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Construction in western Nepal and its potential repercussions on health

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ABSTRACT

In Nepal, the formation of seven provinces has been seen as a driving force in promoting the development of civil engineering structures in remote parts of the nation. Although aimed to promote the livelihoods of people residing in such areas, if aforesaid activities are unplanned and unsustainable they lead to a backlash in the health of the community and the surrounding environment. In our study, bridges in Barjugad, Guigad, Dhangadhi, Kapadi Nadi, Patharaiya, and Thado Khola are taken as references. Some of these bridges are close to the Khaptad National Park. Likewise, the Makarigad Hydropower project is also cited, and the effects of the recommendation made are reviewed. Various American Society for Testing and Materials(ASTM), Indian Standard(IS) codes are validated, and the Environmental Impact Assessment(EIA) is made. The consequences of the boring, field test, groundwater table monitoring, and liquefaction are assessed. Case studies from around the world have also been stated and their health effect over several domains is presented. Potential risks to the health of construction workers based on etiological agents are mentioned, out of which occupational lung diseases are taken further into account. An example of dams and hydropower plants has been taken to explore the long-lasting effects of construction on the health of local residents. Airborne dust, a major hazard, has been identified and described to understand its pathogenicity. An epidemiological triangle, for occupational lung diseases, has been used as a simple model for disease causation. Similarly, four levels of prevention to control dust-related diseases in construction workers have been mentioned. In conclusion, our paper highlights the possible consequences of construction works and also suggests some precautionary measures to mitigate the same.

1. Introduction

With the segregation of seven provinces in Nepal, development has decentralized.

The influx of capitalistic ideas into the nation has made profit the most important criteria for development works. Environmental protection is taken as a minor consideration. As such little importance is placed on environmental impact, several actions need to be taken to complement such construction activities. In Brazil, for the design of a small-span bridge, in an attempt to integrate the decision-making process to minimize the environmental impact, reduce resource consumption and minimize life cycle cost, several parameters were studied (Milani et al., 2020). The study aimed to reduce resource consumption and environmental impact. Twenty-seven configurations, which included steel concrete, cast in-situ, precast, and prestressed concrete bridge were tested. The major variables to mitigate the parameters were material selection and bridge configuration. A Life Cycle Assessment (LCA), which is how the materials are sourced and how they are disposed of is carried out, which protects the environment and improves the financial standings of the project. Environmental aspects considered here were the damage to human health, damage to the ecosystem, and resource scarcity. It was found that cast-in-situ bridges perform the worst in these criteria while the steel/concrete bridges were the best option.

In Malaysia, in a promotion for the sustainable development of a green highway, it was found that the impact on human and environmental health can be improved by weighing on following standards, i.e., construction management plan, noise mitigation control, equipment, and machinery efficiency, quality management, context-sensitive designs, erosion and sedimentation control, and alignment selection (Rooshdi et al., 2014). In these areas, waste management plans, air pollution, use of innovation, and groundwater protection and restoration are taken as priorities. It is found that permeable materials provide superior watershed-driven stormwater management. As a result, the leaching of metals and toxins into streams and rivers can be prevented.

In another study done in Italy, for the human health impact of road construction activities, LCA is used (Moretti et al., 2017). Several factors are studied, the difference in a configuration such as trenches versus embankments are used. It is important to note that even though the bridges follow the standard specifications mentioned in the Indian and American Standards, they alone are not enough to prevent the environ-

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mental catastrophe that might result from insufficient planning and use of assessments such as environmental impact assessment.

In the case of hydropower dams, a study in Vietnam focused on the detection and attribution study in the lower Mekong delta has revealed the correlation between the use of dams and hospitalizations (Phung et al., 2021). The Mekong Delta region encompasses a rich water body flowing from North to South. The construction of dams in that area has improved the electricity output of the region yet challenged the downstream side of the Mekong, leading to adverse hydrological and environmental impacts. Their research has shown that there is a correlation between the construction of a dam upstream and the climate change-induced downstream. It has shown a changing river flood-drought cycle. Statistical analysis from this research has shown that the river drought is directly proportional to hospitalization which includes patients suffering from respiratory, renal, and cardiovascular diseases. Further consequences that can be seen from the upstream damming are habitat loss, deterred water quality, obstructed fish migration, diminished recreational benefits, droughts, and in some cases flood risks.

