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# An Assessment of Environmental Impact on River Bed Sand and Gravel Mining in Eastern Dooars, West Bengal: A Case Study on Raidak-II River

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**Abstract:** ***Mining of Sand and gravel is one of the important economic activities practiced in the Eastern Dooars. Ever-expanding human needs and economic progress creates a massive load on the natural asset base. Dependency on the land and geomorphological setup, the degree of the environmental effects also changes the river sand and gravel mining. The action executes environmental effects on water, air, land, River, and economic circumstances of a stream basin. EIA is a significant process to evaluate the negative (unfavorable) and positive (useful) effects of sand and gravel mining. EIA is a procedure of examining the several actions that would mark the environment based setting that has been looked on as noteworthy in a stated situation. Two distinct techniques—Matrix-based method and RIAM strategy are utilized here to evaluate the Environmental Impact Assessment of sand and gravel mining in one of the important rivers of Eastern Dooars. The present study makes clear that the uncontrolled sand and gravel mining activity is the main danger to the Raidak-II River and the antagonistic ecological impacts of sand and gravel mining command upon the minor and momentary advantages. A lot of suggestions are likewise provided to guarantee maintainable administration of this current nature's blessing.***

**Keywords:** EIA, Sand and gravel mining, Matrix-based method, and RIAM Method

## 1. Introduction

River bed sand and gravel extraction is the procedure of taking away sand as well as gravel from the stream bed. It is much essential inexhaustible resource upon which farming activity relies (Tilman et al. 2002). Extraction of sand and gravel mining is one of the important sources of earning for the local people of the riparian areas in Eastern Dooars. There is no doubt about the importance of the mining sector in the global economy. Nowadays the different extracted materials (major and minor) for constructive purposes play a role in the developmental sectors. Simultaneously, it essential to be mentioned that we have limited river resources and spontaneous extraction may exhaust them. Manual and mechanical techniques are utilized to gather this river bed material from lakes, Rivers, river basin area farming lands all over the world. Manual extraction of river bed material doesn't hamper the environmental conditions as compared to the uses of heavy types of machinery are utilized to gather the material from the stream extensively [1] (Kamboj et al. 2017). The riverbed sand and gravel extraction is done worldwide to build roads buildings and helps to form urbanization. Most of the World's Rivers are rich in sand and gravel materials. This sort of mining is taking place legally and illegally as these materials have high value in the global market. The aggregated extracted materials are around 47 - 59 billion tons annually from the rivers globally. The lion share (68% - 85%) of the extracted materials from the river is sand, gravel pebbles, and various sized boulders. The excavation of these mining resources causes numerous natural impacts such as water, noise, and soil pollution dangers to bio-diversity (aquatic as well terrestrial), and socio-economic condition of the riparian areas. Some analyst everywhere throughout the world environmental impacts assessment made by the riverbed mining and quarrying action (Rinaldi et al., 2005; Jia L & Luo Z, 2007; Erskine, 2008; Peckyen.T & Rohasliney H, 2013; Smolder et al., 2003; Kondolf, 2016)India is of the leading developing nation having the second largest population on the globe Different construction sectors and urbanizations are the primary means for any nation. The resources like sand, gravel, and boulders are acquired from the river bed. India is rich in biodiversity; numerous streams give these important materials on a large scale. The important northern rivers of India are: Indus, Brahmaputra, Yamuna, Ganga, Beas, Jhelum, Satluj, Ravi, and Chenab River give a huge quantity of river bed material. In southern India, significant streams are Peyier, Krisna, Godabari, Pennar, Pennar, Paler, and Kaveri River give a large quantity of sand and gravel for building different infrastructural sectors for the development of the nation. (Kamboj et al., 2018; Padmalal et al., 2008; Singh et al., 2016; Shekhawa, 2013) In India, numerous perennial and seasonal waterways give a lot of resources (sand, gravel, pebble, and Boulder). These supplies are useful for the growing nation due to the large scale urbanization and construction industries. The stream-bed mining activities is turning into an l issue related to the environment due to increasing demands for sand and gravel in the large scale urbanization and construction industries, on the other hand, an expansion of population, the growing industries, and economic developments, trade, and industry during several decades have bothered extraction of stream sand higher as compared to replenishments which truly caused the serious environmental problem to stream biological systems on the planet. People and privately owned businesses are progressively demanding these riverbed materials for development and it creates tremendous pressure on the sand as well as gravel resources which may lead to illegal sand and gravel mining in certain areas, the sand mafia started dominating the sand mining areas. (Kamboj et al., 2017). A large portion of eastern Dooars is covered by coarse sandy and loamy soil and a huge amount of sand and gravel extraction is taking place in the area under study due to the excessive demand in constructive sectors like making

