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General Framework

For Imposing

Environmental Damage Compensation

CENTRAL POLLUTION CONTROL BOARD

MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE

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PREFACE

Environmental Damage Compensation (EDC) is a tool guided by 'Polluter Pays' principle, wherein a cost is paid by the polluter responsible for polluting environment and causing damage to its components. It is applicable in both cases where the release of pollutants is sudden or gradual over a longer period, recoverable for the site where injuries to natural resources have occurred.

While, the EDC is calculated on case to case basis and various CPCB guidelines exists for specific cases & sectors for calculating damage cost, need was felt for a general framework for guiding the damage assessment and cost estimation process.

This document helps in identifying direct and indirect damages caused to environment due to anthropogenic activities and retroactive application of Environment Compensation (EC) charges. It also details a standard procedure for damage assessment including preliminary investigation, analysis of data, identification of EDC liabilities, assessment of direct & indirect liabilities, assessment of eco-system damages, detailed investigation of damaged site, analysis of detailed data, determination of EDC scenario and cost, identify best achievable remediation and restoration methods, action plan imposing over-all EDC and monitoring of implementation of plan by regulatory bodies.

A standard format for preliminary investigation of damaged area is provided along with instructions. Two checklists of direct and indirect liabilities for 19 types of anthropogenic hazards are also provided. Indicative methods of damage quantification and EDC estimation have been compiled and placed at Appendix IV for easy reference.

This document was prepared in pursuant to the directions of Hon'ble National Green Tribunal via order dated April 24, 2019 in O.A. 606/2018. It is authored by Shri B. Vinod Babu, Divisional Head WM II, CPCB and co-authored by Smt. Garima Sharma, AS, CPCB with editing support from Shri Sameer Arora, Consultant (Engineering), CPCB.

Member Secretary
Central Pollution Control Board

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PRELIMINARY FRAMEWORK FOR IMPOSING ENVIRONMENTAL DAMAGE COMPENSATION

1.1 Introduction

Environmental damage means the adverse effects induced on environmental properties (or goods) due to anthropic activity, in this context, environmental goods may be natural resources such as air, soil, surface water, groundwater, flora and fauna, ecosystem, biodiversity and the services they provide to ecosystem or to humans. Some of the ecosystem services are purification, productivity, landscape, climate regulation, nutrient cycling, disturbance prevention and natural mitigation, etc.

Environmental Damage Compensation (EDC) is a cost to be paid by the polluter responsible for causing environmental damage by release of harmful substances or pollutants in excess of stipulated standards due to inadequate control equipment or negligence. Release of pollutants may be sudden or slow and gradual manner in excess of standards over a longer period.

Realising the need for the same, Hon'ble NGT vide its order dated April 24, 2019 in O.A. 606/2018, noted that it necessary to recover cost of environmental damages from identified polluters based on polluter pay principle by undertaking assessment of environmental damage. This concept is needful for effective enforcement of environmental laws.

EDC is also based on the precautionary principle that ensures operators to take appropriate action to prevent environmental damage from occurring. Under the "polluter pays" principle the responsible party will be required to restore environmental damage and also responsible for compensating consequent damages caused on receptors.

It is necessary to ensure that EDC maximize the welfare of receptor population, restoration of environment as well as maintain sustainable environment and eco-systems, however at the same time, scientifically estimated EDC is necessary to justify costs imposed on polluter-pay-principle.

Monetary valuation of environmental damages is a complex process involving multidisciplinary juridical, technical and economic analysis is necessary. Following challenges may arise in assessing environmental damages;

- Establish existence of the damage
- Establish cause-effect link between the damage and the unauthorised or negligent activities;
- Quantify or determine extent of damage;
- Identification of suitable methodologies to valuate damages.

1.2 Environmental Damage Compensation

Environmental Damage Compensation (EDC) is a quantifiable and reasonably estimable future expenditure as on date for restoration of environmental damages caused due to anthropogenic release of pollutants in excess of permissible limits or unauthorised activity. Environmental damage compensation is apportioned to one or more factors relating to degradation of air quality, water resources, soil, groundwater, adverse effect on human health, loss of eco-system services, including damages caused to property, natural assets and productive assets. Thus, EDC includes cost of assessments, cost of restoration and compensation for direct and indirect damages caused to human, property, flora, fauna including ecosystem functions.

1.2.1 Direct Damages

Direct damages or general damages occur through direct interaction of polluting activity with an environmental, social, or economic component. For example, discharge of untreated sewage into a river may lead to a decline in water quality in terms of BOD, DO or rise in bacterial contamination.

1.2.2 Indirect Damages

Indirect or consequential impacts on environment often seen away from source and often occur in pathway of impact. Indirect impacts can also be secondary or even third level impacts. For, example, rainwater run-off over a dumpsite may contaminate a receiving water body with heavy metals or other toxins, which in turn lead to a secondary indirect impact on aquatic flora (phytoplankton) in that water body. This may effect fish population in impacted water body, thereafter, reduction in fish yield may affect income of farming is third level socio-economic impacts.

As discussed, Environmental damage compensation would require monetizing cumulative activities preliminary site investigation, detailed site assessment, restoration and also compensation for environmental and ecological losses arising from direct and indirect damages.

1.2.3 Applicability

Environmental compensation need to be imposed retroactively. Principle of strict liability shall be exercised on the polluter while implementing environment damage compensation. Strict liability is imposition of liability on the polluter without finding a fault such as exceedance of standards, negligence or ill intention.

