg/l, Max                  | 250             |

Source: Government of Nepal, Effluent Standard for Dairy Industries

Dairy processing effluent contains predominantly milk and milk products which have been lost from the process, as well as detergents and acidic and caustic cleaning agents. Milk loss can be as high as 3–4%, with the main source of loss being residues which remain on the internal surfaces of vessels and pipes, accidental spills during tanker emptying and overflowing vessels. (COWI Consulting Engineers and Planners AS)

The annual quantity of wastewater generation from these three industries is 17,239.75 m<sup>3</sup> while the specific wastewater discharged from these three industries is 0.87 liter per liter of milk production. Besides, specific wastewater generated from individual industry varies from 0.127 to 1.31 liter per liter of milk production. The specific wastewater consumption of industry A, B and C are presented in Figure 7 below:

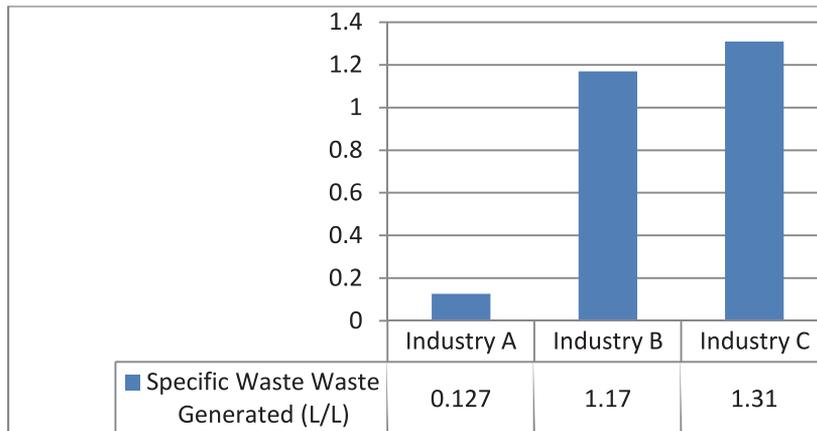


Fig 7: Specific Wastewater Discharged

Opportunities for reducing the pollutant load of dairy plant effluent focus on avoiding the loss of raw materials and products to the effluent stream. This means avoiding spills, capturing materials before they enter drains and limiting the extent to which water comes into contact with product residues. Table 5 presents a checklist of RECP options in reducing wastewater generated during the industrial processes. They are generic ideas that apply to the dairy manufacturing process as a whole.

Table 5: Options for reducing Wastewater

1. Ensure that vessels and pipes are drained completely and using pigs and plugs to remove product residues before cleaning.
2. Use level controls and automatic shut-off systems to avoid spills from vessels and tanker emptying.
3. Collect spills of solid materials (cheese curd and powders) for reprocessing or use as stock feed.
4. Fit drains with screens and/or traps to prevent solid materials entering the effluent system.
5. Install and maintain level controls and automatic shut-off systems on tanks to avoid overfilling.
6. Use dry cleaning techniques where possible, by scraping vessels before cleaning or pre-cleaning with air guns.
7. Use starch plugs or pigs to recover product from pipes before internally cleaning tanks.

(United Nations Environment Programme (UNEP), 1999)

### 3.5 Solid Waste

Dairy products such as milk, butter, cheese and yogurt are typically packed in plastic pouch, plastic bottles and cups, plastic bags or reusable glass bottles. Breakages and packaging mistakes cannot be totally avoided, but awareness among staffs for high efficiency in handling such packaging materials and containers is needed to reduce the quantity of solid waste. Improperly packaged dairy products can often be returned for reprocessing; however the packaging material such as glass bottles are reused and the plastic pouches are generally sold to plastic collector.

The annual quantity of solid waste generation from the three visited industries is 19,345 kg while the specific solid waste generated from these three industries is 0.27 kg per liter of milk production. The specific solid waste generation of industry A, B and C are presented in Figure 10 below:

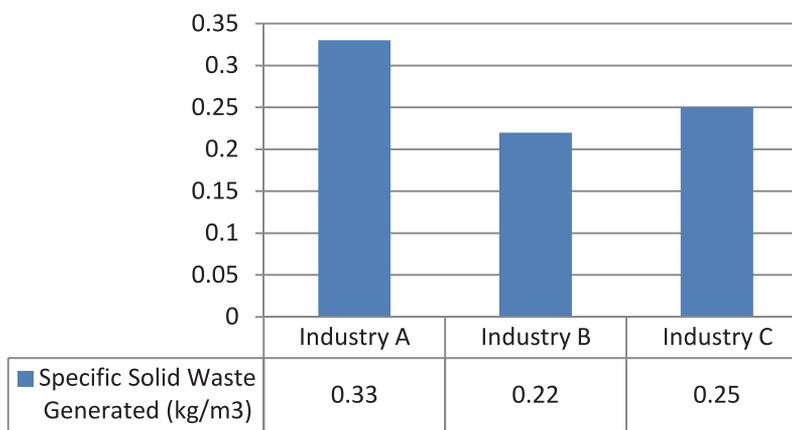


Figure 8: Specific Solid Waste Generated

### 3.6 Chemicals

The annual quantity of chemicals used by the three industries was 32,377.3 kg while the specific consumption of chemicals by the three industries is 1.74 kg per m<sup>3</sup> of milk production. The specific consumption of chemicals by individual industry varies from 0.5 to 1.35 kg per m<sup>3</sup> of milk production. Interestingly, industry C reports no use of any kind of chemicals in its dairy processing. The specific chemical consumption of industry A, B and C are presented in Table 6 below:

Table 6: Specific Consumption of Chemicals

| SN         | Specific Consumption of Chemicals (kg/m <sup>3</sup> ) |             |                 |         |
|------------|--|-------------|-----------------|---------|
|            | Cleaning Purpose                                       |             | Testing Purpose |         |
|            | Sodium Hydroxide                                       | Nitric Acid | Sulpheric Acid  | Ethanol |
| Industry A | 0.33   | 0.162       | 0.006           | 0.0013  |
| Industry B | 0.88   | 0.433       | 0.022           | 0.002   |
| Industry C | 0  | 0           | 0               | 0       |

### 4. Conclusion

From the study in Dairy Development Corporation, Nepal Dairy Industry and Bhaktapur Dairy Industry, it was found that the resource consumption depends upon the resources handling practices and awareness among the staffs in general. In these industries, a significant need of awareness program was observed to motivate staffs for proper resources handling and good housekeeping practices. At present scenario, it might not be feasible for dairy industries in Nepal to make huge investment to change technologies, but there are many no cost and low cost RECP option, which can result in significant saving of resources, leading productivity and profitability enhancement. These options will also help in reducing negative environmental impact and come close to effluent standard set by the Government of Nepal.

### 5. Acknowledgement

I would like to thank Dairy Development Corporation, Nepal Dairy Industry, Bhaktapur Dairy Industry and its staffs who provided me opportunity to visit their industry, understand dairy processing and also provided relevant information and data needed for this research.

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## Defluoridation of Contaminated Water using Zirconium Impregnated Activated Carbon Prepared from Betel Nut

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### Abstract

The feasibility of zirconium impregnated activated carbon prepared from betel nut (*Areca catechu*) for adsorptive removal of fluoride from water was investigated. Activated carbons (ACs) were prepared by chemical activation of betel nut with  $H_3PO_4$  acid of ratio 1:1 by weight at 400 °C for 3hrs under nitrogen atmosphere. The resultant AC was impregnated with zirconium ion. The influence of pH, contact time and adsorbent dose on the defluoridation process was investigated. The percentage of fluoride removal by AC was highly increased after zirconium impregnation. The optimum conditions of defluoridation were pH value 2, adsorbent dose of 20 g/L with contact time of 180 min. The equilibrium adsorption data were analyzed by the Freundlich and Langmuir adsorption isotherm. The adsorption data was fitted Langmuir better than Freundlich isotherm with maximum adsorption capacity of 6.5 mg/g. The zirconium impregnated AC prepared from betel nut could be an efficient adsorbent for defluoridation of water.

**Keywords:** Activated carbon, Zirconium, Defluoridation, Fluoride.

### 1. Introduction

Fluoride in drinking water may be beneficial or detrimental to health depending on its concentration. At low concentration, it is beneficial to health in strengthening teeth and bones but at high concentration, it causes dental and skeletal fluorosis. According to WHO, the maximum permissible limit of fluoride in drinking water is 1.5 mg/L (WHO, 2008).

Groundwater is the major source of drinking water in many countries across the world. Excessive fluoride concentrations in ground water have been reported in more than 27 developed and developing countries. Ground water contaminated with high concentration of fluoride is reported in the various regions of Nepal. However, in Nepal, no serious study has yet been made regarding fluoride contamination in water (Bashir et al., 2013). Since, fluoride contamination in water being a common problem in several parts of the world, defluoridation of the groundwater before using it for drinking purpose is very essential in order to prevent associated health problems.

Precipitation and adsorption are common method applied for defluoridation of water in developing countries. Precipitation method is applicable for defluoridation of water containing high concentration of fluoride. Adsorption has proved to be the effective fluoride removal method, particularly in treating low concentrations of water. Different adsorbents have been used for the removal of fluoride including activated carbon (Sathish et al., 2007), activated alumina (Ghorai and Pant, 2005), bone charcoal (Abe et al., 2004), silica gel (Mondal et al., 2012), etc. Among these, activated carbon (AC) has been the most common. Recently, the use of agricultural waste materials for the preparation of activated carbon has been increased due to their availability at low cost. Agricultural waste materials such as coconut shell (Arulanantham et al. 1989), pecan nut shells (Hernandez-Montoya et al., 2012), walnut shell (Rajan and Alagumuthu, 2013) etc have been used to prepare AC for defluoridation of water. Recently, considerable work has been conducted in developing new adsorbents loaded with metal ions for the adsorptive removal of fluoride. It has been reported that the adsorption capacity of fluoride on zirconium impregnated coconut shell AC is 25-30

times higher than that of plain AC (Sathish et al., 2007). In addition, study on Zirconium impregnated walnut shell carbon (Rajan and Alagumuthu, 2013) and zirconium impregnated groundnut shell AC (Alagumuthu and Rajan, 2010) for defluoridation of water also has shown promising results.

Betel nut (Areca catechu) is very popular in Nepal and India. Different parts of betel nut have been used for preparation of AC such as areca nut shell (Geetha et al., 2009), areca husk carbon (Basker et al., 2014) and areca nut coir (Chakrabarty and Sarma, 2011). However, there are a few reports available on betel nut itself for preparation of activated carbon. So betel nut is of special interest towards preparation of AC for defluoridation of water. The present study deals with the effectiveness of zirconium impregnated betel nut AC for defluoridation of water.

## 2 Material and Methods

### 2.1 Preparation of Zr-imp.betel nut activated carbon (ZIBNAC)

Betel nuts were purchased from local market, Kathmandu, Nepal. Twenty grams of dried, crushed, powdered betel nut was mixed with phosphoric acid ( $H_3PO_4$ ) in the ratio of 1:1 by weight and stirred with magnetic stirrer at 70 °C until partly dried. The sample was dehydrated at 100 °C for 24 hrs in an air oven and then carbonized at 400 °C for 3 hours in a horizontal tubular furnace under flow (75 ml / min) nitrogen. The prepared AC was treated with 0.1N NaOH, subsequently washed with hot distilled water and dried. The resultant AC impregnated with zirconium ion according to the procedure given by Alagumuthu and Rajan (2010). Betel nut AC was mixed with 5%  $ZrOCl_2 \cdot 8H_2O$  solution in the solid/ solution ratio of 1:2. The mixture was stirred for 3 days then filtered, washed with distilled water till free from zirconium ion and dried. The prepared ZIBNAC was used for defluoridation of water. All the reagents used were of analytical grade (Merck and Qualigens Company).

### 2.2 Adsorption (defluoridation) study

Adsorptive removal of fluoride from water using ZIBNAC was investigated by batch method. A definite amount of betel nut AC (BNAC) was suspended with 50 ml of fluoride solution in 100 ml plastic conical flasks. The mixtures were agitated on electric shaker (Digital VDRL Rotator-RPM-S) at 225 rpm for a prescribed time to attain the equilibrium. After equilibrium, the solution were filtered and fluoride ion concentration before and after adsorption was measured with a fluoride ion selective electrode (Orion 94-09, 96-09, Thermo Electron Corporation, USA) according to the procedure (APHA, 2012).

The milligram of fluoride ions per gram of adsorbents,  $q_e$  (mg/g) adsorbed and the percentage of removed fluoride ions was calculated by the following equation.

$$q_e \text{ (mg / g)} = \frac{(C_o - C_e) \times V}{M} \dots\dots\dots (1)$$

$$\text{Removal (\%)} = \frac{(C_o - C_e) \times 100}{C_o} \dots\dots\dots (2)$$

Where,  $C_o$  = initial concentration of fluoride ions (mg/L);  $C_e$  = equilibrium concentration of fluoride ions (mg/L); V = volume of fluoride solution (L) and M = mass of adsorbent (gm).

The adsorption studies were conducted for the optimization of various experimental conditions like pH, contact time, adsorbent dose and adsorption isotherms.

### 3 Results and Discussion

#### 3.1. Adsorption (defluoridation) studies

The percentage of fluoride removal by plain betel nut AC (BNAC) and zirconium impregnated betel nut AC (ZIBNAC) is presented in Figure-1.

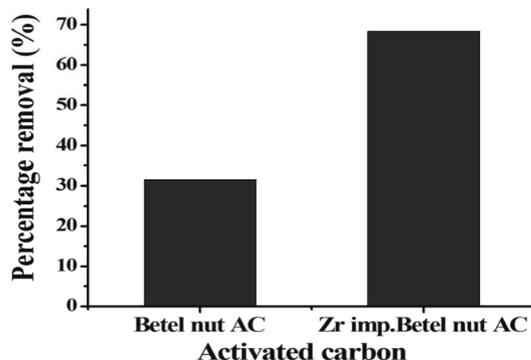
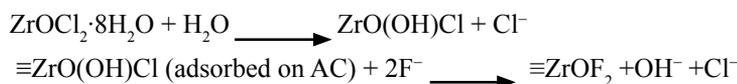


Figure-1: percentage of fluoride removal by plain betel nut AC and zirconium impregnated betel nut AC

The plain AC prepared from betel nut (BNAC) was found to adsorb fluoride from water to certain degree. However the defluoridation capacity is very low i. e. below 40 %. The zirconium impregnated AC (ZIBNAC) has greater adsorption capacity than the plain AC. It seems that, after impregnation of AC with zirconium ion, the defluoridation capacity is greatly increased. The possible fluoride adsorption mechanism can be explained as follows. Zirconyl chloride behaves as a Lewis acid in aqueous solution and is hydrolyzed according to the reaction.

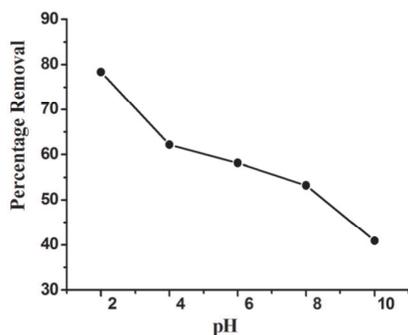


Where,  $\equiv$  represents the surface of the AC

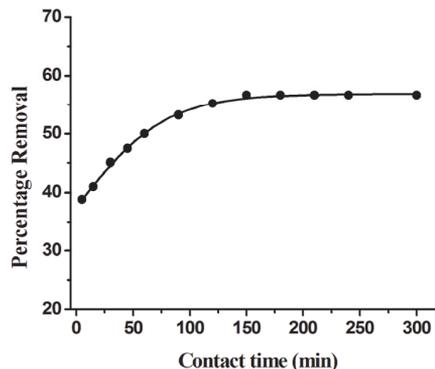
First, Zr (IV) species from the hydrolysis of  $\text{ZrOCl}_2 \cdot 8\text{H}_2\text{O}$  adsorb on AC surface by oxygen functional groups ( $-\text{COOH}$ ,  $-\text{OH}$ ) groups through electrostatic interactions and then forms surface complex on the AC. Once the zirconium based Lewis acid sites are generated by chemisorption on BNAC as a monolayer, they are responsible for the very strong adsorption of Lewis bases, such as the fluoride ion. The fluoride uptake, involves an exchange of the chloride and the hydroxide of the  $\text{ZrO(OH)Cl}$  species adsorbed on BNAC by fluoride, leading to the formation of  $\text{ZrOF}_2$  on the AC surface (Satish et al., 2007). Since ZIBNAC shows high defluoridation capacity, effect of several parameters such as pH, contact time, adsorbent dosage on the adsorption process and adsorption isotherms were carried out.

#### 3.2 Effect of pH

The effect of pH on the percentage of fluoride removal within the range of pH 2-10 is presented in figure-2. The initial fluoride concentration, adsorbent dose and contact time were kept constant at 19 mg/L, 0.25 g and 180 minutes respectively.



**Figure 2 Effect of pH on the percentage of fluoride removal**



**Figure 3 Effect of contact time on percentage of fluoride removal**

The percentage of fluoride removal decreases with increasing pH. The removal of fluoride is maximum ~ 80 % at pH 2. At higher pH, the fluoride removal by the adsorbent was found to decrease. The increase in percentage of fluoride adsorption at low pH can be attributed to the gradual increase in attractive forces between positively charged surface and negatively charged fluoride ions. The reduction in the percentage of adsorption of fluoride at higher pH level is due to the due to the repulsion between the negatively charged surface and the fluoride ions.

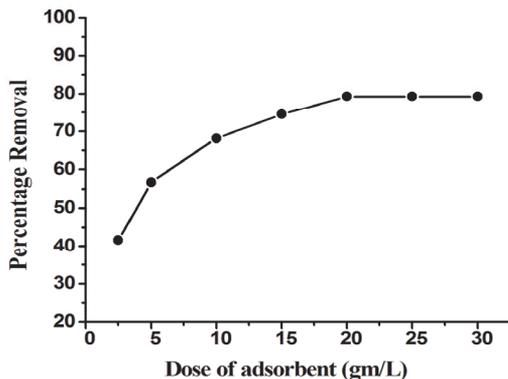
### 3.3 Effect of contact time

The effect of contact time on the percentage of fluoride removal within the range of 5–300 min is presented figure-3. The initial fluoride concentration, adsorbent dose and pH were kept constant at 19 mg/L, 0.25 g and 6.5 respectively.

The percentage removal was increased linearly up to 180 min and thereafter it remained almost constant indicating the attainment of equilibrium. The percentage of fluoride removal is higher in the beginning due to the large vacant surface sites or surface area of the adsorbent being available for the adsorption. But with the passage of time, the remaining vacant surface sites are difficult to be occupied due to the repulsive forces between the fluoride ions on the solid surface and in solution. It led to decrease in the percentage removal. Hence, the minimum contact time for maximum removal was 180 min. Similar results were reported for fluoride removal by Alagumuthu and Rajan (2010).

### 3.4 Effect of Adsorbent Dose

The effect of adsorbent dose on the percentage of fluoride removal with varying adsorbent dose from 2.5 g/L to 30 g/L is presented in figure-4. The initial fluoride concentration, contact time and pH were kept constant at 19 mg/L, 180 min and 6.5 respectively.



The percentage removal increased with the increase in the dose of adsorbent and attained to maximum of ~80% at 20 g/L of the adsorbent. Further addition of the adsorbents did not show a considerable increase in percentage of fluoride removal. The increase in fluoride removal percentage with increasing adsorbent dose is due to the greater availability of the vacant sites or surface area on the adsorbent surface. However, beyond certain dose, percentage removal remains constant even with further addition of dose of adsorbent. This is because the overlapping of the adsorption sites at higher adsorbent dose thus reducing the surface area.

### 3.5 Adsorption Isotherms

The equilibrium adsorption isotherms describe the interactive behavior of adsorbate and adsorbent. The Langmuir and Freundlich isotherms are frequently used. Langmuir adsorption isotherm commonly applied in solid/liquid system to describe the saturated monolayer adsorption where as Freundlich adsorption isotherm describes the adsorption equilibrium, based on adsorption on heterogeneous surface. The linear form of Langmuir isotherm equation is given by

$$\frac{C_e}{q_e} = \frac{1}{b q_m} + \frac{C_e}{q_m} \dots\dots\dots(1)$$

Where  $C_e$  is the equilibrium concentration of fluoride in solution (mg/L);  $q_e$  is the amount of fluoride adsorbed (mg/gm);  $q_m$  is maximum adsorption capacity (mg/gm) and  $b$  is the Langmuir constant. The Langmuir constant ( $b$ ) and maximum adsorption capacity ( $q_m$ ) can be calculated from slope and intercept of the plot. The applicability of the isotherm equations was compared by judging the coefficients of determination  $R^2$ .

The validity of Langmuir adsorption isotherm adsorption data of the adsorbent was tested by plotting the value of  $\frac{C_e}{q_e}$  v<sub>s</sub>  $C_e$ . The typical plot  $\frac{C_e}{q_e}$  v<sub>s</sub>  $C_e$  for adsorption of fluoride is shown in Figure 5.

The linearized form of the Freundlich equation is represented as.

$$\log q_e + \frac{1}{n} \log C_e \dots\dots\dots(2)$$

Where  $q_e$  is the amount of fluoride adsorbed (mg/g);  $C_e$  is the equilibrium concentration of fluoride in solution (mg/L);  $K$  are constant respectively. The value of adsorption intensity ( $n$ ) and Freundlich constant ( $K$ ) can be determined from slope and intercepts of the plot. In order to test the validity of Freundlich adsorption isotherm, adsorption data are tested by plotting the value of  $\log C_e$  vs  $\log q_e$ . The typical plot  $C_e \cdot v_s \log q_e$  for adsorption of fluoride is shown in Figure 6.

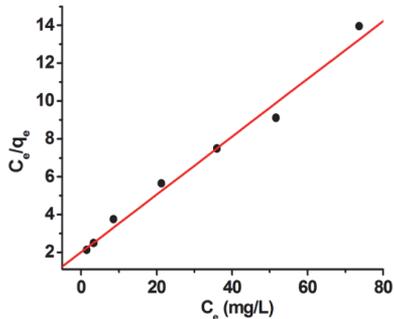


Figure 5 Plot of  $C_e/q_e$  vs  $C_e$  for Langmuir isotherm

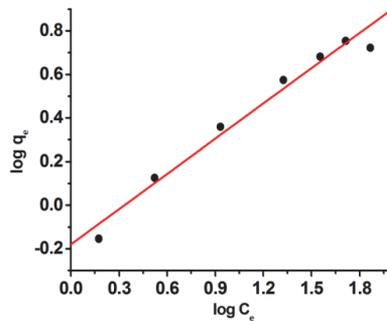


Figure 6 Plot of  $\log q_e$  vs  $\log C_e$  for Freundlich isotherm

Langmuir and Freundlich parameters (maximum adsorption capacity, adsorption intensity and coefficients of determination) are given in the Table 2.

Table-1 Langmuir and Freundlich parameters for adsorption of fluoride ion onto Zr-imp.AC

| Langmuir parameters               |       | Freundlich parameters     |       |
|-----------------------------------|-------|---------------------------|-------|
| Adsorption capacity, $q_m$ (mg/g) | $R^2$ | Adsorption intensity, $n$ | $R^2$ |
| 6.5                               | 0.986 | 1.8                       | 0.973 |

Table-1 shows that the values of coefficient of determination ( $R^2$ ) for Freundlich adsorption isotherm are found to be less than that for Langmuir model. This means that adsorption of fluoride ions onto adsorbent follows Langmuir model more than Freundlich model. It describes the adsorption of fluoride takes place through the formation of monomolecular layer on the surface of the adsorbent.

#### 4. Conclusion

In the present study, a zirconium impregnated betel nut AC was studied for the defluoridation of water. Betel nut AC is prepared by chemical activation with phosphoric acid. The adsorbent was prepared by impregnation of AC with zirconium ion. The optimum conditions for defluoridation are (i) pH - 2 (ii) Adsorbent dose – 20 gm/L and (iii) Contact time – 180 min. The adsorption of fluoride follows more to Langmuir isotherm than to Freundlich isotherm confirming the monolayer adsorption of fluoride with adsorption capacity 6.5 mg/g. The zirconium impregnated AC prepared from Betel nut can be a promising environmental materials for fluoride removal from water.

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# **Analysis of Physico-Chemical Parameters and Conservation Practices at Mai Pokhari, Ilam**

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## **Abstract**

Wetlands are one of the most productive and diverse ecosystem. Wetlands cover 5% of the total area of Nepal. Nepal has ten wetland enlisted as Ramsar site among which Mai Pokhari was enlisted as Ramsar site in 2008. The aim of the study was to analyze the status of physicochemical parameters and conservation practices of Mai Pokhari. Primary as well as secondary data were used in the study. The physico-chemical parameters analyzed by using standard method were pH, Electric Conductivity, Temperature, DO(Dissolved Oxygen), Carbon dioxide, Chloride, Alkalinity, Total Hardness, Turbidity, TDS(Total Dissolved Solid), TSS(Total Suspended Solid), Ammonia, Phosphate and Iron. The other methods used were observation, KII (Key Informant Interview) and questionnaire. The result shows that the physico-chemical parameters are within permissible range for aqua culture and the value differences in sites were found to be minimal difference among which may be due to small area of wetlands. The major conservation activities conducted were found to be afforestation and waste management.

**Key Words:** Mai Pokhari, aquaculture, conservation, Ramsar

## **1. Introduction**

According to National Wetland Policy (2003) of Nepal, wetlands are the water bodies that originate from underground sources or rain that are either natural or man-made. Wetlands in Nepal include high altitude glacial lakes, hot springs, ponds, oxbow lakes, river flood plains, swamps and also marshes (Joshi& Joshi, 2003). Among the total area of Nepal about 743,500 ha is estimated to be covered by wetlands out of which 34,455 ha area is designated as Ramsar sites (Siwakoti&Karki, 2009). Nepal has total ten Ramsarsites, among which Mai Pokhari was designated in 2008.

Although wetlands have a great importance they are being degraded in recent years (MoFSC, 2014). There are various factors that cause changes in a wetland, according to Burkert et al. (as cited by Thapa&Shaund, 2012) wetlands are integrated systems which are affected by the changes in the key physical as well as chemical parameters. The physical and chemical properties of wetlands depend upon climatic, geochemical, geo morphological and pollution condition (Choudhary et al., 2014).

Conservation of wetland is one of the best applications applied to maintain the integrity of wetland and preserve its resources. In Nepal the conservation and management of wetland and its resources has been given focus after realizing the importance of wetlands and their species (Joshi, 2009). Though different conservation activities are being conducted still loss of wetlands in Nepal occurs (Bhandari, 2009).

Among the Ramsar sites of Nepal, Mai Pokhari is given less focus. Invasion of exotic Japanese Pine and gold fish has adversely affected the indigenous floral and faunal species especially birds and amphibians respectively (Kafle&Savillo, 2009). Along with that Mai Pokhari also has its religious and cultural significant to the people living in that area. Insufficient research activities related to physico-chemical parameters of Mai Pokhari are available, which do not explain about the existing water quality situation of this wetland.

This study is conducted to know about the status of physico-chemical parameters of the wetland, to assess existing conservation practices in the wetland and to know about community perception regarding importance of conservation of wetland.

## 2. Methodology

### 2.1 Study Area

The study was conducted in Mai Pokhari which lies in Ilam district of Mechi Zone in Nepal's Eastern Development Region. It is located at the latitude from 26°55'14" N to 27°06'09" N and longitude from 87°51'47" E to 87°56'09" E. It covers an area of 90 ha. The map of the study area is given in the Figure 1. The sample for the analysis of physico-chemical parameters was taken from five sites. The geographical locations of the sites are given in the Table 1.

Table 1: Location of Sample Sites

| Sample Site | Latitude/ Longitude            |
|-------------|--------------------------------|
| Site 1      | 27° 00.439' N<br>87° 55.768' E |
| Site 2      | 27° 00.470' N<br>87° 55.842' E |
| Site 3      | 27° 00.428' N<br>87° 55.867' E |
| Site 4      | 27° 00.414' N<br>87° 55.822' E |
| Site 5      | 27° 00.353' N<br>87° 55.774' E |

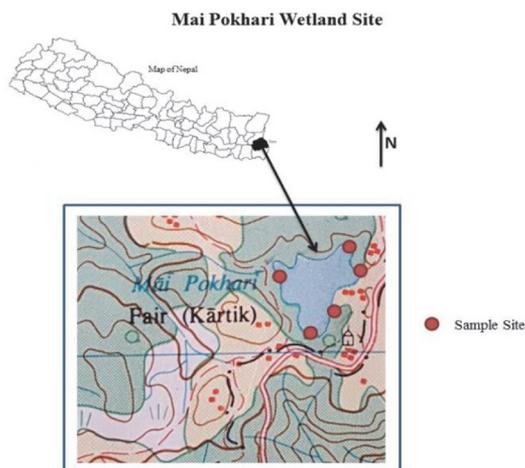


Figure 1: Mai Pokhari

### 2.2 Sample Collection

Water samples were collected from five sampling stations. The five stations were taken as per the accessibility of sites from the pilot survey. However there was no visible inlet and outlet in the wetland. Samples were taken in October 14, 15, 16 and 17, 2016 in the morning hours. Samples were collected in different plastic bottles.

Table 2: Water parameters and method used for analysis

| SN | Parameters                   | Methods                       | Unit                      |
|----|------------------------------|-------------------------------|---------------------------|
| 1  | pH                           | pH meter                      |                           |
| 2  | EC (Electrical Conductivity) | Conductivity Meter            | μs/cm                     |
| 3  | Temperature                  | Thermometer                   | °C                        |
| 4  | DO                           | Winkler's Iodometric          | mg/l                      |
| 5  | Carbon dioxide               | Titration using strong alkali | mg/l                      |
| 6  | Chloride                     | Argentometric method          | mg/l                      |
| 7  | Alkalinity                   | Titration using strong acid   | mg/l                      |
| 8  | Total Hardness               | EDTA method                   | mg/l as CaCO <sub>3</sub> |

|    |           |                      |      |
|----|-----------|----------------------|------|
| 9  | Turbidity | Nephelometric        | NTU  |
| 10 | TDS       | Gravimetric method   | mg/l |
| 11 | TSS       | Gravimetric method   | mg/l |
| 12 | Ammonia   | Phanate method       | mg/l |
| 13 | Phosphate | Stannous Chloride    | mg/l |
| 14 | Iron      | Phenanthronic method | mg/l |

The analysis of physico-chemical parameters like pH, Temperature, Electric Conductivity, Dissolved Oxygen, Carbon dioxide, Chloride, Total Hardness, Total Alkalinity were done on site itself, whereas Turbidity, TDS, TSS, Ammonia, Phosphate and Iron were analyzed in the lab of SchEMS college. Standard methods (as shown in Table 2) were used to determine the physico-chemical parameters. Along with that observation, KII and Questionnaire survey was also conducted to know about various conservation practices and perception of people

### Result and Discussion

The result of the physicochemical parameters in the five stations is given in Table 3. The value of DO in the wetland was found to be little less which may be due to the biomass present in the wetland. Similarly the alkalinity and the hardness in the five sites were also found to be little less. As the alkalinity and hardness depends upon the bedrock type of the bed rock of the wetland, this may be the reason of the minimal value.

Table 3: Physicochemical parameters in five sample sites

| SN | Parameters                  | Site1  | Site 2 | Site 3 | Site 4 | Site 5 |
|----|-----------------------------|--------|--------|--------|--------|--------|
| 1  | pH                          | 8.80   | 8.80   | 7.80   | 7.70   | 7.70   |
| 2  | Conductivity( $\mu$ s/cm)   | 18     | 18     | 18     | 18     | 18     |
| 3  | Temperature ( $^{\circ}$ C) | 13.01  | 13.22  | 13.99  | 14.09  | 14.35  |
| 4  | DO (mg/l)                   | 4.46   | 4.46   | 4.46   | 4.46   | 4.46   |
| 5  | Carbon dioxide (mg/l)       | 2.20   | 4.40   | 2.20   | 2.20   | 2.20   |
| 6  | Chloride (mg/l)             | 11.36  | 8.52   | 11.36  | 9.94   | 8.52   |
| 7  | Alkalinity (mg/l)           | 10     | 15     | 5      | 10     | 10     |
| 8  | Total Hardness (mg/l)       | 2.00   | 2.00   | 4.00   | 2.00   | 2.00   |
| 9  | Turbidity(NTU)              | 1.60   | 3.12   | 1.80   | 1.80   | 1.72   |
| 10 | TDS (mg/l)                  | 600    | 600    | 400    | 400    | 400    |
| 11 | TSS (mg/l)                  | 5940   | 6240   | 6040   | 5820   | 6120   |
| 12 | Ammonia (mg/l)              | 0.183  | 0.197  | 0.313  | 0.321  | 0.291  |
| 13 | Phosphate (mg/l)            | < 0.1  | <0.1   | < 0.1  | < 0.1  | < 0.1  |
| 14 | Iron (mg/l)                 | < 0.05 | < 0.05 | < 0.05 | <0.05  | < 0.05 |

This indicates that the amount of calcium and magnesium as carbonate in the water is low. All the sites were found to have a minimal difference in the value which may be due to small size of wetland and small volume of wetland in the wetland. Likewise, the values were also found to be within permissible range according to Nepalese guideline for environmental statistics for aquaculture.

