5. Water Pollution

5.1 Preamble

Most of the human diseases can be attributed to polluted water, either through direct consumption or consumption through food chain. While mining, water pollution occurs because of the following:

a) Mine drainage
b) Mine impoundment
c) Fouling of water sources

Water pollution may be caused by direct discharge of mine water to the water stream and due to erosion and wash off from the mined out area and waste dumps. The water may be acidic, alkaline, charged with dissolved chemicals and toxic substances or suspended solid particles. Water pumped out from the sulphide deposit, halide deposit, fluoride deposit and from any other waste material is generally injurious to biotic life as well as for human consumption. Water bodies severely polluted by acid i.e. mine drainage are not fit for survival of fish and benthic invertebrates.

5.2 Water Pollution Laws

The Water (Prevention and Control of Pollution) Act, 1974 and the Rules made thereunder (1975), as well as the Water (Prevention and Control of Pollution) Cess Act, 1977 and the Rules made thereunder (1978) are the relevant laws of the land to control Water Pollution. Under the Water (Prevention and Control of Pollution) Act, "Pollution" means contamination of water, alteration of the physical, chemical or biological properties of water, discharge of any sewage or trade effluent or any other liquid, gaseous or solid substance into water (whether directly or indirectly), which may, or is likely to, create a nuisance or render such water harmful or injurious to public health or safety, or to domestic, commercial, industrial, agricultural or other legitimate uses, or to the life and health of animals or plants or aquatic organisms.

The objectives of the Water (Prevention and Control of Pollution) Act 1974 are to provide for the Prevention and Control of Water Pollution and the maintenance or restoration of the wholesomeness of water for the establishment, with a view to carrying out the purposes aforesaid, of Boards for the prevention and control of water pollution, for conferring on and assigning to such Boards powers and functions relating thereto and for matters connected therewith.

Before proceeding further, a look into the important provisions of the above laws, as applicable to mining areas, will be quite useful. Under Section 24 of the Water Pollution Act, the discharge of any poisonous, noxious or polluting matter into any stream or well or sewer or on land is prohibited. It also prohibits discharge of any matter into any stream that may impede the proper flow of the water of the stream. Sec. 25 of the Act provides that no person can establish or expand any industry, operation or process etc. which is likely to discharge sewage or trade effluent into a stream or well or sewer or on land without the previous consent of the State Pollution Control Board. The application form for such consent has been prescribed under Rule 32 of the Water (Prevention and Control of Pollution) Rules 1975. The (Prevention and Control of Pollution) Cell Act, 1977 vide Sec. 3 has provided for levying and collection of a cess on Water consumed by persons carrying on certain industries, etc. with effect from 1st April, 1978 with a view to augment the resource of the Central and State Pollution Control Boards. While for industrial cooling, spraying in mine pits or boiler feed, the rate is 0.75 paise per kilo-litre of water, it is one paisa per litre for water used for domestic purposes. A form for sending monthly return on water consumption has been prescribed under Rule 4 of the Water Cess Rules 1978. A text of the important provisions of the Water Act, Water Cess Act and Rules made thereunder have been furnished in Annexure-6.

The Act is applicable only in areas declared by Central/State Government for this purpose. An up-to-date list of areas declared as 'water pollution control areas' is placed in Annexure-1.

Bureau of Indian Standards (BIS) has laid down general tolerance limits for all industrial effluents discharged into inland, surface waters, marine coastal areas, public sewers and on land for irrigation purposes. The details are given in Annexure-7. As already stated earlier the Environment (Protection) Rules, 1986, vide Rule 3, prescribes the general standard discharge of effluents to the environment as given in the table below, namely to inland surface water (like ponds, lakes, rivers, streams, etc.), to public sewers, to land for irrigation and to sea.