To understand the effects better, Australian scientist Dr. Helen has categorized sustainable hydropower in three parts (UN and Scanlon, 2000). Firstly, divide the factors into three parts namely economic, social and environmental aspects, and then subdivide these. In environmental consideration, ten aspects are mentioned which range from environmental assessment and monitoring, siting & design, construction impacts to seismic, the passage of aquatic species, biodiversity, and environmental flows. In social aspects, she mentions that public health must be studied and their dependence on the source must be cited. Questions like “Does the dam displace populations?”, “Is the river of cultural/community value ?” and “Is the construction of the embankment safe for the surrounding village?” must first be answered. Lastly, economic aspects such as demonstrated need, distribution, and sharing of benefits, cost benefits must be studied. According to the author, if all the parameters for the study are satisfied then the source can be classified as sustainable.

In Nepal, the University of Manchester has conducted a demonstration of how efficient and robust hydropower design can be done under unfavorable and uncertain conditions (Hurford et al., 2020). In this study, an intervention to increase the benefits from energy, food, water, and environment systems has been proposed. As per the research done by them, the decision-making process can be improved by splitting the phases into four stages. The phases are as follows, system and performance metric characterization, uncertainty identification, robust optimization, and stress testing. Performance metrics that can be tested as instructed by the author are the capital, dry season hydropower, total annual hydropower, water deficit, irrigation deficit, flood peak duration, and environmental flow rates. Likewise, uncertainties in the performance of the structure can be modeled by studying the river flows, abstraction demands, and environmental flow. In this paper, stress testing is proposed using Latin Hypercube Sampling generating 150 futures covering the uncertainty space. This four-phase multi-system can prove to be adaptable to the unpredictable future flows in the Himalayan region.

Another study done in the Netherlands has shown that material used in foundation, color, mass, height, span, spacing can play a vital role in the environmental impact of the structure (Ecocostvalue and van den Broek, 2012). They recommend the selection of low-impact materials, reduction in material usage, and optimization of production technology. Contrary to the conventional methods, in Serbia fuzzy models are being used to improve grade dependence and sensitive analysis grade (Stevovic et al., 2015).

1.1. Health concerns

Hazards, whether originating from or accumulating at a construction site, pose a threat to the health of both workers and inhabitants. Some common health risks associated with construction works include physical factors like asbestosis, silicosis, anthracosis, hazards due to dust, noise, radiation, vibration, temperature, etc. Similarly, the chemical health hazards due to mineral oils, lead, mercury, cadmium, isocyanates, exhausts, etc., biological hazards due to sewage and water supplies, infectious illness, etc. (Borup et al., 2017). Also, mechanical risks include muscle strains, sprains, carpal tunnel syndrome, back injury, limb disorder, etc. and the psychosocial risks associated are work-related stress, fatigue, suicide, mental illness, etcetera.

Of the many common hazards, dust exposure is one. The dust particles encompass silica dust, gypsum, limestone, marble and dolomite, and many others (HSE 2021). Occupation-related dust exposure constitutes a significant portion of construction work-related mortality and morbidity (Tavakol et al., 2017). Since dust, as a single group of agents, is responsible for a wide range of diseases, controlling the exposure to this single group of agents can help prevent many forms of diseases with little or similar interventions.

A longstanding exposure to dust manifests as fatal diseases such as asthma, COPD, pneumoconiosis, and lung cancer (Meijer et al., 2011). Construction site dust particles also possess a huge threat to the health of local residents and present as a disease spectrum similar to construction workers (Bhagia, 2012). Habitual inhalation of certain kinds of airborne contaminants, dust particles, and irritants that damage lung tissues, constitute interstitial lung disease known as pneumoconiosis, also commonly referred to as occupational lung disease. These particles cause inflammation and fibrosis in the lung resulting in irreversible lung disease.