Similarly, from the study it was found that TEF, The Religious Forest Group and Department of Plant Resources were the organizations more directly involved with the conservation practices in the wetland. Among these organizations TEF (The East Foundation) was seen more actively involved in the conservation activities. The common activities for conservation included Afforestation and Waste Management. Along with that other activities included: Awareness Campaign, Replacement of Japanese Pine by local plants like Katus (*Castanopsisindica*), Rani Champ (*Magnolia doltosopa*), Phusre Champ (*Magnolia languinosa*), Bajrath (*Quercus lamellose*), and Khasru (*Quercussemecarpifolia*). Likewise a germplasm has also been established to conserve the local species and a new museum has also been established to give information regarding different biodiversities present in the wetland. Similarly, information center has also been established to provide information regarding wetland to tourists as well as researchers. A provision of supplementary water source has also been made by TEF that lies around 5 km from the wetland and provides 2 lakhs water per day, however the water volume in the wetland is still found to be decreasing. Likewise, the involvement of local bodies was seen more in the conservation activities rather than the governmental organization. From the study it was seen that still more focus is required in terms of conservation in Mai Pokhari area.

From the study it was also found that local people around the wetland found wetland important economically, environmentally, as well as socially. It was found that people viewed conservation as one of the important asset for wetland. 95% of the sampled population was ready to contribute for conservation activities of the wetland, among which most of them were willing to contribute for conservation by free labor.

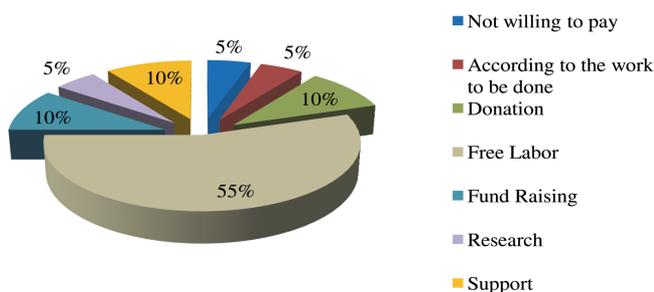


Figure 2: Contribution from people

Similarly, in terms of willingness to pay it was found that 90% of population was ready to pay certain amount for conservation of wetland

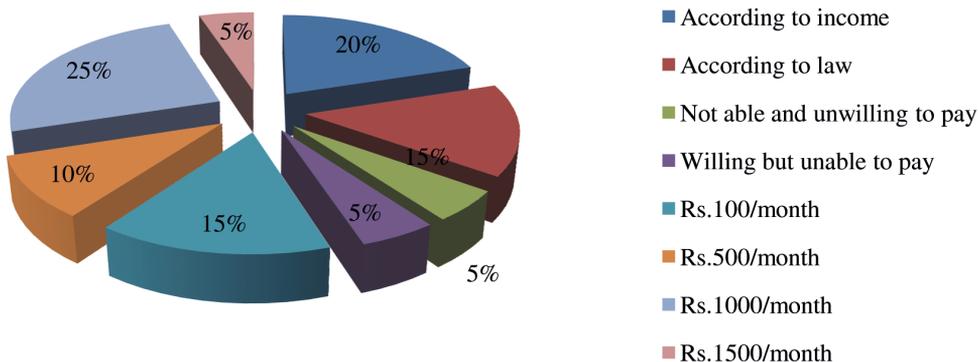


Figure 3: Willingness to Pay

In a study conducted by Bhattarai (2015) in KoshiTappu wildlife reserve it was found that the awareness for wetland conservation in that area was fully dependent on the education level however through the study it was found that perception of people regarding the importance of wetland was not affected by education level in Mai Pokhari. Similarly, from the same study of it was also found that the willingness to pay fully depends on the education, area of land owned and annual expenditure of the people. But contradictory to that it was found that people living around the Mai Pokhari area were willing to pay for the conservation of wetland according to the law and their income level. Even the visitors that visited wetland believed that conservation of the wetland is important to maintain the integrity of the wetland and its surrounding periphery as well as to preserve the culture and tradition of the community.

#### **4. Conclusion**

Thus from the study we can conclude that the water quality is satisfactory for the aquaculture purpose. However the conservation activities requires more incentives as well as the wetland still needs more focus from governmental sector. On the contradictory side, the local communities are concerned about the conservation of wetland and are involved in various conservation activities. Similarly, the wetland also is also seen to be of a great importance to the communities.

However, the study only included some selected parameters and the seasonal variation of the wetland was also not analyzed. Likewise the biodiversity around the wetland and their conservation approach was also not focused in this study.

#### **Acknowledgement**

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## **Impact of Climate Change on Cropping System and Adaptation Strategies Undertaken by Indigenous Community in the Hilly Areas of Chitwan, Nepal**

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### **Abstract**

The study was focused to assess the impact of climate change on cropping system and adaptation strategies undertaken by indigenous community in the hilly areas of Chitwan, Nepal. This study was conducted in 2016 in two VDCs Shaktikhor and Siddi as the sample representing the hilly area of Chitwan, which was dominated by the indigenous community namely Chepang. In survey, 120 households were selected randomly from two VDCs, 60 from each, using simple random sampling technique. Pre-test, questionnaire survey, direct observation, focus group discussion were the primary information source and secondary information were collected and analyzed using SPSS software; Microsoft Excel and Logistic regression model. About 49.17% had the ambiguous knowledge on climate change terminology and major sources of knowledge were by self-experience and through media. About 62.5% of the respondents perceived the change in weather parameters like temperature and rainfall. Majority of respondents (59%) perceived the increase in temperature, about 58.30% of the respondents perceived the decrease in rainfall frequency and majority of the respondents also perceived the increment in climate induced hazards. Trend analysis of temperature data over 26 years of Chitwan showed that maximum, minimum and average temperature were found in increasing trends but the rainfall was erratic. 51.7% respondent farmers changed the old cropping system to cope with the changing trend of climate. Farmers had lesser cropping system practices in their upland as well as lowland area before but nowadays they were using more crops and intensive cropping incorporating with short duration crops to cope with the climate change effect. Farmers were practicing some adaptation strategies knowingly and unknowingly to mitigate the impact of climate change on the cropping system as well as whole farming system in the area, which included water harvesting ponds, agroforestry, mulching, mixed cropping, SALT (sloppy agricultural land technology), use of organic manure, use of bio pesticides, multiple cropping, mix cropping, use of hybrid and improved variety, Fodder tree plantation at the bund of field, etc.

**Key words:** indigenous, chepang, climate, adaptation, rainfall, temperature.

### **1. Introduction**

Agriculture is the tray of the economy of Nepal accounting for about one third (31.1 per cent in 2009-10) of GDP (NRB, 2010), Climate is commonly defined as the weather averaged over a long period of time (AMO, 2009). The standard averaging period is 30 years (BMO, 2009). Climate change refers to persistent change in climatic parameters (Rainfall, temperature, and humidity), due to anthropogenic or nature induced causes. Climate change is defined as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time period (UNFCCC, 1997). Climate change is considered the most critical global challenge of the century.

Since agriculture depends strongly on weather and climatic conditions, an important part of the economy of the country is sensitive to climate change (Alan & Regmi, 2004). The international fund for Agriculture development (IFAD) has also recognized climate change as one of the important factors affecting rural poverty and as one of the challenges that need to be addressed wisely (IFAD, 2009). The Chepang are an indigenous people living in the upper hills of the central region of Nepal. Their settlements are often situated on marginal lands in hilly slopes for e.g. in the hilly parts of Chitwan and they are vulnerable to climate change effect on their agriculture sector. Changing temperatures and erratic rainfall pattern are affecting crop production in Nepal (Malla 2008). Other changes in agriculture, such as loss of local land races of both crops and domestic animals, changes in cropping sequences, scarcity of water due to drying up of wells, and increasing incidences of disease and pest have also been noticed (Regmi et al. 2008). Climate change only not always the main reason behind these changes but it may act as a catalyst for increasing effect on livelihoods of farmers, especially those who are economically more vulnerable e.g. indigenous community of Nepal. According to (CSSA, 2011) understand the physiological, genetic, and molecular basis of adaptation to drought, heat, and biotic stresses likely resulting from climate change; Translate new knowledge into new agricultural systems that integrate genetic and management technologies. In other words, both breeding and agronomy will contribute to adaptation; Transfer knowledge effectively and make technologies and innovations widely available to increase food production and stability. The presence of adaptive capacity has been shown to be a necessary condition for the design and implementation of effective adaptation strategies so as to reduce the likelihood and the magnitude of harmful outcomes resulting from climate change (Brooks & Adger, 2005).

## **2. Methodology**

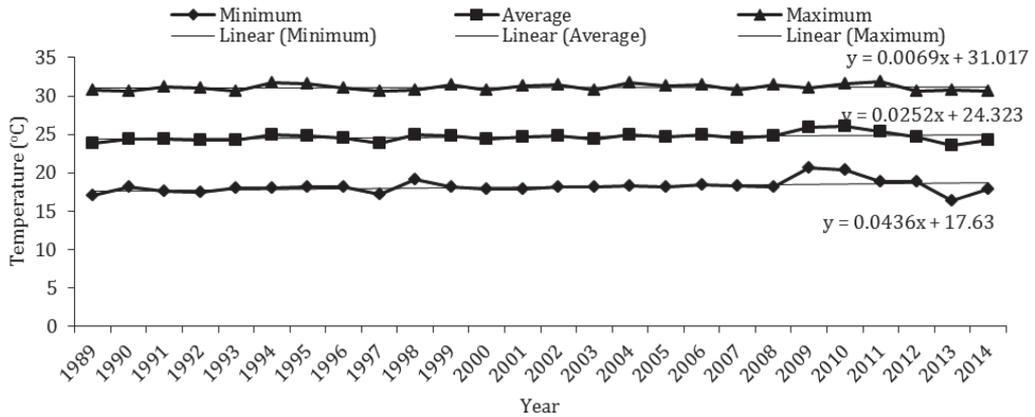
Sample household survey, direct interview and focus group discussion were conducted for primary data collection. Altogether 120 household were selected, 60 from Siddi VDC and 60 from Shaktikhor VDC representing the Hilly area of Chitwan, Nepal by applying simple random sampling method. The collected data were coded, tabulated and analyzed by using Statistical Package for Social Science (SPSS).

Secondary data (data related to agriculture, rainfall and maximum as well as minimum temperature) were gathered through various sources, i.e. DHM, DADO, MoAD published reports.

## **3. Results and Discussion**

### **3.1 Trend of temperature at Chitwan**

By analyzing the Average, maximum and minimum temperature of last 26 years in Chitwan district (from the NMRP, Rampur station), the trend analysis showed that maximum temperature, minimum temperature and average temperature increased by 0.006°C, 0.043°C and 0.025°C per year, respectively in Chitwan (Figure 3). The trend analysis strongly supports the farmer perception as hotness increment in summer and less cold in winter as compared to the past but some farmers also perceived more cold in winter.

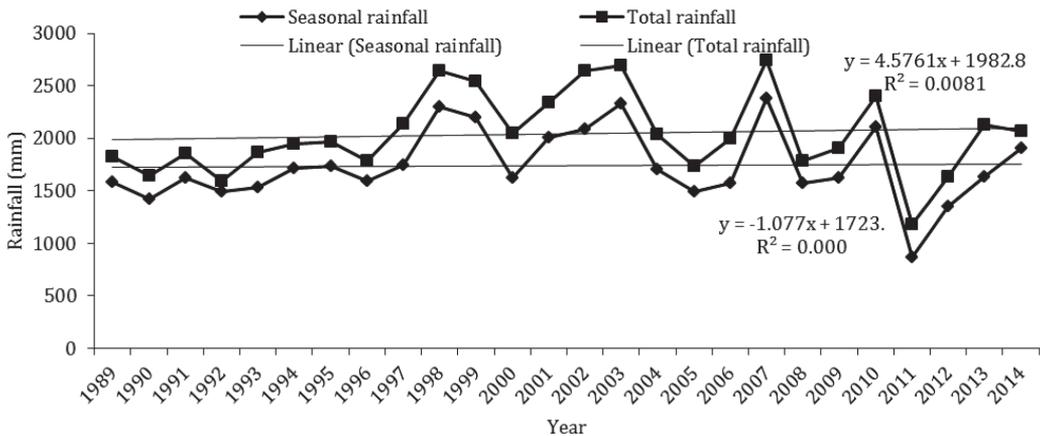


Source: DHM (2016)

Figure 1. Trend of temperature (°C) at Chitwan (1989-2014)

### 3.2. Trend of rainfall at Chitwan

By analyzing the rainfall data (total and seasonal) of last 26 years in Chitwan (from the NMRP, Rampur station) showed the erratic pattern of rainfall over the years. The highest rainfall recorded in 2007 (2742.6) and lowest (1183.6) in 2011. From 1989-1997, rainfall pattern was varied within the narrow range as compared to the other time period and similarly the seasonal rainfall pattern also not constant within these 26 years.



Source: DHM (2016)

Figure 2. Trend of Rainfall at Chitwan (1989-2014)

### 3.3. Farmers' perception on climate change in the study area

#### 3.3.1. Knowledge and categorization of information about climate change

From our study survey, we found that about 62.5% of respondents knew about climate change terminology and 37.5% didn't know about the terminology in the study area. In the same way 49.17% had the little knowledge about climate change. Most of the farmers did not know clearly about climate change due to lack of knowledge, experience and proper implementation of governmental policies about climate change adaptation.

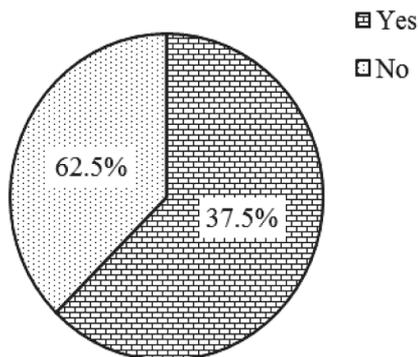


Figure 3. Farmers' knowledge about climate change

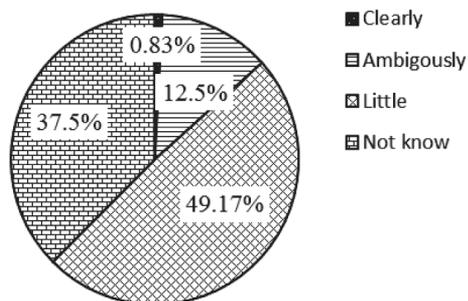


Figure 4. Information categorization of climate change

### 3.3.2. Source of information about climate change and the respondents' perception about impact of climate change on Agriculture

The study revealed that majority of respondents obtained information about climate change by media (32.5%), followed by local leaders/trainers (26.67%), self-experience (22.5%) and Neighbors (2.5 %). Likewise the study revealed that 62.5% respondents felt the real impact of climate change on Agriculture while 37.5% had not felt the direct impact of climate change in their agriculture sector.

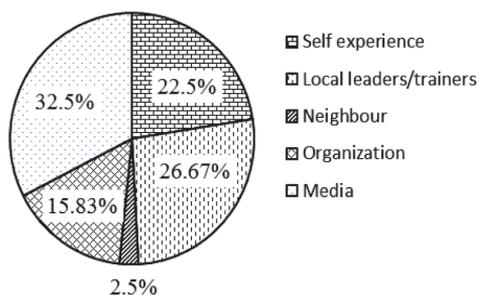


Figure 5. Source of information about climate change

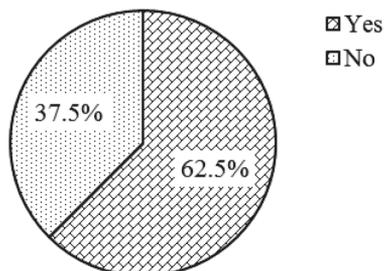


Figure 6. Climate change impact on agriculture

### 3.3.3. Farmer's perception about the change in weather pattern in present year compared to past five years in the study area

Change in Weather pattern is important factor which determine the farmers' perception on climate change. About 52% respondents had observed the increase in temperature in summer and about 36.7% respondents perceived the increase the temperature in the winter season as well.

According to farmers perception there was variation in the rainfall pattern as compared to past. Majority of the respondents (58.30%) perceived the decrease in rainy days and 30.80% perceived the increased intensity of rainfall in recent years. About 83.30% of the respondents perceived decrease amount of rainfall in winter season as compared to past 5 years.

Similar types of trend of temperature and rainfall, and perceptions of local people were observed in various districts of Nepal e.g. in Chitwan, Rampur (Paudel et al., 2014), Banke and Dang (Devkota, 2014), Kaski (Timilsina-Parajuli et al., 2014), Rupandehi (Dahal et al., 2015).

Table 1. Farmer's perception about the change in weather condition in present year compared to past five years in the study area

| Weather condition         | Perception |            |           |               |
|---------------------------|------------|------------|-----------|---------------|
|                           | Increased  | Decreased  | No change | Unpredictable |
| Temperature level         | 59(49.20)  | 15(12.50)  | 28(23.30) | 18(15.00)     |
| Hotness change in summer  | 62(51.70)  | 13(10.80)  | 31(25.80) | 14(11.70)     |
| Coldness change in winter | 39(32.50)  | 36(30.00)  | 27(22.50) | 18(15.00)     |
| Winter temperature change | 44(36.70)  | 29(24.20)  | 26(21.70) | 21(17.50)     |
| Rainfall intensity        | 37(30.80)  | 45(37.50)  | 0(0.00)   | 38(31.70)     |
| Rainfall frequency        | 14(11.70)  | 70(58.30)  | 0(0.00)   | 36(30.00)     |
| Winter rainfall           | 0(0.00)    | 100(83.30) | 9(7.50)   | 11(9.20)      |

Notes: Figures in parentheses indicate percentage

(Source: Field survey, 2016)

### 3.3.4. Respondents experience towards the major climatic hazards before five years and present

According to respondents' farmers experiences about climatic hazards as comparison to last five years, there was almost increment in the climatic hazards. About 59.2% respondents perceived the increment in the landslide severity, 45.8% perceived increment in the landslide frequency, 54% experienced the increment in drought length, and 79.2% experienced the increment in drought frequency and 48.3% respondents experienced about the increment of hailstone severity as comparison to past 5 years.

Table 2. Respondents experience in recent major climatic hazards as comparing before five years

| Climatic hazards            | Perception |           |          |              |           |
|-----------------------------|------------|-----------|----------|--------------|-----------|
|                             | Increase   | Decrease  | Same     | Not constant | Not occur |
| Landslide severity          | 71(59.2)   | 0(0.00)   | 20(16.7) | 29(24.20)    | 0(0.00)   |
| Landslide frequency         | 55(45.8)   | 30(25.00) | 14(11.7) | 21(17.50)    | 0(0.00)   |
| Drought length and severity | 65(54.2)   | 0(0.00)   | 29(24.2) | 26(21.70)    | 0(0.00)   |
| Drought frequency           | 95(79.2)   | 0(0.00)   | 10(8.3)  | 15(12.50)    | 0(0.00)   |
| Hailstorm amount/ severity  | 36(30.0)   | 0(0.00)   | 23(19.2) | 49(40.80)    | 12(10.00) |
| Intensity of hailstone      | 58(48.3)   | 0(0.00)   | 16(13.3) | 40(33.30)    | 6(5.00)   |
| Frost/Dew amount/ severity  | 12(10.0)   | 34(28.30) | 16(13.3) | 25(20.80)    | 33(27.50) |
| Cloudy weather              | 25(20.8)   | 18(15.00) | 34(28.3) | 23(19.20)    | 20(16.70) |

|                             |          |           |          |           |         |
|-----------------------------|----------|-----------|----------|-----------|---------|
| Thundering severity         | 53(44.2) | 4(3.30)   | 24(20.0) | 39(32.20) | 0(0.00) |
| Water level in river/stream | 0(0.0)   | 90(75.00) | 3(2.50)  | 27(22.50) | 0(0.00) |
| Ground water level          | 0(0.0)   | 80(66.70) | 0(0.00)  | 40(33.30) | 0(0.00) |

Notes: Figures in parentheses indicate percentage

(Source: Field survey, 2016)

### 3.3.5. Respondents' perception towards the biological hazards before five years and present in the surveyed area

According to respondent farmers' perception, 45.8% experienced that there was increment in disease nowadays, 35.0% respondents from both VDCs experienced the increment in insect/pest severity while 50.0% respondents experienced the increment in weed infestation as comparison to last 5 years.

Table 3. Respondents' perception towards the biological hazards in comparison before five years and now in the Surveyed area

| Biological hazards   | Perception |           |           |
|----------------------|------------|-----------|-----------|
|                      | Increase   | Decrease  | No Change |
| Disease severity     | 55(45.80)  | 29(24.20) | 36(30.00) |
| Insect/Pest severity | 42(35.00)  | 40(33.30) | 38(31.70) |
| Weed infestation     | 60(50.00)  | 30(25.00) | 30(25.00) |

Notes: Figures in parentheses indicate percentage

(Source: Field survey, 2016)

### 3.3.6. Cropping system being practiced in the area by the Farmers

According to the farmers response on the upland and lowland cropping system, maximum respondents i.e. 38(31.7%) using millet-maize-fallow type of cropping system in upland and maximum i.e. 36(30%) respondents using the maize-rice type of cropping system in lowland. In upland, maize-millet-potato cropping system was followed by only 4.02% respondents and rice-lentil only followed by 3.30% respondents on lowland from both surveyed VDCs.

Table 4. Cropping system being practiced by the respondent farmers in the surveyed area

| Upland cropping system            | Response  | Lowland cropping system | Response  |
|-----------------------------------|-----------|-------------------------|-----------|
| Maize-millet-potato               | 5(4.02)   | Maize-rice              | 36(30.00) |
| Maize-rice-wheat                  | 7(5.80)   | Maize-rice-lentil       | 11(9.20)  |
| Millet-black gram                 | 7(5.80)   | Maize-rice-wheat        | 15(12.50) |
| Millet-maize-black gram           | 7(5.80)   | Rice-fallow             | 20(16.70) |
| Millet-maize-buckwheat            | 29(24.20) | Rice-lentil             | 4(3.30)   |
| Millet-maize-buckwheat-black gram | 7(5.80)   | Rice-maize-fallow       | 19(15.80) |

|                                |             |                          |             |
|--------------------------------|-------------|--------------------------|-------------|
| Millet-maize-buckwheat-mustard | 11(9.20)    | Rice-wheat-maize-mustard | 15(12.50)   |
| Millet-maize-fallow            | 38(31.70)   |                          |             |
| Millet-maize-mustard           | 9(7.50)     |                          |             |
| Total                          | 120(100.00) |                          | 120(100.00) |

Notes: Figures in parentheses indicate percentage

(Source: Field survey, 2016)

**3.3.7. Respondents’ experience about the change in old cropping system and change in crops on different lands**

According to our field survey in respondents’ household, 51.6% respondents experienced that there was change in old cropping system while 48.33% had no any experience in change on previous cropping system.

The study showed that about 39.17% of respondents changed the crops in upland while only 16.67% changed the crops in low land and 25.83% no replaced or changed the crops anywhere as comparison to previous years.

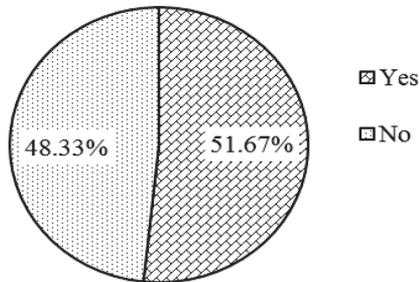


Figure 7. Experience of change in old cropping system

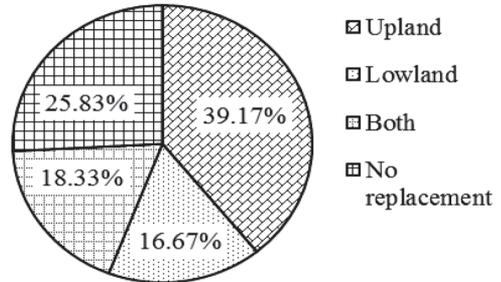


Figure 8. Change of crops on various land system

**3.3.8. Respondents’ practices about the previous cropping system and recent cropping system in last five year**

In case of previous cropping system and changed cropping system as comparison last 5 years to by taking the views from the respondents from both VDCs, in upland area: the previous cropping system were millet-fallow, millet-maize-fallow, maize-fallow but nowadays adaptive cropping system were millet-maize-mustard, millet-maize-mustard-buckwheat, millet-black gram-cowpea, millet-maize-vegetable, maize-rice-lentil-wheat, maize-rice-wheat-legume. In case of lowland area, the major cropping system at previous time was rice-fallow; rice-maize but nowadays the adaptive cropping system were maize-rice-lentil, maize-rice-wheat, rice-lentil-wheat-maize, and rice-wheat-legume-maize. Hence, nowadays farmers were using multiple crops and intensive cropping system to cope with climate change impact in the study area.

Table 5. Respondents' practices about the previous and recent cropping system in comparison to last five years in the Surveyed area

| Land types | Previous Cropping system | Nowadays cropping system       |
|------------|--------------------------|--------------------------------|
| Upland     | Millet-fallow            | Millet-maize-mustard           |
|            | Millet-maize-fallow      | Millet-maize-mustard-buckwheat |
|            | Maize-fallow             | Millet-black gram-cowpea       |
|            | Maize-rice-wheat         | Millet-maize-vegetable         |
|            |                          | Maize-rice-lentil-wheat        |
|            |                          | Maize-rice-wheat-legume        |
| Lowland    | Rice-fallow              | Maize-rice-lentil              |
|            | Fallow                   | Maize-rice-wheat               |
|            | Rice-maize               | Maize-rice-wheat-mustard       |
|            | Grasses                  | Rice-lentil-wheat-maize        |
|            |                          | Rice-wheat-legume-maize        |

Notes: Figures in parentheses indicate percentage

(Source: Field survey, 2016)

### 3.3.9. Farmer's practices about the use of different adaptation strategies to cope with the change in climate

From our Study, we found major of the respondents' farmers were using the different adaptation practices in the surveyed area. 65%. Of the farmers had the facility of irrigation water, 40.80% of farmers were using water harvesting techniques but still it was not used by 59% of farmers there. Likewise Agro forestry system was used by most of the respondents in the surveyed site nowadays. Similarly mulching was practiced by most of the respondents in the surveyed site i.e. by 83% of respondents. The practices of mixed cropping were also increasing as adaptation strategies. The SALT technology i.e. the sloppy agriculture land technology and use of Bio-pesticides and practice of changing crops to livestock were not used by much of the farmers in the surveyed site as adaptation strategies. 65.8% respondent farmers were also using the organic manure as adaptation strategies to cope with changing trend of climatic parameters in the surveyed area.

Table 6. Farmer's practices about the use of different adaptation strategies to cope with changing trend of climatic parameters in the study area

| Adaptation techniques       | Used by respondents |           | Total       |
|-----------------------------|---------------------|-----------|-------------|
|                             | Yes                 | No        |             |
| Irrigation practices        | 78(65.00)           | 42(35.00) | 120(100.00) |
| Water-harvesting techniques | 49(40.80)           | 71(59.20) | 120(100.00) |
| Agro-forestry               | 80(66.70)           | 40(33.30) | 120(100.00) |
| Mulching                    | 100(83.30)          | 20(16.70) | 120(100.00) |
| Mixed cropping              | 106(88.30)          | 14(11.70) | 120(100.00) |

|                              |           |           |             |
|------------------------------|-----------|-----------|-------------|
| SALT                         | 63(52.50) | 57(47.50) | 120(100.00) |
| Bio-pesticide                | 41(34.20) | 79(65.80) | 120(100.00) |
| Use of organic manure        | 79(65.80) | 0(0.00)   | 120(100.00) |
| Change of crops to livestock | 56(46.70) | 64(53.30) | 120(100.00) |

Notes: Figures in parentheses indicate percentage

(Source: Field survey, 2016)

#### 4 Conclusion

The study survey which was carried out in Siddi and Shaktikhor VDCs representing from the hilly area of Chitwan, Nepal, we found most of the farmers perceived the change in climate in term of change in rainfall pattern, duration, timing, frequency, intensity, initiation of monsoon, and change in summer and winter temperatures. The Study area which was dominated by indigenous community i.e. Chepang, were still lacking adequate knowledge, awareness and information about the different related sectors of health, education, agriculture, sanitation, water, etc. In the study area, major of the respondents experienced about the impact of climate change in the lower production of crops, increased severity of diseases, pest and weed nowadays and also they felt the increment in the climatic hazards carried out by climate change in comparison to last five years. The community also not fully acquainted with the climate change impact on agriculture and adaptation practices knowledge although they were practicing different adaptation strategies indirectly to cope with climate change impact. To cope with the climate change impact the major of the farmers in the area were changing the crops and cropping system in intensive manner than previous years and they were also integrating short duration crops in their upland as well as lowland field. Farmer in the study area practiced different adaptation strategies to respond to climate change impacts i.e. water harvesting ponds, agroforestry, mulching, mixed cropping, SALT (sloppy agricultural land technology), use of organic manure, multiple cropping, mix cropping, use of hybrid and improved variety, Fodder tree plantation at the bund of field, use of bio-pesticides, changing cropping pattern, etc. The findings of the study indicated that nowadays the farmers were becoming aware of climate change and its impact on crops and cropping system and were becoming capable for applying adaptation strategies to cope with the adverse effect of climate change.

#### Acknowledgement

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## **Understanding the Climate Change Adaptation Needs of Communities: A Case Study from Nuwakot District, Central Nepal**

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### **Abstract**

Climate change impacts and adaptation needs for farmers residing the rural settlements of Nuwakot district, Central Nepal were analyzed based on both qualitative and quantitative approaches. Qualitative data were collected using participatory social survey techniques *viz.* key informant interview (KI), household survey (HH), focus group discussions (FGDs) and case studies. Quantitative data includes historical precipitation and temperature trends. Result shows that local residents have observed clear signs of climate change over the years. Local farmers have developed their own ways of adaptation, though a systematic adaptation strategy valuing the structural causes of vulnerability is must to scale up adaptive capacity of farmers residing these rural settlements.

**Key words:** Adaptation, Climate change, Livelihood, Vulnerability

### **1. Introduction**

Global climate change has become a major environmental challenge faced by global community in recent decades. Intergovernmental Panel on Climate Change (IPCC) indicates that the anthropogenic greenhouse gas emissions have increased since the pre-industrial era, which is largely driven by the economic development and population growth, and are now higher than ever (IPCC 2014). IPCC further urged that, climate change will amplify existing risks and create new risks for natural and human systems, which are generally greater for disadvantaged people and communities in countries at all levels of development.

Nepal is extremely vulnerable to climate change<sup>1</sup> with a GDP closely associated to the climate sensitive sectors. The geography is extremely complex with significant variation in climates. Nepalese agriculture sector is mostly dominated by the smallholders and rain-fed agro practices. Together with subsistence agrarian economy high poverty levels and limited government capability to generate additional resources to cope with likely impacts made Nepalese communities vulnerable to climate change. Nepal is also highly vulnerable to climate induced disasters such as droughts, floods, landslides, heat stresses, cold waves, hailstones, Glacial Lake Outburst Floods (GLOFs) and natural disasters like earthquake.

Studies revealed that the observed warming trend in Nepal is spatially variable (MoE 2010). An increase in temperature over the years has been documented in many studies. For example, Shrestha et al. (1999) indicated an annual warming trend of 0.06<sup>o</sup>c. According to Sing and Smith (2009) the average temperature in Nepal is rising by an average of 0.41<sup>o</sup>c per decade, while seasonal temperature during the pre-monsoon, monsoon and winter seasons have risen by 0.43<sup>o</sup>c, 0.43<sup>o</sup>c and 0.37<sup>o</sup>c per decade respectively. However the observed precipitation trend does not reveal any significant trends (MoE 2010).

Owing to the multifaceted challenges of climate change, government of Nepal (GoN) has

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<sup>1</sup> Nepal is often ranked the fourth most vulnerable country out of 16 countries with extreme climate risk (<http://maplecroft.com/about/news/ccvi.html>)

identified it as a major development agenda. Subsequent development in climate related policies and integrating climate change in main development course has thus been realized in recent years. However, systematic adaptation strategies are lacking for the sake of benefit to the most vulnerable rural communities who endure hardship in each and every aspect of their lives due to frequent changes in climatic patterns. A systematic adaptation strategy thus needs evidences from the ground. We thus aim to assess grassroots issues having local implications and links to global climate change. A clear understanding of local adaptation strategies and needs will then add value on policy formulation and implementation processes from local to national levels.

The major objective of this research project is to assess climate change impacts and identify adaptation needs of communities residing the two rural settings of Nuwakot district, Central Nepal. Specifically we aim to:

- Assess local impacts of global climate change on rural settings
- Assess local adaptation strategies adapted by the farmers
- Identify immediate adaptation needs

## 2. Methodology

### 2.1. Study Area

The study was carried out on the two settlements of Nuwakot district (figure 1). Assessments were conducted in Taruka VDC (500-650 masl within the coordinates of 270.93472'-270.94119' N to 0850.15965'- 0850.17077' E) in the extreme west and Gerku VDC (924-1022 masl within the coordinates of 270.86852'-270.87071'N to 0850.00198'-0850.00891' E).