In cases where two or more persons are liable in respect of damage, principle of joint and several liabilities may be imposed. Under joint and several liability, a State may pursue obligation of EDC

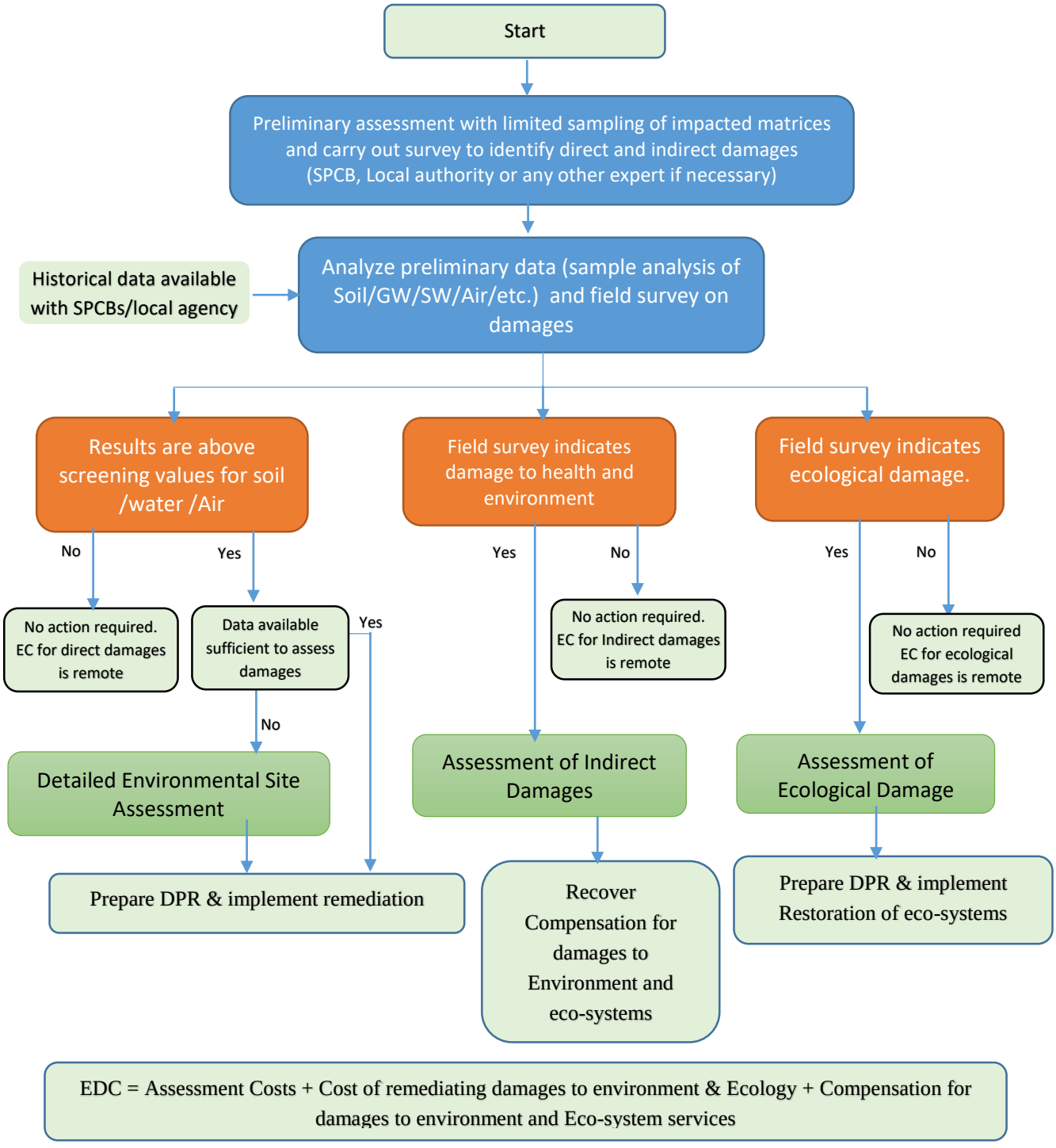
against any one party as if parties were jointly accountable and it becomes responsibility of the defendants to sort out their respective proportions of obligation and payment.

1.3 Scope of EDC & Standard Flow Model for estimating EDC

A standard procedure shall be followed for estimation of damages due to anthropogenic polluting activities. It includes following steps,

i. Preliminary investigation
ii. Analysis of preliminary data
iii. Identification of EDC liabilities
iv. Assessment of direct, indirect liabilities
v. Assessment of eco-system damages
vi. Detailed investigation of damaged site, if required
vii. Analysis of detailed data
viii. Determination of EDC scenario and cost
ix. Identify best achievable remediation and restoration methods
x. Directions/ action plan imposing over-all EDC
xi. Monitoring of implementation of plan by regulatory bodies

The Standard Flow Model for estimating EDC is as presented below,


Start
Preliminary assessment with limited sampling of impacted matrices and carry out survey to identify direct and indirect damages (SPCB, Local authority or any other expert if necessary)
Historical data available with SPCBs/local agency
Analyze preliminary data (sample analysis of Soil/GW/SW/Air/etc.) and field survey on damages
Results are above screening values for soil /water /Air
Field survey indicates damage to health and environment
Field survey indicates ecological damage.
No
Yes
Yes
No
Yes
No
No action required. EC for direct damages is remote
Data available sufficient to assess damages
Yes
No action required. EC for Indirect damages is remote
No action required EC for ecological damages is remote
No
Detailed Environmental Site Assessment
Assessment of Indirect Damages
Assessment of Ecological Damage
Prepare DPR & implement remediation
Recover Compensation for damages to Environment and eco-systems
Prepare DPR & implement Restoration of eco-systems
EDC = Assessment Costs + Cost of remediating damages to environment & Ecology + Compensation for damages to environment and Eco-system services

1.3.1 Preliminary investigation

Following scope of work identified for reconnaissance and preliminary investigation of damaged site;

- To conduct field visits, visual site inspections, review of existing documents, maps and literature and carry out the following activities.
- Current sources of contamination at site and process of release in the influence area.
- Collection of history/background information of the contaminated site
- Basic features of the site i.e. collection of available information on the site like site maps (topographical, geological), hydro-geological information, information from local authorities, information on the type of polluting-sources at site.
- Identification of previous and current land use pattern of the site
- Identification of parameters causing immediate threat to the ecology and environment.
- Discussion with local people and other informed people, district administration, municipal and regulatory authorities, NGOS, etc.
- Selection of the available observation wells (Bore Well) in the watershed covering the site, for monitoring water level and quality monitoring at appropriate locations, & inventory details like total depth of the well, water column; frequency of sampling (pre monsoon/ post monsoon)
- Description of area with respect to existing land use, potential areas of environmental/ecological risk, demographic profile, social economic and environmental conditions of the people in receptor areas, flora and fauna etc.
- Information of prevailing or commonly reported health issues in the area
- Collection of preliminary samples and analysis of soil, sub-soil, surface water, ground water for comprehensive analysis of major ions and heavy metals, organic constituents, pesticides and other relevant parameters related to the contaminated site as per national / international accredited testing procedures.