1.2. Objectives

The main purpose of this paper is to carry out geotechnical investigations on the soil of western Nepal. Validating the quality of resources and mathematical calculations as per the IS and ASTM codes. Likewise, presenting the missing criterion that can be added to improve the project. Listing out certain consequences that come from the construction of the civil engineering structures, namely in bridges and hydropower. In the end, looking at potential health hazards caused due to these activities and suggesting preventive measures for the same. Six bridges and one hydropower project are assessed in this paper. These objectives have been fulfilled by carrying out the SPT tests, calculating water content and bearing capacity, and evaluating the factor of safety for liquefaction. Likewise, design criteria and specifications from IS code and ASTM for these above-mentioned parameters have been found satisfactory. A life cycle assessment technique has also been suggested.

Additionally, potential impacts on the health of people exposed to the hazards at a construction site have been explored. The focus is mainly on dust, as a hazard, and pneumoconiosis, a group of lung diseases attributed to long-term exposure to certain types of dust, commonly present in construction-related sites. The aim of this article is to provide a comprehensive view of the current understanding of different aspects of disease causation, in this case for pneumoconiosis, and to use this knowledge to construct an epidemiological triangle and various levels of prevention, which can be used for making more integrated plans to ensure a safe working environment at construction sites in the future.

2. Methodology

2.1. Description of data

The data presented here are of two types namely, primary and secondary. The primary data encompasses raw data collected from the construction site using various equipment as mentioned in the paragraphs to come. Likewise, the secondary data consists of data refereed from articles, journals, books, and other online sources. The described data is thus further analyzed both quantitatively and qualitatively.

Fig. 1. SPT test.

2.2. Description of the study site

The following Environmental Impact Assessment is modeled after the Government of Nepal's Ministry of Forest and Environment (Government of Nepal Ministry of Forest and Environment 2019). As per the National Census of 2011 A.D., the total population of the Bajura district is 134,912 with a sex ratio(female: male) of 51:49 and with about twenty-five thousand households. The dominant language is Nepali and more than ninety percent of the people follow Hinduism. Likewise, the literacy rate is at a low of thirty-two percent. The net migration rate is not properly documented. The rare species in this region are the impeyan pheasant, peregrine falcon, and the white-rumped vulture. The floral diversity includes chir pine-rhododendron forest, oak forest, and Himalayan fir-hemlock-oak forest, and alder forest. Environmental Impact Assessment is assessed for Barjugad bridge which lies 30 km southeast of the Khaptad National Park. The bridge is located at 29°20′33.5″N latitude and 81°17′54.5″E longitude. The climate of this area is subtropical. The average maximum temperature in this district is 33° centigrade while the average minimum temperature is 4°. Other salient features of the bridge include that it connects a rural road made of earthen and gravel.

2.3. Study design

In each site, the primary objective for the contractor is to examine the soil composition. For this firstly a borehole is dug based on the strata. In our case, a rotary drilling machine was used and a Standard Penetration Test(SPT) was used(as shown in Fig. 1.). As the value was less than 50, CPT was not used. In some cases, Atterberg's limits were also calculated as it would help to better understand the soil classification. Likewise, a pycnometer test was used to deduce the specific gravity of the soil sample collected during the borehole.

The depth of study is from 0m-3 m, then 3m- 6.9 m and 6.9 to 16 m. At the end of the calculation, the water content of the soil was calculated. Also, the bearing capacity of the structure is predicted. After the calculation part, they were verified with the IS standards to meet the required values.

2.4. Calculations

Sample Calculation is given below.

Atterbergs Limits are to be calculated by the following formulas given below:

$$\mathbf{PlasticityIndex = LiquidLimit - PlasticLimit} \tag{1}$$

$$\mathbf{Watercontent} = (\mathbf{Ww/Wd - 1})\times\mathbf{100} \tag{2}$$

where Ww is the weight of the water and Wd is the weight of the solids.

$$\mathbf{Bulkdensity} = (\mathbf{massofdrysoil})/(\mathbf{totalvolumeofsoil}) \tag{3}$$

The Safe bearing Capacity(SBC) a per the Indian Standards is given by the following formula:

$$\mathbf{SBC = qu = CNc + \gamma DNq + 0.5\gamma BNy} \tag{4}$$

where:

$$\mathbf{Nc} = \mathbf{cot}\varphi[\mathbf{\hat{a}2/2co\hat{s}2(45{+}\varphi/2) - 1}]$$
$$\mathbf{Nq} = \mathbf{cot}\varphi[\mathbf{\hat{a}2/2co\hat{s}2(45{+}\varphi/2)}]$$
$$\mathbf{Ny} = \mathbf{0.5tan}\varphi[\mathbf{Kp/co\hat{s}2}\varphi\mathbf{-1}]$$