General Standards for Discharge of Environmental Pollutants*

Parameter	Standards			
	Inland surface water	Public sewers	Land for irrigation	Marine/coastal area
Colour and odour	Removal of unpleasant colour & odour	-	Removal of unpleasant colour & odour	Removal of unpleasant colour & odour
Suspended solids mg/l, max.	100	600	200	(a) For process water (b) For cooling water effluent 10% above total suspended matter of influent
Particle size of suspended solids	Shall pass 850 micron IS Sieve	-	-	(a) Floatable solids, solids max. 3 mm. (b) Settleable solids max. 856 microns
pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
Temperature	Shall not exceed 5°C above the receiving water temp.	-	-	Shall not exceed 5°C above the receiving water temperature
Oil and grease mg/l max.	10	20	10	20
Total residual chlorine, mg./l max.	1.0	-	-	1.0

Ammonical nitrogen (as N), mg/l max.	50	50	-	50
Total kjeldahl nitrogen (as N); mg/l max.	00	-	-	100
Free ammonia (as NH_3), mg/l max.	5.0	-	-	5.0
Biochemical oxygen demand (3 days at $27^{\circ}C$), mg/l max.	30	35C	100	100
Chemical oxygen demand, mg./l max.	250	-	-	250
Arsenic (as As)	0.2	0.2	0.2	0.2
Mercury (As Hg), mg/l, max.	0.01	0.01	0.01	0.01
Lead (as Pb) mg/l, max.	0.1	1.0	-	2.0
Cadmium (as Cd) mg/l, max.	2.0	1.0	-	2.0
Hexavalent chromium (as Cr + 6), mg/l, max.	0.1	2.0	-	1.0
Total chromium (as Cr) mg/l, max.	2.0	2.0	-	2.0
Copper (as Cu) mg/l, max.	3.0	3.0	-	3.0
Zinc (as Zn) mg/l, max.	5.0	15	-	15
Selenium (as Se)	0.05	0.05	-	0.05
Nickel (as Ni)	3.0	3.0	-	5.0
Cyanide (as CN) mg/l, max.	0.2	2.0	0.2	0.2
Fluoride (as F) mg/l, max.	2.0	15	-	15
Dissolved phosphate (as P), mg/l, max.	5.0	-	-	-
Sulphide (as S) mg/l, max.	2.0	-	-	5.0
Phenolic compounds (as C_6H_5OH) mg/l, max.	1.0	5.0	-	5.0
Radioactive materials (a) Alpha emitters micro curie mg/l, max. (b) Beta emitters micro curine mg/l	 10^{-7} 10^{-6}	 10^{-7} 10^{-6}	 10^{-8} 10^{-7}	 10^{-7} 10^{-6}
Bio-assay test	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hrs. in 100% effluent	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent
Manganese	2 mg/l	2 mg/l	-	2 mg/l
Iron (as Fe)	3 mg/l	3 mg/l	-	3 mg/l
Vanadium (as V)	0.2 mg/l	0.2 mg/l	-	0.2 mg/l
Nitrate Nitrogen	10 mg/l	-	-	20 mg/l

**These standards shall be applicable for industries, operations or processes other than those industries, operations or process for which standards have been specified in Schedule of the Environment Protection Rules, 1989.*

Water discharged from mines and mineral processing plants should confirm to these standards, failing which penalty as prescribed under Sec. 15 of the Environment (Protection) Act, 1986 as reproduced below, may be attracted.

Sec. 15 : Penalty for contravention of the provisions of the Act and Rules, Orders and Directions.

(1) Whoever fails to comply with or contravenes any of the provisions of this Act, or the Rules made or Orders or Directions issued thereunder, shall in respect of each such failure or contravention, be punishable with imprisonment for a term which may extend to five years or with fine which may extend to one lakh rupees, or with both, and in case the failure or contravention continues, with additional fine which may extend to five thousand rupees for every day during which such failure or contravention continues after the conviction for the first such failure or contravention.

(2) If the failure of contravention referred to in sub-section (1) continues beyond a period of one year after the date of conviction, the offender shall be punishable with imprisonment for a term which may extend to seven years.

The Bureau of Indian Standards vide IS 10500 (1991) prescribes the quality to be maintained for drinking water as furnished below.