roads, buildings different developmental projects, and administrative buildings, embankments, etc. Even though EIA contemplates are made to assess the impacts of the environment upon the extraction projects, its gradually expanding influences in the mining and quarrying divisions are frequently overlooked Simultaneously, minerals and other resources mining are unavoidable for the nourishment of people (Bradshaw, 1983; Auty and Mikesell, 1998; Sachs and Warner, 1999;). Based upon the area and kind of mining, the degree of mining, and the significance of the environmental effects may differ. These effects are extensively divided into four types - Water, climate, land, and socio-economic conditions of the people of the region (Rau & Wooten, 1980). These unscientific mining activities are taking place in a reckless way and force distress among the neighborhood inhabitants. This is only one part of the issue. Then again, the certainty of extraction for filling and building materials can't be prohibited fully as these supplies are indispensable parts of any development exercises that strengthen the financial base, generation of employment, and, eventually livelihood for the local people. Consequently, it is too vital that most extreme considerations be taken to control or mitigate the unfavorable effects of river bed extraction and quarrying for accomplishing ecological security. **(**Shiekha et al., 2016).

The essential issues that are to be tended to while managing the environmental issues of mining exercises including sand and gravel extraction are as the following:

- Air and noise pollution
- Water pollution
- Degradation of land
- Landslide and land constancy
- Deforestation
- Man-environmental issues ( health, employment, human habitats, and other related problems
- Damages to topographic features, social, and historical background

Every one of these issues is to be handled cautiously while coming to results and for detailing the mitigation measures for environmental problems related to mining and quarrying.

## 2. Study Area

Dooars means the door to Bhutan lies along the Himalayan foothill extended from Kaljani River in the west direction to the river Sankosh in the east direction. The Raidak river originated from Mt. Akungphu at an elevation of 6400 meters of the Himalaya (Government of West Bengal, 2014). The Raidak took entry in India at 'Bhutan Ghat' (Alipurduar district) with a new name known as Raidak. In Bhutan, the Raidak river is familiar to Wang Chhu or Wong Chhu. After entering India Raidak river bifurcated into two sub-streams named_Raidak_I and Raidak_II at Tiyabarighat (Alipurduar district). The Raidak-II mainly flows through Alipurduar and Cooch Behar plains and joins with the Sankosh river at Bainyaguri (Boxirhat, Cooch Behar) and finally, the Sankosh river joins the Brahmaputra in Bangladesh with the new name Gangadhar river. The Raidak-I river is flowing through Alipurduar and Cooch Behar plain and joined with the Torsa River. The present study mainly focuses on the lower part of the Raidak river i.e Raidak II from Bhutan Ghat (AlipurduarDist) to Bainyaguri (Cooch Behar with a length of 50 km. The longitudinal and latitudinal extension of the study area is between 89˚45′E to 89˚50′ longitude and 26˚ 20′N to 26˚ 40′N latitude (Figure-1.1). The river Raidak-II mainly covers the Kumargram Block of Alipurduar district and Tufanganj-II Block of Cooch Behar district. (Singha & Singh, 2017).