φ is the angle of internal friction, Kp is the passive earth pressure, C is the Cohesion of soil, D is the depth of foundation, B is the width of the footing and γ is the unit weight of soil.

$$\mathbf{CSR = 0.65}\times(\sigma vc/\sigma vc1)\times(\mathbf{amax/g})\times\mathbf{rd} \tag{5}$$

CSR=Earthquake induced stress amax=Peak ground surface acceleration

g = Acceleration due to gravity

σvc= Total vertical stress

σvc1= Effective vertical stress rd= Stress reduction factor at the depth of interest

F.O.S=Cyclic shear stress required for liquefaction/Cyclic shear stress induced by earthquake (6)

Where F.O.S is the factor of safety for liquefaction.

3. Discussions and results

There are several beneficial and adverse impacts of constructing this bridge. The immediate benefit would be the rise in local employment while the long-term benefit includes improved connectivity, making it easy for transportation of goods in and outside the district. Likewise, other benefits may include ingress of medical, educational, and horticultural-related activities into day-to-day life. Nevertheless, the adverse effects include the disruption of the environment from noise, air, and water pollution. Construction activity may produce these due to the operation of machinery and vehicles and the use of synthetic chemicals. Seepage and leaking of chemicals into the environmental sources(air, groundwater) possess a challenge. Also, vegetation needs to be removed while clearing the site. Some of the remedies can be using bio-engineering methods such as polymer-based substances to protect from leaking and seeping. All the construction and camp waste need to be disposed of in man-made pits and later neutralized with various chemical processes. Other hazardous chemicals need to be handled carefully and stored in fallow land away from river beds.

The bridge has already been constructed but if we were to mitigate the impact of other bridges, a detailed study needs to be done on the migration of species and their dependence on the area for food/water and shelter. Also, if the area is heavily forested but needs to be cleared another area can be picked so that we can start an afforestation program to provide alternatives for animals. If the area has community value/agricultural value the people involved should be allocated a different area so that no conflict arises.

Environmental impact assessment for the Makarigad Hydropower project was to be set into five phases i.e. pre-construction phase, construction phase, commissioning phase, operation phase, and decommissioning and rehabilitation phase. This has been done with the correct methodology. However, an additional four to five-step Life Cycle Assessment is lacking such as in parameters in Physical and Chemical Environment, Biological Environment, Socioeconomic Environment, and Cultural Environment. If these aspects were to be added to future hydropower projects as per the Ministry of Forests and Environment, construction projects can be fruitful to both natural and manmade structures.

The risk of asthma, cancer, and immune degradation is high. Skin cancer can also result from prolonged exposure to such sites. There is a high risk of endocrine system secretion problems. Likewise, Environmental hazards are present during every step of the open-pit mining process. Hardrock mining exposes rock that has lain unexposed for geological eras. When crushed, these rocks expose radioactive elements, asbestos-like minerals, and metallic dust. During separation, residual rock slurries, which are mixtures of pulverized rock and liquid, are produced as tailings; toxic and radioactive elements from these liquids can leak into bedrock if not properly contained. For workers, the main risk involves risk during excavation, wire setting (electrocution risk), lifting and rigging process, and ladders and height fall risk etcetera.

3.1. Impact of construction on the health of workers

The nature of construction works is such that being exposed to respirable dust is inevitable. This exposure can manifest as respiratory diseases such as pneumoconiosis and lung cancer (Calvert et al., 2012).

Pneumoconiosis is a group of heterogeneous occupational interstitial lung diseases caused by the inhalation of mineral dust in the lungs, which leads to lung dysfunction. There is no effective treatment of pneumoconiosis, which necessitates early diagnosis and treatment (Cullinan and Reid, 2013). Due to the paucity of screening tests in the work setting as well as lack of acknowledgement of material hazards from the workers' party, lung cancer inevitably presents in a later stage. Higher stages of lung cancer have only a 1% to 3% survival rate 5 years after diagnosis (Siddiqui and Siddiqui, 2021). With health resources limited and most citizens living below the poverty line, the condition in Nepal can be assumed to be more abysmal. Screening with pulmonary function tests should be made mandatory for high-risk workers while imaging and lab investigations should be reserved for cases with high clinical suspicion (Qi et al., 2021). Although engineering methods occupy the most important hierarchy of controls, the use of personal protective equipment such as respirators decreases the risk of health hazards (Blackley et al., 2017).