1.3.2 Analysis of preliminary data

- Based on preliminary survey and sampling, a detailed sampling protocol aimed at assessing the contamination level of the site and to establish the baseline environmental status of the project area shall be prepared. The protocol shall include identification of criteria pollutant (parameters) for analysis, sampling frequency (number of seasons), number of samples, etc. and shall be submitted for approval of concerned authorities.
- Identification of Benchmark /Background samples.
- Outlining the extent of contaminant plume or contaminated area based on field survey and preliminary findings.
- Establishing conceptual site plan/model showing link between source and receptor. It comprises three elements (i) Potential sources of contamination, (ii) Potential receptors that may be harmed and (iii) Potential pathways linking the two

1.3.3 Identification of direct and indirect EDC liabilities

This guidance document provides a broad framework for identifying damages, assessing damages and imposing compensation for environmental damage. Step-wise approach shall be adopted for activities such as preliminary assessment, identification of direct and indirect liabilities, detailed environmental and ecological studies, assessment of damages, calculation of compensation for direct and indirect liabilities.

- Following direct liabilities will be applicable for assessment and restoration;
    - Soil and sediment contamination
    - Groundwater contamination
    - Contamination surface bodies
    - Damages to eco-systems

These ecological impacts may constitute clearing/fragmentation/alteration/destruction of native vegetation, animal habitats, pollution of watercourses and wetlands, sediment, nutrient and pollutant run-off into adjacent vegetation and animal habitats, loss of hollows, nesting and feeding habitats for birds, etc. Some of the activities that may cause ecological damages are as given below;

- Sand mining

- Mining activity
- Industrial discharge of wastewater
- Dumping of hazardous wastes and chemicals
- Deforestation
- Release of air pollutants

- The direct liabilities with respect to Air pollution are,
    - Compensation for release of air pollutants in excess of permitted quantities
    - Compensation for release of toxic gases from process

- Indirect damages are those damages which are not directly accountable to an action and may either be fixed or variable. A few important indirect damages are,
    - Cost of compensating indirect damages
    - Social responsibility for supply of safe drinking water
    - Resettlement/Relocation
    - Loss of life
    - Permanent, temporary, total or partial disability or other injury or sickness
    - Loss of wages due to total or partial disability or permanent or temporary disability
    - Medical expenses incurred for treatment of injuries or sickness
    - Damages to private property
    - Expenses incurred by the Government or any local authority in providing relief, aid and rehabilitation to the affected persons
    - Loss to the Government or local authority arising out of, or connected with, the activity causing any damage
    - Local claims including cost of restoration on account of any harm or damage to environment including pollution of soil, air, water, land and eco-systems
    - Loss of business or employment or both

- Any other claim arising out of, or connected with environmental and ecological damages due to release of pollutants
- Long term monitoring costs (for options such as monitored natural attenuation)
- Claims on account of harm to milch and draught animals
- Claims on account of harm to aquatic fauna
- Claims for loss due reduced fishing yield in ponds, rivers or sea

Impacts to the environment can be caused through a variety of mechanisms. It is not the intent of this report to capture all possible contamination scenarios that may occur in a multitude of permutations and combinations that may impact the natural resources. However, this report addresses environmental impacts arising from prominent anthropogenic polluting activities which contaminate natural resources and impact receptors. A check-list of environmental damage scenarios and applicable compensation liabilities is placed at Appendix II & III.

1.3.4 Assessment of direct and indirect liabilities

Development of national framework on environmental damage assessment is a complex exercise requiring consultations with multi sectoral experts of environmental economics, remediation, cost estimates, etc. CPCB utilized expertise of Expert Group comprising experts on damage assessment, environmental economics, valuation, etc. A meeting of Expert Group was held on May 16, 2019 at Central Pollution Control Board to guide efforts for exploring development of national framework. It was suggested that a standard procedure for calculating best estimation of damages due to different scenarios of anthropogenic polluting activities need to be developed over time for quantification and estimation of environmental damages.

In case of environmental damages arising due to improper handling of hazardous wastes, guidelines on imposition of environmental liability published by CPCB may be referred. Indicative methods for assessment of environmental damage compensation for air pollution, river pollution, soil and groundwater is placed at Appendix IV. Specific studies would be necessary for assessing EDC depending on nature of damage. Cost for penal or deterrent charges and criminal damages have not addressed in this reference document while estimating EDC.

1.3.5 Assessment of Eco-system liabilities

Quantification of ecological damages is analytical measure of the extent, severity and duration of the damage in terms of alteration, which is an adverse variation with respect to the baseline condition of the natural resources and services; deterioration, which is a partial loss of the ability of the natural resource to provide an ecological or public service; partial destruction, which is the loss of one or more services; and total destruction, which is the loss of all the services. Thus, assessment of eco-system damage is complex and location specific. It is required to be done on case to case basis by collection, compilation and assessment of data on biological environment, ecosystem functions, communities, etc. in the damaged area. In view of time constraint, the same may be done using archive data available with local agencies & concerned institutions.

1.3.6 Detailed investigation of damaged site, if required

Detailed investigation is build up on findings of preliminary investigation, including extent & significance of direct and indirect damages. Detailed assessment should be carried out as per pre-determined sampling protocol approved by concerned authority. Scope of detailed assessment in case of contaminated areas is given below;

- Clearly delineate the boundaries, longitudinal and cross section of the contaminated site through topographic and other engineering surveys and prepare a base map of the site.
- Water, soil, sediment, and air quality assessment - analysis of criteria pollutants
- Collect data on geological, hydrogeological and hydrological features of the contaminated site - if required necessary studies shall be carried out.
- Development of groundwater flow, surface water flow and mass transport models.
- Estimate the quantity of contaminants and their concentrations including secondary pollutants.
- Socio - economic and environmental assessment of the contaminated area.
- Assess the potential environmental/ecological/health impacts on soil, ground water, surface water bodies, population, flora and fauna
- Pathways of contaminant transport, fate of the contaminant and exposure.
- Assessment of toxicity, bioavailability, biodegradability and mobility of contaminants.

- Identification of significant receptors and establishing trigger values.
- Use suitable quantitative or qualitative risk assessment model.

This report does not prescribe detailed methodology for assessing environmental damages. However, an indicative checklist of possible types of damages and parameters indicating indirect impacts on environment is given at Appendix II & III.