S.No	Substance or characteristics	Requirement/desirable limit
1.	Color, Hazen units, Max.	10
2.	Odour	Unobjectionable
3.	Taste	Agreeable
4.	Turbidity, NTU, Max.	10
5.	pH value	6.5 to 8.5
6.	Alkalinity mg/l, Max.	200
7.	Total Hardness (as $CaCO_3$) mg/l	300
8.	Calcium (as Ca) mg/l., Max.	75
9.	Magnesium (as Mg) mg/1., Max.	30
10.	Alluminium (as Al) mg/l., Max	0.03
11.	Copper (as Cu), mg/l., Max	0.05
12.	Iron (as Fe), mg/l., Max	0.3
13.	Manganese (as Mn),mg/l, Max.	0.1
14.	Chlorides (as Cl), mg/l,Max	250
15.	Residual free chlorine mg/lit Min	0.2
16.	Sulphate (as SO_4) mg/l,Max.	150
17.	Nitrate (as NO_3), mg/l, Max.	45
18.	Fluoride (as F), mg/l, Max.	0.6-1.2
19.	Phenolics (as C_6H_5OH), mg/l,Max	0.001
20.	Mercury (as Hg), mg/l, Max.	0.001
21.	Cadmium (as Cd), mg/l., Max.	0.01
22.	Selenium (as Se), mg/l, Max.	0.01
23.	Arsenic (as As), mg/l, Max.	0.05
24.	Cyanide (as CN), mg/l, Max.	0.05
25.	Boran mg/l Max.	1.0
26.	Lead (as Pb), mg/l, Max.	0.1
27.	Zinc (as Zn), mg/l, Max.	5.0
28.	Anionic Detergents (as MBAS) mg/l, Max	0.2
29.	Chromium (as Cr6+), mg/l, Max.	0.05
30.	Polynuclear Aromatic Hydrocarbons (as-PAH), mg/l, Max.	-
31.	Mineral Oil mg/l, Max	0.01
32.	Radioactive materials:	
	(a) Alpha emitters micro curie in mg/l	-
	(b) Beta emitters micro curie in mg/l	-

It is, therefore, imperative that this standard has to be maintained in all mines and mining establishments including residential colonies. For contravention, the penalty has been prescribed in Sec. 15 of .he Act.

5.3 Water Pollutants

(a) Temperature - The rise of temperature by a few degrees centigrade can be bad to the stream because of the fact that the solubility of oxygen in waste is limited to less than 10 parts per million (PPM). As the solubility of oxygen in water is inversely proportional to the temperature, the water at a higher temperature would have less dissolved oxygen in it. By rise of temperature, it will increase the biological activity thus require greater amounts of dissolved oxygen for respiration purposes. The lower content of dissolved oxygen in the stream water would restrict some of the more delicate fish from its natural growth.

(b) Turbidity - Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Turbidity is mainly due to the presence of colloidal matter or finely divided suspended matter by suspended stage. Common examples of turbidity are river water in monsoon. The waters polluted with milk wastes, sewage or certain ceramic wastes also give rise in turbidity. Iron and manganese salts can also give rise to turbidity. Higher turbidity levels are often associated with higher levels of disease-causing micro-organisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.

(c) Suspended Matter – Suspended matter can be either inorganic or organic. The suspended matter reduce the penetration of sunlight into water and thus reducing the normal plant life.

(d) Colour - The colour is considered as aesthetic pollutant. Colour can be due to toxic elements. Colour in water can be due to natural or artificial sources. When water runs through pasty soil, it obtains a brownish tint which is primarily due to lignins and other related bodies which are also obtained due to decomposition of plant life. These colours can be considered as aesthetic pollution.

(e) Foam or Froth – Foam is a suspension or dispersion of gas or air bubbles in a liquid medium, such as, water. Foam is also caused by natural dropping of water from a height, only for a few seconds. When certain pollutants, such as, detergents are present in water, the foam appears at surface. The increased use of synthetic detergents has advanced the problems of foam formation in sewage effluents and rivers. Foam is hazardous because it can carry suspended solids including pathogenic bacteria.

(f) Total Coliforms (including fecal coliform and *E. Coli*) - Not a health threat in itself, it is used to indicate whether other potentially harmful bacteria may be present. Coliforms are naturally present in the environment, as well as feces. Fecal coliforms and *E. coli* only come from human and animal fecal waste.

(g) Other major objectionable elements & pollutants commonly observed in mine effluents are:

Suspended matter - Material in suspension, such as, untreated sewage, paper pulp, mud, saw dust, rock-powder, etc. Cover the bottom and bring biological life therein which is important as fish food.

Oxygen Demand - Materials having an oxygen demand reduce the dissolved oxygen content of the stream to a point where fish cannot exist. A dissolved oxygen contain of 5.0 mg/l is taken as the minimum for fish, but the value is affected by various other factors.

pH- Most of the fishes require a pH value of 6.5 to 8.4. Acid or alkaline conditions created in the stream by the discharge of wastes affect the fish life directly.

Salinity - Salinity of the water is important for fresh-water fishes as they cannot tolerate sudden changes in climatic pressure.