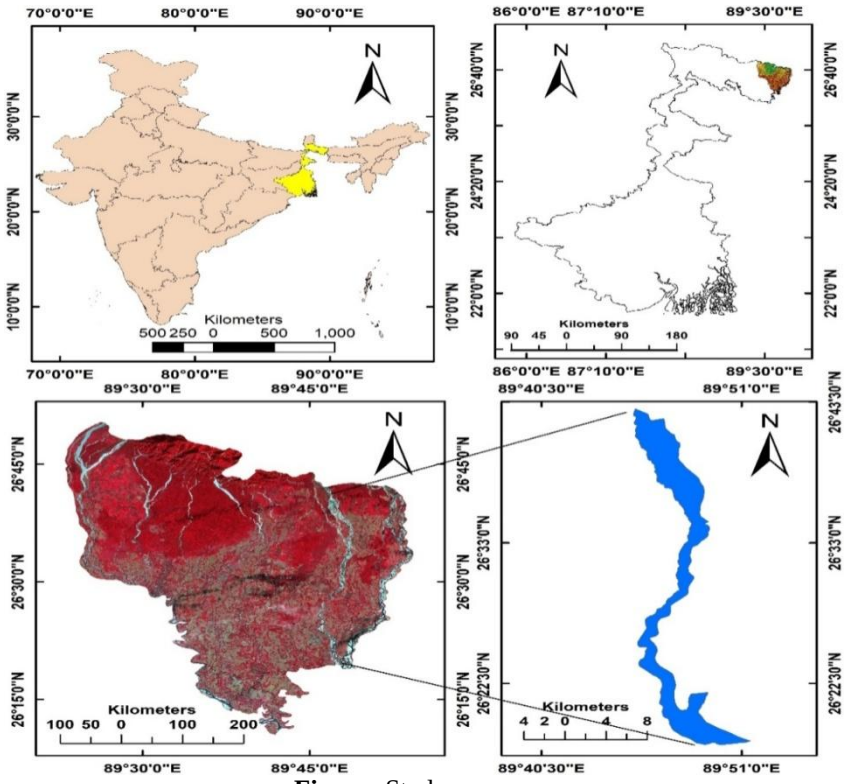



**Figure:** Study area map

## 3. Methodology

In this paper, quantitative and qualitative methods are adopted so that target objectives can be satisfied. Study area maps have been digitized using the Qgis platform. Leading any appraisal on the consequences of sand as well as gravel mining from the river bed on different environmental components of stream biological system is almost tuff since a portion of the unfavorable impacts are dynamic simply after a long period (Kondolf at al., 2002) Extraction and other required data required for the study was gathered through ground-based investigation covering Raidak-II river basin. A questionnaire survey has been carried out with quarry administrators, workers, lorry drivers, govt. authorities of DL& DLRO and local people(age more than 40)and other secondary data were gathered from the DL& DLRO office. The following two strategies are utilized to evaluate the environmental impacts because of the sand and gravel extraction from the stream bed. I) The RIAM Prescribed by (Pastakia, 1998) II) The matrix-based method (Rao and Wooten, 1980) and The matrix method is utilized to feature various effects effectively. It is planned with the list of possible effect localities which are characteristics of the environment and to look at either the circumstance positive or negative to the situations which are to be evaluated against different affecting actions, the states of the environment. RIAM includes recording abstract decisions by characterizing the criteria and scales against which these decisions are to be made. The way toward choosing parts for an EIA which are then evaluated against criteria is known as scoping.

EIA studies employed qualitative as well as quantitative methods. A questionnaire-based survey was initiated to collect the basic information of mining and questionnaire survey was conducted nearby riverside areas and interaction with the stack holders of the village., surface water, air quality, groundwater, and More health-related questions were asked to the local people of the riparian areas with a structured questionnaire so that the health status, air quality. Groundwater and surface water of the surrounding area can be understood. Other secondary data is analyzed in Microsoft excel. The questionnaire was designed to fulfill the objectives of the EIA or find out the basic environmental problems and how positive impacts can be enhanced by reducing the negative impacts. The questionnaire should include basic parameters considered for EIA. The matrix-based method of (Rao and Wooten 1980) is applied to assess the impacts upon the environment caused by river bed extraction (Kitetu and Rowan, 1997; Kondolf et al., 2002). Two different environmental settings have been considered to evaluate the stream-bed and flood plain zones. Significantly two separate evaluations are adopted to deal with the problems associated with these unscientific mining activities. DL & LRO and Pollution Control Board provide the required data to evaluate the EIA. The method regarding the statistics and facts compilation as stated in some guidelines and concerning the existing statistics and a questionnaire survey was conducted nearby riverside areas and interaction with the stack holders of the village., surface water, air quality, groundwater, and More health-related questions were asked to the local people of the riparian areas with a structured questionnaire so that the health status, air quality. Groundwater and surface water of the surrounding area can be understood. Other secondary data is analyzed in Microsoft excel.