1.3.7 Analysis of detailed data

Analysis of data from detailed investigation data will determine the applicable damages for environmental compensation, which should be estimated as per specified methodology, that may be evolved on case to case basis. Some of the indicative methods for assessment of environmental damage compensation for air pollution, river pollution, soil and groundwater are given at Appendix IV.

1.3.8 Determination of EDC scenario and cost

As discussed earlier, environmental damage compensation is cumulative of one or more factors relating to environmental degradation of air quality, water resources, soil, groundwater, adverse effect on human health, loss of eco-system services, including damages caused to property, natural assets and productive assets. Thus, EDC includes cost of assessments, cost of restoration and compensation for direct and indirect damages caused to human, property, flora, fauna including ecosystem functions etc., identified during detailed assessment study.

Environmental Damage Compensation comprises of (i) assessment obligation, (ii) remediation obligation (iii) restoration obligation (iv) compensation to affected third party (v) obligation to compensate damage to natural resources. Thus environmental damage compensation can be calculated as below;

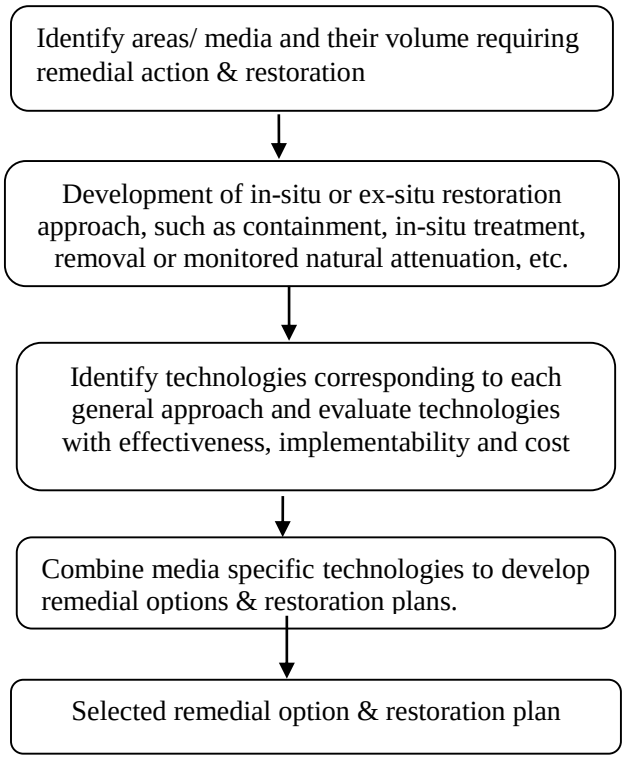
EDC = Assessment Costs + Cost of remediating damages to environment & ecology + Compensation for damages to environment and eco-system services

The concerned regulatory agency (or SPCBs/PCCs) may approve applicable EDC scenario.The key parameters that will ultimately dictate the level and costs of remediation activities are degree of ecological damage, number of impacted receptors, impacted media volumes, volume of indirect damage liabilities,

pollutants (constituents) of concern, number of contaminants, impact matrix, current and intended future land use, migration of contamination, etc.

1.3.9 Identify best achievable remediation and restoration methods & its cost

Having completed the preliminary and detailed site assessment as above, the polluter may be liable to undertake remediation and restoration activity, as applicable. A remediation plan is to be prepared specifying most applicable remedial technology to bring the site-specific contamination levels down to no risk or an accepted risk level (based on environment/ human health scenario) and estimated costs for remediation. Upon review of the same, the concerned agency (or SPCB/PCC) may specify remediation objective and site specific target levels for restoration for specific constituents of concerns along with intermediate target levels vis-à-vis time schedule so as to monitor the progress of remediation. Evaluation and fixation of site specific target levels for restoration of environmental and ecological damages may be specified by concerned SPCB/PCC on their own or by constituting an Expert Committee thereof. A restoration plan of the site may be evaluated by concerned SPCB/PCC or Expert Committee and target levels fixed for intermediate monitoring. An indicative approach for arriving at an appropriate remediation option and restoration plan is presented in the flow sheet below,



Expert Committee may also finalize applicable compensation liabilities due to indirect damages based on detailed investigation studies.

Once the plan with site specific target levels is approved by the agency (or SPCBs/PCCs), responsible party shall undertake site restoration accordingly under supervision of agency or any third party appointed for the same. During such period, few sampling and analysis shall also be carried out by the SPCB/PCC for validation.

1.3.10 Directions/ action plan imposing over-all EDC

Upon receipt of the assessment reports, which shall comprise of damage assessment, remediation objective and restoration plans along with the cost estimation and time schedule, the concerned agency (SPCB/PCC) may firm up the remediation objective and duly approve the plan for implementation by specifying site specific target levels. Directions may be issued to responsible party(ies), as necessary.

1.3.11 Monitoring of implementation of plan by regulatory bodies

The approved restoration plan and recovery of environmental compensation for damages caused to environmental properties shall be executed by the responsible party(ies), which may be monitored by SPCB/PCC as per the time schedules and phase wise remedial targets thereof as declared in the assessment report so as to meet the said remediation objective/standard. During such monitoring, few sampling and analysis thereof shall also be carried out by the SPCB/PCC for validation.

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APPENDIX I

FORM - I

FORMAT FOR PRELIMINARY INVESTIGATION OF DAMAGED AREA

1.	Date and time of inspection	
2.	Location of damaged area	
3.	Coordinates of damaged area	
4.	Nature of damage	
5.	Possible cause of damage	
6.	Single source contamination or multi source contamination	
7.	Estimated date or duration of activity resulting in damage	
8.	Impacted receptors (tick whichever applicable)	□ Air □ Surface water …… □ Drinking water □ Ground water □ Soil □ Sediment □ Flora □ Fauna

		□ Cattle □ Crops/ Agriculture land/ Orchid □ Infrastructure/property □ Others…….
9.	Pollutants suspected to be discharged	
10.	Pollutants of most concern	
11.	Estimated quantification of damage media (in terms of area, volume, numbers, percentage, as applicable and possible)	
12.	Land use (industrial, commercial, agricultural, residential, combinations thereof, etc.) Specify if needed.	Historic Current Future
13.	Site situation (climatic conditions, hydrology, groundwater flow, surface waters, underground structures, etc. in damaged area)	
14.	Type of geology (sand, clay silt, weathered rocks, fracture rocks, competent rocks)	
15.	Depth to ground water (m) (if applicable)	
16.	Offsite migration of pollutant possible, specify	Yes / No
17.	Location of damaged area with respect to nearby wetland or eco-sensitive areas (if any)	