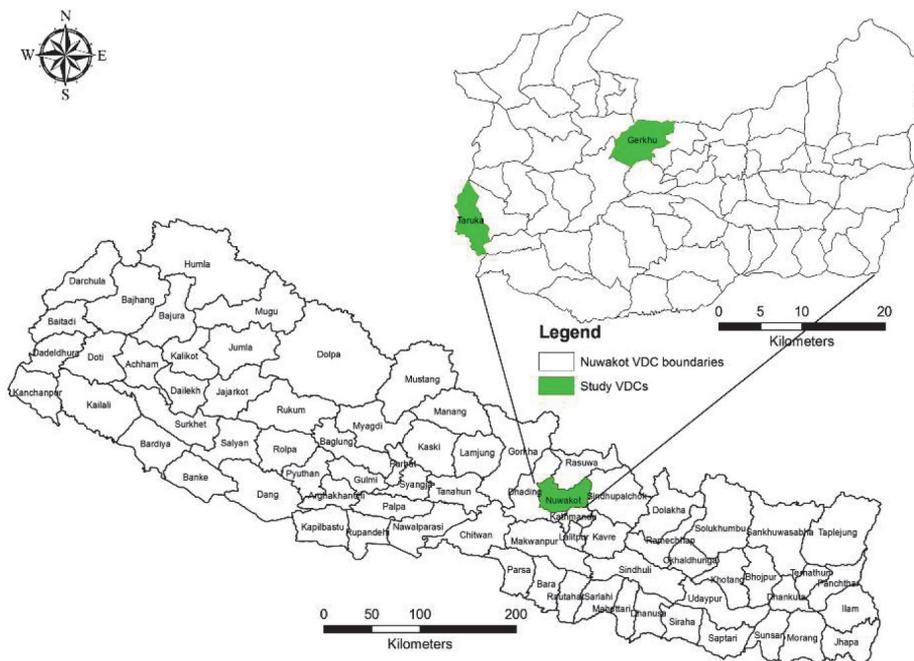


Figure 1 Map of the study area

Gerkuh VDC was ranked among the most vulnerable VDCs in terms of landslide and unexpected precipitation (Redcross 2012). Within five years period 32 different disasters related incidents occurred and 186 people were injured. Most of the clusters surveyed in the Taruka VDC were predominantly inhabited by the poor marginalized community. The site was also selected based on the recommendations of district disaster reduction plan of action for Nuwakot district.

Nuwakot district is highly vulnerable to flood and landslide related vulnerabilities and moderately vulnerable to temperature and rainfall changes (MoE 2010). Soil erosion is regarded as one of the major environmental challenges in Nuwakot district which is considered more pronounced under rain fed cultivation system (Shrestha 1997). The Thulo khola watershed's (adjoining area of Devighat-a famous pilgrimage site for Hindu devotees) livestock system has experienced forest degradation and the disappearance of natural springs, which in turn leads to poor animal health, and impaired water quality (Poudel et al. 2012).

Historical disaster incidents from this district are not well documented in literatures. The available data from Ministry of Home Affairs showed that 28 VDCs of Nuwakot district were affected by severe drought in the year 1994 (GoN 2009).

### **3. Sampling Methods**

Field sampling was conducted in the year 2012. The data were collected based on the social survey techniques including Key Informant Interviews (KI), Household Surveys (HH) and Focus Group Discussions (FGDs). Altogether two FGDs, eight KIs and 41 HH (Sampling size: 14.54% in Taruka VDC and 10.3% in Gerkuh VDC) surveys were conducted. The qualitative information was also collected through case studies, photographs and audio-visuals. A simple linear regression analyses was performed to assess the historical temperature and precipitation pattern of Nuwakot district.

## **4. Results**

### **4.1 Socio Economic Attributes of the Study Area**

The average family size in both villages is seven. The major sources of income in Taruka village is remittance (37.5%) followed by agriculture (41.67%) and service (20.83%). Most people in this village own rain fed agricultural lands with an average of 5.25 hectares land holding. In Gerkuh village the major source of income is agriculture (52.95%) followed by service (17.64%). As in Taruka village, most people in this village own rain fed agricultural lands with an average of 7.23 hectares land holding.

Most people have access to electricity by the national grid with an average consumption of 20 units per month. However, firewood is the main source of energy with an average consumption of 2160-1440 kg per year. Few well-being families have access to biogas and liquefied petroleum gas (LPG). People depend on community tap as well as pipe in yard for daily water needs. Average water storage quantity is 48-65 liters. Surprisingly about 47.59% of total households do not still have access to toilet. Most people have food sufficiency for five-six months a year.

### **4.2 Observed Changes in Temperature and Precipitation**

Historical temperature (of 25 years: 1984-2009) and precipitation (of 37 years: 1972-2009) data were obtained from the Department of Hydrology and Meteorology of Nepal. Although, available data has number of shortcomings to genuinely explain historical climatic trends, simple linear regression analyses allowed us to understand a general trend of temperature and precipitation over the years. Analysis suggested a clear decline in precipitation over the time; however the

temperature trend is not uniform.

A clear decline in annual maximum, minimum and average maximum, minimum temperature by 0.0050C, 0.0080C and 0.0110C respectively has been observed (figure 2), whereas the average annual summer minimum, maximum and mean maximum, minimum temperature shows an increasing trend by 0.0120C, 0.0090C and 0.0060C respectively (figure 2). The precipitation trend on other hand shows a clear decline by 10.25 mm per year (figure 3).

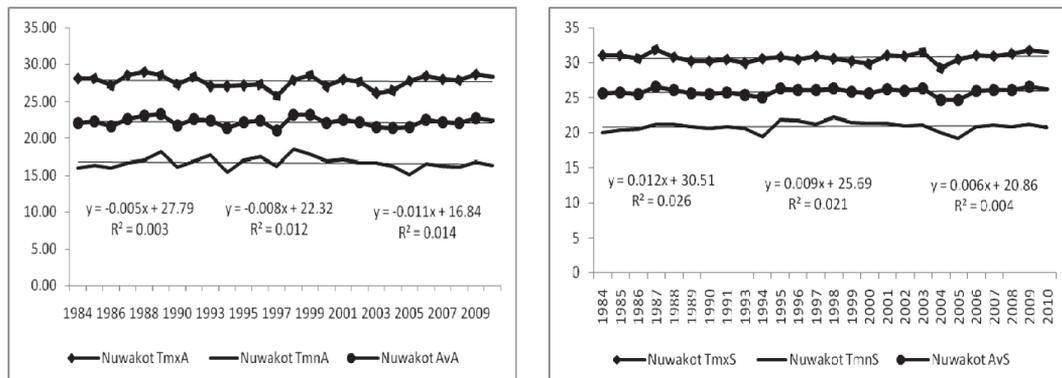


Figure 2 (left). Average annual temperature trend (TmA = max annual temp, TmNA = min annual temp and AvA = average max min annual temp) of Nuwakot district (1984-2010). (right). Average annual summer temperature trend (TmxS = summer max, TmnS = summer min and AvS = average summer max min temp) of Nuwakot district (1984-2010)

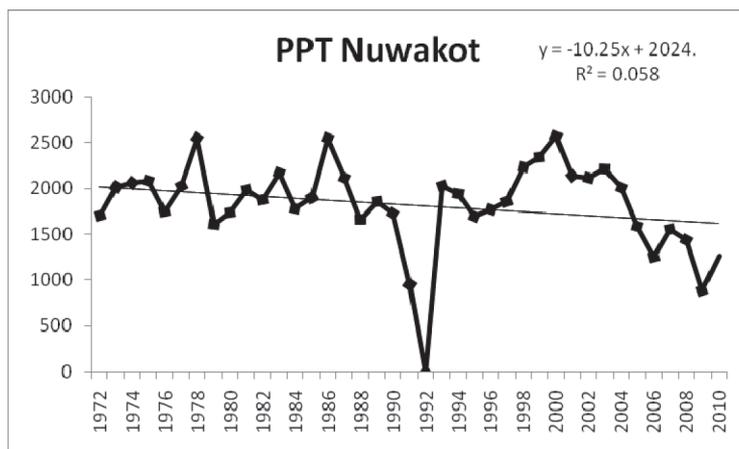


Figure 3. Precipitation trend of Nuwakot district (1972-2010)

### 4.3. Observed Impacts of Climate Change and Local Coping Measures

#### 4.3.1 Water Resources

More than five drinking water sources in Taruka village have been permanently disappeared these days. Among them the water sources like; Kuwa pani, Khote pani, Badelo dhara, Tallo Raikaw dhara etc. were the main sources of drinking water for local residents since last few years. Most respondents believe that water resources are disappearing due to the vigorous growth of Pine trees (Pinus roxburghii). Similarly dozens of wells (locally called Gairi -low land wells), and other fresh

water sources like Rukse dhara have been dried out on the due course of time in Gerkhutar. Long lane for water in summer is obvious; people need to travel approximately 1-1.5 hr to collect water for daily consumption. Extreme rainfall in September is quite unexpected. Erratic rainfall pattern-a recent climatic phenomenon, is leading to the frequent occurrence of natural disasters like landslide and soil erosion posing threats to agricultural practices.

#### **4.3.2 Agriculture**

Spreads of beetles of different types have profound negative impact on agricultural production as well as harvested agricultural goods in both the studied villages. According to the local respondents some of such beetles have been recently emerged, possibly because of warming climates. Some examples of such spreads for example include Khapate kira and Tyote kira.

Changing climatic pattern is leading to phenological irregularities in many tree species. Most respondents have observations on fruits fall before maturity. Early flowering, fruiting and shooting of many fodder and food plants like; Populus, Litchi chinensis (Litchi), Magnifera indica (Mango) etc. has been observed by the respondents. In response to the resulting climatic irregularities, traditional cereal crops like Pisum sp. (Bodi), Machyang and varieties of rice like; Anandi, Masino, Kajira etc. have been replaced by the hybrid varieties like; Makwanpure, Phalame, Bindheshwor etc. Due to the regular shortcomings on production a near disappearance of traditional crop varieties like Dhaiya dhan, Kharbhujja (Water melon), Sweat potato, Chile Brinjal and varieties of lentils like: Lathyrus sativus (Khesari), Sorghum vulgare Pers. (Junelo) and red lentil-Lens culinaris (Musuro) have been realized by the farmers.

An overall decline in crop productivity has been realized by the farmers in recent years. This decline is partly related to the limitedly available irrigation water. Farmers are thus compelled to depend more on hybrid seeds for better production. The use of commercial seeds in the mean time has caused dramatic reduction in quality of harvested agricultural goods.

People have observed frequent outburst of previously unknown diseases in chicken and goats. Some of the common outbursts seen in recent years include sudden death of chicken followed by white stool, khoryat (diarrhea) in oxen, buffalo and cow.

#### **4.3.3 Forest and Biodiversity**

Exotic invasive species like Eupatorium adenophorum, Ageratum houstonianum Mill. and many others are spreading in a way that they have replaced number of local fodder plant species. The response of forest canopy however is diverse. Forest canopy gains in some places whereas in some places it is in reverse trend. As experienced by the respondents of both studied villages, the availability of timber and firewood is sharply decreasing, which is probably correlated with the loss of forest biodiversity.

Frequent occurrence of forest fire by natural as well as anthropogenic causes has been observed in Gerkhutar village in recent years. Few trees of Shorea robusta (Sal) and Pinus roxburghii (Rani Sallo) together with few other species of fodder trees and herbs make the forest canopy. This type of forest in the mid hills cannot be considered as a good forest type. In this condition unusual fire brings more pressure on the threatening forest biodiversity leaving chances for land degradation, loss of animal population, decreasing availability of fodder and firewood, and making lives much harder.

According to the local farmers, many species of wild birds and animals become rare nowadays. Few year back people in Gerkhutar village used to observe a good population of wild animals, for instance the leopard, fox and deer. One can now hardly hear the pleasant sound of wild animal rearing in wilderness. This is also a symbol of threatening aesthetic values of biodiversity by

global environmental challenges.

### **Nuwakot farmers' testimony on changing cropping cycle**

Few years before people in Gerkhutar village used to plant maize in their field immediately after the leaf fall in Populus tree. This trend however has been shifted earlier these days. Ramchandra Pandey (49 yrs, Male), a local resident of Gerkhutar village added, this type of unusual phonological behavior brings together uncertainties. Farmers get confused about the suitable times for planting and harvesting their crops. This confusion makes them to plant and harvest their agro products in some of the worst climatic conditions of the season.

#### **4.3.4 Identification of thematic recommendations**

We have identified following immediate sectorial recommendations to strengthen climate change adaptation capacity of the local residents of both study areas. The recommendations are based on the consultations with the communities, and reviewing of existing coping capacity of community, availability of resources and expected additional inputs.

|                                |   |
|--------------------------------|---|
| <b>Water resources</b>         | <ul style="list-style-type: none"> <li>• Source conservation and wise use of limitedly available water</li> <li>• Rainwater as well as excess water in summer can be conserved for the sake of use in winter and at the time of extreme drought</li> </ul>  |
| <b>Agriculture</b>             | <ul style="list-style-type: none"> <li>• Installation of check dams to control soil erosion in</li> <li>• Scoping and use of bio fertilizers and limiting the use of modern synthetic fertilizers</li> <li>• Synthetic seed varieties are blamed to be the main cause of loss of crop genetic diversity. Optimum use of such races may lead to the disappearance of many local races, which were once familiar for good taste, hygiene and having the ability to resist diseases. Thus, traditional crop varieties must be conserved for the sake sustainable agriculture.</li> <li>• Improved agricultural calendar</li> </ul> |
| <b>Forest and biodiversity</b> | <ul style="list-style-type: none"> <li>• Afforestation/plantation of multipurpose indigenous plant species in community forest areas/field bounds and home gardens Control and/or economic use of invasive plant species</li> </ul>   |
| <b>Cross-cutting</b>           | <ul style="list-style-type: none"> <li>• Mass awareness campaigns</li> <li>• Alternative livelihoods support to the needy households</li> <li>• Subsidy on biogas and improved cooking stoves</li> <li>• Community preparedness for early warning of weather conditions and likely impacts</li> </ul>   |

## **5. Discussions**

Regardless of geographic and socio-economic boundaries, climate change has severely hardened the lives of people residing the typical rural settings of Nepal (please refer MoE 2010). Frequent changes in weather patterns and long term climate abnormalities, both posed threats to the livelihoods. Climate change has altered the functioning of all the major aspects of livelihoods in the villages; however the impacts have been more pronounced in the case of water resources, agriculture, and forest and biodiversity. Both the studied villages represent a typical rural setting that sustains

life of ultra poor depending on agrarian agriculture practice. A traditional rain fed agriculture system can no way sustain on long run with increasing incidents of erratic rainfall pattern. Loss of forest diversity, values and norms on the other hand have negatively impacted traditional livelihood system adapted by the community.

By assessing the basic socio-economic attributes of the communities we have concluded that climate change impacts should not be understood in a holistic approach. A comparative access to income generating opportunities and exposure to social stigma (driven by the socio-cultural norms and values) determines differential impacts of climate change in a heterogeneous community made up of in combination of different caste and ethnicities. We have found that although vulnerabilities are primarily determined by the bio physical determinants, a significant contribution to those vulnerabilities is related to the socio-economic and socio-cultural attributes. Adaptive capacity of an individual or group of people differs in respect to land holding, access to outdoor income opportunities, gender and social hierarchy. Disparity on land holding among the households for example determines relative vulnerability among the households. We have found that most of the households who own significant proportions of available agricultural land area also have access to other outdoor income opportunity, but the households who lack outdoor income opportunities have very less access to productive land area. Similarly, a majority of the people suffered from smoke related health problems were from the underprivileged groups because they were more dependent on traditional firewood sources for cooking and heating purposes. A few wellbeing families had access to modern renewable energy sources. Such families had better access to all other developmental outputs like clean drinking water and sanitation and other household amenities. In this way climate change vulnerabilities are deeply associated with socio-economic and cultural attributed within the society and among the households. We thus argue that any adaptation strategies should primarily value these issues; otherwise such strategies hardly contribute to reduce climate vulnerability.

Although seasonal shift and long term changes on weather conditions is not systematically documented from the study area, most people have experienced unpredictable weather conditions and shortage of water resources causing severe decline on agricultural production. Since the agriculture system is mostly rain fed type, any changes on weather cycle thus causes significant effect on crop yield, food supply and food security. Earlier studies shows that the rainfall pattern in Himalaya is becoming erratic (see Negi et al. 2012) with sever effects on the irrigation systems, resulting changes in crops and cropping patterns, and drastic decline of traditional crops and loss of crop genetic diversity. The same consequences of erratic rainfall pattern have been observed from the study area. Similarly, problems of frequent drought, landslides and mixed type of effects in agriculture crops have been experienced in the study area as experienced in many parts of Nepal Himalaya (Malla 2008).

The forest condition in both villages is very sparse. The lowland areas are covered by sal forest and few areas of higher altitudes by pine forest. In both types of forests the diversity of fodder trees is very low. Local people have observations on disappearance of local fodder trees due to wider spread of invasive weeds. Shortage of fodder trees in the mean time have posed farmers to own less number of livestock. A dramatic reduction in livestock number has again direct influence on agriculture. In this way locals' livelihoods is seriously impacted by one or other forms of changes mostly driven by the climatic abnormalities.

Local communities have been adapting these changes from generations. They have modified and or adjusted to the existing scenarios in many respect, for example changing cropping cycle and breeds, storage of available water for use in scarce conditions, changes in roofing patterns etc. However, these traditional adaptation measures are no more sufficient. Diversification in livelihoods

strategies is needed in the form of alternative income generation. In order to secure the lives of local's alternative livelihood programs need to be implemented. Alternative income generating opportunities like bee farming, fish farming, goat farming etc. could add value on agricultural dependency of the local residents.

## 6. Conclusions

Climate change impacts to the communities residing typical rural settings in Nuwakot district, Central Nepal were systematically assessed based on the historical climatic patterns, and assessment of changing paradigms in the socio-economic attributes of the communities. Analyses of historical temperature trend suggests decline in annual average temperature, however a significant rise in average summer temperature has been assessed. In the mean time, we have assessed a clear decline in annual precipitation.

Both the studied communities were dominated by the ultra poor households representing different caste and ethnicities, which is a common feature of rural mountain communities in Nepal. Agriculture and remittance both contributes significant part of local livelihoods.

Impacts of climate change were observed among all the aspects of local livelihoods. Significant impacts were seen in the case of water resources, agriculture and forest biodiversity. Most of the local water sources have been dried out. An erratic rainfall pattern has posed significant negative impact on agriculture. The rain fed agriculture system is seriously threatened because of this rainfall pattern. Traditional agriculture calendar has been disturbed due to irregularities in rainfall. Spread of beetles, phenological irregularities and disappearance of local races are other challenges faced by the local communities. Forest biodiversity has been threatened due to the emergence of invasive and exotic plant species.

Communities have adapted both traditional as well as modern adaptation strategies to cope with these changes overseen on the due course of time. However, limited coping capacities of households have posed continuous threats in locals' livelihoods. A systematic adaptive strategy and assurance of additional resources are immediately needed to ensure climate smart livelihoods.

## Acknowledgments

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Singh B and Smith P. 2009. An assessment of climate change, forests and biodiversity in Nepal. USAID, Nepal.

## **Vegetation Analysis of Sharke and Thanye Forests in Prok VDC of Manaslu Conservation Area**

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### **Abstract**

Forest inventory was carried out in two forests of Prok VDC in Manaslu Conservation Area. 18 Plots each having area of 20x 20 m were confined having 1% sampling intensity. Basal area, Frequency and Density of each species was calculated to find out Importance Value Index (IVI) was calculated from the tree species taken from those 18 plots. Similarly, Shannon- Weiner Diversity Index was also calculated from the data. Higher number of species in lower dbh class indicated developing forest. *Pinus wallichiana* was the dominant species in term of Important Value Index (IVI). But higher value of evenness index and lower value of heterogeneity indicated homogenous distribution in the community.

**Key words:** Diversity, Evenness, Manaslu Conservation Area, Vegetation analysis

### **1. Introduction**

Nepal has unrivalled topography with diverse climatic and altitudinal zones. A total of 118 ecosystems, 75 vegetation and 35 forest types have been described from the country (Dobremez, 1972).

The exploitation of the forest has led the environmental problems such as biodiversity and habitat loss. In developing countries, although the protected areas are established to protect the unique biodiversity of the region, there has been an increasing threat to biological diversity due to surrounding human pressure (Chaudhary, 1998). Disturbance is now often playing a central role in maintaining species diversity (Peet *et al.*, 1983). Physical and biological disturbances in the landscape including excess human manipulation can fragment the vegetation into patches, discrete communities embedded in an area of dissimilar community structure or composition (Forman and Godron, 1980). As the green forest areas continue to decrease for settlement and other purposes the ecological balance in such human dominated landscape becomes more important. Nowadays, during management of forest stands, priority is given to conserve biological diversity. Habitat loss and degradation are major causes of biodiversity reduction. So the understanding of the structure and development processes in such forests is much important. The floristic and quantitative studies of the vegetation of an area gives the clear picture of the species present, distribution, diversity as well as the relative dominance of each species.

The overall objective of the study was to analyze the floristic composition and structure of the forest community.

### **2. Methodology**

#### **2.1 Study Area**

Vegetation analysis was done in two forests patches of Prok VDC of Manaslu Conservation Area. These two forests are separated by a foot trail. These two forest patches under consideration cover an approximate area of 70 hectares and were located at an altitude ranging from 2100 to 2700 masl. The forest is managed and protected by Conservation Area Management Committee (CAMC) since the time of establishment of MCA.

The study area have temperate climate with rainy summer and very cold winters. The rainfall ranges from 1200-1400 mm per year and. Snowfall is also experienced in the winters. The meteorological data shows that the temperature of the valley varies from below 0-3°C during winter to beyond 18-21°C during summer (ICIMOD, 1996). The forest has been an important habitat for many species of bird and animal.

## **2.2 Survey and sampling**

A total of 18 plots were fixed for the study. For the tree canopy, a square quadrat of 20mx20m was laid out. The minimum sampling intensity of 1% was taken (Rana *et al.* 2008) for the determination of the required number of plots for the study. For convenience, regarding the aims and objectives of the study, several data forms were designed and prepared to obtain topography, environmental data, floristic composition, disturbance and other quantitative data.

The diameter of the trees at their breast height was measured using a diameter tape. Also, the height of each trees were noted with the help of Silva clinometers. Similarly, the quadrates were prepared by using 100m measuring tape.

## **2.3 Quantitative data analysis**

### **Density and relative density**

Density shows the number of individual trees per unit area and it indicates the numerical strength of a species in a community (Zobel *et al.*, 1987)

$$\text{Density} \left( \frac{\text{no}}{\text{ha}} \right) = \frac{\text{No of individuals of species}}{\text{Total no. of plots studied} \times \text{area of each plot}} \times 1000$$

The proportion of density of species with respect to total density of all the species within an area is referred to as relative density. In other words it is the numerical strength of a species in relation to the total no. of individuals of all species.

$$\text{Relative density (\%)} = \frac{\text{Density of species A}}{\text{Total densities of all species}} \times 100$$

### **Frequency and relative frequency**

Frequency indicates the dispersion of species in a community. It is the percentage of sampling units in which a particular species occurs.

$$\text{Frequency (\%)} = \frac{\text{No. of plots in which species A occurred}}{\text{Total no. of plots sampled}} \times 100$$

Relative frequency is the frequency of a particular species in relation to total frequency of all the species present in the community.

$$\text{Relative Frequency (\%)} = \frac{\text{Frequency of species A}}{\text{Total frequency of all the species}} \times 100$$

### **Basal area and relative basal area**

Basal area refers to the ground actually penetrated by the stems (Hanson and Churchill, 1961). It is one of the characters that determine the dominance.

$$\text{Basal area} = \frac{(3.1416) \times (\text{dbh})^2}{4}$$

$$\text{Relative basal area} = \frac{\text{Basal area of sp. A}}{\text{Total basal area of all species}} \times 100 \%$$

For assessing the general situation of forest regeneration and population structure, density-diameter distribution curves were developed for the trees (dbh $\geq$ 10) using the relative no of stems.

### Important Value Index (IVI)

In order to express the dominance and ecological success of any species, with a single value, the concept of Important Value Index has been developed. It can be calculated by adding the relative values of the three parameters density, frequency and basal area. (Curtis, 1959).

#### I.V.I was calculated by

$$\text{I.V.I} = \text{R.D} + \text{R.F} + \text{RBA}$$

### Species richness and species diversity

Species richness (S) is simply the number of species per unit area (Whittaker, 1960). Species diversity is the kind of diversity at the species level. It is used to describe the frequency and variety of species within a geographical area. Among the species in the community, relatively few are abundant and most of them are rare. These two factors- no. of species and their relative importance, determine the species diversity of a community. The simplest index of diversity is the number of species present -Species richness(s). Species richness was calculated for each forest category.

Index of Diversity was computed based on Shannon and Weiner's Information Index (Shannon and Weiner, 1963). Shannon-Wiener index (H') is one of the widely used diversity index and can be manipulated as-

$$H' = -\sum (n_i/N) \ln(n_i/N) = -\sum p_i \ln p_i$$

Where N=Total no of species.

$n_i$ = no. of individuals of species.

Similarly, Equitability or Evenness (J) can be calculated as

$$J = \frac{H'}{H'_{\max}} = \frac{\sum p_i \ln p_i}{\ln S}$$

### 3. Results and Discussion

*Pinus wallichiana* was dominant in 12 plots out of total 18 plots. In 4 plots, *Pinus wallichiana* was with other associated species such as *Cedrus deodara* and *Castanopsis*. From the overall analysis of vegetation, it was evident that *Pinus wallichiana* was as the most dominant tree followed by *Cedrus deodara*. The upper canopy was generally formed by the tall tree species like *Pinus wallichiana* and *Cedrus deodara*, varying in height.

Vegetation analysis at sample plot is shown in

Table 1. Vegetation analysis of tree species

Table 1: Importance Value Indices of different Vegetation

| S.N. | Name of trees                    | Freq.         | RF            | Basal area    | RBA           | Density       | RD           | IVI            |
|------|----------------------------------|---------------|---------------|---------------|---------------|---------------|--------------|----------------|
|      |                                  |               | %             | sq. m.        | %             | no/ha         | %            |                |
| 1    | Bhosi (V.N.)                     | 5.55          | 1.7           | 0.49          | 3.6           | 5.55          | 1.83         | 7.13           |
| 2    | <i>Castanopsis spp.</i>          | 33.33         | 10.17         | 1.52          | 11.31         | 22.22         | 7.34         | 28.82          |
| 3    | <i>Cedrus deodara</i>            | 38.88         | 11.86         | 2.08          | 15.46         | 48.61         | 16.05        | 43.37          |
| 4    | Garam (V.N.)                     | 5.55          | 1.7           | 0.1           | 0.73          | 2.77          | 0.91         | 3.34           |
| 5    | Nashi (V.N.)                     | 16.66         | 5.08          | 0.033         | 0.25          | 6.94          | 2.29         | 7.62           |
| 6    | <i>Panax pseudoginseng</i>       | 11.11         | 3.39          | 0.1           | 0.77          | 2.77          | 0.91         | 5.07           |
| 7    | <i>Pinus wallichiana</i>         | 94.44         | 28.81         | 8.81          | 65.23         | 163.88        | 54.13        | 148.17         |
| 8    | <i>Rhododendron arborium</i>     | 55.55         | 16.95         | 0.14          | 1.06          | 18.05         | 5.96         | 23.97          |
| 9    | Thamali (V.N.)                   | 5.55          | 1.7           | 0.007         | 0.05          | 4.17          | 1.38         | 3.13           |
| 10   | Toksang                          | 16.66         | 5.08          | 0.06          | 0.45          | 13.89         | 4.59         | 10.12          |
| 11   | Unknown                          | 11.11         | 3.39          | 0.007         | 0.06          | 2.77          | 0.92         | 4.37           |
| 12   | <i>Gaultheria fragrantissima</i> | 5.55          | 1.7           | 0.006         | 0.05          | 1.39          | 0.46         | 2.21           |
| 13   | Verja (V.N.)                     | 5.55          | 1.7           | 0.002         | 0.015         | 1.39          | 0.46         | 2.175          |
| 14   | <i>Pleione praecox</i>           | 22.22         | 6.78          | 0.13          | 0.93          | 8.33          | 2.75         | 10.46          |
|      | <b>Total</b>                     | <b>327.71</b> | <b>100.01</b> | <b>13.485</b> | <b>99.965</b> | <b>302.73</b> | <b>99.98</b> | <b>299.955</b> |

**Abbreviations:** BA-Basal area, RBA- Relative basal area, Dens. - Density, RD- Relative density, Freq.- Frequency, RF- Relative frequency, I.V.I- Important Value Index.

The total basal area at canopy layer was 18.73 m<sup>2</sup>/ha and the density was 302.73 stems/ha. *Pinus wallichiana* had the highest density of 163.88 stems/ha and basal area 12.23 m<sup>2</sup>/ha (Table.1).

In a heterogeneous community, the overall ecological importance of a species in relation to community structure can be obtained by adding the relative values of density, frequency and basal area. The important value index (IVI) varied from 2.21 (*Gaultheria fragrantissima*) to 148.17 (*Pinus wallichiana*). From table 1, it was observed that *Pinus wallichiana* was the most dominant species in this mixed forest and were associated with the tree species- *Syzygium cumini*, *Myrica esculenta*, *Castanopsis indica*, *Rhododendron arboreum* and *Engelhardia spicata* etc. These species represented the major species occupying most of the tree canopy in the forest.

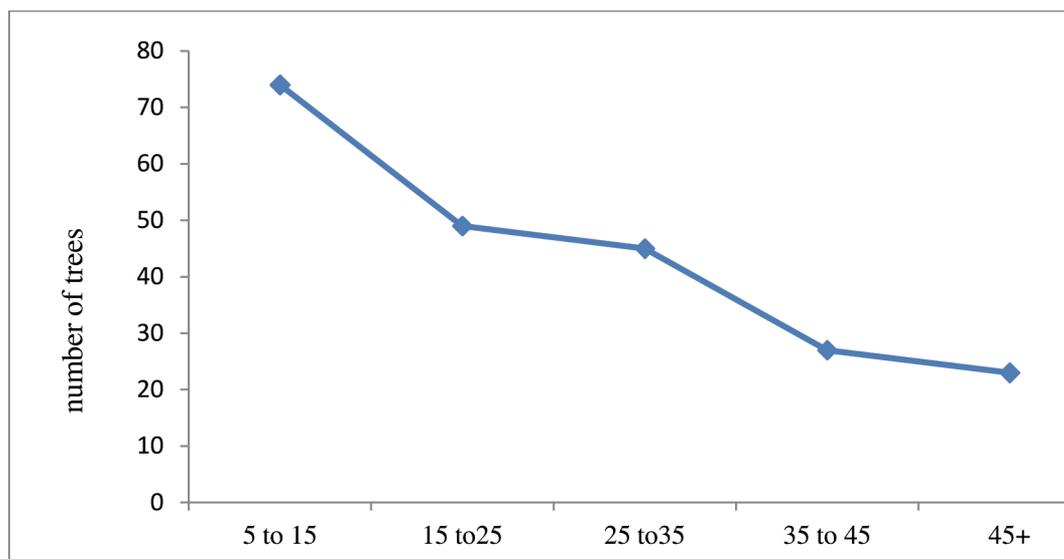


Fig 1 : Tree distribution in different dbh class

From Figure 1, it is evident that Maximum number of trees had the dbh class of 5-15 cm whereas least number of trees had the dbh exceeding 45 cm. This indicated the good regenerating capability of the forest.

### 3.2. Species richness and diversity index

Notably, 14 plant species were listed in the sample plot. Shannon's diversity index ( $H'$ ) ranged from 0.02 to 0.33 within the plots. The value of Shannon Weiner Diversity was found to be 1.62 and Equitability and Heterogeneity were 0.694 and 0.306 respectively. *Pinus wallichiana* had the maximum value of species density it was found to be the dominant species. Higher the value of  $J$ , the more even the species are in their distribution within the quadrat (Kent and Coker, 1992). Low species diversity should be due to plantation management of single or few preferred species in the past.

Table 2: Species richness and diversity of trees

| S.N. | Name of species            | ni  | pi=ni/N | lnPi    | Pi ln Pi | J       | Heterogeneity |
|------|----------------------------|-----|---------|---------|----------|---------|---------------|
| 1    | Bhosi (V.N.)               | 4   | 0.0183  | -3.9986 | -0.07337 | 0.69424 | 0.30576       |
| 2    | <i>Castanopsis spp.</i>    | 16  | 0.0733  | -2.6131 | -0.19179 |         |               |
| 3    | <i>Cedrus deodara</i>      | 35  | 0.1605  | -1.8291 | -0.29366 |         |               |
| 4    | Garam (V.N.)               | 2   | 0.0091  | -4.6994 | -0.04311 |         |               |
| 5    | Nashi (V.N.)               | 5   | 0.0229  | -3.7766 | -0.08662 | 0.69424 | 0.30576       |
| 6    | <i>Panax pseudoginseng</i> | 2   | 0.0091  | -4.6914 | -0.04304 |         |               |
| 7    | <i>Pinus wallichiana</i>   | 118 | 0.5412  | -0.6138 | -0.33224 |         |               |

|    |                                  |            |        |         |                |         |         |
|----|----------------------------------|------------|--------|---------|----------------|---------|---------|
| 8  | <i>Rhododendron arborium</i>     | 13         | 0.0596 | -2.8195 | -0.16814       | 0.69424 | 0.30576 |
| 9  | Thamali (V.N.)                   | 3          | 0.0137 | -4.2859 | -0.05898       |         |         |
| 10 | Toksang                          | 10         | 0.0458 | -3.0819 | -0.14137       |         |         |
| 11 | Unknown                          | 2          | 0.0091 | -4.6994 | -0.04311       |         |         |
| 12 | <i>Gaultheria fragrantissima</i> | 1          | 0.0045 | -5.3845 | -0.0247        |         |         |
| 13 | Verja (V.N.)                     | 1          | 0.0045 | -5.3845 | -0.0247        |         |         |
| 14 | <i>Pleione praecox</i>           | 6          | 0.0275 | -3.5928 | -0.09888       |         |         |
|    | <b>TOTAL</b>                     | <b>218</b> |        |         | <b>-1.6237</b> |         |         |

In higher altitude, the species like *Pinus wallichiana* and *Cedrus deodara* were more common and the dominant trees in lower altitude, such as *Castanopsis spp*, were rarely found in higher altitude. *Pinus wallichiana* was the most widely distributed tree with highest frequency of 94%. However, *Rhododendron arborium*, *Cedrus deodara*, *Castanopsis spp*. were less frequent compared to *Pinus wallichiana* but they possessed higher basal area. Similarly, the equitability or evenness value (J) of 0.615 indicated that the species in the forest are evenly distributed.