The Center for Construction Research and Training (CPWR), in alliance with the Occupational Safety and Health Administration (OSHA) of the United States Department of Labor, is committed to reducing construction-related injuries, illnesses, and fatalities. One of the ways CPWR does this is by providing the public with access to safety and health research findings (OSHA, CPWR 2021). The official CPWR website mentions the following salient pronouncements:

I Workers involved in construction inhale dust (containing silica, asbestos, and other particulates), welding fumes (seating heavy metals), and toxic gasses.

II They account for disproportionately high blood lead levels at 17%, while adjudging for only 8% percent of the workforce. The damaged nervous system, kidneys, infertility, and miscarriages have been observed with workers exposed to lead.

III While welding, three-fourths of the boilermakers, less than a fifth of the ironworkers, and less than a tenth of the pipefitters exceed the accepted 8-hour level limit of the neurotoxin, manganese, which can cause neurological damages paralleled to Parkinson's disease.

Physical agents are responsible for another major group of occupational hazards in the construction industry. Research conducted in Malaysia suggests slip, trip, and fall, electrocution, and, noise and vibration are the common physical hazards at construction sites with slip, trip, and fall responsible for slightly over 60% of the accidents reported (Salim et al., 2017).

3.2. Impact of construction on the health of inhabitants

Construction workers are under continuous exposure to construction dust throughout their work lives. In contrast, residents of a construction site are exposed to construction dust only for the duration of the construction work. While it is unlikely for pneumoconiosis to develop from such a short period of exposure, diseases that take lesser time to develop, such as asthma or other allergic reactions, can still affect the residents' health. Similarly, noise from construction sites can cause disturbances in the local lifestyle.

Sometimes the effects of construction may last longer than the work itself. Dams and hydroelectric projects are likely to increase concentrations of the neurotoxin methylmercury in food webs near indigenous communities. Microbes convert naturally occurring mercury in soils into potent methylmercury when land is flooded, such as when dams are built for hydroelectric projects. The methylmercury moves into the water and animals, magnifying as it moves up the food chain. This makes the toxin especially dangerous for indigenous communities living near hydroelectric projects because they tend to have diets rich in local fish, birds, etc. thereby causing impaired neurological, gastrointestinal, and kidney functions in humans. Microbial production of the bio-accumulative neurotoxin methylmercury (MeHg) is stimulated in newly flooded soils by degradation of labile organic carbon and associated changes in geochemical conditions (Calder et al., 2016).

3.3. Airborne dust: a major hazard

Control of a hazard starts with its recognition. While airborne dust has been linked with many other occupational or dust-related lung diseases, this along with the following sections will be focused on pneumoconiosis. Although agents with specific chemical compositions are responsible for specific kinds of pneumoconiosis, these agents are generally grouped as dust, based on their grossly common physical form. Dust is a form of aerosol which in turn is a form of airborne contaminants. Dust found in a work environment can be broadly classified into five groups: I) mineral dust, II) metallic dust, III) other chemical dust, IV) organic and vegetable dust, and V) biohazards. Mineral dust is of special interest when it comes to pneumoconiosis (WHO 1999). In the context of pneumoconiosis, the route of entry is by inhalation, either through the nose (nasal route) or the mouth (oral route). The particles then get deposited at various sites of the respiratory tract, mainly by sedimentation and impaction.

Size and shape are important in determining the pathogenicity of a particle. When referring to a particle's size, in the context of an occupational hazard, the particle's "aerodynamic diameter" is more appropriate than simply its geometric size. This is because the former is better than the latter at fully explaining how a particle behaves in its airborne state and therefore, its ability to penetrate and deposit in the respiratory tract. For a particle of size greater than 1 μm, its terminal velocity, a measure of its ability to remain airborne, is important. In contrast, for a particle smaller than 1 μm, its movement with air is more important. "Fibers" are particles with diameters lesser than 3 μm, lengths greater than 5 μm, and aspect ratio (length to width) greater than or equal to 3 to 1 (WHO 1997). For asbestos, fibrous dust, its shape has evident implications on the severity of the manifestations after harmful exposure.