Chloramines (as Cl_2) - Eye/nose irritation, stomach discomfort, anemia
Antimony - Increase in blood cholesterol, decrease in blood sugar.

Arsenic - Skin damage or problems with circulatory systems, and may have increased risk of getting cancer.

Asbestos (fibre > 10 micrometers) - Increased risk of developing benign intestinal polyps

Barium - Increase in blood pressure.

Beryllium - Intestinal lesions.

Cadmium - Kidney damage.

Chromium (total) - Allergic dermatitis.

Copper - Short term exposure : Gastrointestinal distress, Long term exposure: Liver or kidney damage, People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level.

Cyanide (as free cyanide) - Nerve damage or thyroid problems.

Fluoride - Bone disease (pain and tenderness of the bones), Children may get mottled teeth.

Lead - Infants and children : Delays in physical or mental development, children could show slight deficits in attention span and learning abilities, Adults : Kidney problems, high blood pressure.

Mercury (inorganic) - Kidney damage.

Nitrate (measured as Nitrogen) & Nitrite (measured as Nitrogen) - Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.

Selenium - Hair or fingernail loss, numbness in fingers or toes, circulatory problems.

Thallium - Hair loss, changes in blood, kidney, intestine, or liver problems.

(h) Radioactivity – Alpha & Beta particles and photon emitters, Increase the risk of cancer. Radio-active substances present in sufficient concentration can damage tissues and organs of the body and can give rise to diseases such, as leucomia and cancer, as well as impaired fertility. It can also produce genetic effects in the offspring. While we are all being exposed to small quantity of natural radio-activity occurring in our environment, it is important that we make sure that we are not getting it beyond certain limits through water supplies.

5.3 Adverse Effects of Water Pollutants

For better implementation of the pollution standards, it is felt that one must first understand and appreciate the adverse effects of the different pollutants on life and property.

Fish and other aquatic animals require the presence of an appreciable concentration of dissolved oxygen, this oxygen content is likely to be reduced or completely exhausted by industrial wastes and other pollution. Silt blankets at the stream bottom also cut off much of the food supply required for fish life. Organic wastes, under the influence of bacterial action, deplete the dissolved oxygen by consuming it in biochemical oxidation reactions. This oxygen depletion is the most important single aspect of pollution in natural streams. Replenishment of dissolved oxygen after it has been consumed or reduced occurs naturally by re-aeration of the stream through its surface and by the photosynthetic reactions of green aquatic plants. Reaeration, however, is retarded by oil films on the surface or by floating solids that decrease the amount of surface available. Turbidity, colour, and suspended solids affect the rate of dissolved oxygen replenishment because they diminish light penetration into the water and thereby retard photosynthesis. High-temperature waste also retard dissolved oxygen restoration because oxygen is less soluble in warm water. The degree of pollution of a stream, especially the degree of dissolved oxygen, depletion, determines the types of aquatic life that survive.

Discharge of acids and occasionally of other industrial wastes leads to property damage through corrosive attach. Acid wastes affect steel objects, such as, ships and navigation aids, and also damage concrete structures in the stream. Corrosion by acid wastes may be even more harmful when the water is taken into a plant for use as cooling water, or for treatment for municipal or industrial use. Piping, pumps, valves and other equipment in the plant are then subjected to corrosive action, and damage may be severe.

Dissolved metals make the water toxic to human, animal and plant life. The toxicity limits of some of the heavy metals to living organisms are shown in Table below.

Toxicity Limits of Heavy Metals to living Organisms

	Cu	Zn	Pb	Cd	Cr	Ni	Fe	Mn	Al	Hg
Toxicity in solution to plant	0.02	1.3	1.7	2.1	3.8	0.18	9.3	0.05	0.93	6.6
Toxicity in solution to Fish	0.02	1.3	1.7	2.1	120	30	250	100	1.5	0.06
Maximum concentration in drinking water WHO (1971) recommendation	1.5	15	0.1	0.01	0.05	-	1.0	0.5	-	0.001
Maximum concentration in water for farm animals	0.5	25	0.1	0.05	1.0	-	-	-	5	0.01
Maximum concentration in irrigation water, EPA, USA (1972) recommendations	0.2	2.0	5.0	0.01	0.1	0.2	5.0	0.2	5.0	-

It would be evident from the above table that even in low concentration the metals like copper, zinc, lead, mercury, aluminium and manganese are quite toxic to human beings, plants and animals and are very lethal to the aquatic life. As a general rule concentration of a metal, excepting sodium, potassium, magnesium and calcium should not exceed 1.0 mg per litre. If a number of metals occur in concentration of less than 1.0 mg per litre each and their combined total combination exceeds 1.0 mg per litre then it may prove to be a potential source of pollution.