18.	Location of damaged area with respect to sensitive receptors that could possibly require remedial actions such as, potable water supply, surface water bodies, residential area, sensitive ecosystem, etc.	
19.	Any immediate measure taken to control damage, specify	Yes / No
20.	Any other observation requiring mention,	
21.	Documents to be attached (if available) ▪ Relevant permits, consent, license, etc. (if applicable) ▪ Site layout map ▪ Photographs ▪ Videos	

Signature

Name & designation of team members

Date & Place

INSTRUCTIONS FOR FILLING FORM - I

- This form serves as a preliminary factsheet to gather general information on damaged site
- The inspecting team shall perform dry inspection including observation of damaged site, neighborhood & operations/ activities in the area, interviewing stakeholders/site/receptors representatives, collecting records & reports available, taking photographs or making videos, etc.
- Preliminary inspection can be a rapid walk-through inspection or slightly more elaborated, if required.
- While informing 'nature of damage' and 'possible cause of damage', an estimate may be made on most possible scenarios that may have occurred resulting in environmental damage to the site. In case, team fails to make an estimate, a list of probable scenarios may be prepared.

- ‘Pollutants suspected to be discharged’, it is required to mention all the pollutants suspected to have been discharged during the incident. However, with respect to information under ‘Pollutants of most concern’, it is to remember that it is the function of nature of pollutant, its impact of human & environment, toxicity and concentration at damaged site. For example, it may include but not limited to a pollutant which is carcinogenic or hazardous or radioactive. It may include toxic pollutants which are pollutants or combinations of pollutants, including disease-causing agents, which after discharge and upon exposure, ingestion, inhalation or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions, (including malfunctions in reproduction) or physical deformations, in such organisms or their offspring.
- ‘Estimated quantification of damage media’, in case air quality is affected, it may be reported in terms of area and population under direct impact and physical observations on air quality.

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APPENDIX II

CHECKLISTS OF DIRECTLY IMPACTED ENVIRONMENTAL COMPONENTS

The most possible scenarios that may occur due to anthropogenic activities resulting in damage to environment and applicable compensation scenarios are as given in Tables below,

Type of damage	Directly impacted environmental properties (tick the appropriate box)					
	Ambient air	Ground Water	Surface Water	Soil	Sediment	Ecology
Effluent discharge from an industry exceeding limits/ untreated or inadequate pollution control device	√ (VOCs & Acidic fumes)	√	√	√	√	√
Emission from an industry or incinerator; absent or inadequate pollution control device	√			√	√	√
Un-scientific dumping of municipal solid waste	√	√	√	√		√
Untreated sewage in water bodies		√	√		√	√
Improper disposal of C&D Waste	√					
Leakage or failure of sanitary and secured Landfills		√		√		
Unscientific recycling of E-Waste	√	√	√	√	√	

Type of damage	Directly impacted environmental properties (tick the appropriate box)					
	Ambient air	Ground Water	Surface Water	Soil	Sediment	Ecology
Improper disposal of bio-medical waste						√
Biomass burning	√			√		
Vehicular emissions exceeding limit	√					
Diesel generator sets exceeding limit	√					
Road dust & soil dust	√					
Illegal Hazardous waste dumping by industry		√	√	√	√	√
Chemical spills or leakages	√ (Gases, VOCs & fumes)	√	√	√	√	√
CETP – Failing to meet standards (case to case basis)			√		√	√
Fire, explosions, Reactions of hazardous substances/wastes (case to case basis)	√		√	√		√
Marine spills			√	√ Beach	√	√
Mining Activity	√	√	√	√	√	√

APPENDIX III

CHECKLIST – APPLICABLE COMPENSATIONS FOR INDIRECT IMPACTS

Type of Environmental damage	Parameters indicating indirect liabilities for compensation												
	Supply Drinking water	Harm to Flora & fauna, animals	Property damage	Loss of ecological services	Resettlement/ relocation/ Relief	Health	Injury /sickness	Loss of life	Loss of recreation	Reduced yield fishing / agriculture	Loss of earnings	Medical expenses	Other claims indirect losses
Un-acceptable Effluent discharge from an industry	√		√	√		√	√	√	√	√	√	√	√
Un-acceptable Emission from industry or incinerator	√	√	√	√	√	√	√	√	√	√		√	√
Un-scientific dumping of municipal solid waste	√	√	√		√	√	√	√	√	√			Monitoring etc.
Untreated sewage in water bodies	√	√		√		√			√	√			

Type of Environmental damage	Parameters indicating indirect liabilities for compensation												
	Supply Drinking water	Harm to Flora & fauna, animals	Property damage	Loss of ecological services	Resettlement/ relocation/ Relief	Health	Injury /sickness	Loss of life	Loss of recreation	Reduced yield fishing / agriculture	Loss of earnings	Medical expenses	Other claims indirect losses
Improper disposal of C&D Waste		√	√	√		√							Noise
Leakage or failure of sanitary and secured Landfills	√	√		√	√	√	√	√	√	√			Visual nuisance, Odour
Unscientific recycling of E-Waste	√	√		√		√	√	√		√			
Improper disposal of bio-medical waste	√	√		√		√	√	√		√			
Biomass burning		√				√	√						√
Diesel generator sets exceeding limit		√		√		√	√						√
Road dust & soil dust		√	√			√				√			

Type of Environmental damage	Parameters indicating indirect liabilities for compensation												
	Supply Drinking water	Harm to Flora & fauna, animals	Property damage	Loss of ecological services	Resettlement/ relocation/ Relief	Health	Injury /sickness	Loss of life	Loss of recreation	Reduced yield fishing / agriculture	Loss of earnings	Medical expenses	Other claims indirect losses
Illegal Hazardous waste dumping by industry	√	√	√	√	√	√	√	√	√	√	√	√	
Chemical spills or leakages	√	√	√	√	√	√	√	√	√	√	√	√	√
CETP – Failing to meet standards (case to case basis)		√				√	√		√	√	√	√	√
Fire, explosions, Reactions of hazardous substances/wastes (case to case basis)		√	√	√	√	√	√	√	√		√	√	√
Marine spills		√	√	√		√	√		√	√	√		√
Mining Activity	√	√	√		√	√	√	√	√	√	√	√	√
Deforestation	√	√		√	√	√			√	√	√		√