Disturbance either natural or artificial is considered as that agent who brings change in community or ecosystem. The forest area is under the moderate influence of human activities. Many stumps of trees were observed in the forest and the use of the pine trees in the form of fuel wood were found frequent.

Since the forest was managed by conservation area management committee (CAMC), the forest cannot be used for random cutting of trees. But, the major problem is the extraction of resin from the Pine trees. The locals peel off the stem for the resin extraction of resin. The dominance of Pine species is greatly observed in the forests, especially in the Sharke forest. But, other high altitude plants such as *Rhododendron* and *Cedrus deodara* are also found in association with Pine species.

Low temperatures and steep slopes were some major causes for the high dominance of *Pinus* and other associated species. The *Castanopsis spp* were also found in relatively lower altitudes and in comparatively moist plots.

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## **Carbon Monoxide Emissions and Human Exposure Assessment of Different Cookstoves in Kaski, Nepal**

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### **Abstract**

Commonly, women and children are exposed to very high level of criteria pollutants daily over many years. The study aimed to compare the Carbon monoxide (CO) emissions in between traditional, improved and LPG Stoves, and to determine the human exposure level to CO during cooking period. This research was conducted among 21 households in Kaski, Nepal, selected from stratified random sampling. Data were collected by deployment of ToxiRAE Pro and analyzed by Microsoft Excel. Results showed that TCS has 5 times and 6 times higher CO emissions, 7 times and 20 times higher exposure level than ICS and LPGS respectively. In addition, ICS has less than 1.5 times higher emissions and almost 3 times higher exposure level than LPGS. Consequently, the kitchen room with TCS was the dirtiest in terms of CO emissions, time consumption, and exposure level. LPG stoves could be used to improve indoor air quality, health conditions and reduce time spending in kitchen. ICS could also be best option in the sense of cost effectiveness for installation and operation in rural areas of developing countries.

**Keywords:** Indoor air pollution, CO emissions, cookstove, exposure

### **1. Introduction**

The toxic contaminants that we encounter in our homes, schools and workplaces in daily lives are referred as an indoor air pollution. Cooking fuels such as biomass, kerosene oil and liquefied petroleum gas (LPG) contain a large number of pollutants named particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO<sub>2</sub>) and formaldehyde (Ezzati & Kammen, 2002). Indoor air pollution (IAP) in developing world from biomass smoke is considered to be a significant source of public health hazard. The traditional domestic practice of cooking in primitive stoves with low-grade fuels and in badly ventilated kitchens can have serious implications for the health, particularly to the women and children (Joshi, 2006) & (Saksena, et al., 2002).

CO is one of the component of 'criteria pollutants' recommended by WHO. It is a colorless, tasteless, odorless, nonirritating, and poisonous gas emitted from incomplete combustion of carbonaceous material used as fuels for transportation, cooking, and heating (Fierro, O'Rourke, & Burgess, 2001). A health effect is determined not just by the pollution level, but also by the time people spend breathing polluted air, i.e. the exposure level. Compared with concentration, exposure is a more accurate measure of human contact with pollution (Zou et al., 2009).

Nepal is a country of village where more than 80% live in villages and among them, 75% population are using the unprocessed biomass. The housing structure is very vulnerable for IAP because 70% households have wooden and mud bonded house with poor ventilation (Kim, et al., 2015). In Nepal, biomass is a dominant source of energy (about 87%), whereas 89.1% of total energy is consumed in the residential sector for cooking and heating purpose (Lohani, 2011).

In developing countries, poor women and young children are commonly exposed to very

high levels of pollution daily over many years. Though there have been no large-scale statistically representative surveys about the household CO emissions from different cooking fuels (especially biomass vs LPG fuel), therefore it is very difficult to find literatures about real image of CO emissions and exposure level during cooking period. The testing protocols and experimental setup that simulate cooking practices under the controlled and replicable conditions of laboratory may not be realistic of the real world application of a stove. Hence, this study was conducted to compare the CO emissions in between traditional cook stove (TCS), improved cook stove (ICS) and LPG stove and to determine the level of human exposure to CO during cooking period inside the kitchen of people in the study area.

## 2. Methodology

### 2.1 Study Area Location and Sampling techniques

The study was conducted in Kaski District at Sarangkot VDC of Nepal. This area was chosen purposively because there is variation in cooking fuels and stoves, heterogeneity in socio-economic, and geographical structure. Stratified random sampling method was applied to meet the objectives in this research. Three different strata were made according to the type of cooking stoves and did not include those households who have been used more than one stoves for a particular meal. A representative sampling of 21 households (7 households of each TCS, ICS, and LPG Stove) were surveyed in the study area during April to May 2016 to obtain the required data.

### 2.2 Data Collection and Analysis

The study was based mainly upon primary data so data were obtained by device setup and household questionnaire survey. The CO detector named “ToxiRAE Pro” was used for the quantitative measurement of CO emissions from kitchen during cooking period. Ambient CO level on same time was also measured to obtain exact CO emission from cooking fuels. Data had been downloaded from the devices with the help of “ProRAE Studio II” software. Various literatures and dissertations regarding the CO emissions and exposure related to IAP were collected and reviewed from internet, books, journals etc. as a secondary source to facilitate the research.

The collected data were entered into Microsoft Excel 2013. All the necessary statistical tools like tables, graphs, charts, mean values were formulated by that program. The one minute average value of CO emission was recorded by the device and analysis had been done on the basis of that average value. Actual CO emissions from stoves had been calculated by subtraction of ambient CO level from CO level inside the kitchen.

Actual CO emissions = CO level inside kitchen – CO level in ambient air.

CO Concentration of kitchen room had been calculated through;

$$\text{CO Concentration} = \frac{\text{CO Emissions}}{\text{Volume of room}}; \text{ where unit of CO concentration is mg/m}^3.$$

Exposure Level = Concentration of kitchen  $\times$  Total time that they spend

i.e.  $E = C \times T$  ; unit of exposure level is ppm-h (Ott, 1982).

### 3. Results

The average time taken for cooking in 3 different cookstoves has been presented below.

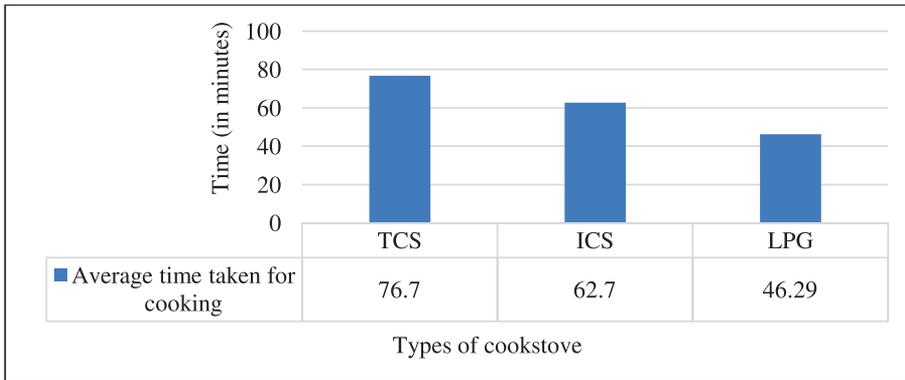


Figure 1. Average time consumption for cooking

In figure 1, it can be clearly seen that people spent maximum time for cooking in TCS with the value of 76.7 minutes while they spent minimum time (i.e. 46.29 minutes) in LPG stove. In ICS, they spent 62.7 minutes in average for making their meal.

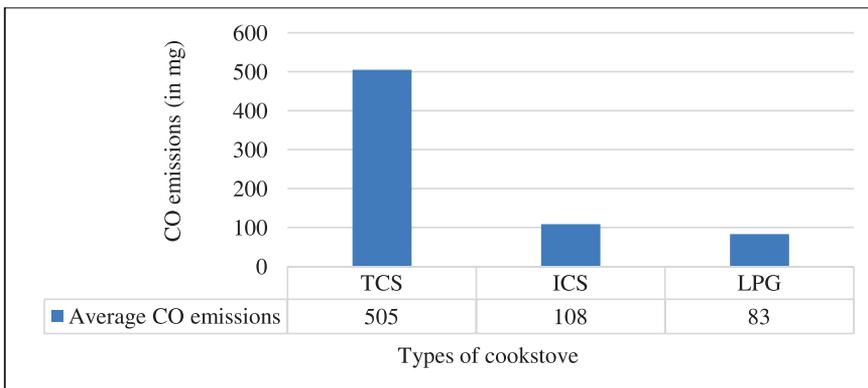


Figure 2. Average CO emissions

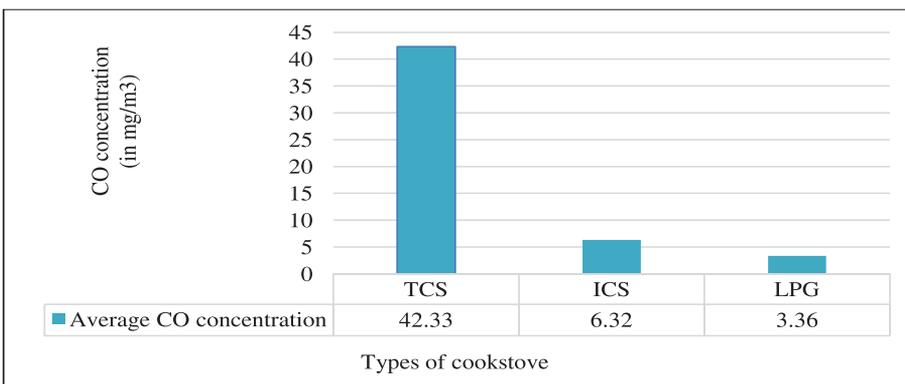


Figure 3. Average CO concentration of kitchen

Among three different types of cookstove, TCS released more CO than others. From Figure 2, average CO emissions from TCS (505 mg) was almost 5 times higher in compared to ICS (108 mg) and almost 6 times higher than LPGS (83 mg). Emissions from ICS was less than 1.5 times higher in compared to LPGS.

Figure 3 shows the graphical presentation of average CO concentration among compared cookstoves. As per emissions pattern, it is obvious that kitchen room of having TCS has maximum CO concentration than that the kitchen of having other stoves. Moreover, kitchens with TCS have around 6 times higher CO concentration than that of kitchens with ICS and around 13 times higher concentration than that of kitchens with LPGS. The difference among kitchens with ICS and LPGS was not really great, kitchens with ICS have almost 2 times greater CO concentration in compared to kitchens with LPGS.

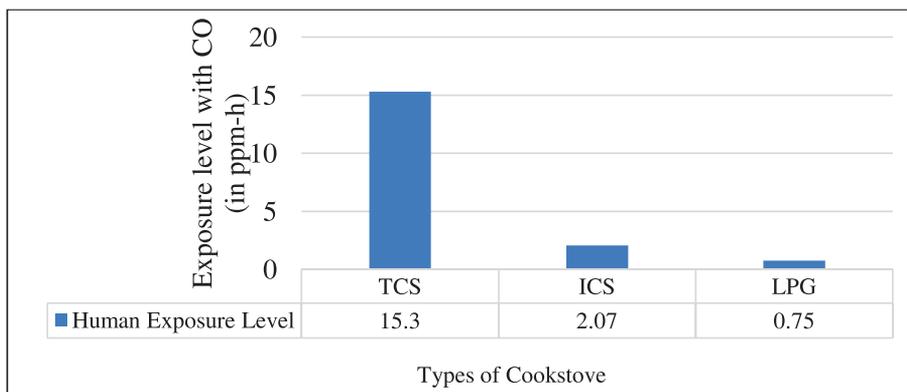


Figure 4. Average exposure level with CO

In Figure 4, level of human exposure has been calculated with the help of CO emissions from cookstove, size of room and total time they spent inside the kitchen room. From the previous results, it is obvious that the human exposure level with CO is much higher in kitchen with TCS in comparison with ICS and LPGS. Average exposure level of peoples in the kitchen of having TCS was 15.3ppm-h which is almost 7 times greater than kitchen of having ICS (2.07ppm-h) and almost 20 times greater than the kitchen of having LPGS (0.75ppm-h). Moreover, average exposure of people in the kitchen of having ICS was approximately 3 times greater than kitchen of having LPGS.

#### 4. Discussion

Carbon monoxide monitoring will remain a useful tool in qualitative ranking of households in terms of emission levels (Ezzati et al. 2000). Most of the researches are based upon the comparisons in between TCS and ICS, therefore it is very strenuous to find researches about CO emissions comparison in between LPG stove and biomass fuel stove during specific cooking time period. ICS has improved fuel efficiency and lower pollutant emissions compared with the traditional 3-stone fire (Jetter & Kariher, 2009). Even though the emission from ICS to the atmosphere is not changed. An improved cookstoves can reduce CO from burning firewood by 24 %–70 % and also LPG stoves emit 50 times less pollutants than biomass burning stoves (GIZ, 2014).

The use of improved biomass cookstoves significantly reduces the concentrations of pollutants in the kitchen and consequently reduces the exposures and health risks (Kumari et al. 2014). Primary cooks in households without chimneys were exposed to substantially higher levels

of HAP than those in households with chimneys, emissions from solid fuel is higher than from gas fuel was found by Chartier et al. (2016). Combustion of biomass fuel soared the level of domestic indoor air quality which exceed WHO standards and are in the detrimental range for human health. (Bartington, et al., 2016)

## **5. Conclusion**

The use of biomass fuels for cooking was the largest source of indoor air pollution. TCS emits 5 times higher CO than ICS and 6 times higher CO than LPG stove, while ICS emits less than 1.5 times higher CO in comparison to LPGS. The study showed that, peoples were spending about 1 hour more time in kitchen per day of having TCS to make their meal in comparison of LPG stove. ICS can reduces half an hour time per day in kitchen during cooking than that of TCS. Level of human exposure in kitchen of having TCS was far greater than LPGS and ICS. Level of exposure in TCS was 20 times higher than in LPGS and 7 times higher than in ICS, whereas kitchen of having ICS has approximately 3 times higher exposure level than having LPGS.

Taking everything into consideration, the kitchen room with traditional cookstove is the dirtiest in terms of CO emissions, time consumption, and exposure level while LPG cookstove is finest form of cooking fuel among three analyzed type of stoves.

LPG stoves could be used to improve indoor air quality, health conditions and reduce time spending in kitchen. To reduce IAP and enhance health quality, improved cookstoves could also be best option in the sense of cost effectiveness for installation and operation in rural areas of developing countries.

## **Acknowledgement**

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## **Community Fire Vulnerability Assessment in Bhaktapur Municipality**

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### **Abstract**

The study was done with the purpose to assess the community fire vulnerability. The traditional community wards of Bhaktapur municipality were selected on the basis of past fire records and Community Vulnerability Assessment Tool (CVAT) were applied in four steps to develop vulnerability map. Vulnerability of the community towards fire was found to be moderately vulnerable. Among the studied wards, ward number 8, 11, 12, and 15 were more vulnerable. Ward number 1 was moderately vulnerable while ward number 2, 5, 10 and 17 were found to be less vulnerable towards fire hazard. Among 137 households, 88% people didn't know the use of fire extinguisher, 71 % didn't know the contact number of fire brigade, 56% responded that carelessness towards fire was the major cause of fire, 20% mentioned that load shedding and electric short circuit were the other causes of fire in community. Narrow roads, delayed service during fire incident, compact and old settlements were the other factors which contributed to fire hazard. Only 8 wards among 17 wards of Bhaktapur had organizational arrangement for disaster management. Functional district level and ward level organizational structure should be formed for disaster management, capacity building and awareness raising towards fire hazard. Increment in firefighting vehicles with proper management should be done to lessen the vulnerability towards fire hazard.

**Key words:** Disaster, Fire hazard, Vulnerability Map, Vulnerability Assessment, Risk management

### **1. Introduction**

The most recurrent disasters in Nepal are the flood and landslide as well as fire. Fire has been taking lesser number of lives compared to flood and landslide but the total physical damage is more when compared with the flood and the landslide (Pokharel, 2014). Fires occur in Nepal for many reasons, including poor settlement planning, lack of preventive measures, inadequate fire resistant construction, mishandling of inflammable substances, poor awareness of fire hazards, and criminal activities. The three major reasons for fire can be categorized as technical, human and agricultural (MoFALD, 2011).

As per disaster preparedness plan of Bhaktapur 2012, after Earthquake and Landslide, fire is the third major disaster which had been occurring in Bhaktapur time and again. Every year huge amount of loss including human loss has been reported due to fire hazard. Due to old and wooden house, high density especially in the month of Chait and Baishak fire incidents takes place most often. Hazard (DPPB, 2012). Despite a 74-year history, firefighting services are inadequate and vehicles are in poor physical condition (MoFALD, 2011).

According to UNISDR (2007), vulnerability refers to the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. To strengthen the resiliency of a community to natural and man-made hazards, before they become disasters, must first begin with a comprehensive risk and vulnerability assessment. CVAT is a useful method to assess vulnerability of a community to any hazard (Islam et.al.,2007). To develop the resiliency of a community to natural and man-made hazards, before the fire hazard turns to disaster, must first begin with a comprehensive risk and vulnerability assessment. CVAT is a useful method

to assess vulnerability of a community to any hazard (Islam et.al.,2007).

## 2. Methodology

### Study Area

Bhaktapur lies 13km east from the capital city Kathmandu, Nepal. It is located between 27°36' to 27°44' N latitude and 85°21' to 85°35' E°longitude, with the total area of 119 km<sup>2</sup>. It lies 1,372m to 2,191m elevation about mean sea level. It is surrounded by Mahabharat range from east, north, and south. Bhaktapur Municipality (6.88sq.km) consists of 17 wards among which ward 4 is the largest and ward 9 is the smallest. The total population of Bhaktapur Municipality is 83, 658 with 42,678 as male population and 40980 as female population. The total household number of Bhaktapur Municipality is 17,655. (CBS, 2011). Among the 17 wards, 9 wards have been selected by using purposive sampling method.

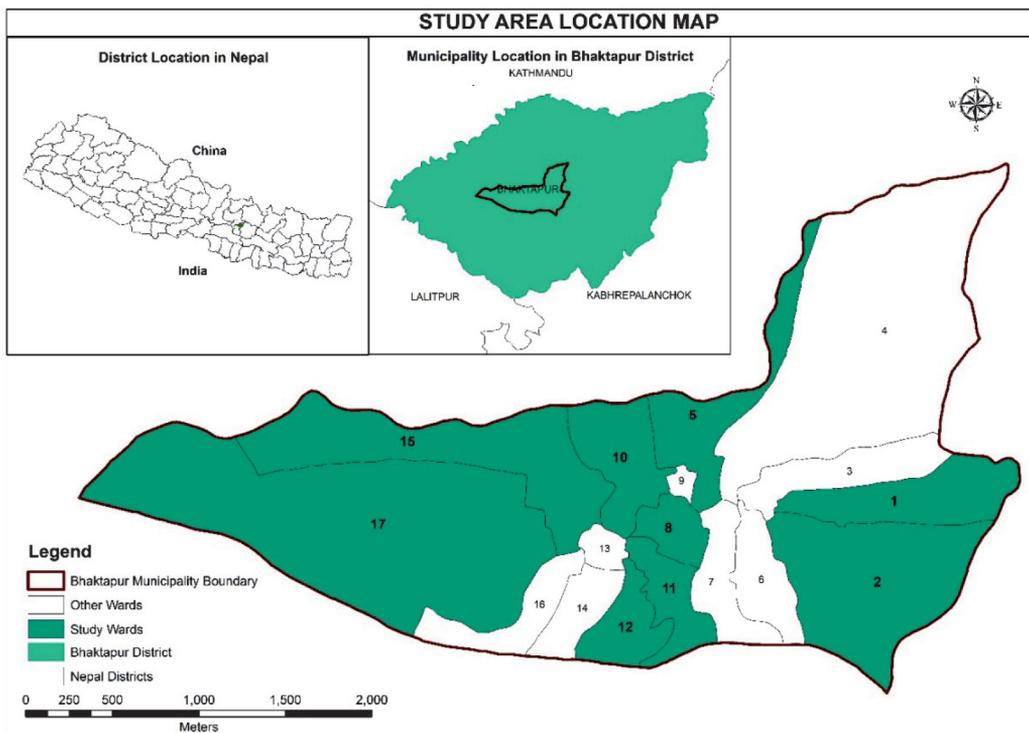


Figure 1. Map of Study Area

## 2.2 Data collection

### 2.2.1 Sample size determination

Total 9 wards of Bhaktapur municipality had been selected as per purposive sampling method and the sample size was determined by using a formula devised by Arkin and Colten (1963), whose confidence and error levels are 95% and p% respectively,

$$n = \frac{NZ^2 P (1-P)}{Nd^2 + P (1-P)}$$

Where,

n = sample size

N = total number of households in the study wards i.e 10177

Z = level of confidence ( 95% i.e 1.96)

P = estimated proportion of Household (10% i.e 0.1)

d = level of error (5% i.e 0.05)

Based on above assumptions the total sample size “n” becomes

$$n = 10177 (1.96)^2 0.1(1-0.1)/10177 (0.05)^2 + 0.1(1-0.1)$$

$$n = 3518.63669/25.5325$$

$$n = 137$$

Data was to be taken from 17 wards, so 137 were divided proportionally according to the population of each ward of the municipality. Calculation is attached to the Annex.

Using the above formula, the sample size was calculated as n= 137.

## **2.2.2 Primary Data Collection**

### **2.2.2.1 Field visit and direct observations**

For the collection of various fire attributes like accessibility of fire brigade for which road less than or more than four meter was observed and measured using the measuring tape, presence of fire source nearby, presence of transmitter and electric pole, type of house, firefighting scenario etc. through direct observation was done. With the help of GPS the location of the houses were noted which was the main component for the preparation of fire vulnerability by using ARC GIS Software.

### **2.2.2.2 Questionnaire Survey**

Primary data was collected through household questionnaire survey method for getting the information of the physical, social, economic, environmental vulnerabilities and capacities as well as for the perception of people towards the fire hazard in the municipality. 137 households were surveyed for which interview with the respondent was done. In the wards with comparatively less number of houses, one day was spent and for the wards with comparatively large number of houses, 2 to 3 days were spent and in total 18 days were spent.

### **2.2.2.3 Key Informant Survey (KIS)**

Key informant Survey was done with the Stakeholders and person related to the fire hazard and its management. The Head of Department (HOD) of Fire Brigade, the Focal person of Disaster Management of Bhaktapur District, victims of Past fire accident, Chairperson of concerned wards, Army and Disaster Co-ordinate of INGO and NGO were interviewed.

### **2.2.2.4 Focus Group Discussion (FGD)**

Altogether two FGDs were done. One FGD was done with the staff and members of fire Brigade including the call receiver, army, rescue staffs and call responder while the next FGD was done among the group of local people representing the studied nine wards.

## **2.3 Preparation of fire vulnerability map**

The fire vulnerability map was prepared by integrating four layers of information using ARC GIS, ARC VIEW software. Each layer was prepared on the basis of single attribute which was selected from the study area while the inventory data was collected. Selected Fire hazard attributes were:

- i. Accessibility

- ii. Transformer and power line
- iii. Building material type
- iv. Existence of fire source

To prepare the fire vulnerability map, individual maps were prepared for each attribute. The attributes are described below.

**Accessibility:** Accessibility is one of the important attributes for making fire vulnerability map. Because fire affected buildings are served by fire engines coming from fire stations. If the road in front of the affected building is not accessible for fire engines, the buildings cannot be served effectively by fire fighters and it becomes vulnerable to fire. To prepare the accessibility map, at first assumptions was made on the basis of expert opinion. Assumptions like – "Road less than 4m wide are not assessable for fire vehicles." Roads which are less than 4m wide were selected and marked as "Not accessible" and Road which were 4m wide as "Accessible" in the accessibility map.

**Transformer and power lines:** To prepare this map, the poles bearing electric transformers and electricity wire were located by field survey. Then the certain buffer area of 4meter was demarcated around each pole and the plots within this buffer area were located.

**Building material type:** All the buildings were classified as old wooden house, new house with Reinforced Cement Concrete (RCC) pillar and some new house with Wooden pillar.

**Availability of fire sources:** In the study area, there are activities that can either ignite or intensify a fire. Plots with such activities were located and demarcated in the map.

Next, these four maps were integrated to create the fire vulnerability map.

The above mentioned attributes were ranked according to importance, using Analytic Hierarchy Process (AHP). But the AHP process requires a pre-defined score or weight.

The fire vulnerability map of the study area was prepared by integrating four attribute maps together. These are accessibility, transformer and power line, building material type and existence of risky fire source in the study area. Each attribute was expressed as a map and then all the attribute maps were integrated to make fire vulnerability maps. Before that, the above mentioned attributes were ranked according to importance using the AHP. But the AHP process requires a pre-defined score or weight to input and that has been taken from 15 renowned fire experts of the country Bangladesh as the scenario (similar community with dense population, market areas, both South Asian developing countries) of study carried out in Bangladesh was taken as reference. This study was similar and also due to lack of any such predefined score of Nepal same weightage had been considered in this report too.

The process of obtaining the score is given below:

Score for building = weight for accessibility  $\times$  (1 for No access or 0 for Access) + Weight for transformer and power line  $\times$  (0 for Not Vulnerable or 1 for Vulnerable for electricity pole or 2 for Vulnerable for Transformer) + Weight + Weight for building material type  $\times$  (1for new RCC house or 1.5 for new but house with wooden pillar or 2 for Old wooden House) + Weight for availability of fire source  $\times$  (1for Available of fire sources and 0 for No available of fire source)

#### 2.4 Analytic Hierarchy Process (AHP)

AHP is a multi-attribute modeling methodology. AHP is systematic method for comparing a list of objectives or alternatives or attributes. Weight of the attribute of fire hazard calculation process using AHP is given below:

**Table 1. Weight of the attribute of fire hazard**

| Attribute                   | Weightage |
|-----------------------------|-----------|
| Accessibility               | 0.247     |
| Transformer and Power lines | 0.122     |
| Building Material Type      | 0.135     |
| Availability of fire source | 0.354     |

**Secondary Data**

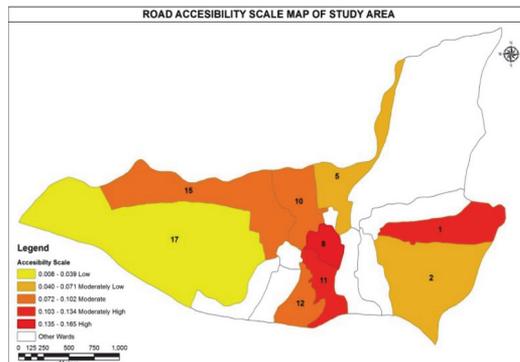
Data review of related documents obtained from various organizations like Red Cross Society of Bhaktapur, District Disaster Plan of Bhaktapur, District Profile of Bhaktapur, Central Bureau of Statics CBS 2011, Ward Office, Fire Record of Fire Brigade of Bhaktapur, Disaster Preparedness Report of Nepal and other related documents were reviewed and analyzed for the research purpose.

**3. Results and Discussion**

**3.1 Analysis of vulnerability map**

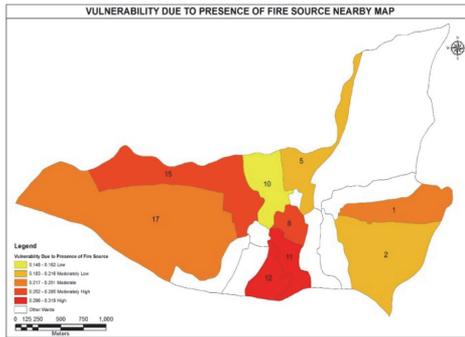
**Table 2. Vulnerability scores of studied wards**

| Wards | Accessibility Score | Pole Related Score | House Type Score | Fire Vulnerability Score | Total Vulnerability Score |
|-------|---------------------|--------------------|------------------|--------------------------|---------------------------|
| 1     | 0.114               | 0.000              | 0.213            | 0.245                    | 0.57                      |
| 2     | 0.062               | 0.037              | 0.162            | 0.195                    | 0.46                      |
| 5     | 0.049               | 0.033              | 0.243            | 0.189                    | 0.51                      |
| 8     | 0.165               | 0.000              | 0.225            | 0.275                    | 0.67                      |
| 10    | 0.082               | 0.071              | 0.203            | 0.148                    | 0.50                      |
| 11    | 0.124               | 0.031              | 0.219            | 0.310                    | 0.68                      |
| 12    | 0.099               | 0.037              | 0.189            | 0.319                    | 0.64                      |
| 15    | 0.096               | 0.041              | 0.225            | 0.275                    | 0.64                      |
| 17    | 0.008               | 0.051              | 0.179            | 0.228                    | 0.47                      |
|       |                     |                    |                  | Average score:           | 0.544702206               |



In average the fire brigade vehicle needs 4m wide road for mobility. Among the studied wards, Ward no. 1 and 8 consisted of narrower roads less than 4m making it vulnerable to fire hazard. While, ward number 2, 5, 10, 12, 15 and 17 consisted of more accessible roads. Hence, these wards were less vulnerable in regard to accessibility of fire brigade.

Figure 2: Road accessibility map

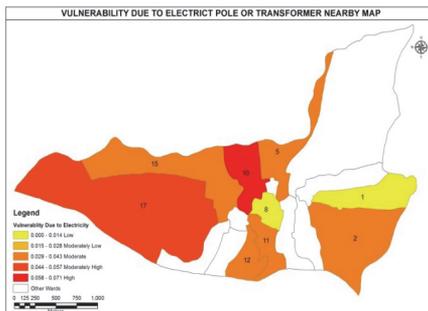
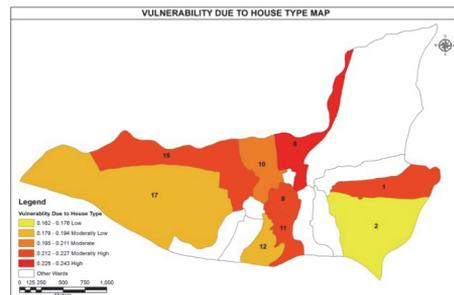


According to the availability of fire sources nearby, ward no. 11 and 12 seems to be more vulnerable as they were mostly the centers of various types of shops, market and heavy human flow. However, ward no. 1, 2, 5 and 10 had less availability of fire sources with less busy market areas and new settlement areas.

Figure 3: Map showing presence of fire source nearby of the studied houses

In terms of house type, wards with more number of old wooden houses like ward no. 1,5,8,11,15 were more vulnerable due to fire. While new settlement areas like ward no. 2, was least vulnerable and others wards with mixed settlement of old and new houses were moderately vulnerable.

Figure 4 : Map showing vulnerability due to house type



Wards no 10 and 17 consist of more number of transformer and poles nearby the houses as they were the wards with busy highways with more electric poles nearby resulting in more vulnerability due to fire. Wards like ward no 1 had less number of electric poles or transformer nearby houses due to more number of courtyard and narrow roads.

Figure 5: Map showing presence of electric poles and transformer nearby houses

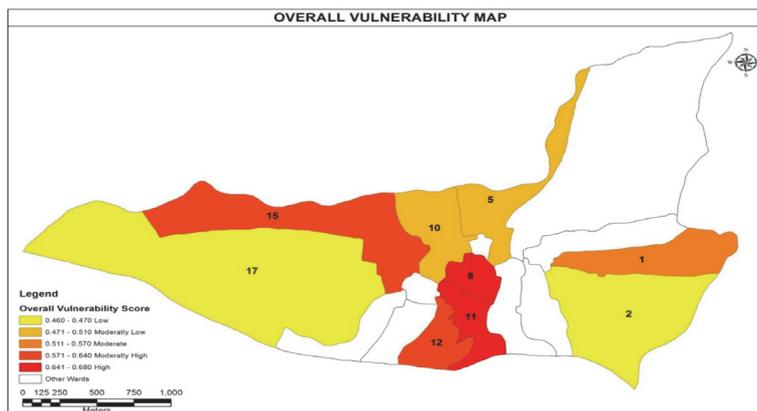


Figure 6: Overall vulnerability map

Hence, the overall vulnerability map showed that wards no. 8, 11, 12, 15 were more vulnerable with high vulnerability score. Likewise, ward no. 1 was found to be moderately vulnerable while ward no. 2, 5, 10 and 17 were found to be less vulnerable due to fire hazard.

Ward number 8, 11, 12 and 15 included mostly crowded dense and old settlement areas like Taumadhi, Sukuldhoka market areas. The settlement areas comprised of crowded roads, existence of fire sources nearby like clothes shops, stores, restaurants, jewellery shops etc making it more vulnerable to fire. While ward number 1 consisted of mixed settlement areas like Suryamadhi, Chyamasingh, with old and new houses making it moderately vulnerable to fire. Other remaining wards like ward no. 2,5,10 and 17 (Jelan, Libali, Bharwachho, Dudhpati, Sallaghari and Sreejananagar) were found less vulnerable to fire as those wards comprised of mostly new settlements areas with presence of more open spaces, less density of houses and wider roads.