Impact of mine drainage on aquatic life depends on the type of mine drainage (acidic or alkaline), concentration of deleterious agents, duration of discharge and the ability of surface waters to accommodate the chemical loading. Fishes are killed specifically by toxic substances even when all other conditions of the environment are favourable. Most of these materials are effective even in very low concentrations. High carbon dioxide concentration in water is also harmful to fish.

Sometimes the concentration may not be harmful to the aquatic life but it may be harmful to human beings when it comes in food cycle. The acid mine drainage lowers pH of soil and consequently increases the solubility of aluminium, manganese and other heavy metals which are toxic to plants as well as for human beings. Some of these metals dissolved like chromium, cobalt, nickel, etc. are carcinogenic. These elements can also enter into food chain, through phyto-accumulation & concentrations. They can also enter into food chain through aquatic life. Common toxic metallic pollutants observed in different metalliferous mine effluents, their threshold limits and their harmful effects are given in the Annexure 8.

5.4 EFFECTS ON HYDROLOGY

The two most severe impacts of mine drainage on water regime are the degradation of surface and subsurface water quality and the alteration of surface run-off, stream flow and depletion in ground water regime.

Mine drainage also causes erosion and subsequent sedimentation of the soil particles encountered during its flow. The soil particles are finally settled in water bodies. The deposition of the eroded soil particles into stream reduces the stream capacity and increase the chances of stream clogging.

In the background of the above legal provisions, stringent penal clauses and an appreciation of the adverse role of the different pollutants, one would like to know about the ways and means to ensure that the quality of water discharged from mine and mineral processing plants to the environment is within permissible limit.

The best way is not to discharge the water or the industrial effluent to the environment at all and to confine them to tailing ponds and re-circulate for in-house utilisation. This is specially necessary in case of base metal processing plants where due to the presence of dissolved heavy metals and chemicals (used in the process of mineral beneficiation) the water becomes toxic. Examples may be found in Malanjkhand Copper Mine of HCL (MP) and Zawar Lead-Zinc mine of HZL (Rajasthan).

In case of mines of non-toxic minerals like iron ore, etc. having mineral beneficiation plants i.e. crushing, screening and washing (CSW) plants, the excess water from the tailing pond is allowed to bedischarged into the surrounding environment like inland surface water (e.g. Lakya dam of Kudremukh Iron Ore Company Limited – Karnataka, Bailadila Iron Ore Mine Deposit No. 14 in MP, Kiriburu-Meghataburu Iron Ore Mine of M/s SAIL, Bihar/Orissa), on land for irrigation (e.g. Noamundi Iron Ore Mine of M/s TISCO in Bihar, Kitkasa tailing pond of Dalli Iron Ore Mine of M/s SAIL – MP etc.) into marine coastal areas (e.g. Pelletisation Plant of M/s KIOCL, Mangalore, Karnataka). These mines/plants should hold valid permission to discharge industrial effluents, from the SPCB and the quality of discharge water must conform to the respective standards laid down by SPCB. Where the process water is discharged via a tailing pond, the suspended solids get enough time to settle in the pond, and the overflow excess water generally contain very less quantity of total suspended solids (TSS), excepting the rainy season, when it may probably be in excess. In some limestone mines captive to Cement Plants (e.g. Jamul Limestone Mine of M/s ACC, MP) the discharged water from working pits is impounded in old abandoned pits for meeting inhouse requirements. Such impounded water in tailing ponds, and old pits can be gainfully utilised for pisciculture (if the water is not toxic as in case of iron ore and limestone mines).