APPENDIX IV

INDICATIVE METHODS OF DAMAGE QUANTIFICATION & EDC ESTIMATION METHODS

1. AMBIENT AIR

1.1 Applicability

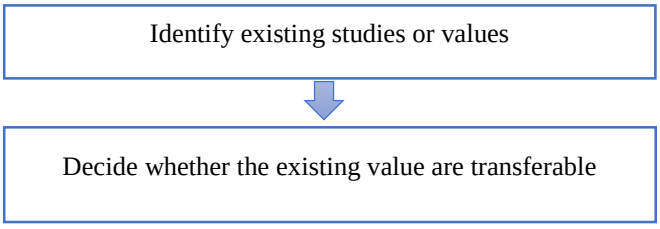
- Discharge of air pollutants from ducted and/or non-ducted emissions above prescribed limits or general standards
- Deposition of toxic particulates on land from localized air polluting source (lead, mercury, cadmium, etc.)
- Formation of complex secondary pollutants due to nucleation, condensation and other chemical reactions of primary pollutants discharged from a polluting activity

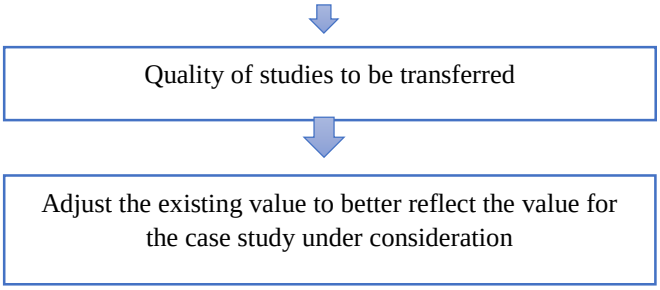
1.2 Quantification

The monitoring & analysis of applicable parameters (as per prescribed norms) upwind, mid site and downwind may be conducted as per established methods of measurement. Dispersion model such as AERMOD, CALPUFF, CALINE, etc. can be used to determine the change in concentration over the specific area. For estimating affected population, ArcGIS can be used or else can be done manually using population details available in public domain for damaged site and downwind area.

1.3 Estimating cost due to mortality & morbidity using direct cost transfer method

This method is based on the method of transferring available information from already completed studies in another location or context. It is economical and less time consuming than other available method for economic assessment. It can be used as a screening process to decide whether original valuation study would be required or not. Steps for valuation through this method are as presented below,





For ease of understanding, a case study by Muller & Mendelssohn, 2007 is used for estimating damage cost due to mortality and morbidity (Chronic bronchitis, Cardiac issues etc) due to air pollution in an area using direct cost transfer method. Assuming that the conditions at the referred site are similar in total or portion to damaged site under study, we utilize cost estimates of referred study to deduce cost per tonne of pollutant emitted reworked to Indian context by considering exchange rates and inflation.

Damage cost on Health (Rs/tonnes) = Damage cost per tonne (USD, 2011) × Exchange rates × inflation

It is elucidated as below,

Damage cost due to mortality and morbidity per tonne of emitted pollutants				
Sl. No	**Pollutant**	**Damage cost per tonne (USD,2011)***	**Damage cost per tonne (INR)****	**Damage cost per tonne (2019)*****
Mortality				
1	NOx	319.82	22,084	36,062.15
2	VOC	143.79	9,929	16,213.6
Morbidity				
1	NOx	5.07	350	571.53
2	VOC	2.24	155	253.11

**Findings of referred study*

***Exchange rate applied*

****Inflation rate applied*

1.4 Estimating cost of life & health through value of statistical life and disability adjusted life year

Value of statistical life (VSL) is the amount people are willing to pay to reduce risk so that on average one less person is expected to die from the risk. Alternatively, it can be thought of as how much people are willing to pay for safety. VSL estimates are based on studies of the wage compensation for occupational hazards or studies that elicit people's willingness to pay for mortality risk reduction directly. On the other hand disability-adjusted life year (DALY) is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. Both of these values are powerful indicators for understanding impacts of air pollution on affected population. There are numerous studies done for calculating VSL. With regard to DALY, values are published in WHO publication "Global Burden of Disease'.

The mortality cost is calculated using following equation,

$Tc\ (Mortality) = Pa \times VSL \times (1+i)^n$

Where,

Tc = Total mortality cost

Pa = Affected Population (calculated as below)

VSL = Value of statistical life (Using data from existing literature)

i = inflation rate

n = number of years

The morbidity cost is calculated using following equation,

$Tc\ (Morbidity) = Pa \times DALY \times Ai \times (1+i)^n$

Where,

Tc = Total morbidity cost

Pa = Affected population (calculated as below)

DALY= Disability Adjusted Life Years (Using data from WHO database)

Ai = Annual Income (Using data from latest National / State economic survey reports)

i = inflation rate;

n = number of years

The value for Pa is calculated using equation below,

Pa = AF × Bi × Pe

Where,

Pa= Affected Population

Pe, Exposed Population = (Total population * ambient concentration of pollutant / relative risk)

Bi = Baseline Incidence*

AF, Attribution Factor** = ((Relative Risk- 1) / Relative risk)

*It is expected level of disease that is usually present in a community. Baseline Incidence per 100,000 population is based on threshold limit given in WHO guidelines.

**Attributable risk is the rate (proportion) of a disease or other outcome in exposed individuals that can be attributed to the exposure. Further, relative risk is the ratio of the risk of occurrence of a disease among exposed people to that among the unexposed. WHO guidelines provide value of relative risks for various air pollutants and relevant diseases.