Parts of the appraisal have appeared in four groups:

1) Physical and chemical
2) Biological and ecological
3) Social components
4) Economical and functional

The significant appraisal criteria are partitioned into two clusters:

(X) Criteria that are of significance to the situation, and which can individually change the score acquired

(Y) Criteria that are of value to the situation, however completely ought not to be capable of changing the score attained. The category of the class (Y) scores is multiplied by the result of the category(X) scores to give a final assessment score (ES) for the situation. The procedure can be expressed by (i), (ii) and (iii)

(X1) x (X2) = XT …… (i)
(Y1) + (Y2) + (Y3) =YT……..(ii)
(XT) x (YT) =ES……(iii)

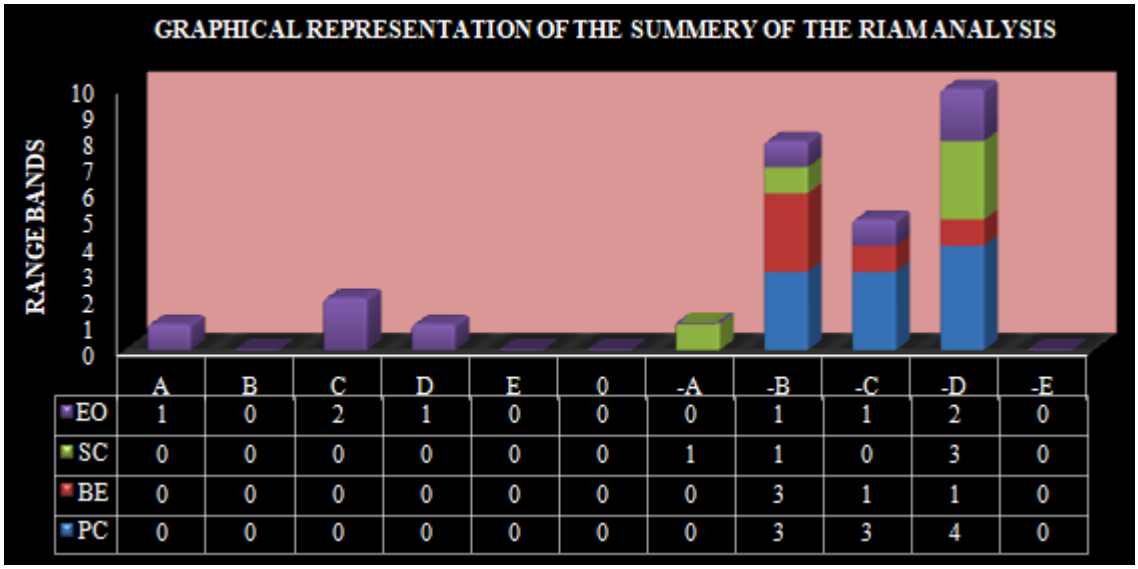
Where,

(X1) and (X2) are both the different criteria scores of the category(X)
(Y1) to (Y3) are the individual criteria scores for classification (B)
XT is the outcome of the multiplication of every one of the (X) scores
YT is the outcome of the compilation of all (Y) scores
ES is the evaluation score for the entire situation of the study area.

**Table 1:** Assessment criteria (Rapid Impact Assessment Matrix)

| Cluster | Criteria | Level value | Level quality |
|---|---|---|---|
| X | X1: Significance of the condition | 4 | worldwide significance |
| | | 3 | nationwide significance |
| | | 2 | Out of the domestic situation |
| | | 1 | Domestic condition |
| | | 0 | No importance |
| | X2: The magnitude of change/ effect | +3 | Major positive benefit |
| | | +2 | Significant improvement |
| | | +1 | Improvement in status quo |

| | | | |
|---|---|---|---|
| | | 0 | No change/ status quo |
| | | -1 | Negative change |
| | | -2 | Significant negative change |
| | | -3 | Major negative change |
| Y | Y1: Stability | 1 | No change/ not applicable |
| | | 2 | short-term |
| | | 3 | everlasting |
| | Y2: Reversibility | 1 | No change/ not appropriate |
| | | 2 | Reversible |
| | | 3 | Irreversible |
| | Y3: Cumulative | 1 | No change/ not appropriate |
| | | 2 | Non-cumulative |
| | | 3 | Cumulative |




| | A | B | C | D | E | 0 | -A | -B | -C | -D | -E |
|---|---|---|---|---|---|---|---|---|---|---|---|
| EO | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 1 | 1 | 2 | 0 |
| SC | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 3 | 0 |
| BE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 0 |
| PC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 4 | 0 |