Where tailing ponds or abandoned old pits are not available, the mine water is discharged directly to the environment, generally without any treatment (e.g. Moubhandar smelting plant HCL, Bihar discharging industrial effluent to Subarnarekha River). However, HCL, has a proposal to set up a tailing pond for the purpose. Where such discharge water is not toxic, the main pollutant is the suspended solid material, as in the case of iron ore mines. If the volume of water is not much, the quantum of suspended solids (TSS) may be somewhat reduced (though rarely within permissible limits) by dampening the velocity of the flow by erecting a series of 'Check dams' across the watercourse. With reduced velocity of the flow at these check dams, much of the suspended solids settle down progressively at the dams, and the final discharge to the environment is much cleaner. Designing of tailing dams is a specialised job, beyond the scope of this publication. The walls of tailing ponds are generally made of earth to impound large volume of industrial effluent. "Rock filter dams" (e.g. M/s KIOCL – Karnataka) erected across the valleys channels of water are useful to treat large volume of non-toxic turbid water. In this type of dams, the direct discharged water from a mine gets filtered through a specially prepared vertical 'filter bed', made of sized stones (rather than earth), embedded into the dam walls. The rock walls and the filter bed arrest most of the suspended solids leaving the discharge water much cleaner. The mine management as tailor-made to suit a specific situation can erect a simple 'Check'.

5.5 MONITORING OF WATER QUALITY AND SAMPLE SELECTION CRITERIA

- Observation of the natural conditions in the upstream part of the catchment, i.e. above the area of mining activities and beyond any possible mining impact on surface water and ground water. This observation will serve as a reference level.

- Observation and measurement of the water management at all the sites of mining activities, i.e. in the pit water discharge, waterlogged pits, beneficiation plants, tailings ponds, loading points, wash-off/storm-water discharge from waste dumps/ore stacks, workshops, etc. The observations will be both quantitative (water levels, pumping rates) and qualitative (chemical analysis) and will provide information about the actual source of any impact and/or pollution.

- Observation of the quantitative and qualitative impacts of mining activities at different distances along the down-stream, from the mines, up to the catchment outlets. The number and locations of the stations have to be identified for surface water and ground water, so as to (a) obtain a fairly regular spatial distribution and (b) estimate the total surface water flow in the main sub-catchments (nallah network).

- Observation of the eventual impact on the water quality of the main rivers.

Stream water

Stations selected for stream-water monitoring are to be located on water courses/nallahs (both perennial & seasonal) and will be subject to flow gauging, field analysis and sampling for surface water quality.

Pit-water

Water quality monitoring at each of the quarries will include:

- Water level measurement in the abandoned pits, with reference to mean sea level (m.s.l.).

- Where water is pumped out of the pit, measurement or estimation of the discharge rate. The discharge rate can be expressed by the estimated total volume (cubic metres) of water pumped during the previous month, or during the previous three months, according to the frequency of visits.

- The water samples will be taken from the outlet of the pipes where water is pumped out of the pit and from the pit itself where there is no pumping.

Process water

The tailing ponds existing have to be selected for the effluent water quality monitoring. For this the monitoring has to include:

- Measurement or estimation of the discharge rate, if the water is discharged from the pond.

- Field analysis for effluent quality for pH, temperature, electrical conductivity, DO, COD.

- Water sampling for chemical analysis in the laboratory (major ions & metallic elements).

Groundwater

Water quality monitoring at each well will include:

- The depth of water from the ground level.

- Continuous recording of the groundwater level, at least every month for one year duration.

- Selection of atleast two of the monitoring wells are to be so made that one of them will record the natural variations in groundwater level on the up-stream of the area, not affected by any mining activity and the second site to be located in the down-stream, below the mining activities.

Monitoring Frequency

Three representative samples per day are required to be collected on two different days, at each station for each season, covering all the 4 seasons. The same frequency will be adopted for gauging, field analysis and sampling for water quality. For stations located on rivers, near estuaries, field analysis and water sampling have to be repeated twice at high tide and at low tide.

Water-quality monitoring to include:

- **Field analysis**: measurement of pH, temperature, electric conductivity (micro-ohms/cm), DO, BOD, and coliforms in respect of drinking/ground water;

- *Chemical analysis in the laboratory*. Required quantities are
  For Major ions: 100 ml polyethylene flask filled to be brim (i.e. no air);
  For ICP analysis: 100 ml polyethylene flask, 0.45 or 0.1 micron filter, addition of HNO_3 down to pH <2,

For NO_3, NO_2, NH_4, F, Br and PO_4: 100 ml polyethylene flask, or 0.1 micron filter. It is recommended that the NH_4 & Cr(VI) analysis is to be carried out within 24 hours.

Equipment

- for gauging:

Current meter, rope, tape measure, rod for measuring water depth/electrical tape (dipper).

- for field analysis :

Field kits, pH meter, thermometer, conductivity meter, DO and BOD equipment, Portable spectro-photometer, colorimeter.

- For sampling: bottles, filters, HNO_3.

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