1.5 Estimating cost of impacts on biodiversity, crops & property

Direct cost transfer method is most suitable and less time consuming method for estimating damage cost with respect to crops, flora fauna, orchids, cattle, property, etc. The results from referred study are transferred to the site under assessment and values are adjusted considering exchange rates and inflation. It is presented below for a study on effects on flora due to NOx & VOC conducted by Muller & Mendelssohn, 2007,

Damage cost due to effect on flora due to pollutants				
Sl. No	**Pollutant**	**Damage cost per tonne (USD,2011)**	**Damage cost per tonne (INR)**	**Damage cost per tonne(2019)**
1	NOx	28.67	1980	3,233.25
2	VOC	14.96	1033	1,686.84

2. SURFACE WATER

2.1 Applicability

- Discharge of untreated or partially treated effluent into nearby streams or nalla ultimately discharging into larger surface water bodies
- Runoff from waste dumps entering into surface water bodies
- Variety of exposure pathways to receptor including but not limited to dermal contact with polluted water, ingestion by human, ingestion by livestock & its potential bioaccumulation in foodchain, ingestion by aquatic species
- Pollutants include organic, inorganic constituents, pathogens, nutrients, suspended solids, radioactive pollutants, oil & grease, thermal pollution, etc.
- Damage to human health, water supply suspension, fishery, recreational function, biological diversity, environmental property and indirect damages

2.2 Quantification of discharge of conservative substances into rivers

This method can be applied to calculate concentration of conservative substance such as, total dissolved solids, chlorides and certain metals which remain conserved i.e. there is no losses due to chemical and biological degradation and its concentration remains unchanged until the encroachment of next tributary. If the source of discharge is a point source (that enter from a fixed discharge point such as effluent pipe or tributary stream), downstream concentration of pollutant can be estimated by using mass balance principle at the point of discharge. Assuming that the river is homogeneous with respect to water quality parameter across its depth and height. Also there is no mixing of one parcel with another due to dispersion and velocity gradient. The order of magnitude of the distance from a single point source to the zone of complete mixing is obtained from following equation (Muller & Thomann)

$$Lm = 2.6\, U \frac{B^2}{H} \qquad \text{(For side bank discharge)}$$

$$Lm = 1.3\, U \frac{B^2}{H} \qquad \text{(For midstream discharge)}$$

Where,

L_m = distance from the source to the zone where discharge has been well mixed in ft

U = average stream velocity in fps

B= average stream width in ft

H= average stream depth in ft

By assuming complete mix condition, the principal statement for mass balance at outfall will be

mass rate of substance upstream + mass rate added by outfall = mass rate of substance immediately downstream from outfall,

$$Q_uS_u + Q_eS_e = QS$$

$$S = \frac{QuSu+QeSe}{Q}$$

Where,

Q_u, S_u = Upstream flow and upstream concentration respectively

Q_e, S_e = Outfall flow and concentration respectively

Q, S = Downstream flow and downstream concentration respectively

Assuming upstream concentration of substance as zero (S_u= 0), then downstream concentration can be calculated using equation given below,

$$S = (\frac{Qe}{Q}) \times Se$$

2.3 Quantification of discharge of non-conservative substances in river

Non conservative substances decay with time due to chemical reaction, bacterial degradation, radioactive decay, or settling of particles. Thus, assuming that the decay of substance is according to a first order reaction, i.e. rate of loss of substance is proportional to concentration at any time.

At boundary condition i.e. S= S_0 at x= 0 where So is calculated from equation above and by assuming uniform cross-sectional area, the concentration of non-conservative pollutant can be determined using equation below,

$$S = s_0\, e^{(\frac{-Kx}{U})}$$

Where K is the decay rate, since x/u = t (time to travel a distance x at velocity u)

2.4 Quantification using modelling approach

USEtox model can be used for calculation of characterization factor of toxic pollutant. This model offers more than 1250 substances and reflect more updated knowledge and data on effect factors. This model was specifically designed to determine the fate, exposure and effect of toxic substances with the ability to consider spatial differences with the country specific parameters. The characterization factor in the USEtox model includes a Fate Factor (FF), Exposure Factor (XF) and an Effect Factor (EF).

2.5 Cost estimation to human health damage

Evaluation of economic losses related to human life and health includes sum of two components (i) evaluation of cost of fatality (ii) evaluation of cost of affected persons.

$$\boldsymbol{L_{HH} = V_d N_d + \sum_{k=1}^{3} V_{k,p} N_{k,p}}$$

Where,

L_{HH} = Total cost to human health damage

V_d = Economic loss of one fatality

N_d = Number of fatalities

$V_{k,p}$ = Economic valuation of affected person in the category k

k= 1 slightly affected, k= 2 severely affected, k= 3 very severely affected

$N_{k,p}$ = Number of person affected

<u>Evaluation of cost of one fatality</u>

According to " the year of potential life lost" proposed by U.S. Centres for diseases control and prevention in 1982 , life is valued in proportion to person's potential economic production. Cost of one fatality also includes living cost of dependents. Thus cost of one fatality depend on age of victim, his income, number of dependent on him. The life expectancy of healthy human is assumed to be 80. Cost of one fatal victim is presented in table below,

Cost of one fatal victim ('a'= age of victim, 'ae'= age of dependant elder, 'ay'= age of dependent child)				
		a <60	60 < a < 75	a >= 75
Victim's own loss in age 'a'		Income×20	Income×(80-a)	Income×5
Cost of dependent's living needs	Living expenses of one elder of age 'ae'	60 <ae <75	ae >= 75	
		Income×(80-ae)	Income×5	
	Living expenses of one child of age 'ay'	Income ×(18 - ay)		

Evaluation of cost of affected person

Evaluation of affected people is the function of their age and severity of affect. It is classified into three categories slightly affected, severely affected and very severely affected using coefficient of 0.4, 0.7 and 1 respectively. Duration of sick leaves and medical fees associated with the cure of affected people is also taken into consideration while evaluating economic valuation of affected people.

Evaluating cost of one affected victim			
Detail of loss estimation	Slight	Severe	Very severe
Affected people own loss and living cost of the dependant	Cost in homologous death ×0.4	Cost in homologous death ×0.7	Cost in homologous death ×1
Loss of sick leaves	Average daily wages × dh × 3		
Medical Fees	Average hospitalization expenses		

2.6 Estimating cost of damage to fisheries

Surface water pollution directly affects the fish yield, to recover the same certain time period is required. Assuming that fishing is forbidden before recovery of fish yield, the economic loss of damage to fishery can be evaluated using the following equation,

$$\mathbf{L_f = AI_f \times rt}$$

Where,

L_f = economic loss due to damage to fishery

AI_f = annual gross income from fisheries in polluted water

rt = the recovery time of aquatic product (for estimating same AQUATOX model, by USEPA can be used)

Estimating cost of damage to recreational function

Surface water pollution affects the economic function of recreation activities such as swimming, angling, boating etc. To evaluate the cost of damage to recreation functional, following equations can be used. The data required on number of people swimming, boating, angling in the concerned water body per day can be obtained from local agencies or socio-economic studies conducted in the area.