In the similar study carried out by Islam et.al in 2007 in Bangladesh, the fire vulnerability was found to be low where five attributes were taken for map preparation. In the fire vulnerability study by Girdhar and Tomer, 2013 in Delhi, only three attributes were taken for map preparation where the vulnerability was found to be high due to fire hazard. In this study four attributes were taken and the average vulnerability score of Bhaktapur municipality was found to be 0.54 which indicated that the municipality was moderately vulnerable to fire disaster.

### **3.2 Social and economic, physical and environmental vulnerability**

In Pakistan, the survey of the fire exposed structures indicated that negligence, violation of building codes, unawareness of safety measures, carelessness, and lack of training were the major causes of fire incidents. An acute shortage of facilities and infrastructure for firefighting was noted. The recording mechanism of data related to fire incidents was found to be inadequate (Rafi, Wasiuddin and Siddiqui, 2012). Similarly in this study, out of 137 household surveyed, 88% of people had lack of knowledge regarding the use of fire extinguisher. 71% of the respondents were unaware about the contact number of fire brigade which showed insufficient knowledge on fire preventive measures. Recording of fire incidents was unsystematic and unmanaged in Bhaktapur municipality comparing to Kathmandu Metropolitan city. Kathmandu fire service department have digital recording of data while in Bhaktapur, there was practice of record keeping manually without further synthesis of it.

As per 56% of respondent, the causes of fire were mostly due to be carelessness of people themselves. Similarly load shedding and electric short circuit were another major causes of fire incidence in Bhaktapur. In regard to physical vulnerability, 45% of the responded perceived that narrow road was the cause of problem during rescue and 25% of responded consensus that delay of service was the major cause resulting in socio- economic vulnerability of fire. 65 % of the respondent stated that there were frequent problem of fire, due to electric short circuiting, voltage fluctuation and blast of transformer. Also, 75% of responded agreed that there was more probability of spreading of fire to nearby buildings in case of fire incidence. While, 65% of responded showed their concern towards impacts on environment like air pollution due to fire.

### **3.3 Fire brigade operation in Bhaktapur**

About the fire rescue situation of Bhaktapur, Juddha Barun Yantra Karyalaya Bhaktapur was the main responsible department. However, it consisted of only one fire vehicle and one fire bike which were not sufficient for the densely populated city like Bhaktapur. In case of huge fire incidence, fire brigade of Kathmandu was called to assist as second rescue which had got 6 real fire fighting vehicles with 9 fire bikes. So, comparing to Kathmandu, vehicles for fire were not

sufficient in Bhaktapur. Also in Kathmandu, fire department had got more systematic and managed data keeping system compared to the fire Brigade department of Bhaktapur.

### 3.4 Organizational structure for disaster

On the ward wise level, only 8 wards had formed the disaster management committee till 2013 A.D in collaboration with Red Cross Society of Bhaktapur. The committee was primarily focused on earthquake preparedness program and was planning to go for fire preparedness program. However, other wards had committed to form the disaster management committee soon.

### 4. Conclusion

As indicated by the vulnerability map, Bhaktapur Municipality was found to be moderately vulnerable in community fire hazard. According to questionnaire survey, majority of people were found less aware about the fire brigade contact number, proper methods of putting out fire and arrangement of fire extinguisher. Presence of narrow roads, old wooden houses, dense population, few fire fighting vehicles amplified the risk of fire in community. Similarly rare provision of fire preventive measures in houses, less fire insurance provision, inadequate trainings on fire prevention and rescue methods made the community moderately vulnerable in fire hazard.

### Acknowledgement

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## Biogenic Silica Nanoparticles for Ecofriendly Agriculture

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### Abstract

The increasing world population has proportionately increased the demands of food. The development of sustainable and ecofriendly agricultural practices for amelioration of complications regarding climate change and food scarcity are major concerns of the modern agriculture. The recovery of useful materials from earth-abundant substances is of strategic importance for industrial processes. Silica is appeared to be corroborating multi-beneficial effects on plants by improving productivity, disease and drought tolerance. However, despite the fact that Si is the second most abundant element in the Earth's crust, processes to form Si nanomaterials is usually complex, costly and energy-intensive. Here we have shown that pure Si nanoparticles (SiNPs) could be derived directly from the abundant agricultural by-product rice husks (RHs). Biogenic silica nanoparticles were isolated from rice husk using modified sol-gel method and characterized by SEM, XRD and FTIR. Further, its impacts in different physiological parameters of rice seedlings were also investigated. The results are thought to open new avenues in modern sustainable agriculture.

**Keywords:** Silica, nanoparticles, solubility, Chlorophyll.

### 1. Introduction

Rice (*Oryza sativa*) is one of the most produced crop species worldwide and rice husks is one of the highest-volume agricultural process residues as an environmental nuisance (Liu *et.al.*, 2013) with around 20% of milling waste; (Roth A., 2015), and developing technologies for efficient uses of this waste resources for sustainable development would be of great importance. Application of such agricultural waste back again in the agriculture would be of paramount importance for recyclability and cyclic economy. The modern agriculture demands for an ecofriendly agricultural alternative and the nanotechnology that is emerging with impressive applications in agriculture (Bhattacharyya *et. al.*, 2014) could be of handy alternative in extracting silica nanoparticles from rice husk since rice husk is known to contain 60% of silica (Kalapathy *et.al.*,2002). Silica nanoparticles with very good biocompatibility, better surface functionalization, small size, high porosity and large surface areas (Lieberman *et.al.*,2014) has been reported to be a better tool towards new green revolution (Sekhon B.S. 2014). In addition, there reports that also claim an increased photosynthesis, drought, metal and disease tolerance with the application of silica in agriculture. (Currie and Perry, 2007, Ahmed *et.al.*,2013, Meharg, C.,2015). Hence, isolation of silica nanoparticles from rice husk was the primary objective of our research so that we could analyze its impacts in plant development and the management of rice husk ash is pivotal as it causes environmental pollutions if left improperly and is of concern.

### 2. Methodology

#### 2.1 Recovery of silica

Rice husk was washed with distilled water for three times and was dried in hot air oven at 120°C. Dried rice husk was firstly charred in char stove and then heated in Muffle furnace at 600°C

for 6-8 hours. This resulted in white ash. From the resulting rice husk ash (RHA) 10g was transferred in round bottom flask which was soaked with 30% (w/v)  $H_2SO_4$  plus 10% (v/v) HCl (Le *et.al.*, 2013) and was heated at 80°C on heating mantle fitted with reflux condenser for 4 hours. Acid treated solution was then filtered with Whatman filter paper No 1 and filtrate was discarded. The filtered residue was then washed with distilled water till the pH of this second filtrate was around 7.0. Then acid washed RHA residue was transferred into borosil round bottom flask and treated with 1N NaOH for 6 hours at 80°C on heating mantle for solubilizing the silica present in the RHA in the form of sodium silicate. Sodium silicate solution thus formed was then filtered through Whatman No1 filter paper. The filtrate consisting sodium silicate was then titrated with 1N HCl until the solution pH reached 7.0 to start making silica gel. This gel was aged for 18 hours. After aging, the gel was washed with 100 ml of distilled water (DW) by agitating using magnetic stirrer for 10-15 minutes. Then solution was centrifuged at 3,000 rpm for 15 minutes and supernatant was discarded. (Kala-pathy *et.al.*, 2004). Gel was collected with the help of glass rod. These washing steps were repeated for three times. Gel was then dried at 110°C for 10 hours and then calcined at 450°C for 6 hours. The dried material was presumed to be silica nanoparticles and was collected in polypropylene Falcon tubes that was then stored in desiccator to prevent absorption of any moisture.

### **2.1.1 Characterization of silica**

Surface functional groups of the silica were determined by recording Fourier Transform-Infrared (FTIR) spectra using Thermo Electron Corporation, Nicolet 4700. The spectra of the samples were recorded between 4000 and 400  $cm^{-1}$  at 25°C. Rigaku X-Ray diffractometer, RINT, Japan operated at 40 kV and 40 mA with  $Cu-K_{\alpha}$  radiation at room temperature was used to record the X-ray diffraction (XRD) patterns. The surface morphology of the isolate was analyzed by recording scanning electron microscopy (SEM). SEM samples were prepared on a clean silicon wafer and images were taken operating U-4800, Hitachi Co. Ltd. Japan at 10 kV. The concentration of molybdate reactive silica was determined following Indian standard (Ref : Doc : CDC 26 (9306)),

### **2.2 Effects of isolated silica nanoparticles in germination of rice seedling**

The rice seeds were dehusked and rinsed with sterile DW. The seeds were surface sterilized using 4% sodium hypochlorite containing 2-3 drops of tween 20 for 20 minutes and washed with sterile DW and 95% (v/v) ethanol for 1 minute (Oyebanji *et.al.*, 2009). The sterilized seeds were cultured in culture jars. The culture jars consisted 10ml of sterile distilled water and filter paper with 1g/l to 6g/l of the isolated dry silica nanoparticles by weight. For each experiments 10 seeds per bottle were inoculated for germination with three replicates per concentration. After inoculation, the jars were kept in the incubation chamber. Illumination was provided with four fluorescent tubes (40W) with 16 hours day: 8 hours night cycle for 9 days. After 9 days, all the physiological and biochemical parameters were recorded under controlled aseptic conditions and the respective results were analyzed. The 9 days old rice seedlings were used to analyze the physiological parameters like root and shoot length from base to tip using a 30cm scale. The leaves and roots numbers were counted manually. For root length, the length of all the primary and secondary roots were recorded and averaged as a whole. The wet mass of root and shoot were weighed in weighing balance. The entire experiment was repeated two more times to obtain 9 replicates of jars per concentration.

### **2.3 Determination of Antioxidant enzyme activity**

The antioxidant enzyme activity of the rice seedlings was determined following the protocol by Elavarthi and Martin, 2010.

### 2.3.1 Determination of catalase activity

The determination of catalase activity was based on the decomposition of  $H_2O_2$  following the decrease in absorbance at 240nm. The molar extinction coefficient of  $H_2O_2$  ( $40mM^{-1} cm^{-1}$  at 240nm) was used to calculate the enzyme activity that was expressed in terms of millimoles of  $H_2O_2$  per minute per gram fresh weight.

$$\text{Catalase activity} = (\text{Change in absorbance/time}) \times \text{d.f.} \times (1/\epsilon),$$

Where d.f. is the dilution factor and  $\epsilon$  is the molar extinction coefficient of  $H_2O_2$

### 2.3.2 Determination of Ascorbate activity

The APX activity was determined with the decrease in absorbance at 290nm due to oxidation of ascorbate in the reaction recorded for 3 min at an interval of 1 min. The molar extinction coefficient of  $2.8mM^{-1} cm^{-1}$  for reduced ascorbate was used in calculating the enzyme activity that was expressed in terms of millimole of ascorbate per minute per gram fresh weight.

$$\text{Ascorbate activity} = (\text{Change in absorbance/time}) \times \text{d.f.} \times (1/\epsilon),$$

Where d.f. is the dilution factor and  $\epsilon$  is the molar extinction coefficient of ascorbate

### 2.3.3 Determination of Chlorophyll content

The leaf extracts and reagents for determination of chlorophyll were prepared following the protocol by Sumanta *et.al.*, 2014. The extracts were assayed using spectrophotometer at 480nm, 649nm and 665nm. Finally, the calculation of chlorophyll content was carried using the equations proposed by Wellburn, 1994.

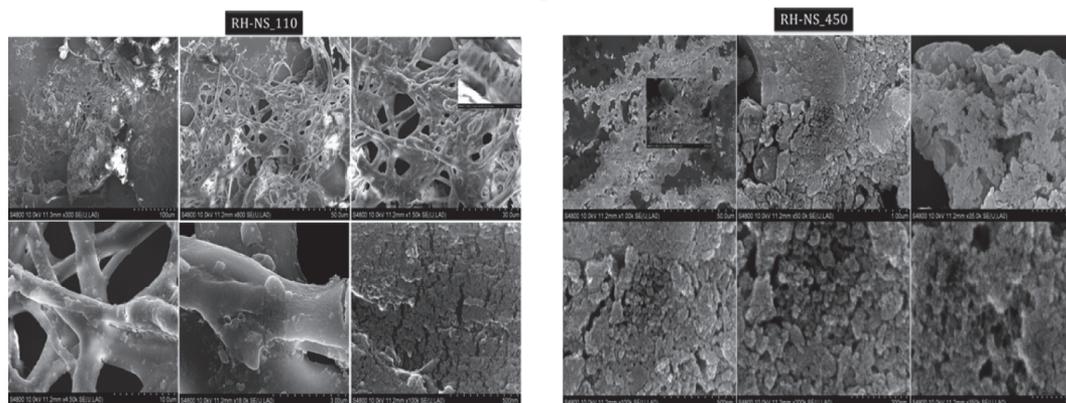
$$\text{Chl}_a = 12.47A_{665} - 3.62A_{649}$$

$$\text{Chl}_b = 25.06A_{649} - 6.5A_{665}$$

$$C_{x+c} = (1000A_{480} - 1.29\text{Chl}_a - 104.96\text{Chl}_b)/221,$$

## 3. Results

### 3.1 Isolation and characterization of silica nanoparticles from rice husk



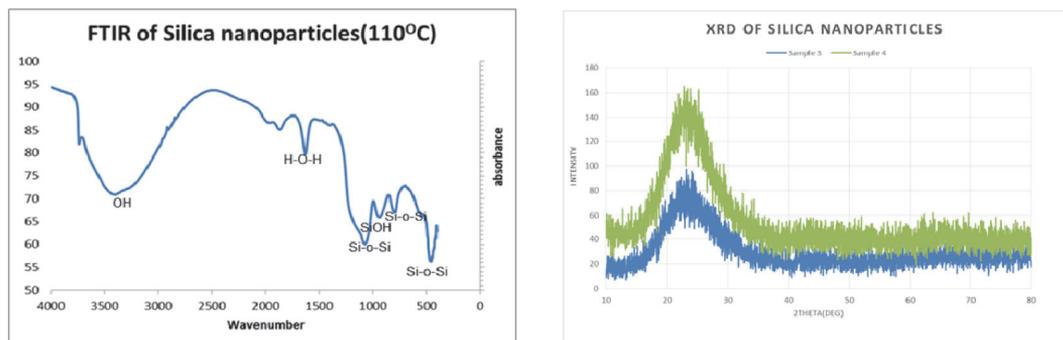


Figure 1. Characterization of isolated silica nanoparticles

A: SEM image of silica nanoparticles dried at 110°C, B: SEM image of silica nanoparticles dried at 450°C, C: FTIR image of silica nanoparticles(110°C), D: XRD image of silica nanoparticles(110°C)

Isolation of putative silica nanoparticles from rice husk was done with slight modification of sol-gel method. Although charring of rice husk was done in char stove but ash making from char was performed at controlled temperature of 600°C to prevent any clumping of silica nanoparticles that are reported to occur above this temperature. The silica nanoparticles were then isolated from the rice husk ash by modified sol-gel method. The obtained white powder that is presumed to be amorphous silica nanoparticles were then subjected to various methods of characterization i.e. SEM, FTIR and XRD. The SEM images of silica nanoparticles isolated and calcined at two different temperatures 110°C (Figure 1.A) and 450°C (Figure 1.B) showed no any large particles and presumably particle sized smaller than 100 nm. The results corroborated with the works of Kalapathy *et al.*, 2002. However, presence of fibrous structure at 110°C and its disappearance upon increasing calcination temperature to 450°C indicated that at lower temperature the water molecules could potentially be attached on the surfaces thus resulting those structures which at higher temperatures the complete evaporation of water molecules could have potentially exhibited complete breakdown of those structures.

Analysis of the silica nanoparticles using Fourier transform infrared spectroscopy (FTIR) gave various peaks at different wavelengths (Figure 1.C) confirming the presence of silica in the isolated particles. As observed, the peaks corresponding 470 $\text{cm}^{-1}$  and 810 $\text{cm}^{-1}$  wave numbers indicated presence of Si-O-Si and Si-O-Si, respectively, with the symmetric stretching of siloxane groups as has been reported for them. The presence of peak corresponding to wavenumber 950 $\text{cm}^{-1}$  indicates the presence of high concentration of silanol groups, hence, Si-OH configuration. The peak corresponding to wave number 1101  $\text{cm}^{-1}$  indicates the asymmetric stretching of siloxane, Si-O-Si. The peaks corresponding to 1640  $\text{cm}^{-1}$  wave number and its corresponding stretching seen at 3450  $\text{cm}^{-1}$  represent H-O-H with O-H bending vibration due to the adsorbed water molecule and O-H, respectively (Essien *et al.*, 2012). All these peaks ensures the presence of silanol groups in the isolated particles which is the indication to the presence of silica in various forms but without other impurities.

The isolated nanoparticles were further analyzed using X-ray powder diffraction (XRD) for structure elucidation. FTIR indication of silica nanoparticles was further characterized through XRD for its structural analysis. A broad peak centered around 2 theta of 22-24°, without any sharp peak (Figure 1.D) clearly indicated that the isolated silica nanoparticles are amorphous in nature and there is no crystalline structure as in agreement with the characteristics of amorphous  $\text{SiO}_2$  (Afandi *et al.*,

2009) Thus, the biogenic silica that has been isolated is not crystalline rather amorphous.

### 3.2 Determination of silica yield from rice husk

Charring of rice husk in char stove gave around 13.75% char. This was further burnt in Muffle furnace at 600°C and 8.1% of ash was obtained. From this ash around 6% of silica nanoparticle was isolated (Table 1).

Standard curve of molybdate reactive silica was drawn to determine amount of molybdate reactive silica in isolated samples. Silica nanoparticle isolated from rice husk that gave 8% ash which consisted of about 6% silica nanoparticles gave 3.90% reactive silica nanoparticles (Table 1). After washing and resuspending in sodium hydroxide it was found that the isolated silica nanoparticles had more than 60% of molybdate reactive silica. The decreasing absorptivity (Weijden *et.al*, 2007) of silica nanoparticles at lower pH due to the larger silanol groups may lead to the aggregation of particles leading to lower ionic silica. This suggests that some of the soluble silica nanoparticles in alkali could have undergone similar fate in titration method where mild acid is used.

The Table 1 gives the values for silica yields from rice husk and rice husk char. Using rice husk directly only 3.9% of molybdate reactive silica has been obtained while when we used rice husk char it gave comparatively higher i.e. 28.42% silica as most of the carbon present have been removed during pyrolysis to form char. The final silica gel obtained was dried to obtain 7.42gm of white amorphous silica powder indicating 74.2% yield from 10 gms of rice husk ash or in total 6.01% yield from rice husk as starting material. This amorphous silica powder constituted 65% of the molybdate reactive silica.

Table 1: Silica yield % from rice husk as starting material

| Sample                    | %      |
|---------------------------|--------|
| Rice husk                 | 100%   |
| Rice husk char            | 13.75% |
| Rice husk ash             | 8.10%  |
| Silica nanoparticles      | 6.01%  |
| Molybdate reactive silica | 3.90%  |

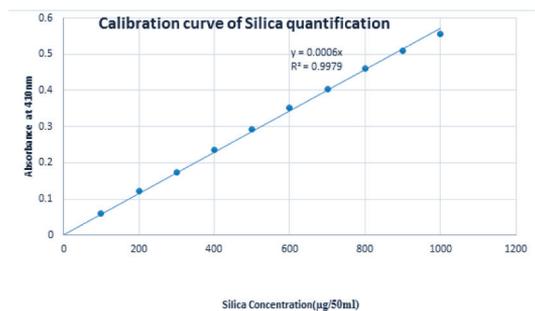


Figure 2. Calibration curve for quantification of molybdate reactive silica in isolated silica nanoparticles

### 3.3 Impacts of silica nanoparticles on rice seedlings' physiological parameters

An increasing trend is observed for root length (Figure 3.A), leaves number (Figure 3.B) and shoot weight (Figure 3.C) with increased concentration of silica nanoparticles. The root lengths has no drastic variations in concentration dependent manner where the maximum root length (5.0 cm) was observed at 3g/l that appeared to be slightly decreasing with increasing silica concentration after 3g/l. The leaves' numbers were found to have a slight increment from control to 2g/l and there after indicates the higher biomass that could be the results of greater photosynthesis. However, upon increasing the concentration above this the leaves number has significantly increased. Scientific reasoning could not be done from present works.

Shoot weight also showed slight increment from control with maximum weight of 0.6g at 3g/l concentration i.e. that showed decrease in the shoot weight upon increasing the silica concentration above this.

The significance of these readings were all analyzed by ANOVA using R-programming. The results showed the significant difference in root length and leaves number of rice with different silica concentration at 5% and 0.1% level of significance, respectively. However the results were insignificant for root number and shoot length.

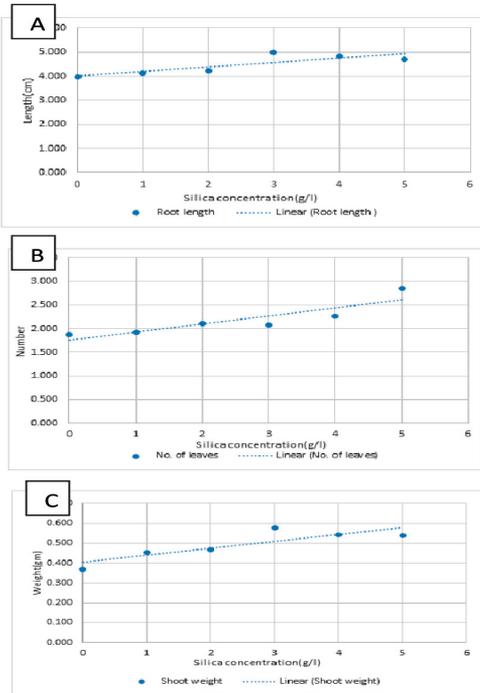


Figure 4. Impacts of silica nanoparticles in physiological parameters of rice

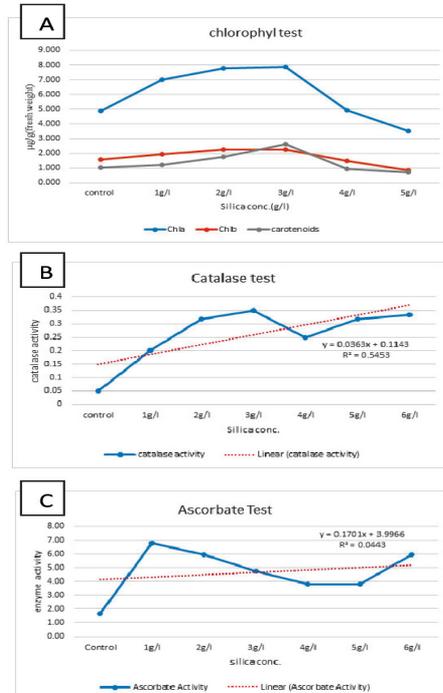


Figure 3. Impacts of silica nanoparticles in chlorophyll content and antioxidant enzyme activity

### 3.4 Impacts of silica nanoparticles in chlorophyll content and antioxidant enzyme activities

Chlorophyll and carotenoids content analysis revealed similar patterns as that of physiological parameters where 3g/l was optimal. The chlorophyll content had slight variations (Figure 4.A) for Chlorophyll b. The quantity of Chlorophyll a is found maximum among other two pigments.

The maximum chlorophyll a concentration observed was 7.853µg/g fresh weight at 3g/l concentration and minimum at 5g/l, 3.512µg/g fresh weight. For carotenoids, the maximum concentration 2.626µg/g fresh weight was again at 3g/l, and minimum 0.716µg/g fresh weight at 5g/l again. Similarly, in case of Chlb, the maximum concentration was 2.253µg/g fresh weight at 2g/l and 2.233µg/g fresh weight at 3g/l and minimum 0.834µg/g fresh weight at 5g/l. Here after 5g/l again an abrupt rise in concentration of all the three pigments was observed (data not shown).

As shown (Figure 4.B), the catalase activity has increased in dose dependent manner in a good manner with the increment in concentration of silica nanoparticles. A slight decrease can be seen at 4g/l otherwise the increasing trend is observed. The maximum catalase activity observed is 0.35µg/min/g fresh weight at 3g/l and second to it is 0.33µg/min/g fresh weight at 6g/l.

A slight increment in ascorbate activity with increasing concentration (Figure 4.C). The maximum activity in this case is  $6.79\mu\text{g}/\text{min}/\text{g}$  fresh weight observed at  $1\text{g}/\text{l}$ . After this there is continuous decrement upto  $5\text{g}/\text{l}$  with minimum activity  $3.81\mu\text{g}/\text{min}/\text{g}$  fresh weight. Again the abrupt increment has been observed at  $6\text{g}/\text{l}$ .

#### 4. Discussion

Silica has been reported to exert several beneficial effects but its poor solubility hinders the study of silica's effect in plants growth. Use of nano-sized silica could provide advantage over the solubility issue as they can easily penetrate into plant cells, as nanosilica accumulation was seen in leaves and stem of wheat (D. Sun *et.al.* 2016). To analyse the impacts of silica on the plants' growth and development, biogenic silica nanoparticles from the rice husk have been isolated from modified sol-gel method as mentioned by Kalapathy and Shultz (2000). However, in the last drying step, two different temperatures were applied. The one was at  $110^{\circ}\text{C}$  in oven and the other at  $450^{\circ}\text{C}$ , the later showing slight blackish coloration.

Characterization of both of these samples showed that the particles synthesized were amorphous, pure and particles size ranged 50-100nm. The particles at  $450^{\circ}\text{C}$  seemed more separated comparative to those at  $110^{\circ}\text{C}$  as seen in the SEM. At  $110^{\circ}\text{C}$  the fibrous structures of nanoparticles observed could probably be an indication to the significance of drying temperature, such that at lower temperature the O-H groups on the surface of the nanosilica were not much removed as at  $450^{\circ}\text{C}$ . Thus, the silanol groups present on the surface of the nanoparticles could have aggregated among themselves giving the structures as appeared (Figure 1.A). This could probably be due to the high temperature implied, and this higher temperature might have led to reduced water molecules causing less solubility of the nano-silica. Thus, subsequent experiments were done with the nanoparticles dried at  $110^{\circ}\text{C}$ .

The reactive silica in synthesized nanoparticles were quantified calculating from the constants derived through the standard calibration curve with sodium metasilicate as standard and found that the molybdate reactive silica concentration to be around 65% of the isolated silica nanoparticles. Taking into account the lesser solubility of silica at higher concentration and its tendency to form  $\text{SiO}_2$  at higher concentration, it is presumed that the remaining 35% of the particles could be the molybdate non-reactive nano-silica that was not detected in the spectrophotometry, as the XRD diagram showed no noticeable impurities.

The isolated and characterized silica nanoparticles were subjected to the germination of rice seedlings. Only used water was used for germination and no other nutrients were applied except silica nanoparticles at different concentration and investigated the physiological parameters, chlorophyll contents and antioxidant enzyme activities (CAT, ABA) of the plantlets. Among the physiological results (root length, shoot length, root number, leaves number, shoot weight and root weight) significant difference was observed in the root length and leaves' number while no any significant impact was noticeable in other physiological parameters. No specific pattern of physiological results were seen, the concentration of  $3\text{g}/\text{l}$  was seen to bring better results in most of the cases. However, no inhibitory impacts of silica nanoparticles with increasing concentration was observed proving the statement that silica is non-toxic to plants at any concentration (Slomberg and Schoenfisch, 2012). The increment in root length may probably be due to the increase of cells in the growth region with the application of silica as reported by (Hattori *et.al.*,2003). This increment in root length is an indication that the plants can penetrate deep down indicates that they can absorb nutrients from soil areas below the top soil that have not been exposed to agriculture and there is possibility that this may support for plants to be drought tolerance where absorbing embedded water below the top soil

that have neither leached to groundwater and was prevented from evaporation..

Chlorophyll concentration was found to show incremental pattern along with the increasing concentration of silica nanoparticle in the medium. Although peak was observed in 3 g/l concentration, gradual decrease was observed after this concentration. Literature review have revealed that increasing concentration of silica nanoparticle gave increase in chlorophyll concentration (Zhu. *et.al*, 2004). In another research expression of gene that have important roles on photosynthesis were expressed highly in presence of silica than in absence of silica (Song, A. *et al.*, 2014). The present study also found that the total chlorophyll content of 12.7 $\mu$ g/g fresh weight with 3mg/ml silica is about 70% more than in the control (7.4  $\mu$ g/g fresh weight). However, the results were not consistent at all concentrations and it is presumed that the solubility of silica could have been one of the factors as our works was in water only contrary to the pot experiments. The aggregates of silica in water with filter paper might have hindered even distribution of the applied silica impacting the concentration of aggregates in higher concentration and this could have been the factor for decrease in chlorophyll content after 3g/l but slight increase in the chlorophyll content at 6 g/l concentration (data not shown). Hence, it is thought that silica nanoparticle augments chlorophyll content since it has been reported that silica activates GDH function in bacteria. The increase GDH activity potentially results in increased accumulation of glutamate which gives glutamyltRNA (Moser, J. *et al.*, 2001) that is the precursor for d-amino levalonic acid (ALA) which is used in biosynthesis of tetrapyrrole, the core electron transfer ring of chlorophyll. This could be further supported by the fact that the increased catalase activity observed in the plant could be to neutralize hydrogen peroxide produced during increased photosynthesis where some of the electrons get leached during high activity.. Similar increase in H<sub>2</sub>O<sub>2</sub> and catalase activity (Han. *et al.*, 2016) has been reported when treated with silica. Hence, it is suggested that silica fertilization can help increase plant growth and development at the same time help fighting different biotic and abiotic stresses.

Most of the experiments conducted were performed using dry silica nanoparticles and using silica nanoparticles in MS media with agar, the main problem was liquefaction of agar. Using silica nanoparticles the usable silica concentration was only upto 3g/l, beyond that no agar setting was obtained that prevented to use silica nanoparticles at higher concentration. Thus, the dry silica nanoparticles in only water was used. Since the accumulation of silica is different for silica accumulators and non- accumulators plants due to limitations on preventing liquefaction of agar in MS media experiments were performed for rice as it is a potent silica accumulator and putative could have shown better results even at high silica concentration in primary growth pattern, leaves nature and plant development in early 9 days that requires further field trials for definite outcomes.

## **5. Conclusion**

In conclusion, this research has opened avenues for utilizing agricultural waste rice husk as a source of nanosilica that can be used in agriculture. This in a way reduces the pollution aided by rice husk ash and on the other its positive agricultural impacts on application in agriculture that also contributes to increased CO<sub>2</sub> capture due to increased shoot and root length and weight. Therefore silica nano particles can really be a smart agricultural alternative. However further intense research in this regard needs to be taken in order to establish and utilize biogenic silica nanoparticles as better, cheaper and eco-friendly alternative in modern agriculture.

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## Nutrient Status (NPK) of Vermicompost Prepared from Vegetable Market Waste and Tea Waste using *Eisenia fetida* (Red Worm)

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### Abstract

The study highlighted mainly nutrient quality; Nitrogen, Phosphorus and Potassium (NPK) of vermicompost prepared by vegetable and tea wastes. The seasonal vegetable waste and tea waste were used as feeding materials for worms. On the basis of nutrient quality, the study found that the average nitrogen content is rich in vermicompost derived from tea waste. However, there is no significant difference between nitrogen content in both samples ( $P>0.05$ ). Total phosphorus and potassium content in vegetable waste were significantly higher in vermicompost prepared from tea waste as feeding materials ( $P<0.05$ ).

**Keywords:** Vermicompost, bedding materials, feeding materials, NPK

### 1. Introduction

#### 1.1 Background

Vermicomposting is simply composting with worms. It involves the stabilization of organic solid waste through earthworm consumption which converts the material into worm castings. It is the result of the combined activity of microorganisms and earthworms (Domínguez, 2004). It is one of the most environment friendly methods of waste disposal. The rate of production of vermicompost depends upon the density and species of the earthworm. There are around 4000 species of earthworms in the world. Only few species are used to make compost manure. Out of these, *Eisenia fetida* is the commonly used in the world due to its efficient conversion of organic waste into vermicompost and high reproductive rate. Vermicompost comprises of worm castings or manure, some bedding materials and partially decomposed organic matter.

Plants depend upon organic as well as mineral matter to support their growth and high level of productivity. No single source of plant nutrients can meet the total nutrients need of modern agriculture. There are at least 13 elements which are absolutely essential for the growth, development and maturation of plant. Out of 13 plant nutrients, Nitrogen, Phosphorus and Potassium (NPK) are fairly needed in higher amount for the growth of plant. Vermicompost may be a best option to supply different nutrients for most of the plants.

It is very important to measure and analyze the nutrient status in vermicompost using by different feeding materials so that more and more quality organic fertilizer can be produced in large scale to meet the demand of sustainable agriculture. The present study focused on such objective.

### 2. Methodology

#### 2.1 Experimental set up (for making vermicompost)

For the present study, Kalimati Vermi Farm was chosen. It is located near to Kalimati Vegetable wholesale market.

For the preparation of Vermicompost, 20 equal size plastic containers were taken, volume of 22 liters. The containers were named as Bed no.1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 for vegetable waste

and Bed no. 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 for tea waste. The containers were made holes at the bottom in order to prevent water logging condition. The saw dust was soaked and placed (3inches) in each container which is used as bedding material for the worms. 600 compost making worm (*Eisenia fetida*) was used in each container. Most of them are in matured stage. Every week, the equal amount of vegetable and tea waste (1 kg) in each container was kept for earthworms as feeding material for 3 months. From the prevention of direct sunlight, the containers were covered jute bag. After 3 months, the vermicompost was harvested and analyzed the quality.