**Figure:** Graphical representation of the summary of the RIAM analysis

## 4. Result and Discussion

RIAM requires explicit appraisal components to be characterized through a procedure of scoping, and these environmental options are often categorized jointly of 4 classifications, which are characterized as follows:

- Physical and Chemical (PC): All physical and chemical parts of the environment.
- Biological and Ecological (BE): All biological parts of the environment
- Sociological and Cultural (SC): All human parts of nature, including social perspectives.
- Economic and Operational (EO): Qualitatively to differentiate the financial outcomes of ecological change, both permanent and temporary.

As per the formulae given earlier, the Environmental Score (ES) is set and recorded. To provide a progressively certain arrangement of evaluation, the individual ES scores are joined together into ranges where they will be checked out Table 4 gives the ES esteems and range groups right away utilized in RIAM. When the ES score is ready into a range band, these can be demonstrated exclusively or clustered by component type and presented in whatever graphical or numerical structure the presentation needs.

The impacts of sand and gravel extracting legitimately depend upon the quarrying method practiced within the region, topographical, geological background, human settlement in the area, and mining pit depth. The impact assessment performed utilizing the RIAM method for sand and gravel quarrying from the river bed within the study region is represented in Table 3 and the outcomes are condensed in Table 6 and Fig. 4. Mechanical mining is mainly practiced with heavy types of machinery for national and international business purposes while manual mining is completed uniquely in small patches of mining areas especially to meet the local demands for house construction in the study reach. Both manual and mechanical mining create a critical negative effect on land use, landscape, soil, and various features of landform highlights. (Table-3).

**Table 2:** Alteration of ES to RV

| RIAM | Ranging Value | Ranging Value | Details |
|---|---|---|---|
| 108 - 72 | +E | +5 | most important positive impacts |
| 71 -36 | +D | +4 | Important positive impacts |
| 35 - 19 | +C | +3 | Moderate cum low positive impacts |
| 10 - 18 | +B | +2 | Low positive impacts |
| 1 - 9 | +A | +1 | Very low positive impacts |
| 0 | N | 0 | No alteration |
| (-1) - (-9) | -A | -1 | Very low negative impacts |
| (-10) - (-18) | -B | -2 | Low negative impacts |
| (-19) - (-35) | -C | -3 | Moderate cum low negative impacts |
| (-36) - (-71) | -D | -4 | Important negative impacts |
| (-72) - (108) | -E | -5 | Most important negative impacts |

After (Pastakia, 1998; Yousefi et al. 2009, 2010.)