Both duration and level of exposure to the dust are important in the development of the disease. As discussed earlier, a particle's aerodynamic features can be important in determining its pathogenicity. Furthermore, a particle's ability to remain airborne or to move with air can also determine the duration as well as the level of exposure. It is important to understand the process of dust generation and release to design effective methods of controlling dust emission at the source. Dust can either form as a result of the breakdown of the larger mass of the same material through mechanical processes, in which case they are called "primary airborne dust", or through the dispersal of materials already in powder or granular form. Even more, dust is formed during the process of dust dispersal as smaller particles are formed from larger ones through impaction and friction. Ways of handling powdered material, the dust-generating capacity of bulky materials, and falling height have important roles in dust generation. This highlights the importance of properly planning and designing processes and of maintaining adequate work practices.

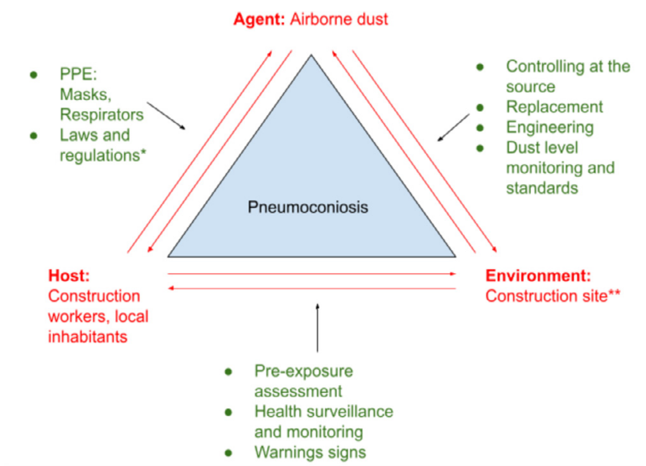

Fig. 2. Epidemiological triad or triangle for pneumoconiosis in the construction industry.

3.4. Epidemiological triad: a simple model for disease causation

An epidemiological triad or triangle is one of the simplest models of disease causation. While traditionally used for infectious or communicable diseases, it has been useful in representing some non-communicable diseases as well. An alternative, especially one that is used for modeling the causation of chronic non-communicable diseases, is the web of causation. It is made up of complex interactions between various risk factors at multiple levels, giving a web-like appearance to the whole model. It is particularly useful in representing diseases that might not have an identified single major agent to which the causation can be attributed to. Given that the occupational lung diseases do have definite causative agents, and because of its simplicity which allows clear targets for interventions, the authors have opted to construct an epidemiological triangle for pneumoconiosis (Fig. 2.)

The vertices of the triangle represent the components of the triad (red text). Interventions (green text) on different interactions (red arrows) are presented in bulleted form.

PPE = Personal Protective Equipment.

Laws and regulations can be made targeting any of the three interactions.

While this epidemiological triad was made with focus on the construction industry, it must be noted that the construction industry is only one of several work environments where harmful levels of dust exposure takes place.

An epidemiological triad, as the name suggests, consists of three main components: an external causative agent, a susceptible host, and an environment where the host is exposed to the agent or which favors the interaction between these (ISDP, U.S. 2006). Additionally, there are interactions between all three of the components.

Out of two ways of diagrammatically representing this triad, the authors have chosen one in which the vertices of a triangle represent each of the components. Each side of the triangle then represents the interaction between the components it connects. This allows better visualization of interventions, targeting specific interactions. Categorizing interventions based on the type of interaction they target can help plan a more integrated approach to disease prevention and control.

3.5. Levels of prevention

There are four main levels of prevention: primordial, primary, secondary, and tertiary. While primordial and primary prevention techniques aim to decrease the disease incidence, secondary and tertiary prevention techniques aim to slow down or stop the disease progression, decreasing the incidence of morbidity and mortality among the diseased.

Primordial prevention consists of undertaking actions and measures that inhibit the emergence of risk factors. Education about healthy and safe habits since childhood like proper dietary lifestyle, regular physical activities, discourage smoking, legislation and enforcement to ban or control the use of hazardous products, safe and healthy practices, etc. can be done.