## 2.2 Nutrient analysis of prepared Vermicompost

Different parameters such as Total Nitrogen, Total Phosphorus, and Potassium of prepared vermicompost were measured and analyzed. Following methods were used for determination of different parameters (Table no.1).

Table 1: Test method of nutrient quality

| S.no. | Parameters                     | Methods                             |
|-------|--------------------------------|-------------------------------------|
| 1     | Total Nitrogen (%)             | Kjeldhal method                     |
| 2     | Total Phosphorus ( $P_2O_5$ %) | Modified Olsen's-bicarbonate method |
| 3     | Potassium ( $K_2O$ %)          | Flame photometric method            |

## 2.3 Statistical Analysis:

Statistical Analysis was carried out using SPSS for windows version 16.0. Independent T-Test was carried out to analyze the significant difference between two mean.

## 3. Results and Discussion:

### Nutrient Quality of prepared vermicompost:

Vermicompost is nutritionally rich natural organic fertilizer which is produced by biodegradation of organic material through interactions between earthworms and microorganisms. The quality of Vermicompost mainly depends upon the type of feeding materials. Besides that it also depend upon the waste and worms ratio, moisture content, aeration process etc.

From the study, the NPK content in prepared vermicompost is shown in Table 2 and 3. The average value of NPK of each vermicompost derived from vegetable waste and tea waste and P-value is shown in table 4.

Table 2: Nutrient quality of prepared vermicompost from vegetable waste

| Bed no.  | Parameters         |                      |               |
|----------|--------------------|----------------------|---------------|
|          | Total Nitrogen (%) | Total Phosphorus (%) | Potassium (%) |
| Bed no.1 | 2.12               | 0.64                 | 2.12          |
| Bed no.2 | 1.58               | 0.68                 | 2.24          |
| Bed no.3 | 1.72               | 0.52                 | 2.29          |
| Bed no.4 | 2.21               | 0.87                 | 2.72          |
| Bed no.5 | 2.32               | 0.72                 | 2.81          |
| Bed no.6 | 1.88               | 0.76                 | 2.92          |

|           |      |      |      |
|-----------|------|------|------|
| Bed no.7  | 2.02 | 0.58 | 3.02 |
| Bed no.8  | 1.81 | 0.60 | 2.36 |
| Bed no.9  | 2.38 | 0.52 | 3.12 |
| Bed no.10 | 1.91 | 0.58 | 2.56 |

**Table 3: Nutrient quality of prepared vermicompost from tea waste**

| Bed no.   | Parameters         |                      |               |
|-----------|--------------------|----------------------|---------------|
|           | Total Nitrogen (%) | Total Phosphorus (%) | Potassium (%) |
| Bed no.11 | 3.88               | 0.52                 | 0.92          |
| Bed no.12 | 4.12               | 0.60                 | 0.85          |
| Bed no.13 | 4.02               | 0.64                 | 1.22          |
| Bed no.14 | 3.75               | 0.58                 | 0.75          |
| Bed no.15 | 3.62               | 0.52                 | 0.98          |
| Bed no.16 | 3.68               | 0.58                 | 0.88          |
| Bed no.17 | 3.76               | 0.67                 | 0.96          |
| Bed no.18 | 3.88               | 0.60                 | 1.06          |
| Bed no.19 | 4.38               | 0.62                 | 1.12          |
| Bed no.20 | 3.91               | 0.61                 | 1.22          |

**Table 4: Statistical Analysis of two different vermicompost derived from vegetable and tea waste**

| Parameters           | Vegetable waste |                |                 | Tea waste |                |                 | p-value |
|----------------------|-----------------|----------------|-----------------|-----------|----------------|-----------------|---------|
|                      | Mean            | Std. Deviation | Std. error Mean | Mean      | Std. Deviation | Std. error Mean |         |
| Total Nitrogen (%)   | 1.99            | 0.26           | 0.082           | 3.90      | 0.22           | 0.071           | 0.438   |
| Total Phosphorus (%) | 0.64            | 0.11           | 0.035           | 0.594     | 0.047          | 0.015           | 0.024   |
| Potassium (%)        | 2.61            | 0.352          | 0.11            | 0.99      | 0.157          | 0.049           | 0.005   |

Nitrogen is an essential plant nutrient which helps plants grows quickly, while also increasing the production of seed and fruit. It also helps in photosynthesis. The present study showed that the total nitrogen content in vermicompost derived from tea waste was higher than vegetable waste. However, there is no significant different between nitrogen content in both samples ( $P>0.05$ ) as shown in table no. 4. The increased in nitrogen content in this vermicompost is dependent upon supplements. Earthworms can boost the nitrogen levels of the substrate during digestion in their gut adding their nitrogenous excretory products, mucus, body fluid, enzymes, and even through the decaying dead tissues of worms in vermicomposting subsystem (Suthar 2007). Kaushik et al.,

2004 found that inoculation with N-fixing bacteria significantly increased the nitrogen content of the vermicompost.

Phosphorus is responsible for root growth and flower and fruit development. The transformation of solar energy into chemical energy is also contributed by phosphorus. The average Phosphorus content of two different vermicompost samples were found as 0.64 % (vegetable waste), 0.59 % (tea waste) respectively. The worms during vermicomposting converted the insoluble phosphorus into soluble forms with the help of P-solubilizing microorganisms through phosphatases present in the gut, making it more available to plants (Suthar et al. 2008, Padmavathiamma et al., 2008 and Ghost et al. 1999).

Potassium is the third essential nutrient which is demanded by plants for building proteins and the reduction of diseases. It is an activator of enzymes involved in the photosynthesis as well as protein and carbohydrate metabolism. The value of Potassium in vermicompost derived from vegetable waste is found significantly higher than vermicompost that is derived from tea waste ( $P < 0.05$ ) as shown in table no. 4.

#### **4. Conclusion:**

Vermicomposting is an appropriate technique for the disposal of organic waste like vegetable waste. On the basis of nutrient quality, Vermicompost produced from vegetable waste is rich in phosphorus and potassium content. The average concentration of total nitrogen is rich in vermicompost that is derived from tea waste.

#### **Acknowledgement:**

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## Severity of Disaster Destruction Hinders Infant and Young Children's Feeding Practices and Growth

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### Abstract

Child under-nutrition is a major public health concern in South Asia. Nepal being one, with a high prevalence of under-2 underweight, stunting, and wasting. In addition, earthquake on 25 April 2015 exacerbated the situation. Acknowledging the presence of limited study on the effect of earthquake on Infant and Young Children (IYC) growth and feeding practices, this study was conducted two months after the mishap, in the worst affected district; Sindhupalchok and comparatively less destructed; Kathmandu. The study hypothesized that the severity of the calamity destruction is associated with inappropriate feeding practices and higher prevalence of wasting & underweight amongst IYC. Ecological study was conducted based on purposive sampling, after receiving informed consent from the caretakers of 200 children aged 0–24 months. WHO standardized questionnaire was referred to obtain qualitative and quantitative information on knowledge, attitude and behaviors on IYC growth and feeding via mobile-based questionnaire. 55% of the children in the study from Sindhupalchok were stunted, 90% were wasted and 93% underweight; whereas, 45% of the children from Kathmandu were stunted and 10% were wasted and 7% underweight. While stratifying the variables in response to possible confounders; maternal and paternal education; poor growth was prevalent amongst the children in Sindhupalchok. Findings also suggest that responsive feeding practices were practiced more in Sindhupalchok. Hence, not only intervention and awareness on complementary responsive feeding practices but also availability of nutritious food in disaster-affected areas could play a vital in proper growth and development of the disaster affected children.

**Key words:** Disaster, Earthquake, Infant and Young Children, IYCF

### 1. Introduction

South Asia carries the highest burden of childhood under-nutrition with close to 50% of the world's undernourished children living in this region (Menon, 2012). This contributes to about one-third of annual child deaths out of 7.6 million under-five deaths worldwide (World health organization, 2013 and Adhikari, 2013). In 2005, under-5 mortality rate in Nepal was 64 per thousand live births with 85% of these deaths during the first year of life (World health organization, 2013 and Ministry of Health, 2004). According to WHO Child growth standards, childhood under-nutrition poses a serious public health problem to infants and young children, with 49% of children below 5 years stunted (low height for age), 39% underweight (low weight for age) and 13% wasted (UNICEF, 2009).

Nepal is one of the poorest countries in South Asia with 54% of the country's population living on less than \$1.25 per day and three and half million people moderately to severely food insecure (Asian Development Bank (ADB), 2012). Nepal was struggling with its food insecurity and poverty, but was on the path of meeting the Millennium Development Goal target on reducing hunger by half by the end of 2015 (The Himalayan Times, 2015). Sadly, a massive earthquake struck Nepal on 25 April 2015, measuring 7.8 on the Richter scale and affecting 35 districts; 14 severely, amongst 75 districts of Nepal. This accounted for 20% of the country's population, and had about 1.2 million households (Paulin, Katayama, & Yousaf, 2015 and Asian Development Bank, 2015).

Because of this disaster, incalculable human losses and suffering was encountered, with millions of people rendered homeless, with nearly 300,000 houses completely or partially destroyed (Shelbayah & Mullen, 2015). This earthquake caused unimaginable destruction that resulted in overflowing hospitals, scarce water, bodies buried under the rubble and people sleeping in the open, leaving diseases to flourish easily, according to Rownak Khan, U.N. Children’s Fund senior official in Nepal (Gurubacharya & Daigle, 2015). Nepal had not faced a disaster of this magnitude for over 80 years, and so was neither prepared for the destruction nor equipped for the response (The Himalayan Times, 2015 and Paulin, Katayama, & Yousaf, 2015). In addition to this destruction, heavy monsoon rains exacerbated the situation, with frequent landslides and road blocks hindering humanitarian assistance by road, while the erratic weather caused multiple flight cancellations obstructed help by air.

Proper reporting of the destruction was made, and records of the rising death tolls were continuously updated following earthquake, but what was not taken care of was the manifestations of the earthquake associated with the victimization by this quake. Most neglected aspects were on the health and nutrition of the infants and young children. During the aftermath of the disaster, with the rise in food prices and the financial crises, it was more difficult to move out of poverty and improve nutritional health in the country (UNICEF, 2009). This could hence lead to an increase in maternal and child under nutrition and the susceptibility of these groups to illnesses, which are estimated to be the underlying cause of 3.5 million deaths annually (WHO. Multicenter Growth Reference Study Group, 2006).

Therefore, in this research we explored the infant and young children’s feeding practices and growth status in two of the disaster affected regions of Nepal; more affected Sindhupalchok and comparatively less destructed Kathmandu. Along with poor feeding habits and diminished responsive complementary feeding following earthquake, we hypothesized that in the more disaster affected area, the prevalence of underweight and wasting would be higher than in the less affected area.

## 2. Materials and Methods

### 2.1 Study design

A year-long ecological study was held starting from April 2015 located at Bagmati zone, hilly region of Central Development Region, Nepal. This research was based on two districts Sindhupalchok and Kathmandu, which are 55 kms apart from each other.

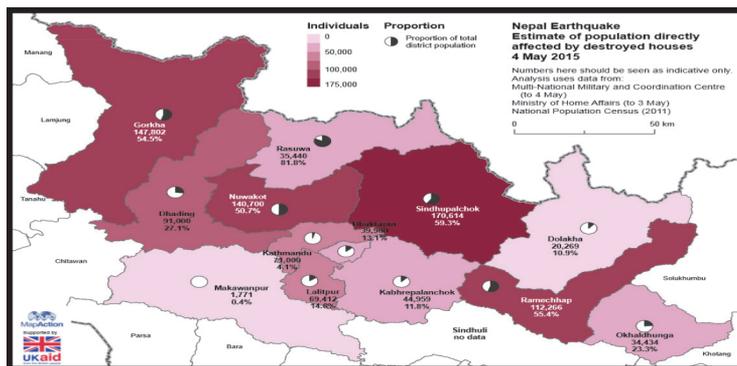


Figure 1: Aftermath destruction shown by the number and percentage of death tolls in each of the affected districts of Nepal

## **2.2 Ethical considerations**

The study was approved by the Institutional of Review Board (IRB) of the Asian University for Women Chittagong, Bangladesh.

## **2.3 Characteristics of samples**

Data were collected based on purposive sampling, from the places where the people were collectively living in the open space under the tents while continuous aftershocks were felt in the region. The caretakers with the children between 0 to 24 months were interviewed. Sample population was 200, which included people of various ethnic backgrounds like, Brahmin/ Chhetri, Dalits and Newars and of varying religion. All measurements and interviews were carried out after attending the training and supervision from Asian University for Women, which is located in Chittagong, Bangladesh.

## **2.4 Questionnaire**

Questionnaire was developed as per the indicators recommended by WHO. In-depth interview was conducted with the child's caretaker. The questionnaire consisted of 7 different sections that included qualitative as well as quantitative questions. Mothers/caretakers were surveyed on knowledge, attitude and behaviors that were related to infant and young child growth and feeding habits. For the children who were fed complementary food, the questionnaire tended to observe the responsive feeding habits of the caretakers and also dietary diversity through 24-hour dietary recall. In this way we could get information on what, how and when the children were fed in the camp. Data was also collected on the child's parent's socio-demographic information. Finally, the current height and the weight of the children were also noted.

## **2.5 Measurement tools**

The weight of each child was determined using a portable child weighting scale, Salter infant spring scale while the length was measured using the measuring board, infantometer. The z-score was measured based on the average measurement of height and weight of the child. The child's weighing machine was observed and standardized every time before weighing the child. For every child, two recording were noted for height as well as the child's weight and the averages of these two measurements were recorded as the child's weight/height.

## **2.6 Data collection**

Since the application of innovative techniques are promising for surmounting formidable challenges to data collection in disaster affected regions, the investigator preferred data collection, utilizing the personal digital assistant-based platforms (Morton & Levy, 2011). For this study, tablet and android phone were used, so the collected data as well as the archived data were both electronic.

Initially, database was created in excel that was based on the WHO standardized questionnaire for IYC feeding. This excel file was synchronized with the online software named ONA so that the initial version of excel database could be retrieved as an electronic questionnaire. Software named KLL (Kathmandu Living Labs) collect was synchronized with ONA. KLL collect displayed the electronic questionnaire in the tablet and the android phone, which was used for data collection. Data collected through KLL was retrieved and archived in excel file.

It took around two months, from June to July; in order to collect data from both the earthquake affected areas of Nepal with the help of three researchers. After sample selection and before each survey, verbal consent was obtained from all the mothers or guardians/caretakers of the children.

### 2.6.1 Independent Variable

The study tends to assess the varying feeding habits and development of young children caused due to the difference in intensity of earthquake destruction. Sindhupalchok was more destructed by earthquake with highest number of death tolls, amongst 35 out of 75 districts that were adversely affected. Moreover, Figure 1 provides us the overview of destruction damage in all the earthquake-affected regions of Nepal. We can see that the highest proportion of the people have been affected in Sindhupalchok that is 59.3%. Also, it wouldn't be incorrect to say that the highest number of people in Nepal who were affected by earthquake was living in Sindhupalchok. Because not only highest proportion of people were affected in Sindhupalchok but also highest number of people were living in Sindhupalchok when this mishap occurred. On the other hand, in case of Kathmandu, only 4.1% of the households were affected, hence, making Kathmandu the lesser earthquake affected region in Nepal.

### 2.6.2 Dependent Variables

#### 2.6.2.1 Responsive Feeding Behaviors

Responsive feeding behavior was targeted to infants and young children whose mothers or caregivers had started introducing complementary food; for the children above 6 months. The four open-ended questions that were administered to the caretakers included:

- To evaluate verbal encouragement for the children, the caretakers were asked, "*Do you ever say anything to (infant) to encourage her/him to eat more? If yes, what do you say to (infant) as encouragement to eat more?*"
- To evaluate the action of the caretakers towards the children, they were asked, "*What do you do to (infant) as encouragement to eat more?*"
- To understand how the caretakers react when their children denies, they were asked, and "*What do you do if your child refuses to eat?*"
- To understand how the caretakers react when their children ask for more food, they were asked, "*What happens if food is served to child and child asks for more?*" (WHO, 2016)

#### 2.6.2.2 Anthropometric Calculation for Wasting and Underweight

Anthropometric indices were the indicators to evaluate child nutritional status through weight and height. In order to assess malnutrition in children, z-scores were used. The z-scores evaluate the prevalence of protein-energy malnutrition; stunted, underweight and wasted. Stunting, underweight, and wasting were defined as having a z-score  $< -2.0$  for length-for-age, weight-for-age, and weight-for-length, respectively (WHO. Multicenter Growth Reference Study Group, 2006).

### 2.7 Data management and statistical analysis

Data archived in excel 2013 was recorded and was derived into SPSS software (Windows version 14.0) and Stata SE for data analysis. Z-scores were calculated using WHO Anthro and Nut Pro software evaluated the growth and nutritional intake of the children.

Descriptive statistics were used to examine the parental as well as child's demographic information. Sample means  $\pm$  standard deviations were computed for all continuous variables while frequencies (n, %) were observed in case of categorical variables.

Chi-square ( $X^2$ ) tests and cross tabulations were used to understand the associations between the independent variables and dependent variables, that is region and the complementary

feeding practices, region and responsive feeding practices, and region and underweight/wasting. Potential confounding variables were tested with these dependent as well as independent variables. Stratification was done with respect to possible confounders for identifying the effects of potential confounders; maternal and paternal education. A significance level of  $p < 0.05$  was considered for statistical significance.

### 3. Results

#### 3.1 Demographic Characteristics of the Participants

Amongst the 200 caretakers of the infant and young children who were interviewed, 54% of them were the residents of Kathmandu while the other 46% were from Sindhupalchok.

In case of level of education of the parents, illiterate was defined as not receiving even a year of formal education, while literate were those who received at least a year of formal education. In case of level of education of the parents, illiterate was defined as not receiving even a year of formal education, while literate were those who received at least a year of formal education. 33% of total mothers were found to be illiterate in the study; 30.3% of the total from Kathmandu were illiterate while in Sindhupalchok, 69.7% of the total were illiterate. Highly significant difference ( $p\text{-value} \ll 0.001$ ) was attained in case of maternal education between both the regions. Moreover, in case of the fathers of the infant and young children, 33.3% of the total living in Kathmandu was found to be illiterate and 66.7% of them from Sindhupalchok were illiterate. In case of father's education as well significant difference was witnessed between the regions ( $p\text{-value} < 0.050$ ) (Table 1).

In case of mother's occupation, 33.3% of them living in Kathmandu were housewives while 53.2% were involved in various works outside home like farming, family business, etc. In contrast, 66.7% of them were housewives in Sindhupalchok and 46.8% were working. In case of father's occupation, 57.9% of them were staying at home in Kathmandu while 53.6% were engaged outside. But in case of Sindhupalchok, 42.1% were staying at home and 46.4% were working outside. None of the parental occupation was statistically different. (Table 1).

Amongst all the mothers who were interviewed, 48.0% of those living in Kathmandu were of age 17-24 years, 60.0% age group 25-40. On the other hand, in case of Sindhupalchok, 52.0% were of age group 17-24 years and 40.0% were of between 25-40 years. In case of the children's fathers, 48.1% of those living in Kathmandu were of age-group 20-28 years and 60.6% between 29-46 years. While 51.9% of them in Sindhupalchok were of 20-28 years and 39.4% were of 29-46 years. In case of age group of both the parents, there was no any significant difference was observed, but the difference was heading towards the level of significance ( $p\text{-value} = 0.076$ ). In other words, younger parents were evident in Sindhupalchok than in Kathmandu (Table 1).

Table 1: Demographic characteristics of the respondents based on the study in the two districts of Nepal (N=200)

| Characteristics        |                 | Residence of the respondents |                      | P-value |
|------------------------|-----------------|------------------------------|----------------------|---------|
|                        |                 | Kathmandu, N (%)             | Sindhupalchok, N (%) |         |
| Respondent's residence |                 | 108 (54)                     | 92 (46)              |         |
| Mother's education     | *Illiterate     | 20 (30.3)                    | 46 (69.7)            | <0.001  |
|                        | *Literate       | 88 (65.7)                    | 46 (34.3)            |         |
| Father's education     | *Illiterate     | 8 (33.3)                     | 16 (66.7)            | 0.030   |
|                        | *Literate       | 100 (56.8)                   | 76 (43.2)            |         |
| Mother's occupation    | Housewife       | 83 (54.2)                    | 70 (45.8)            | 0.899   |
|                        | **Other         | 25 (53.2)                    | 22 (46.8)            |         |
| Father's occupation    | Stays at home   | 11 (57.9)                    | 8 (42.1)             | 0.720   |
|                        | **Works outside | 97 (53.6)                    | 84 (46.4)            |         |
| Mother's age           | 17-24 y         | 48 (48.0)                    | 52 (52.0)            | 0.089   |
|                        | 25-40 y         | 60 (60.0)                    | 40 (40.0)            |         |
| Father's age           | 20-28 y         | 51 (48.1)                    | 55 (51.9)            | 0.076   |
|                        | 29-46 y         | 57 (60.6)                    | 37 (39.4)            |         |

\*Literate: at least 1 year of study accomplished; Illiterate: attended no any schools or classes

\*\*Other/Works outside home: Personal business, labourer, driver, farmer, etc.

‡ Pearson Chi-Square was used

### 3.2 Demographic Characteristics of the Infant and Young Children

Out of 200 infants and young children in this study, 47% of the male children were from Kathmandu, while 53% of them were from Sindhupalchok. In case of female children, 53% were from Kathmandu, while 47% were from Sindhupalchok (Figure 2).

In this study, the age group of the children has been divided into three categories; 0 to 5 months, 6 to 12 months and 13 to 24 months. These categories were defined based on what these age-groups are supposed to be fed. The first category 0-5months are expected to be exclusively breastfeeding, the second group of 6-12 months children is expected to be initiated with complementary food along with breast feeding and the third category 13-24 months children are expected to be fed almost everything that an adult consumes along with breast feeding. Out of 108 children from Kathmandu, 37% were below 6 months, 30% were 6 to 12 months and 33% were 13 to 24 months. In case of Sindhupalchok, out of 92 children, 51% were below 6 months, 27% were of 6 to 12 months and the rest 22% were of 13 to 24 months (Figure 2).

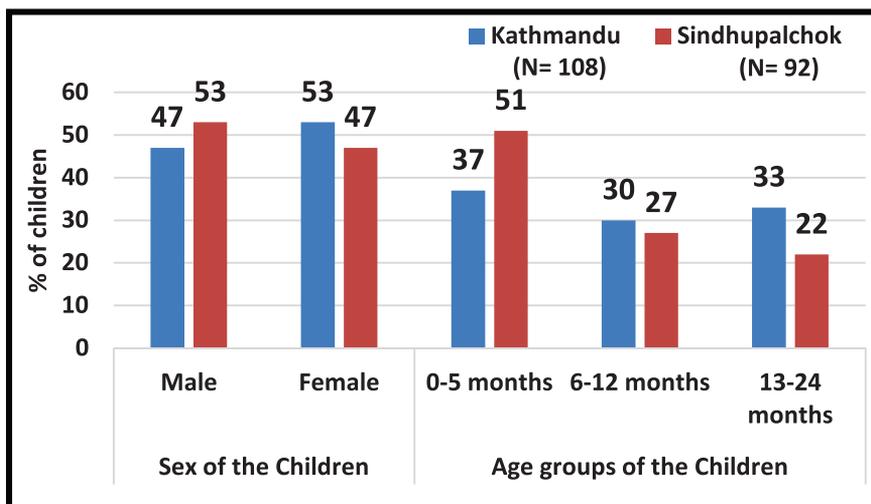


Figure 2: Demographic information of the infants and young children in the study by residence (N=200)

### 3.3 Under-nutrition and Region

Figure 3 shows the prevalence of Stunting, Wasting and Underweight in both the regions. As we can see that Sindhupalchok holds 55% of total stunted children in this study, while 44% are from Kathmandu. In case of wasting, Sindhupalchok has 90% of total wasted children while Kathmandu carries only 10% of them. Also, in case of underweight, Sindhupalchok holds 93% of total underweight while it is only 7% in case of Kathmandu. Also, significant difference based on the region has been observed in case of wasting and underweight ( $p\text{-value} \ll 0.01$ ) (table 2).

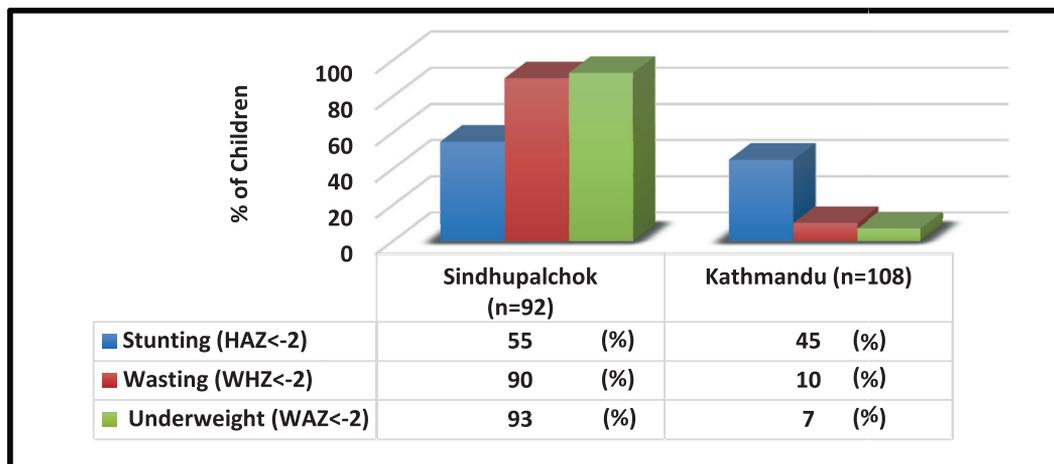


Figure 3: Prevalence of stunting, wasting and underweight

### 3.4 Under-nutrition and Other Variables

Table 2 presents the number and percentage of children in the study who were stunted, wasted or underweight based on their sex, age, residence and mother's education. No any statistically different value was observed in case of sex of the child. However, when the children were distributed in terms of their age-group, statistical difference is observed in case of stunting ( $p$ -value $<0.01$ ). In case of maternal education, significant difference has been observed in case of wasting ( $p$ -value $<0.01$ ) and under-weight ( $p$ -value $<0.05$ ). While 80% of the mothers had children who were wasted, only 20% of them were educated with a wasted child. Similarly, 64.3% of uneducated mothers had underweight child, while 35.7% of educated mothers had underweight child.

**Table 2: Prevalence of stunting, wasting and underweight according to socio-demographic variables (N=200)**

| Characteristics                 |                      | Stunting<br>(HAZ<-2)<br>N (%) | P-value | Wasting<br>(WHZ<-2)<br>N (%) | P-value | Underweight<br>(WAZ<-2)<br>N (%) | P-value |
|---------------------------------|----------------------|-------------------------------|---------|------------------------------|---------|----------------------------------|---------|
| Infant and Young Children's sex | Male (n=102)         | 16 (55.2)                     | 0.627   | 8 (80.0)                     | 0.101   | 7 (50.0)                         | 0.938   |
|                                 | Female (n=98)        | 13 (44.8)                     |         | 2 (20.0)                     |         | 7 (50.0)                         |         |
| Infant and Young Children's age | 0-5m (n=87)          | 11 (37.9)                     | 0.001   | 6 (60.0)                     | 0.654   | 7 (50.0)                         | 0.133   |
|                                 | 6-12m (n=113)        | 18 (6.9)                      |         | 2 (20.0)                     |         | 1 (7.1)                          |         |
|                                 | 13-24m (n=56)        | 16 (55.2)                     |         | 2 (20.0)                     |         | 6 (42.9)                         |         |
| Residence                       | Sindhupalchok (n=92) | 16 (55.2)                     | 0.284   | 9 (90.0)                     | 0.006   | 13 (92.9)                        | <0.001  |
|                                 | Kathmandu (n=108)    | 13 (44.8)                     |         | 1 (10.0)                     |         | 1 (7.1)                          |         |
| Maternal education              | Uneducated (n=66)    | 12 (41.4)                     | 0.299   | 8 (80.0)                     | 0.003   | 9 (64.3)                         | 0.016   |
|                                 | Educated (n=134)     | 17 (58.6)                     |         | 2 (20.0)                     |         | 5 (35.7)                         |         |

\*Literate: at least 1 year of study accomplished; Illiterate: attended no any schools or classes

\*\*Other/Works outside home: Personal business, labourer, driver, farmer, etc.

<sup>†</sup>When  $n < 5$  in the cells, Fisher's Exact Test was used; otherwise Pearson Chi-Square was used

### 3.5 Complementary foods, Age group and Region

Variety of foods was fed to the children of 6 to 24 months of age. Here, as we can see in the figure 4, we expect the caretakers to be feeding their children with the first 15 foods (from rice to fish). And we expect the caretakers to not feed their children with the last 5 foods (sugar, oil, biscuits, candies and other junk foods). Regardless, not all the children have been introduced with all the variety of nutritious foods. Moreover, less variety of nutritious foods is fed in Sindhupalchok. In case of junk foods, the children of Kathmandu are being fed more of this unnecessary diet.

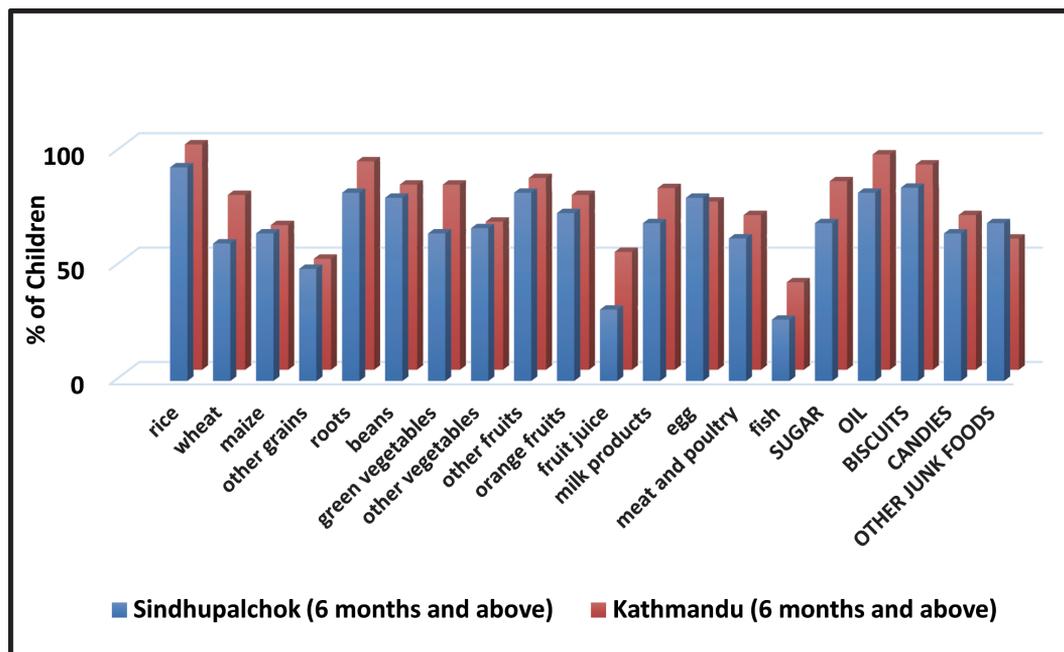


Figure 4: Variety of foods that were ever fed by the caretakers to their children between 6 months to 2 years of age in Sindhupalchok and Kathmandu

Interestingly, it was also found that the children below 6 months had also been introduced with a variety of foods in both the regions. As we can see in figure 5, more number of children has been introduced with a variety of foods in Kathmandu in comparison to Sindhupalchok. In contrast, the children of below 6 months must be exclusively breastfeeding.

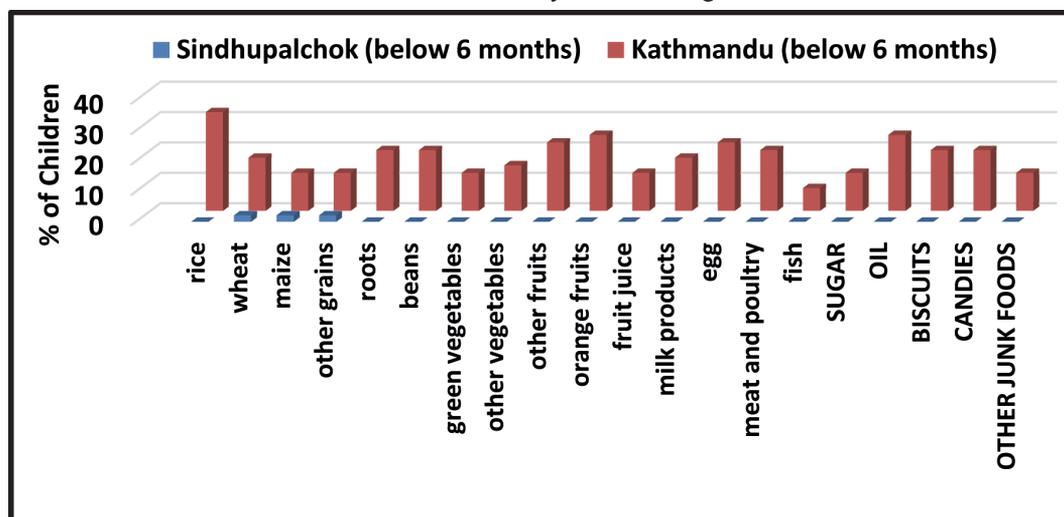


Figure 5: Variety of foods ever introduced by the caretakers to their children below 6 months of age in Sindhupalchok and Kathmandu

### 3.6 Responsive feeding and the Area of Residence

In case of responsive feeding, mothers or caregivers who encourage their children to eat more by ‘doing’ something seems to be approaching towards significant difference (p-value=0.067). Also, in case of the mothers who responded when the child ‘refused’ to eat also seem to be heading towards significant difference (p-value=0.099). However, in case of the mothers/caretakers who encourage IYC to eat more by ‘saying’ or the mothers’ response when their children ‘asked for more’ to eat were not significantly different (Table 6).