**Table 3:** Environmental parameters and their impacts in the Raidak-II River in Eastern Dooars

| Environmental parameters | Assessment criteria | | | | | | | ES | RV |
|---|---|---|---|---|---|---|---|---|---|
| | Cluster (A) | | | Cluster (B) | | | | | |
| | Aa | Ab | At | Ba | Bb | Bc | Bt | | |
| Physical & Chemical components (PC) | | | | | | | | | |
| Landscape | 3 | -2 | -6 | 3 | 3 | 3 | 9 | -54 | -D |
| Land constancy | 1 | -3 | -3 | 3 | 3 | 3 | 9 | -24 | -B |
| Land use | 2 | -3 | -6 | 3 | 3 | 3 | 9 | -54 | -D |
| Soil | 1 | -2 | -2 | 3 | 3 | 3 | 9 | -18 | -C |
| Landform | 2 | -3 | -6 | 3 | 3 | 3 | 9 | -54 | -D |
| Aesthetics | 1 | -2 | -3 | 3 | 3 | 3 | 9 | -27 | -C |
| Air quality | 1 | -3 | -3 | 2 | 2 | 3 | 7 | -21 | -C |
| Noise level | 1 | -2 | -2 | 2 | 2 | 3 | 7 | -14 | -B |
| Status of Ground water | 2 | -3 | -6 | 3 | 3 | 3 | 9 | -54 | -D |
| Status Surface water | 2 | -3 | -6 | 2 | 2 | 3 | 7 | -42 | -D |
| Ecological and Biological Components (BE) | | | | | | | | | |
| Living beings(vegetation) | 1 | -3 | -3 | 2 | 3 | 2 | 7 | -21 | -C |
| Living beings(fauna) | 1 | -2 | -2 | 3 | 3 | 3 | 9 | -18 | -B |
| Status of ecosystem | 2 | -3 | -6 | 3 | 2 | 3 | 8 | -48 | -D |
| Habitat loss | 2 | -2 | -4 | 3 | 3 | 3 | 9 | -36 | -D |
| Habitat fragmentation | 1 | -3 | -3 | 3 | 3 | 3 | 9 | -27 | -C |
| Social & Cultural components (SC) | | | | | | | | | |
| Mass wellbeing | 1 | -2 | -2 | 1 | 1 | 1 | 3 | -6 | -A |
| Healthiness status | 2 | -2 | -4 | 1 | 1 | 1 | 3 | -12 | -B |
| livelihood circumstances | 2 | -1 | -2 | 3 | 3 | 3 | 9 | -18 | -C |
| Heritage sites | 3 | -2 | -6 | 3 | 3 | 3 | 9 | -54 | -D |
| Livelihood | 4 | 2 | 8 | 2 | 2 | 3 | 7 | -56 | -D |
| Economic & Operational components (EO) | | | | | | | | | |
| Job opportunity | 2 | 2 | 4 | 3 | 2 | 3 | 8 | 32 | C |
| Value of land | 1 | 2 | 2 | 3 | 3 | 3 | 9 | 18 | B |
| Land assets | 2 | -3 | -6 | 3 | 3 | 3 | 9 | -54 | -D |
| Economic base | 2 | 2 | 4 | 2 | 2 | 3 | 7 | 28 | C |
| Constructional zone | 3 | 3 | 9 | 3 | 3 | 3 | 9 | 81. | E |
| farming | 1 | -3 | -3 | 2 | 2 | 3 | 7 | -21 | -C |
| Tourism | 3 | -2 | -6 | 2 | 2 | 3 | 7 | -42 | -D |
| Infrastructural condition | 2 | -3 | -6 | 3 | 3 | 3 | 9 | -54 | -D |

After ( Pastakia, 1998).

**Effect on physical and chemical parts**:

The landscape is an important resource that should be protected for keeping up the social, economic, and political, existence of the human being. A landscape contains the physical components, for example, biotic components landforms of widely varied vegetation. The most exceedingly awful effects of extraction are to disbalance the physical and chemical components in the area under study. These effects get acceleration due to the movements of vehicles and different mechanical types of equipment. Mechanical means of extraction of sand and gravel from the river bed alters the characteristics of the landforms, ensuing damage in biodiversity, the precariousness of the adjoining land, loss of structures/houses, biodiversity and vegetation, quickened disintegration of soil masses, and so forth., Along with stability issues uncontrolled sand and gravel quarrying activities could bring about extensive variation in the landscape of the area. The random mining in the river bed will bring down the water table which may cause water scarcity in the local area. Additionally constancy problems, because of uncontrolled extraction actions could affect extensively the landscape/aesthetics condition of the area (ES = -54/-27).

Extraction in the stream bed will disturb the biological system of the river. Sand and gravel quarrying additionally causes a remarkable negative effect on the quality of the air (ES= -21). The uncovered extraction sites, evacuation of the vegetation cover, and crumbling of sand and gravel causes windborne particulates that sustain in the air for a long time and insist on environmental contamination. Motorized quarrying forms river bed creates a burden in the air which causes respiratory infirmities or other wellbeing impacts when assimilated through the skin. The excavation of sand and gravel, it's stacking, movement of the loaded vehicles along the riverbank, and so on might lessen the neighboring quality of the air. Additionally, the excessive emission of large scale mining dust may decay the neighboring air quality of the region. Arise in the clamor level because of the motorized extraction method. Neighboring farm holders of mining spots are the definitive sufferer of the negative effects of mining activity.