Primary prevention is focused on preventing disease or injury at the source, before it can even occur, and is by the far the most effective. Health Promotion efforts like health education, environmental and nutritional interventions, lifestyle modifications, and specific protections like medical prevention measures which comprise immunization, chemoprophylaxis, supervision of working environment, pre-placement examination. Similarly, engineering, legislation, and personal preventive measures like workplaces providing personal protective equipment, use of masks, workers, and workplaces being compliant with regulations and exposure limits, monitoring workers of their exposure, air quality, and environmental monitoring.

To assure primary prevention is adequate in preventing disease, screening is done which is the most important component of secondary prevention (Hall et al., 2019). Screening also assists in the detection of disease in the early stages, so that early intervention can be possible. A mandatory screening test should include pulmonary function tests and while imaging modalities like X-ray and CT-Scan, examination of Bronchoalveolar lavage, and in selected cases lung biopsy should be reserved for those with high clinical suspicion. In resource-limited settings such as Nepal, 6 min walk test and MMRC grading can be useful screening tools (Williams, 2017) (Ovid 2021). Designing ideal criteria for respiratory surveillance is challenging, as there is no single test that accurately identifies the early disease (Pellegrino et al., 2005). Since pneumoconiosis has no effective treatment early diagnosis and exposure control are the only ways to prevent the disease.

Tertiary prevention is directed towards pulmonary rehabilitation such as breathing retraining, low or high-intensity exercise training, endurance training, and also towards things such as psychosocial support and palliative care (DeLight and Sachs, 2021).

3.6. Results of soil exploration

Table 1 shows the calculation for the water content and specific gravity as well as the soil profiles found at various depths via the boreholes for the Barjugad area. Likewise, Table 2 shows the calculation of bearing capacity using the formulas listed above in spread foundation type at 1.5 m depth. Furthermore, the standard size of aggregates for bridge construction as per ASTM D 448 – 98 has been verified (ASTM D448-98 1998). Moreover, the bending for ductility of the material is satisfied (ASTM E290-97a 1997). It is found that standard code practice for road bridges has been followed (IRC:5 2015).

For the Hydropower project in Makarigad, Shear failure criteria, settlement and liquefaction were also tested. A sample calculation is given below:

The sample calculations give us a good idea about the conditions we can expect in the field for structure. It tells us about the soil type present in this area and the potential dust emissions characteristics based on the type of soil. For instance, finer-grained soil such as silt and coarser-grained soil such as sand is more likely to be blown away by the wind and enter the worker/inhabitants' body. Likewise, they also tell us about the potential strength and stability of the structure and whether or not the structure will exhibit the required properties throughout its expected life span.

From the analysis, it is evident that the construction of civil engineering structures in western Nepal is at par with Indian and American standards. For instance, The factor of safety of 3 was achieved for the hydropower project which is safe according to Indian standards. Likewise, in the above case, the Bearing capacity achieved is more than the

Table 1
Sample calculations for Barjugad bridge.

BH.	Depth	% of				Atterberg Limits			Water	Specific	Unit Weight		qu	mv
		Gravel	Sand	Fines		LL	PL	PI	Content	Gravity	Dry	Bulk		
No	m			Silt	Clay				%		gm/cc	gm/cc	kN/m^2	cm^2/kg
1	0.00–8.70	3.00	65.00	31.00		-	–	–	18.17	2.59	–	–	–	–
	8.70–16.00	Gravels, Boulders & Rock				–	–	–	8.84	–	–	–	–	–
2	0.00–3.90	7.00	87.00	6.00		–	–	–	14.62	2.62	–	–	–	–
	3.90–16.00	67.00	31.00	2.00		–	–	–	7.35	–	–	–	–	–
3	0.00–4.50	5.00	58.00	37.00		–	–	–	16.67	2.58	–	–	–	–
	4.50–9.00	0.00	91.00	9.00		–	–	–	12.63	–	–	–	–	–
	9.00–16.00	57.00	37.00	7.00		–	–	–	6.76	–	–	–	–	–

Table 2
Summary of bearing capacity of spread foundation with different sizes and depths.