Table 6: Responsive feeding behavior among Infant and Young Children (IYC) aged 6 to 24 months based on the residence (N=200)

| Mother’s Responses   |          | Residence of the Respondents |                                    | P-value |
|--|----------|------------------------------|------------------------------------|---------|
|  |          | N (%)                        |                                    |         |
|  |          | Kathmandu<br>(Total N=76)    | Sindhupal-<br>chok<br>(Total N=45) |         |
| Mothers who responded by ‘saying’ something to encourage IYC to eat more | Positive | 33 (43.4)                    | 21 (46.7)                          | 0.729   |
|  | Negative | 43 (56.6)                    | 24 (53.3)                          |         |
| Mothers who encouraged by ‘doing’ something to encourage IYC to eat more | Positive | 26 (34.2)                    | 23 (51.1)                          | 0.067*  |
|  | Negative | 50 (65.8)                    | 22 (48.9)                          |         |
| Mothers who responded when the child ‘refused’ to eat                    | Positive | 21 (27.6)                    | 19 (42.2)                          | 0.099*  |
|  | Negative | 55 (72.4)                    | 26 (57.8)                          |         |
| Mothers who responded when the child ‘asked for more’ to eat             | Positive | 53 (69.7)                    | 31 (68.9)                          | 0.922   |
|  | Negative | 23 (30.3)                    | 14 (31.1)                          |         |

<sup>†</sup> Pearson Chi-Square was used

\*Approaching significance, p-value <0.050

### 3.7 Factors significantly different between two places

In Table 8, we can see the factors that were significantly different between two regions. We can see that in case of maternal and paternal age, the difference in both the regions are approaching towards significance. Maternal and paternal education are also significantly different. While around 66% of the mothers who were interviewed had attended at least a year of schooling, in case of Sindhupalchok, it was 34% (p-value<.001). In case of paternal education, 57% fathers have attended more than 10 years of schooling in Kathmandu while in case of Sindhupalchok was 43%. Along with the difference between educational level of father and mother in these two regions, the disparity in education between men and women can also be observed in this table.

**Table 8: Factors that were significantly different between the two residence, more affected, Sindhupalchok and comparatively less affected, Kathmandu (N=200)**

| Characteristics    |            | Residence of the respondents |                      | P-value  |
|--------------------|------------|------------------------------|----------------------|----------|
|                    |            | Kathmandu, N (%)             | Sindhupalchok, N (%) |          |
| Mother's education | ♦No        | 20 (30.3)                    | 46 (69.7)            | <0.001** |
|                    | ♦Yes       | 88 (65.7)                    | 46 (34.3)            |          |
| Father's education | w<10 years | 36 (33.3)                    | 50 (66.7)            | 0.003**  |
|                    | w>10 years | 72 (56.8)                    | 42 (43.2)            |          |
| Mother's age       | 17-24 y    | 48 (48.0)                    | 52 (52.0)            | 0.089    |
|                    | 25-40 y    | 60 (60.0)                    | 40 (40.0)            |          |
| Father's age       | 20-28 y    | 51 (48.1)                    | 55 (51.9)            | 0.076    |
|                    | 29-46 y    | 57 (60.6)                    | 37 (39.4)            |          |

♦No: attended no any formal education; Yes: at least 1 year of formal education

w<10 years: less than 10 years of formal education; >10: more than 10 years of formal education

\*Pearson Chi-Square was used

\*\* Highly significant, p-value<<0.050

### 3.8 Variables stratified Confounders

Since the maternal education seems to be affecting the relation between the regions and the z-scores, table 7, has stratified maternal education with respect to underweight and wasting. In case of the mothers who have attended at least a year of formal education, in Kathmandu there are no any children who are underweight; whereas, in case of Sindhupalchok, there were 11%. Similarly, in case of Kathmandu, only 1% children were wasted while in Sindhupalchok, it was 2%. On the other hand, in case of mothers who have never attended any kind of formal education, in Kathmandu there were 5% of the children with underweight, while in case of Sindhupalchok around 17% children were underweight. Moreover, in case of Kathmandu, no children were found to be wasted while in Sindhupalchok, around 17% children were found to be wasted.

Table 9: Underweight &amp; Wasted stratified according to maternal education

| Characteristics | Mothers with at least a year of formal education |                      | Mothers with no formal education |                      |
|-----------------|--|----------------------|----------------------------------|----------------------|
|                 | Region   |                      | Region                           |                      |
|                 | Kathmandu, N (%)                                 | Sindhupalchok, N (%) | Kathmandu, N (%)                 | Sindhupalchok, N (%) |
| Underweight     |  |                      |                                  |                      |
| No              | 88 (100.0)                                       | 41 (89.1)            | 19 (95.0)                        | 38 (82.6)            |
| Yes             | 0 (0.0)  | 5 (10.9)             | 1 (5.0)                          | 8 (17.4)             |
| Wasted          |  |                      |                                  |                      |
| No              | 87 (98.9)  | 45 (97.8)            | 20 (100.0)                       | 38 (82.6)            |
| Yes             | 1 (1.1)  | 1 (2.2)              | 0 (0.0)                          | 8 (17.4)             |

Also, in case of paternal education, highly significant difference was found between the two regions and the z-scores. Therefore, underweight and wasted has been stratified according to the paternal education, in both the regions in table 8. We can see that, in case of the children who have attended less than 10 years of formal education, around 3% children in Kathmandu were underweight while 10% of them in Sindhupalchok were underweight. And none of the children in Kathmandu were wasted while 8% of the children in Sindhupalchok were wasted. Similarly, in case of the children whose father attended more than 10 years of formal education, none of the children in Kathmandu were underweight; whereas 19% of the children in Sindhupalchok were underweight, and only around 1% of the children in Kathmandu were wasted while around 12% of the children in Sindhupalchok were found to be wasted.

Table 10: Underweight &Wasted stratified according to paternal education

| Characteristics | Fathers with <10 years of formal education |                      | Fathers with >10 years of formal education |                      |
|-----------------|--|----------------------|--|----------------------|
|                 | Region                                     |                      | Region                                     |                      |
|                 | Kathmandu, N (%)                           | Sindhupalchok, N (%) | Kathmandu, N (%)                           | Sindhupalchok, N (%) |
| Underweight     |  |                      |  |                      |
| No              | 35 (97.2)                                  | 45 (90.0)            | 72 (100.0)                                 | 34 (81.0)            |
| Yes             | 1 (2.8)                                    | 5 (10.0)             | 0 (0.0)                                    | 8 (19.0)             |
| Wasted          |  |                      |  |                      |
| No              | 36 (100.0)                                 | 46 (92.0)            | 71 (98.6)                                  | 37 (88.1)            |
| Yes             | 0 (0.0)                                    | 4 (8.0)              | 1 (1.4)                                    | 5 (11.9)             |

#### 4. Discussion

Nepal had been working on fulfilling the MDGs by the end of 2015 (Asian Development Bank (ADB), 2012). However, due to the sudden inevitable earthquake, loss and misery also became inevitable (The Himalayan Times, 2015; Paulin, Katayama, & Yousaf, 2015 and Asian Development Bank, 2015). Various governmental and non-governmental organizations did work collaboratively to get Nepal out of this disastrous situation. But difficulty in approaching all the disaster-affected regions became more challenging due to monsoon.

In addition, the major part of health was left behind that could bring about long-term damage in the health and well-being of the future of the nation. Infant and young children’s health, growth and development have been compromised because of lack of responsive complementary feeding practices in these disaster-affected areas. Therefore, this paper highlights the inclusion of IYC feeding interventions and availability of nutritious foods, which could diminish the mortality and morbidity of young children that occurs as a result of natural disasters (WHO. Multicenter Growth Reference Study Group, 2006). Moreover, even two earthquake affected areas may produce different results depending on a number of circumstances, which basically involve the background of the stricken population (its ‘disaster culture’, knowledge of disasters and preparedness, level of immunity against certain diseases, endemicity, etc.) and the physical and sociological environment (e.g., type of housing, high mountains vs. pantanous jungles, etc.) (World health organization, 2013).

Hence, this paper has claimed that based on the severity of calamity destruction, infant and young children's feeding habits are altered and hence difference in the growth and development of the children below 2 years of age.

In order to see the association between the severity of calamity destruction and IYCF practices, severity of calamity destruction was defined by the property and household destruction following earthquake, and in case of IYCF practices, eight core WHO recommended feeding indicators, 24-hour recall of the children's diet, and responsive feeding behaviors, minimum kilocalorie intake and minimum micro-nutrient intake were analyzed. And in case of growth measurement, z-scores were used to examine stunting, wasting and underweight. However, only wasting and underweight was considered as the measures that would define the growth falter in children. Stunting was excluded because the data was collected within a short duration of 2 to 3 months after the earthquake. Research says that weight is more affected by shorter term deprivation than height/length. Moreover, weight gain typically results in a doubling of birth weight by age 5 months and a tripling by 1 year; whereas, length in normal-term infant increases about 30% by age 5 months and more than 50% by age 12 months that means infants typically grow about 10 inches (25 centimeters) during the first year, and height at 5 years is about double the birth length (WHO/UNICEF, 2008). In other words, length growth is slower in comparison to weight. Therefore, we would not expect to see much of height changes within a short duration of 2 months. In this study as well, as expected, stunted was not significantly different between the two regions.

According to WHO child growth standards, the cases of stunting was higher that is 49% of the total children below 5 years in comparison to 39% of the children who were underweight and 13% wasted (UNICEF, 2009). Similar was the case in this study. Hence, the total percentage of children who were stunted were higher that is 54.7% in comparison to 18.9% and 26.4% which was the total percentage of children who were reported to be wasted and underweight, respectively. Despite the fact that stunting occur in long duration, the factors like intra-uterine growth retardation, mother's feeding habits during pregnancy and lactation, all have an adverse effect in the children's growth and so does effect stunting. Similar might have been the case here in both the regions.

It was vigilant that infants and young children feeding practices were poor in both the disaster-affected areas of Nepal. For instance, more consumption of junk foods and other unhealthy diets seem to be prevalent. It could be due to advertisement, easy availability and increased accessibility to junk foods. Regardless of the age of the children, especially the children below six months, who should be avoided feeding anything; were introduced with unhealthy junk foods as an alternative to nutritious breast milk.

Several previous studies has been reported that the poor or no formal maternal education is associated with poor infant and young children's responsive feeding practices (Marriott BP, 2012). However, in this research, maternal education does not seem to be a contributing factors in case of responsive feeding practices of the children. However, further studies based on intervention program could help generate more ideas and evidence that would support the importance of awareness and education on infant and young children's feeding practices.

While assessing the association between severity of calamity destruction and responsive feeding, and severity of calamity destruction and maternal education, the findings were observed to be significantly different between the two regions. Interestingly, the findings show that responsive feeding habits were more prevalent amongst the mothers of the children living in more disaster affected region and with the mothers and fathers who have possess comparatively less education, that is, in Sindhupalchok.

Since maternal and paternal education were significantly different between both our dependent as well as independent variables, they could be possible confounders in this study. Hence, they were stratified on the basis of the growth of the children and the region. Findings show that in case of the growth of the children, children's growth were poor in the more disaster affected Sindhupalchok. Suggesting that the children from more destructed areas are more vulnerable to wasting and underweight, even within short time lapse.

Interestingly, responsive feeding practices were more prevalent in more disaster affected region while poor growth of the children was also retrieved from the more disaster affected region. Findings suggest that poor growth could have been due to lack of nutritious diet. Not because the mothers were not aware of responsive feeding, but possibly because of unavailability of nutritious foods. Hence, not only infant and young children feeding intervention but also proper humanitarian assistance focusing on nutritious food availability is vital, aftermath of destruction.

However, there were some limitations of this study that should be averted in the future study. Possibly, more strong association could have been seen if the sample size had been larger. The study had a small sample size of only 200 children; 108 from Kathmandu and 92 from Sindhupalchok. In addition, the researcher would suggest adding few more questions that would evaluate more on the background of the participants. All natural disasters are unique in that the regions affect different social, economic, and health backgrounds (Noji, 2000). So, more data on them might be helpful. Considering the audience appropriate questions, for they recently faced a crucial stage and are overcoming disastrous effect, it might be sensitive but vital for further research.

This study might not be representative to the population because the sample was chosen based on purposive sampling from the areas where people were living collectively under the tents. Due to the same reason, the distribution of age-group and sex of the children were not even between these two regions. Moreover, the study was an ecological study and lacked information before the earthquake. Therefore, we couldn't compare the difference in feeding practices and growth before and after earthquake. Hence, further research should take it into consideration for more firm results. Same might have been the case for maternal education. Since the study participants were not representative, the study could have missed out a great chunk of well-educated mothers. However, the data was stratified to nullify the effect of maternal education, so not much could have been altered.

Despite some limitations, the study showed an interesting finding which could help in designing awareness programs and including IYCF practices during recovery stage of humanitarian assistance. Most important of all, this study is the only study that has been conducted 2 months after the earthquake in Nepal to assess infant and young children's feeding practices and growth in the disaster affected areas. Hence, this study would help in projecting light on the importance of nutritious IYCF practices that has been left ignored, especially in the disaster-affected areas. Since responsive feeding could result in less wasting and underweight amongst children, it is vital for their proper growth and development, even during the time of emergency. Hence, focus should be on not only knowledge development of the caregivers to aware and teach them about nutritious responsive feeding but also focus should be on assisting the victims by providing them with nutritious diet.

## **5. Conclusion**

Lack of nutritional requirement due to poor responsive feeding leads to poor growth amongst infant and young children below 2 years of age. Most important of all, it is more likely that adverse effects can be observed in the more severely affected region. In other words, based on the severity of disaster destruction, feeding practices to the young children could altered and so does growth. Child nutritional status has not reached to the expected levels as required for the children to achieve

optimum health in these earthquake affected regions. And the consequences are appalling for the long-term health and well-being of the child, which could result in malnutrition, morbidity and mortality in infants and young children (UNICEF, 2009). However, through prompt planning and intervention, during humanitarian assistance focusing on responsive complementary feeding awareness and educational activities could enhance proper growth and development of the children in the long run.

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## Study on Drought of Gorkha District and Its Impact on Agricultural Production

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### Abstract

Drought is the most complicated and least understood natural hazard, affecting many people nationally and regionally. To analyze the drought 40 years precipitation data was taken from Gorkha meteorological station for the period of 1975-2015. Drought was analyzed by using SPI software and compared with productivity data. The drought analysis showed that 1999 January has highest drought event with SPI index -4.07. There has a prolonged drought condition in the year 1992, 1998 and 2006. The highest paddy production data is in 2013 i.e. 3231 kg/ha and for the millet 1373 kg/ha in 2014. However, in 2015, production has decreased with increasing drought condition. In 2015, the decreasing of rainfall and after the earthquake, farmers face an irrigation problem due to the damaging of canals and loss of source of surface water by the aftershock of earthquake are possessing the significant impact on productivity on crop productivity.

**Key words:** Agricultural Productivity, Drought, Gorkha, SPI

### 1. Introduction

Drought is generally defined as severe deficiency of moisture below the expected level that restricts some type of activity. It is an insidious, slow natural hazard that produces a complex web of impact that ripples through different sectors of the economy (Wilhite et al. 2007). It is a natural calamity but different than others such as flood, earthquake, tropical cyclone etc. (Wilhite et al. 2000). Mostly drought appears as below the normal rainfall within a normal part of climate, it can develop as an extreme climatic event and turns into a hazardous phenomenon which may have a severe impact on the socioeconomic sector and water-dependent sector (McKee et al. 1993). Agricultural drought is related to the deficiency of soil moisture in relation to meteorological drought and climatic factors and its impact on agricultural productivity. This paper is mainly focused on the drought condition of Gorkha by using SPI and its impact on paddy and millet production.

### 2. Methodology:

Gorkha district is located in the Gandaki zone Western Development Region of Nepal with the elevation extending from 228 m to 8163 m altitude and it is situated between 27°15'N - 28°15'N latitude and 84°27'E-84°58'E longitude with the area 3610 km<sup>2</sup>. It covers 2.45% of the total area of Nepal which is also known as 4<sup>th</sup> largest district of Nepal.

## Map of Study Area

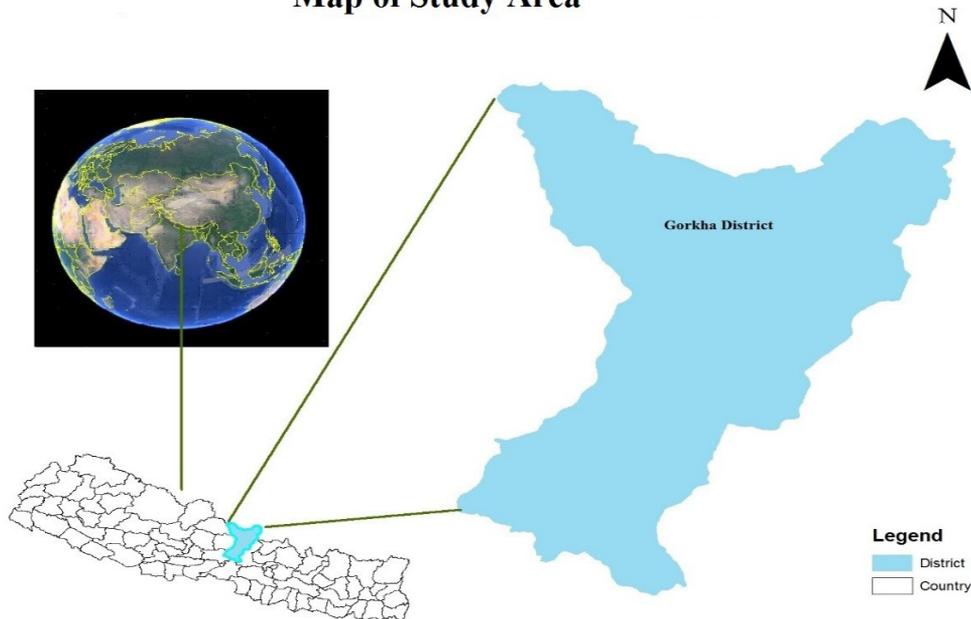


Figure 1: Map of study area

The agricultural productivity data was obtained from the Ministry of Agricultural Development, Singha Durbar and District Agricultural Development Office (DADO), Gorkha and the precipitation data (1975-2015) was collected from Department of Hydrology and Meteorology (DHM), Nagpokhari, Kathmandu, Nepal. The missing precipitation data was analyzed and filling the gap of the missing precipitation data by using normal ratio method. The data quality was checked for missing data out layer and others. For the calculation of drought, SPI software was used. The monthly precipitation data was prepared in specific format to run with the SPI software. All input files follow in 3-column: year, month and precipitation value. The precipitation value shouldn't be include in decimals. The input data file name must be in .txt file if not SPI software will not recognized any other file. And the output file must be in .out file. The three time scale was include for 3-month, 6-month and 12-month SPI drought whereas the output file was analyzed for the result.

**SPI:** SPI was developed by McKee et al. 1993, for the purpose of defining and monitoring drought. It is widely used around the world for drought forecasting, frequency analysis, spatio-temporal analysis and climate impact studies (Mishra & Singh, 2010). World Meteorological Organization (WMO) is also recommended SPI to analysis meteorological drought index (Hayes et al., 2011). The main advantage of SPI exist in a quantitative analysis of shortage of precipitation with reference to climatic mean state and analysis of different time scale can identify various drought types (McKee et al. 1993). It is comparable in both time and space, but it is not affected by geographical and topographical differences (Lana et al., 2001).

A data set of averaging periods are selected to determine a set of time scales of period  $i$  months where  $i$  is 3, 6, 12, 24, or 48 months (McKee et al. 1993) however in this research, three month six month and 12 month data was analyzed to know the drought condition. It is usually computed by fitting the Gama probability distribution to observe precipitation data, it is basically the transformation of precipitation of the precipitation time series into a standardized normal distribution. The computation of the SPI index require the following steps (McKee et al. 1993).

The SPI is computed by fitting a probability density function to a given precipitation summed over the time scale of interest. The monthly precipitation is fitted to gamma distribution. The probability density function of Gamma distribution is defined as

$$g(x) = \frac{1}{\beta^\alpha \Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta}$$

Where,  $\alpha > 0$ ,  $\alpha$  is a shape parameter.  $B > 0$ ,  $\beta$  is a scale parameter.  $X > 0$ ,  $x$  is a precipitation amount.  $\Gamma(\alpha)$  is a gamma function i.e. . The estimated parameters can be used to find the cumulative probability distribution function of observed precipitation for a given month and particular time scale. The cumulative probability is given by:

$$G(x) = G(x) = \int_0^x g(x) dx = \int_0^x \frac{1}{\beta^\alpha \Gamma(\hat{\alpha})} x^{\hat{\alpha}-1} e^{-x/\hat{\beta}} dx$$

$$\hat{\alpha} = \frac{1}{4A} \left( 1 + \sqrt{1 + \frac{4A}{3}} \right)$$

$$\hat{\beta} = \frac{\hat{x}}{\hat{\alpha}}$$

$$A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n} \quad \text{Where } n = \text{number of precipitation observation}$$

Transform the cumulative distribution function to the standard normal distribution with zero mean and unit variance, which is given as below:

$$SPI = \varphi^{-1}[G(x)]$$

A positive value for SPI indicates that precipitation is above average and negative value indicate that below average value. The drought begins when the SPI first falls below zero and ends of positive value of SPI following a value of -1 or less. The drought intensity is defined for values of SPI with the following categories:

Table 1: Standardized Precipitation Index

| SN | SPI Values     | Drought category |
|----|----------------|------------------|
| 1  | -1 to -1.49    | Moderate drought |
| 2  | -1.50 to -1.99 | Severe drought   |
| 3  | $\leq -2$      | Extreme drought  |

Source: McKee et al., 1993

### 3. Results and Discussion

#### 3.1 Analysis of drought

Analysis of the drought for the period of 40 years showed that the frequency of drought in the recent decade is in increasing order. The analyses found that before 1992 there was not extreme drought however afterward repeated extreme drought was observed. In the year, 1992, 1994, 1998, 1999, 2000, 2008 and 2015 have moderate to extreme drought. The highest SPI value is -4.07 January of 1999 for 6-month SPI drought, -4 May of 1998 and -3.57 March 1999 for 3- month and 12-month SPI drought respectively. The drought event is well agrees with (Sigdel and Ikeda 2010). The year 1999 is the year with highest temperature regionally and globally (Shrestha et al 1999, Saravi et al 2009). Precipitation variability studies with tree ring also indicate the year 1999 is the driest year (Dawadi et al 2014; Liang et al 2015). These studies using precipitation data, using SPI index and tree ring also matched well with our finding on the dry year. The 3-month, 6-month, 12-month drought condition of Gorkha district is shown in figure 2.

This study shows that major drought events in 1982, 1992-1993, 1995, 1998-1999, 2001 which is perfectly matches with the Sigdel & Ikeda (2010). According to Miyan et al. (2014), Nepal had experienced drought in the year 1977, 1982 and 1992 from this our result is exactly matches. Since 2002, the frequency of drought event is increasing such year 2004, 2005, 2006, 2008, 2009, 2014 and 2015. From this result, the drought event in the regional and in the local level drought are in co-related to each other.

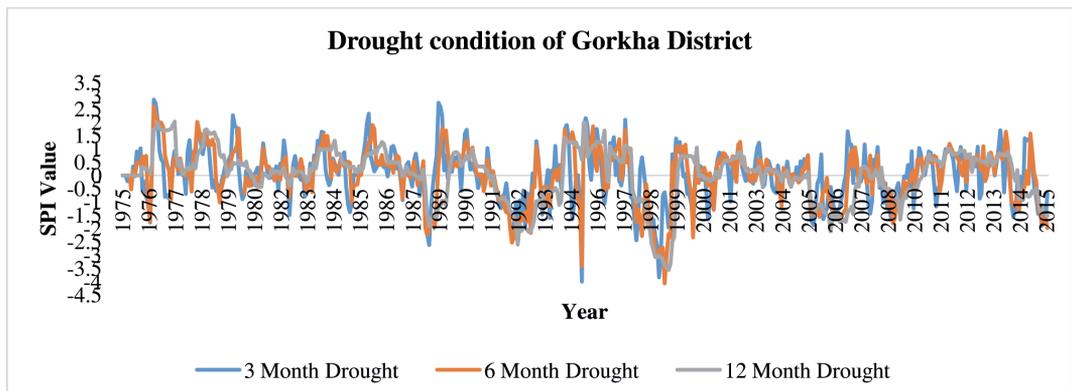


Figure 2: 3-month, 6-month and 12-month SPI drought condition of Gorkha

#### 3.2 Analysis of crop production:

The crop productivity data (paddy and millet) analysis showed the annual and multi- annual fluctuations. The result showed the impact of drought is major on the paddy whereas impact of drought on millet is less. The productivity of cereal crops (paddy and millet) from 1999 to 2015 is shown in the figure 3.

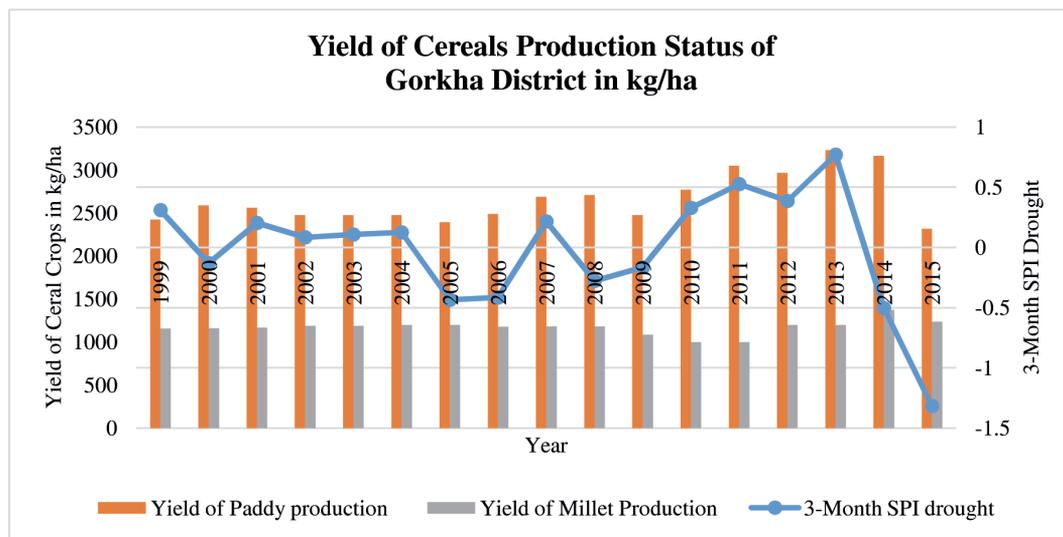


Figure 3: Paddy and Millet Production in Gorkha from the year 1999 to 2015

The average yield production of paddy and millet are 2661 kg/ha and 1171 kg/ha respectively from the year 1999 to 2015. In the year 2013 had highest paddy production i.e. 3231 kg/ha and then it slightly decreased in the year 2014-2015. However, millet is higher in the year 2014 i.e. 1373 kg/ha yield is production and it decreased in 2015. This is because in the year 2015 has more drought which is shown figure 3 and the decreasing of rainfall and after the earthquake, farmer faces in irrigation problem due to the damaging of canal and loss of source of surface water by the aftershock of earthquake are possesses the significant impact on productivity of these cereals. The inadequate rainfall and gradual increase in temperature has caused the reduction of rice production (Bhandari, 2013). Nepal had experienced prolonged drought in the year of 1992 and agricultural yield was decreased in western region (Bhandari & Panthi, 2014). The yield of rice was reduced in 1992 due to the reduction of precipitation in this year but millet didn't show any effect in the same year (Bhandari & Panthi, 2014).

#### 4. Conclusion

The deficiency in precipitation over a long period usually a season or more, from this water shortage causing an adverse impact on environment. Due to the less precipitation, the frequency of drought is increasing in the last decade. From that, it is one factor that directly impact on crop yield productivity if another factor that need for a crop is constant. The decreasing of paddy production is related to increasing of drought condition however it is very less effect on production of millet by drought event.

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## Study on Sustainability of Ecological Sanitation: A Case of Darechowk VDC, Chitwan

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### Abstract

Eco-Sanitation is the concept to solve the sanitation related issues with multiple benefits. The objective of the present research is to analyse the sustainability of eco-san toilet in Darechowk VDC, Chitwan. Qualitative as well as quantitative methods were adopted among the eco-san user as well as non-user group.

From analysis, 84 percent of eco-san users are continuously reaping multiple benefit of eco-san toilet via utilization of fertilizer produced from eco-san toilet. From comparative analysis among sample from field with chemical fertilizer and field with urine as fertilizer, it is found that pH value of soil sample from field with chemical fertilizer is higher than that of sample from field with urine as fertilizer.

Study is inclined towards the sustainability of eco-san toilet from communal ownership, their increasing willingness to install the eco-san toilet among current non-user groups, increment in agricultural productivity and soil fertility boosting financial ability.

**Key words:** Sustainability, Ecological Sanitation, Willingness, Soil Fertility, pH

### 1. Introduction

Sanitation is the fundamental requirement to ensure safe health, environment and the overall well-being of the society. Ecological sanitation is based on three fundamental principles: preventing pollution rather than attempting to control it after we pollute; sanitizing the urine and the faeces; and using the safe products for agricultural purposes. Therefore Eco-Sanitation is concept to solve the sanitation issue since it confers multiple benefits.

The promotion of various types of toilet and the aspects of their sustainability has been most talked issues in recent times in context of rural settlement. In case of Darechowk VDC, researches has been conducted in past to derive the drivers and barriers of Eco-Sanitation but the adaptive pattern or the sustainability aspect has been ignored. Thus with the motive to derive the factors behind adopt Eco-San technology and its sustainability, communal capacity to cope with it and the additional benefits such as economic, socio-cultural and environmental benefits, this research is the first of its kind.

The specific objective of the study is to analyse the sustainability of community based Eco-Sanitation management practice in the rural and low-income settlement area. General objectives of the study are to define the adoption of eco-san toilet from users and non-users perspective; to identify the consequences of Eco-San toilet on livelihood changes; and to analyse the sustainability of Eco-San toilet.

### 2. Materials and Methods

Research was conducted in Darechowk VDC, Chitwan District (Figure 1). The VDC has

altogether 1546 households of which, 162 have Eco-San toilets. The detail of total household with permanent latrine, temporary latrine and other coverage is explained in Table 1 with figures.

Table 1: Total Households with Eco-san Toilets in Darechowk VDC

| Ward         | Total HHs   | Perm. Latrines | Temp. Latrines | San. Coverage      | WS Coverage         | Eco-San Latrines      |
|--------------|-------------|----------------|----------------|--------------------|---------------------|-----------------------|
| 1            | 42          | 18             | 1              | 19                 | 42                  | 15 wet (used)         |
| 2            | 52          | 21             | 12             | 33                 | 24                  | 17 wet (used)         |
| 3            | 570         | 171            | 131            | 302                | 554                 | 5 wet (used)          |
| 4            | 362         | 272            | 41             | 313                | 351                 | 4 wet (used)          |
| 5            | 92          | 50             | 15             | 65                 | 54                  | 50 wet (used)         |
| 6            | 48          | 38             | 7              | 45                 | 22                  | 36 wet (used)         |
| 7            | 196         | 103            | 85             | 188                | 180                 | 15 wet (used)         |
| 8            | 33          | 6              | 13             | 19                 | 24                  | 6 wet (used)          |
| 9            | 151         | 54             | 66             | 120                | 150                 | 14 wet (used)         |
| <b>Total</b> | <b>1546</b> | <b>734</b>     | <b>370</b>     | <b>1104 (70 %)</b> | <b>1401 (90.6%)</b> | <b>162 wet (used)</b> |

*A Concept paper on Darechowk VDC, As ECO-SAN Resource Center, 2009, Government of Nepal*

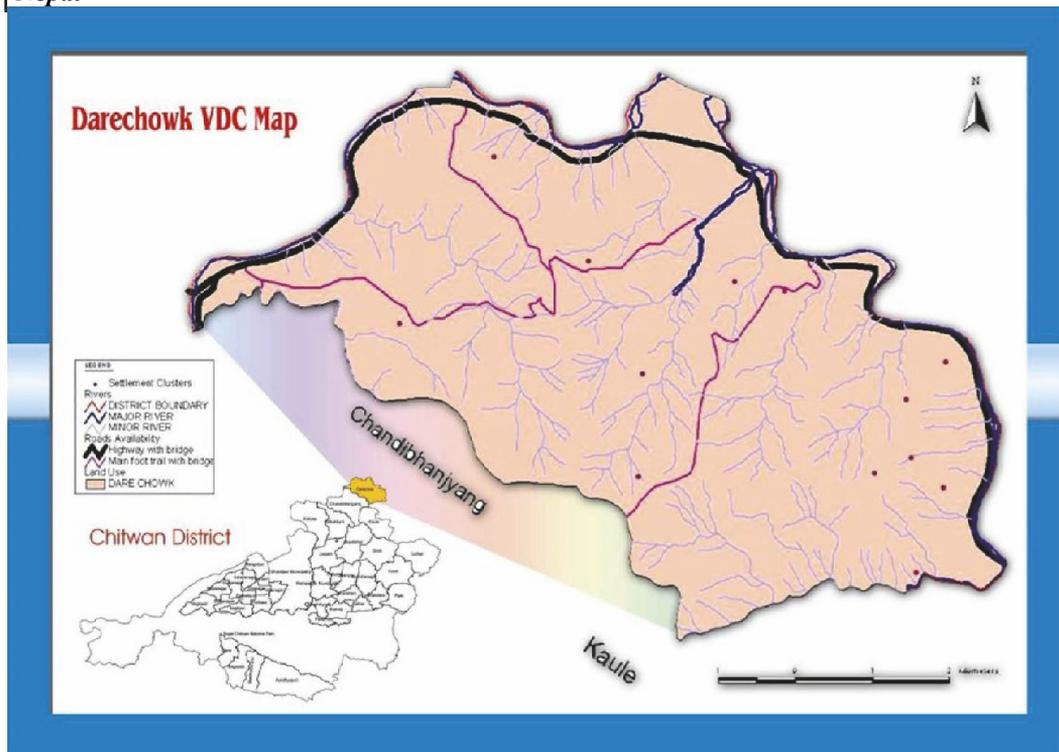


Figure 1: Location Map of Study Darechowk VDC (Chitwan District, ECO-SAN 2009)

During the data collection, both quantitative and qualitative methods were adopted. Qualitative analysis was done in order to get the overview about people's living context, fertilizer application and perception of people towards Eco-San, changes caused by Eco-San, technical issues and satisfactory level of users towards Eco-San. Quantitative method was adopted in order to extract the existing scenario and make comparison analysis among eco-san user and non-user group.