(A) Mining pits hampering river health

(B) River bank slide due to unscientific mining activities

(C) Frequent movement of the heavily loaded vehicle

(D) Mining nearby artificial structures

**Impact on biological components**: Dooar's biological systems are quite different than the other part of the north Bengal, India for an assortment of flora and Fauna. The sand and gravel extraction causes critical harmful effects on vegetation (ES= -21) and animals (ES= -18) of the influenced region. The change in land-use because of quarrying causes loss of habitat (RS= -36) as well as local/agrarian vegetation in the region. The top portion of the surface is the house of many soil bacteria and microbes that keep up soil richness and ferlity as well as uppermost sediment deposits for plant development. Along these lines, the destruction of the sand and gravel at the appropriate time could decrease the net bio-productivity of the region. This type of mining promptly changes the soil profile, quality, and actions adversely influencing the working of the whole biological system (ES= -48). Further, quarrying letdowns the regular natural surroundings of specific creatures possessing in the study region and can even destruct the habitat of some specific animal's environmental annihilation. This type of unscientific quarrying in Eastern Dooars may be misfortunate to humankind.

**Effect on socio-economic conditions**: Based on the previously mentioned unfavorable impacts, sand and gravel quarrying could likewise carry certain temporary constructive advantages or some short-term profits to the individuals of the region. Sand and gravel quarrying can contribute positive effects by generating employment opportunities (ES= 32), a method for the formation of business openings, improvement of the financial base (ES= 28), and land value (ES=18). Among the two types of sand and gravel quarrying typically rehearsed manual and mechanical the manual extraction contributes just medium positive effects while the mechanical produce low positive effects. High positive effect upon cost of the land, simultaneously high negative effect on land holdings (ES= -54), aesthetics land use (ES= -54), and landscape (ES= -54). Sand and gravel quarrying make it hard to reestablish the biological balance to a pre-mine situation, the maximum number of the effects of the action are negative on different environmental segments yet a limited number of certain advantages like business employment and collection of revenue, although just till the asset is depleted. In this way, the uncontrolled extraction from the river bed brings about unfavorable environmental problems in addition to just as social ramifications. shows the conclusive outcomes of appraisal utilizing the RIAM method for extraction exercises in the area.

(E) Workers manually loading vehicles

(F) Manual sieving of extracted materials


(G) Manual crushing of extracted materials


(H) Grading of materials using stone crusher

## 5. Conclusion

Based on the above discussion and perception, it is obvious that unscientific sand and gravel quarrying throughout all seasons have forced hopeless harms to the riverine environments in the Raidak-II river of Eastern Dooars of India. Unscientific stream sand and gravel extraction have created a severe loss of river environments. The absence of enough systematic as well as scientific methods leads danger to the environment appropriately tending to the issue. Hence, there should be an urgent requirement for mounting our pondering on the manmade degradation of the river. This study reveals the way that the river Raidak-II has degraded extensively because of uncontrolled sand mining in recent days The abundance of sand and gravel in Eastern Dooars maintains the ecological balance of the surrounding area. Unpredictable sand and gravel mining will prompt hopeless harms to the living condition. In this way, every action must be taken to manage sand and gravel extraction in the study area with proper mitigation measures. The following are some suggestions to control the adverse and unfavorable impacts of extraction in the area under study.

- Mining should be done on the specific areas identified as safe for mining by the geologist as per the govt. order.
- Sand and gravel extraction, whenever allowed dependent on the scientific way and ought to be done under the supervision of the D.L & DLRO Department, Public Health Department, and Revenue Department. Mining and Geology Department, Pollution Control Board, This is to guarantee that the action is occurring according to guidelines given by the concerned authority.
- The Specific mining site boundary should be well fenced to stay away from a different accident to the local people.
- In dry seasons regular wetting (water splashing) of the streets in addition to the adjacent areas of the extraction site to lessen dirt contamination during extraction or carrying the extracted sand and gravel must be done
- The limits of the plot that are inclined to giving in ought to be fortified with rock dividers or solid structures.
- The prolific top soil ought to be gathered independently and utilized for topping off the zone after consummation of the quarrying procedure.
- Different Awareness programs ought to be conducted to aware of the adverse effect of the sand and gravel and various seminar to be conducted about the sustainable way of sand and gravel mining.

Above mentioned points need to be considered against unscientific sand and gravel extraction activities for improving the health of the river. An extended/modified 'redline idea' of ( Kondolf 1993) is the best way to account for the actual sand that can be extracted from the small river like Raidak-II, specifically.

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