Foundation Type	Depth (m)	Foundation Size (*B* × L)			Unit Wt(ϒ) (kN/m^2)	Angle of internal Friction(Ø)	Cohesion C	Bearing Capacity (KN/m^2)		Allowable Bearing Capacity (kN/m^2)	Modulus of subgrade rxn (MN/m^3)
								Shear (kN/m^2)	Settlement (kN/m^2)		
Spread	1.5	1.5	×	1 0.5	19.4	41	0	969	289	285	18
		2.0	×	2 0.0	19.4	41	0	1032	266	265	17
		2.5	×	2 0.5	19.4	41	0	1107	250	250	16
		3.0	×	3 0.0	19.4	40	0	940	235	230	14
		3.5	×	3 0.5	19.4	40	0	1004	226	225	14
		4.0	×	4 0.0	19.4	40	0	1070	216	215	13
		4.5	×	4 0.5	19.4	40	0	1137	213	210	13
		5.0	×	5 0.0	19.4	40	0	1205	208	205	13
		5.5	×	5 0.5	19.4	40	0	1273	206	205	13
		6.0	×	6 0.0	19.4	40	0	1342	202	200	13

allowable bearing capacity. So, the structure can be considered to be safe. Moreover, the specification for the size of aggregates and specifications for road bridges has been followed as per ASTM. However, we cannot overlook the fact that Life Cycle Assessment has not been made, thereby, making the structure unsustainable in the long run. Likewise, the four to five-stage split has not been made on the hydropower and bridge projects which raises a question over the lifespan of these structures.

Furthermore, even during and after construction, workers and locals may face diseases such as pneumoconiosis, lung cancer, and silicosis. Moreover, instigation of the passage of mercury in the food chain via the dams can further complicate the health of the people in the long run.

4. Conclusion and future work

The strength and stability characteristics of the projects have been met according to the Indian and American Standards. The earth profiles, bearing capacity, and liquefaction factor of safety has been studied and found to hold for the given soil. However, a four to five-stage life cycle assessment represents an ideal addition to mediate the detrimental effects on the environment and health of workers. As it not only raises the lifespan of the structure but also improves the sustainability of the project. Likewise, other methods such as the use of polymer-based cellular confinement systems and biodegradable geosynthetic material have been proposed to make the project more environmentally friendly.

Impact on public health is an essential consideration when planning for sustainable development. Dust is one of the major hazards responsible for a myriad of diseases in the construction workers exposed to it. One of the diseases that make the list is pneumoconiosis. Due to the nature of such diseases and also due to cost-effectiveness, primordial and primary preventions have important roles in controlling the dust exposure and thus development of many diseases including pneumoconiosis. While planning measures to control a hazard, integration of various kinds of interventions can yield better results, possibly with lower costs. This can be done by identifying and segregating the interventions based on the link in disease causation they target. The authors have tried to demonstrate this by constructing an epidemiological triangle and a list of preventions classified into various levels. While simple, both of these methods can depict a clear pathway for planning interventions. Similar methods can be applied to plan more integrated approaches towards disease control in general.

Further, quantitative analysis of this hypothesis can be done over a few years and statistical analysis of its reliability can be made. For this, a thorough literature review must be done on dust emission and health aspects, and subsequently, a model can be developed to assess a correlation between the two. This will take a substantial amount of time, even decades to do this evaluation, which we couldn't consider as our study time on the site was limited.

5. Authors contributions

Saurav Dev analyzed the case studies from around the world regarding the environmental impacts of the construction of hydropower and bridges. He also conducted the SPT Test, found the Atterberg's limit at various depths, and found the bearing capacity for the spread foundation. He validated the results with the Indian and American standards and demonstrated a sample E.I.A. and proposed a further 4-step Life Cycle Assessment. Ashhrik Pahari, Shashank Mishra, and Aayam Adhikari have worked together on the health-related portion of the article. All three have contributed to performing literature searches for the article. Ashhrik Pahari, Shashank Mishra, and Aayam Adhikari have constructed the epidemiological triad and divided the intervention methods based on levels of prevention. All four authors have equal contributions in drafting, proofreading, and preparing the final manuscript.

Disclaimer

The statements made in this paper are those of the authors. They do not reflect the opinions of ICIMOD, concerning the legal status of any regions and nations of its authorities. Further, it does not endorse any products or limits the scope of the article in any way. Eq. (1)-5

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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