Numerous forms of primary data collection was adopted such as reconnaissance survey, transect walk, Participatory Rural Appraisal (PRA), etc. Furthermore, Focal Group Discussion (FGD) with local people, Youth club members, Women Group, teacher, farmers, and social worker was conducted in order to understand the overall perception of community people on the current practices of urine fertilizer, urine and faeces management, long term continuation, positive and negative impact in livelihood, also in agriculture and the level of satisfaction and dissatisfaction. *Key Informant Interview was conducted with local leader/initiator of eco-san toilet in Darechowk VDC, teacher and women group. KII involved the questions related to Eco-San and its relation to livelihood and agriculture, Eco-San sustainability, Current Practices and long term scenario, benefits and loss, people perception towards using Urine as fertilizer.*

Structured Questionnaire survey was conducted in the two wards of Darechowk VDC. From ward 1, 24 out of 42 HHs has been surveyed and in ward five, 21 out of 92 HHs has been surveyed as Overall, 33.33% of the HHs has been covered through structured questionnaire survey. Table 1 data were used to sample household so as to finalize the household survey as mentioned in Table 2; which gives information about sampled or surveyed houses.

**Table 2: Household surveyed in the Sampling at Ward 1 and Ward 5 of Darechowk VDC**

| S.N           | Total Household No. | Total Eco-San User | No. Total sampled households | % sampled households | No. User (out of sampled HH) | %            | No. Non User (out of sampled HH) | %           |
|---------------|---------------------|--------------------|------------------------------|----------------------|------------------------------|--------------|----------------------------------|-------------|
| <b>Ward 1</b> | 42                  | 15                 | 24                           | 57.14                | 13                           | 54.2         | 11                               | 45.8        |
| <b>Ward 5</b> | 92                  | 50                 | 21                           | 22.82                | 12                           | 57.1         | 9                                | 42.8        |
| <b>Total</b>  | <b>134</b>          | <b>65</b>          | <b>45</b>                    | <b>33.58</b>         | <b>25</b>                    | <b>55.56</b> | <b>20</b>                        | <b>44.4</b> |

Source: Field house holds survey 2016

Questionnaire Survey was more or less focused on the driving factors of Eco-San toilet, health related issues, positive as well as negative impacts of Eco-San toilet on livelihood, utilization of technology to enhance the productivity, etc. Furthermore, the questions were focused on the factors associated with sustainability of Eco-San which makes the objective attainable by identifying the application and implementation status and people reaction, support, discomfort and perception on overall use of Eco-San toilet in their locality.

#### **Soil test:**

Soil test was also undertaken in order to make the comparative analysis among the soil sample from field with chemical fertilizer and from field with urine as fertilizer so as to show use of Eco-san toilet. Soil Parameters to be analysed and Methods with Corresponding Apparatus used in the laboratory is explained in Table 3.

The GPS location of the both field are

For Urine applied field= 27° 51' 30" N and 84° 38' 21" E

Chemical Fertilizer applied field= 27° 51' 30" N and 84° 38' 31" E

The purpose of soil sampling was to analyse the nutritional values in both soil sample. To show the difference between urine NPK value and Chemical fertilizer NPK values, so that we can analyse whether chemical fertilizer can be replaced by Urine fertilizer.

Following steps was followed during soil sampling:

- Selection of sampling site after field study
- Spot selection (five different spots 5m/5m) using measurement tape.
- Collection of soil samples from each spot from 1and half m. depth.
- Collection of all samples at common point.
- Well- stirring of samples.
- Extraction of final sample of 500 gm. weight.

Soil samples were taken to Nepal Agriculture Research Centre's (NARC) Lab, Khumaltar. Chemical parameters such as pH, Nitrogen, Potassium and Phosphorous were tested using different instruments as mentioned in Table 3.

Table 3: Soil Parameters to be analysed and Methods with Corresponding Apparatus

| S.N. |                      | Method                              | Apparatus   |
|------|----------------------|-------------------------------------|---|
| 1.   | pH                   | Digital pH Meter                    | pH Meter Horizontal Shaker  |
| 2.   | Total Nitrogen       | Kjeldahl Distillation Method        | Burette Kjeldahl Distillation Unit. Whattman no. 42 filter paper. |
| 3.   | Available Phosphorus | Modified olsens (spectrophotometer) | Spectrophotometer Whattman no. 42 filters paper.                  |
| 4.   | Potassium            | Flame photometer                    | Flame Photometer Dispenser Automatic Pipette                      |

### 3. Results and Discussion

From the structured questionnaire survey, following results were obtained:

- a) Eco-San User Group
  - 64% of the users stated the motivation factor to have eco-san toilet as production of fertilizer.
  - 80% responded with the use of faeces and urine as fertilizer purpose.
  - 65% were using urine as fertilizer for soil conditioner purpose as well as an alternative to pesticide.
  - 16% were found to hesitate the utilization of urine whereas 84% of the users are quite happy to use the urine as fertilizer.
- b) Eco-San Non User Group
  - 90% of the non-users are aware about the situation of Eco-San toilets of which 70% are planning to shift towards Eco-San toilet.

- Non-users are willing to shift towards eco-san toilet with following reasons:
  - Could be used as an alternate or replacement of chemical fertilizer.
  - Much more convenient than the traditional type of pit latrines.
  - Act as alternative of chemical
  - Positive feedbacks from neighbourhood or Eco-San users.
  - Health effective.

From the laboratory test by using Methods with Corresponding Apparatus as mentioned in table 3, following result for soil samples were obtained:

Table 4: Analysis of soil Parameters in Human Urine and Chemical Fertilizer

| S.N. | Elements tested in soil | Values form Human urine as Fertilizer land | Values form chemical Fertilizer land |
|------|-------------------------|--|--------------------------------------|
| 1    | pH                      | 5.97                                       | 6.72                                 |
| 2    | Nitrogen                | 0.15%                                      | 0.12%                                |
| 3    | Phosphorous             | 48kg/ha                                    | 65kg/ha                              |
| 5    | Potassium               | 181kg/ha                                   | 195kg/ha                             |

The land where Human urine was applied for fertilizer purpose since last 5years (before that no cultivation was in practice) indicates that human urine has similar nutritional value as chemical fertilizer has; which is mentioned in Table 4 after the laboratory analysis.

- pH of human urine land was 5.97 which indicates the land showing acidic property. Similarly, land with chemical fertilizer was found to have pH value of 6.72 that too indicating the acidic property. Generally, pH of soil in range of between 7-7.5 is considered as good soil for cultivation.
- In case of Nitrogen, field with human urine has 15% of nitrogen and that of field with chemical fertilizer is 12% indicating the field with urine fertilizer being suitable for cultivation.

To conclude the situation (positive or negative changes), study has recommended a change with symbol "+ve" or "-ve" depending upon the findings.

Table 5 and Table 6 are developed and explained in order to show the linkage of surveyed

socio-economic data. These tables tried to explain the importance of Eco-san toilet; which component has brought the changes with corresponding indicators.

Table 5: Overall Scenario of the consequences of Eco-San toilet on various socio-economic issues

| S.N | Component                           | Changes   | Source of Indicator                     | Remarks  |
|-----|-------------------------------------|---|---|--|
| 1.  | Urine and Fecal management Practice | <ul style="list-style-type: none"> <li>• 21 out of 25 Eco-San users applying Urine as a Fertilizer on Their Fields.</li> <li>• Reduction in buying behaviour of chemical fertilizer i.e. Chemical users buying 70kg of chemical fertilizer in previous days has turned down in to 40 kg now.</li> </ul>                 | Survey<br><br>Tokdang Youth Club record | +ve<br><br>+ve changes on agricultural land quality. |
| 2.  | Agricultural Aspect                 | <ul style="list-style-type: none"> <li>• Increment in production scale of vegetables and fruits particularly oranges.</li> <li>• Increment in demand of oranges from outside market stating the taste and quality of product.</li> </ul>  | KII and Survey                          | +ve  |
| 3.  | Environmental Aspects               | <ul style="list-style-type: none"> <li>• Enhancement of scenic beauty and surrounding environment.</li> <li>• Enhancement of soil quality with reduction of use of chemical fertilizer.</li> </ul>  | KII and Survey                          | +ve  |
| 4.  | Financial Aspects                   | <ul style="list-style-type: none"> <li>• Increment in income from increasing production of oranges.</li> <li>• Replacement of chemical fertilizer by organic fertilizer hence reducing the fertilizer cost almost 30% with limited investment on Eco-San toilet.</li> <li>• Increment in eco-tourism market.</li> </ul> | KII                                     | +ve  |
| 5.  | Health Aspects                      | <ul style="list-style-type: none"> <li>• Decreased water borne diseases.</li> <li>• Reduction in treatment cost.</li> </ul>   | KII and record book of health post.     | +ve  |

|    |                   |  |                |  |
|----|-------------------|--|----------------|--|
| 6. | Social Acceptance | <ul style="list-style-type: none"> <li>Increased number of HH using Eco-San toilet.</li> </ul>   |                |  |
|    |                   | <ul style="list-style-type: none"> <li>Increased willingness to shift towards Eco-San toilet.</li> <li>Increased Eco-San practice even in HH with non-users.</li> </ul>  | KII and Survey | +ve message about urine application.     |
| 7. | Technical comfort | <ul style="list-style-type: none"> <li>90% of users complained about the pan and urine pipe blockage problem.</li> <li>Discomfort to use if new people came to visit them.</li> <li>No idea about making another vault in future.</li> </ul> | KII and Survey | -ve results of pan due to its Thickness. |

This explains how uses of eco-san toilet make difference in focused to seven components and brought changes as the indicators. For understanding beneficial changes are marked as +ve change and inconvenient changes are marked as -ve changes.

Table 6: Indicators of Sustainability

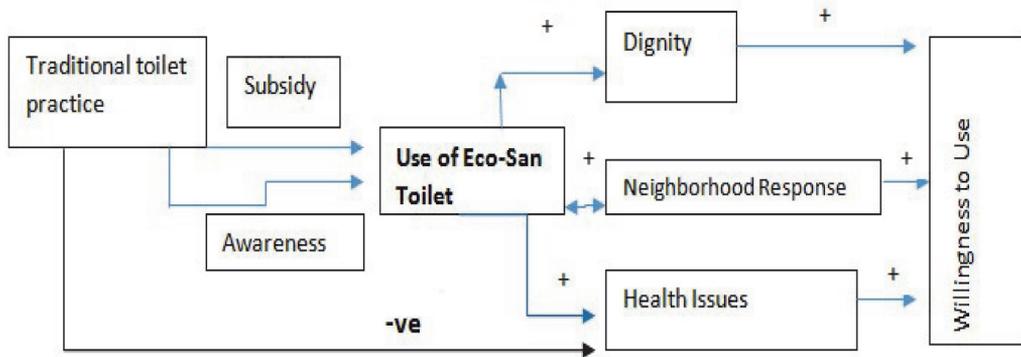
| S. No. | Motivating Factors | Indicators for sustainability                 | Ward 1 (n:13) |       | Ward 5 (n:12) |       | Total (n:25) |    |
|--------|--------------------|---|---------------|-------|---------------|-------|--------------|----|
|        |                    |   | Yes           | No    | Yes           | No    | Yes          | No |
| 1      | Social             | Subsidy or Utility                            | 69.23         | 30.77 | 58.33         | 41.67 | 64           | 36 |
|        |                    | Facility to wash                              | 76.92         | 23.08 | 91.67         | 8.33  | 84           | 16 |
|        |                    | Dignity after Installation                    | 69.23         | 30.77 | 66.67         | 33.33 | 68           | 32 |
|        |                    | Reaction from society                         | 92.31         | 7.69  | 75            | 25    | 84           | 16 |
| 2      | Technical          | Outlook and Cleanliness of pan comfort to use | 38.46         | 61.54 | 50            | 50    | 44           | 56 |
|        |                    | Easy to manage faeces                         | 92.31         | 7.69  | 75            | 25    | 84           | 16 |
|        |                    | Smooth diversion of urine                     | 100           | 0     | 91.67         | 8.33  | 96           | 4  |
|        |                    | Awareness regarding maintenance               | 53.85         | 46.15 | 33.33         | 66.67 | 44           | 56 |
| 3      | Utility            | Use of Urine                                  | 100           | 0     | 100           | 0     | 100          | 0  |
|        |                    | Use of faeces                                 | 38.46         | 61.54 | 50            | 50    | 44           | 56 |
|        |                    | Agricultural productivity                     | 92.31         | 7.69  | 83.33         | 16.67 | 88           | 12 |

|              |               |   |              |              |              |              |             |             |
|--------------|---------------|---|--------------|--------------|--------------|--------------|-------------|-------------|
|              |               | Quality of production                     | 84.62        | 15.38        | 66.67        | 33.33        | 76          | 24          |
|              |               | Quality of soil                           | 84.62        | 15.38        | 75           | 25           | 80          | 20          |
|              |               | Awareness regarding urine use and benefit | 100          | 0            | 83.33        | 16.67        | 92          | 8           |
| 4            | Public Health | Health issues                             | 100          | 0            | 100          | 0            | 100         | 0           |
|              |               | Digestion of faeces                       | 23.08        | 76.92        | 41.67        | 58.33        | 32          | 68          |
|              |               | Application of faeces (safety issues)     | 61.54        | 38.46        | 75           | 25           | 68          | 32          |
|              |               | Application of urine (safety issues)      | 61.54        | 38.46        | 75           | 25           | 68          | 32          |
|              |               | Hygiene practices                         | 92.31        | 7.69         | 66.67        | 33.33        | 80          | 20          |
|              |               | Methods of using urine and faeces         | 76.92        | 23.08        | 100          | 0            | 88          | 12          |
| <b>Total</b> |               |   | <b>75.38</b> | <b>24.62</b> | <b>73.33</b> | <b>26.67</b> | <b>74.2</b> | <b>25.8</b> |

Above table explain the four motivating factors and corresponding sustainability indicators in focused to eco-san toilet. Furthermore, explain which factors encourage to use ecosan toilet as the sustainability indicator.

**Sustainability of Eco-San Toilet in Darechowk VDC:** As four Motivating factors explained in Table 6 their flow chart is show below as

**Social Factor:**



**Fig: Flow chart of Social Factor representing the sustainability of Eco-San toilet**

This flow chart has been developed and tried to explain social factors also encourage or discourage the use of ecosan toilet and finally governs its sustainability. Similarly, others three factors do have their role in sustainability.

**Technical Factor:**

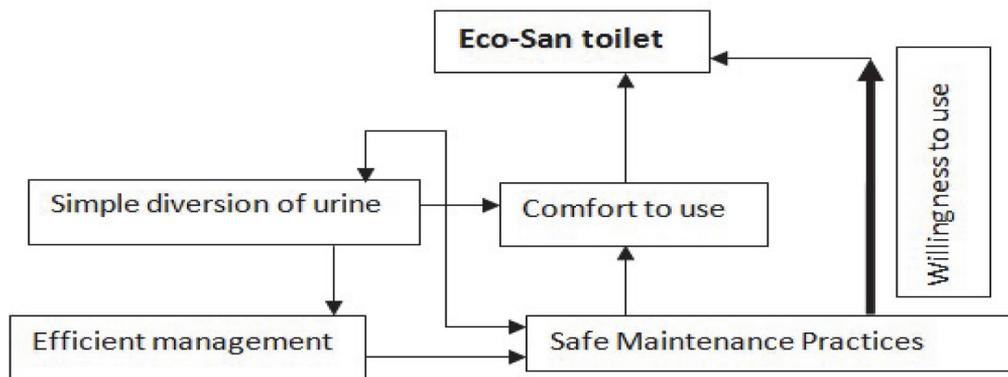
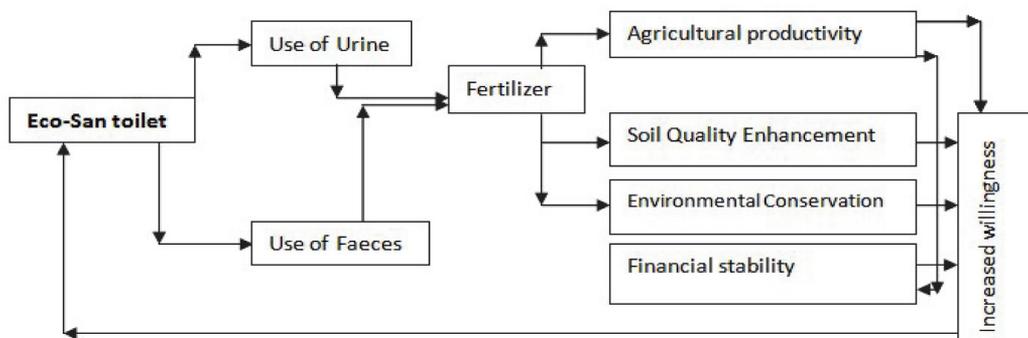


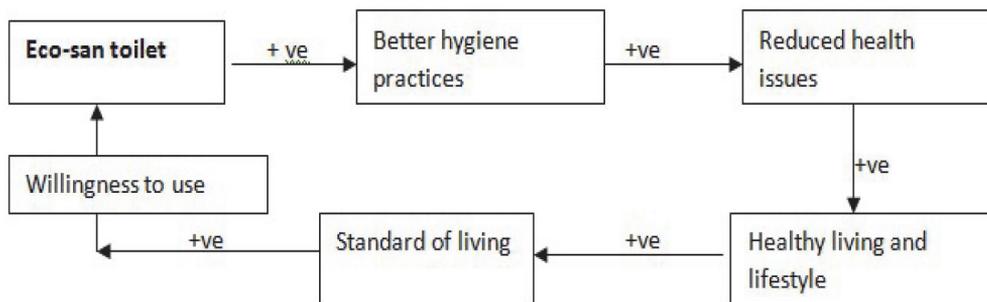
Fig: Flow Chart of Technical Factors representing the sustainability of Eco-San toilet

**Utility Factor**



Flow Chart of Utility Factors representing the sustainability of Eco-San toilet

**Public Health and Sanitation Factor**



Flow Chart of Public Health and Sanitation Factors representing the sustainability of Eco-San toilet

#### **4. Conclusion**

From the research, Darechowk VDC seems to be moving forward in better direction in terms of sanitation and hygiene related issues. Statistics shows that, when other VDCs are just moving towards toilet installation, Darechowk VDC started installing eco-san toilets with the help of local NGO and government support. The only question remains was about the sustainability of such eco-san toilet. Survey was conducted among 33.3 percent of total HH from ward 1 and ward 5 collectively. Out of 45 sampled household, 55.56 percent HH were eco-san users whereas 44.4 percent HH belongs to non-user.

Among the eco-san user group, 76 percent were using eco-san toilet from more than 5 years. They were using eco-san toilet mainly for increasing health status and utilizing fertilizer from urine and faeces. Eco-san users were found to satisfy with the fertilizer produced from eco-san toilet as it aid in their annual agricultural productivity ultimately increasing their financial status. Among the eco san non-user HHs, 15 were using pit latrine and 2 were not using any type of latrine at all. Study found that, such HHs (71 percent) are willing to shift towards eco-san toilet in near future if they are provided with proper guidance and training to handle eco-san toilet and utilize the fertilizer produced from such toilet. Since, the village is moving towards organic farming, non-users feels that the utilizer produced from eco-san toilet will be the initiation towards creating village as organic village which ultimately aids to VDC's long term aim of creating eco-village.

Though there are number of indicators to determine the sustainability of eco-san toilet, study was conducted on the basis of sub components of sectors such as social, technical, utility and public health. Study found that the households used to practise either open defecation or traditional toilet in previous years. But with the provision of subsidy and awareness about benefits of Eco-San toilet, households started installing the Eco-San toilet in "Let's try it for one time" approach. With time, households found several indirect benefits along with direct benefits of fertilizer such as increment in dignity in society, positive response along with curiosity from neighbourhood and reducing water-borne health issues increased the willingness to make the Eco-San toilet permanent in their houses. This willingness has increased not only in Eco-San users but also among neighbourhood increasing the number of household with Eco-San user. But this willingness to continue eco-san toilet has halted by technical problems such as negative outlook, difficulty in diversion, awareness regarding maintenance problems, etc. The case of the sustainability of eco-san toilet was boosted by their persistence towards eco-san toilet even with numerous technical difficulties just because they can produce and utilize the fertilizer, enhance their agricultural productivity, soil fertility and boost their financial ability.

With the detail study of all the indicators towards sustainable use of eco-san toilet, analysis of soil samples from the field with chemical fertilizer and the use of urine as fertilizer and the benefits or negativity associated with all studied subcomponents of motivating factors, study concludes with the statement, since 68% of subcomponents are indicated towards sustainability of eco-san toilet in Darechowk VDC, future prospects should focus on following points:

- Skill sharing for the production and proper utilization of fertilizer.
- Eradication of technical difficulties associated with eco-san toilet.
- Provision of subsidy or rewards for the promotion of eco-san toilet from the government.

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## **The Nesting statistics and Behavior of Trigon Bees in Sub- Tropical Forest in Asurkot, of Arghakhanchi District**

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### **Abstract**

Trigona locally known as Putko play significant role in the pollination of agricultural crops as well as naturally grown plants and trees. This study tries to visualize the importance of proper conservation status of these Trigona bee colonies in Nepal and promote the conservation biology for maintaining biodiversity through scientific management of Trigona nesting sites. The research field covers the sub-tropical forest dominated by many hard wood trees covering 50 squares Km in each cluster. The Asurkot of Arghakhanchi district covers the sub-tropical forest areas in which trigona nest are found. Simple data collection tools and methods were used. The total size of hard wood tree with hollowed tree trunk in whole cluster was found 5600. The number of hollowed tree trunks with entrance made by Woodpecker birds and anthropogenic activities were observed. After having the frequencies and proportional values from each cluster, Z-test, ANOVA and chi-square test were used to find the significance difference in between different proportion values and distribution pattern of Trigona Nest. The average Trigona nest was found 5.3/each cluster in 2.25 square km. The total estimated nest sites were found 258. The nesting behavior is found dependent with the types of tree.

*Key Words: Trigona, Putko, Pollination, Honey, Propolish, Proportion, Nest, Probability*

### **1. Introduction**

Trigona or Putko is important asset for conservation biology. It play significant role in production of honey and conservation of natural ecosystem. Trigona bee farming has been found to be as informal activities of the rural areas of Nepal. Community people have less knowledge about farming and management practices of this species. It is generally found in the tropical and sub-tropical forest having warm and humid climate. The trigona honey is harvested from its nest is widely used in medicine and health in Brazil, Australia, Malaysia, India and Nepal. Putko or trigona produces honey and propolish which is rich in antioxidants and differ with ordinary honey bees. The honey from Trigona is brown in color, its taste is not like the other honey bee and its honey flavor is impressive. Sometimes its honey taste varies according to the nest site of the hard wood tree. Generally the trigona bees prefer to build nest in the middle and higher part of hollowed trunk of the hard wood tree. Its product such as propolish is reported that anti-fungal, anti fungus, anti-bacterial and anti-inflammatory. Hence it is also used as active ingredients in cosmetics and creams products. Its honey is still in the research and potential to commercialize. Antioxidants have many functions, especially in the cancer problem. Researcher reported that propolish is also used in the treatment of Diabetes, mellifluous, stroke, hepatitis, cancer, hypertension, kidney stones, and HIV / AIDS.

Current population of these stingless bee colonies in Nepal is in declining order due to irrational harvesting practices and forest fire. This study tries to highlights the importance of Trigona and conservation status of these stingless bee colonies in Nepal. Its statistics is varied according to locational height and types of forest. The awareness level about Putko is found Low with the community people. Govt. of Nepal don't have any kinds of policies for its conservation and protection of this species. The Statistics of Trigona nesting, distribution pattern, role in pollination

and its habitats are the prime concern issues in present context. These are the proposed areas of the exploration. The study is chosen to Asurkot because its coverage is found low land to high land. Similarly this VDC is divided into four clusters from Jhimruk basin to Thamka which is peak of the Asurkot VDC.

This research tried to explore the existing situation of the *Trigona* species in Asurkot VDC of Arghakhachi and tries to focus to estimate the distribution pattern, strength of the *Trigona* colony and relationship in between *Trigona* nest and location Height.

## 2. Methodology

The nest site location, nesting behavior and their distribution pattern of *Trigona* bee colonies were investigated using camera, GPS system and other information were collected through interview, group discussion. Four clusters were managed with 2.25 square km having 100 hard wood hollowed tree trunks with each cluster for the research and Fifty entrance holes were made in hollowed tree trunks in one cluster with same size of area. Out of total hollowed tree trunk in each cluster only 100 hollowed tree trunks were selected from 2.25 square Km. The number of hollowed tree trunks with entrance made by Woodpecker birds and anthropogenic activities were observed using tools and equipments. The proportion value of the settled nest of *Trigona* bee colonies was determined from each cluster using statistical formula  $P = x_i/N_i$  where,  $p$  = proportional value,  $x_i$  = number of nest sites of *Trigona* bee colonies and  $N_i$  = number of selected hollowed tree trunk in each cluster. After having the proportional value from each cluster, Z-test was used to find the significance difference in between different proportion values of different clusters for settled *Trigona* Nest. Z tabulated value at 5% level of significance = 1.96 is used to measure significance to difference about proportions. Similarly ANOVA and chi-square test at 5% level of  $s$  were used to draw the conclusion of the data.

### 2.1 Data Management and Analysis

#### 2.1.1 Different types of Settled log of *Trigona* in Community Households:

After having the field survey in study area the community people replied the settled nest and preferred tree by the *trigona* is presented below. Similarly dependency pattern is measure by the help of Chi-square tests. Sal, Tuni, Baidaro, karam, jabuno, churee, aapa, ghithi, khanew, Shiddha, fadel, saj, jewat, bada, khager, tuni, baidaro, shiddha, fadel, saj, kutmero, pipal sheeris. These tree were found the preferred tree by the *trigona* nest (Table 1).

Table 1: Trigona nest sites and dependency pattern on different trees

| Types of tree                 | Number of Nest site of bee species | Number of trigona bee nest settles in the logs | Ratio of collected Number of trigona bee nest settles in the logs in community households | Remarks  |
|-------------------------------|------------------------------------|--|---|--|
| Sal(shorea Robusta)           | 257                                | 12   | 0.046   | The whole ratio ratio is found $P=15/455=0.32$ which is different with $p=0.346$ |
| Baidaro                       | 32                                 | 0  | 0   |  |
| Karam                         | 40                                 | 0  | 0   |  |
| Paiyer                        | 12                                 | 0  | 0   |  |
| Ghithi                        | 10                                 | 1  | 0.1   |  |
| Chiuree(Aesandra butybacea)   | 6                                  | 0  | 0   |  |
| Jamun(syzygium cumini)        | 11                                 | 1  | 0.09  |  |
| Saj(Terminalia alata)         | 9                                  | 1  | .11   |  |
| Jewoot()                      | 7                                  | 0  | 0   | The whole ratio ratio is found $P=15/455=0.32$ which is different with $p=0.346$ |
| Pipal(Ficus Riligiosa)        | 5                                  | 0  | 0   |  |
| siris(Litsea Monopetala)      |                                    |  |   |  |
| Kutmero(Litsea Monopetala)    | 5                                  | 0  | 0   |  |
| Khaniyu(Ficus semicordata)    | 5                                  | 0  | 0   |  |
| Badar(Artocarpus Lkoochoo     | 5                                  | 0  | 0   |  |
| Kalo Shrees(Albizia lebbeck)  | 5                                  | 0  | 0   |  |
| lampate(Duabanga Grandiflora) | 5                                  | 0  | 0   |  |
| Khayar(Acacia Catechu)        | 5                                  | 0  | 0   |  |
| Total                         | 455                                | 15   | 0.346   |  |

Source: Field Survey (2016)

### 2.1.2 Relationship in between Trigona nest and location Height

The scale of relationship in between these variables was found high degree of negative relationship ( $r = -0.98$ ). In other words, high land of subtropical forest consists few numbers of nest sites of Trigona and vice-versa.

Table 2: Trigona nest and location height

| Cluster and Location height of Trigona Nest | Location height              | Location height              | Location height             | Total |
|---|------------------------------|------------------------------|-----------------------------|-------|
|   | (below 800 m from see level) | (800m to900m from see level) | (Above 900m from see level) |       |
| Cluster(1)                                  | 4                            | 2                            | 0                           | 6     |
| Cluster(2)                                  | 3                            | 1                            | 1                           | 5     |
| Cluster(3)                                  | 3                            | 1                            | 1                           | 5     |
| Cluster(4)                                  | 4                            | 1                            | 2                           | 7     |
| Total                                       | 14                           | 4                            | 5                           | 23    |

### 2.1.3 Rate of sampling Distribution of Trigona Nest in different clusters with respect to location height in Study sites

The researcher conducted the survey in the study sites using observation schedules. After having the survey following nesting sites were collected from different clusters. Following table reflected the nesting sites in each clusters.

Table 3: Distribution of Trigona nest in different clusters

| Cluster and Location height of Trigona Nest | Location height (below 800 m from see level) | Location height (800m to900m from see level) | Location height (Above 900m from see level) | Total |
|---|--|--|---|-------|
| Cluster(1)                                  | 4  | 2  | 0   | 6     |
| Cluster(2)                                  | 3  | 1  | 1   | 5     |
| Cluster(3)                                  | 3  | 1  | 1   | 5     |
| Cluster(4)                                  | 4  | 1  | 2   | 7     |
| Total                                       | 14   | 4  | 5   | 23    |

Analysis of variance (ANOVA)

| Source of Variation | SS       | df | MS       | F    | P-value  | F crit    |
|---------------------|----------|----|----------|------|----------|-----------|
| Between Clusters    | 9.555556 | 2  | 4.777778 | 21.5 | 0.001836 | 5.1432528 |
| Within clusters     | 1.333333 | 6  | 0.222222 |      |          |           |
| Total               | 10.88889 | 8  |          |      |          |           |

From the above table, it is concluded there is significant difference between the number of nesting sites and it varies according to location heights within different clusters. It is clearly reflected from the p- value i.e.p=0.0018.

### **3. Results and Discussion**

Technical knowledge about farming of *Trigona* is found scarce, and management practices are very poor. *Trigona* bee colony nests were found in sub-tropical forest having warm and humid climate. There is no significance difference of difference about the proportion values of different clusters. Derivation of population for selected region was determined by using mean proportion. The mean proportion was found 5.3/100. The probability of selected tree by the *Trigona* nest was found less than 0.1, instead of binomial distribution, Poisson Probability distribution was used with parameter(  $k=5.3$ ). The distribution pattern of the stingless bee colonies were found in scattered pattern. In research area it is found that High concentration of *Trigona* bee colony nests in low land and vice versa (height of the land and *trigona* colony nests are the two variables). The scale of relationship in between these variables was found high degree of negative relationship,i.e  $r=-0.98$ . This result reflected that there is no significance difference about the frequency of settled nest in different clusters and there is significant difference about the number of nesting sites and it varies according to location heights within different clusters. Out of all hollowed tree trunk *Shorea robusta*(sal)was found more preferred tree.The number of *Trigona* nest settles in the logs in community is found very low as compared to the harvested *Trigona* nest .The dependency of habitat selection by *trigona* was measured by the help of chi-square test .The chi-square calculation was 1359.4 of observed frequency and chi –square tabulated with d.f.(15,5%)=24.9. Nesting behavior was found highly dependent with respect to the types of tree i.e.*Shoria robusta* was found most preferred tree by the *Trigona*. The mean proportion value of *Trigona* nests was found 5.33/100 in 2.25square km. The estimated population size of *trigona* nests was 298 in 50 square km in tropical region of Asurkot of Arghakhanchi District.

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