$L_R = L_{SM} + L_{BT} + L_{AG} + L_{LM}$	L_R : the loss of damage to recreation L_{SM} : the loss of swimming L_{BT} : the loss of boating L_{AG} : the loss of angling L_{LM} : loss of leisure means
$L_{SM} = P_{SM} \times N_{SM} \times d$	P_{SM} : the price of replacement of swimming per person (rs/cap/ day) N_{SM} : the number of people swimming in the water per day (cap/ day) d : duration of the pollution episode (day)
$L_{BT} = P_{BT} \times N_{BT} \times d$	P_{BT} : the price for replacement for boating (rs/cap/ day) N_{BT} : the number of people boating in water per day d : duration of pollution episode (d)
$L_{AG} = P_{AG} \times N_{AG} \times d$	P_{AG} : the price for angling for boating (rs/cap/ day) N_{AG} : the number of people angling in water per day d : duration of pollution episode (d)

2.7 Estimating cost of damage to environmental property loses

Pollution released in water bodies deteriorate the water quality and decrease the value of surface water. Pollutant may also deposit in sediments and percolate in nearby sources of groundwater. Pollution clearance cost analysis is applied to evaluate the cost associated with damage to environmental property due to water pollution using following equations,

$L_{EP} = C_{SW} + C_{GW} + C_{SO}$	L_{EP} = loss of environmental property (rs) C_{SW} = cost of pollutant removal from surface water C_{SO} = cost of pollutant removal from sediment C_{GW}= cost of pollutant removal form ground water
$C_{SW} = P_{SW} \times V_{SM}$	P_{SW} = price of removing pollutant from surface water (rs/m^3) V_{SM} = the volume of polluted surface water (m^3)
$C_{GW} = P_{GW} \times V_{GM}$	P_{GW} = price of removing pollutant from ground water (rs/m^3) V_{GM} = the volume of polluted ground water (m^3)
$C_{SO} = P_{SO} \times A_{SO}$	P_{SO} = price of sediment remediation (rs/m^2) A_{SO} = the area of polluted sediment (m^2)

3. GROUND WATER

3.1 Applicability

- Leaching of contaminants from wastes dumped onto open parcels of land
- Leaching of chemicals from storage tanks or leaking underground storage tanks/ fuel tanks/ septic tanks
- Leaching of contaminants from landfills that are leaking below ground
- Reverse injection of effluent into deep injection wells
- Leaching of contaminants from underground leaking pipelines carrying liquid chemicals

- Contaminated aquifers provide a variety of exposure pathways to various receptors, including but not limited to, most importantly Humans, Livestock, including cattle, poultry, flora, fauna etc. These pathways include, but are not limited to dermal contact with contaminated groundwater, ingestion of contaminated groundwater and ingestion of crops that are irrigated with contaminated groundwater.

3.2 Quantification of damage to groundwater

The pollutant which enter subsurface zone creates a contamination plume within the aquifer. Thus, small amount of certain pollutant can contaminate large areas. Flow through groundwater is govern by two physical process that are advection and hydrodynamic dispersion. Advection is the component of solute movement attributed to transport by flowing groundwater. The rate of transport is equals to average linear groundwater velocity, v* where v*=v/n, v being the specific discharge and n the porosity.

Further, solute transport equation is used to represent the movement of flux of solute mass through a control volume. The equation states that the sum of all mass, which creates solute with the control volume, must be equal to a change in the concentration of solute with the control volume.

$$\frac{\partial C}{\partial x} = \left[\frac{\partial}{\partial x}\left(D_x \frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(D_y \frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial z}\left(D_z \frac{\partial C}{\partial z}\right)\right] - \left[\frac{\partial}{\partial x}(V_x C) + \frac{\partial}{\partial y}(V_y C) + \frac{\partial}{\partial z}(V_z C)\right]$$

Where,

V_x, V_y,V_z = Seepage velocities in x,y,z directions, m/s

D_x, D_y,D_z = Dispersion coefficient, m^2/sec

C = Solute concentration, mg/m^3

T = Time, (s)

Visual MODFLOW can also be used to predict the ground water flow with the contaminate transport. With the use of geological and hydraulic data the potential area of pollutant transport and its concentration can be simulated with the help of MODFLOW and MT3D. Using this model the concentration of pollutant at the user end can be determined.

3.3 Cost estimation to damages

Methods for estimating cost to human health and cost of damage to environmental property described under surface water may be transferred for ground water damage cost estimation. However, while calculating EDC for groundwater pollution ecological economic assessment of groundwater is essential. This is elucidated with an example on removal of groundwater (GW) deposit due to mining activity in an area,

Relevant parameters are,

- Monetary value co-efficient of the damage caused by destruction & removal of ground water (K *deposit*)
- Static reserve's assessment co-efficient of the ground water (K *static reserve*)
- Monetary value co-efficient of damage caused by the water removed (K *water infiltration*)
- Basic price of ground water (Rs./ m^3)
- Volume of groundwater that is being removed (m^3)
- Water return coefficient of groundwater

Total cost of GW removed = Basic price of GW X Water return coefficient of GW X Volume of GW being removed (K *deposit* + K *static reserve* + K *water infiltration*)

4. SOIL

4.1 Applicability

- Illegal dumping of waste (hazardous or nonhazardous) on open parcels of land
- Discharge of untreated or inadequately treated effluent onto open parcels of land
- Boundary breaches wherein wastes might either get spilled onto open parcels of adjoining land, and/ or sub grade breaches where wastes and/ or leachate seeps into the subsoil and potentially ultimately into the aquifer
- Spills of chemicals/ wastes during transportation, leakages from trucks, tanks, pipelines etc.
- Impacted soils can lead to indirect impacts including rendering the land as not usable for agricultural purposes, serving as a continuous source of contamination to groundwater, serve as a direct exposure pathway to humans who may come into contact with the contaminated soil media.

- Soils that are contaminated provide a variety of exposure pathways to various receptors including but not limited to, most importantly humans, livestock, including cattle, poultry, etc. These pathways include, but are not limited to dermal contact with contaminated soils, incidental ingestion of contaminated soils, ingestion of crops that are grown on contaminated soils, inhalation of vapors from wastes that are dumped on soils

In India, there are no comprehensive soil quality regulations and standards to ascertain the seriousness and quantification of contamination, however, internationally adopted standards can be applied selectively for setting screening and response levels for contaminated soils.

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