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Unit-IV

Management of Water Pollution

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Water quality and standards of BIS

WATER QUALITY

- Water is usually tasteless, odorless, colorless and, a liquid in its pure state. But, water is one of the best naturally occurring solvents on earth and almost any substance will dissolve in it to some degree.
- This is why it is seldom found in its "pure" state and it usually contains several impurities (gases, solids, color). Water falling to earth as rain dissolves some of the gases in the atmosphere and when it falls on the earth and percolates through it, it dissolves the minerals present in the earth.
- Water Sources: Surface waters are those that come from rivers, streams, ponds, lakes and reservoirs, while ground waters come from wells, mines and springs. Ground water usually contains large amounts of dissolved substances (minerals) because it percolates(slowly filters) through rock and soil formations.
- The greater the depth below ground from which the ground water comes, the higher the level of dissolved minerals in the water. However, since it percolates through the earth, ground water contains relatively small quantities of suspended impurities and very little color. In contrast, surface waters contain lower levels of dissolved minerals , but higher suspended impurities , color and industrial pollutants.

Physical Impurities

Physical Impurities: These are usually in the form of suspended impurities and color which can be separated from the water by filtration. Suspended impurities are usually due to soil erosion and this silt gives the water a hazy appearance.

This is referred to as ‘turbidity’ and will often settle out slowly in reservoirs or tanks when this water is retained in these for some time.

Odor and taste in water are due to the presence of dissolved gases such as sulfides, micro organisms, natural organic contaminants such as lignins, tannins and humic acids, and, increasingly now, due to industrial contaminants.

Color and turbidity are usually measured by instruments available for these purposes and are expressed in “Hazen units” for color and in “Nephlometric Turbidity Units (Ntu)” for turbidity.

Mineral impurities:

- Water dissolves the minerals present in the strata of soil it filers through in the case of ground water and, in the case of surface water, the minerals present in the soil over which it flows (rivers/streams) or over which it stands (lakes, ponds, reservoirs).
- The dissolved minerals in water are commonly referred to as Total Dissolved Solids (TDS). The TDS content of any water is expressed in milligrams /litre (mg/l) or in parts per million (ppm).
- The minerals are basically compounds (salts) of Calcium(Ca), Magnesium(Mg) and Sodium(Na) which is commonly called as 'hardness in water' is due to the compounds/salts of Ca and Mg such as Calcium or Magnesium Chloride, Calcium or Magnesium Sulphate (CaSo4, MgCl, etc).
- In some areas of India, there are ground waters which contain fluoride salts of Ca and Mg. Fluoride in water above 1.5 mg/l is dangerous and causes a disease called 'Fluorosis' which affects the teeth and the bones of humans who consume water with high levels of fluoride.
- Iron is another contaminant/impurity which is not safe for human consumption if it is present in water in excess of 0.3 mg/l.
- In several parts of eastern India, Arsenic is an impurity which has been found in ground water and needs to be removed as it is a slow poison.

Organic Impurities:

- The upper layer of the earth's crust contain residual vegetable and animal matter along with bacteria and other micro-organisms. Surface waters therefore usually contain some organic matter (tannins, lignins, humic acid, fulvic acid) and are more readily exposed to biological contamination.
- Surface waters are subject to seasonal changes because of rainfall and also due to domestic as well as industrial pollution.
- Agricultural run offs which bring with it pesticides and fertilizer residues are starting to cause serious problems with the use of surface waters.
- The constituent nutrients of fertilizers such as phosphorus and nitrogen can cause rapid, wide spread growths called "algal blooms" in lakes, ponds and reservoirs.
- Ground waters were relatively free from such contamination because of the filtering effect of the strata of soil through which the water percolates, but, over the decades industrial contaminants have begun to show up even in ground waters.

- This is because of the laxity in implementing/enforcing pollution control laws as a result of which untreated domestic and industrial effluents which has been discharged into open land has over the years percolated down to the water table and contaminated the ground water.
- This shows up in water in the form of BOD (biodegradable/biochemical oxygen demand) and COD (combined oxygen demand).
- These are two important parameters normally associated with effluents which are an indication of the extent of contamination which have now begun to show up in ground water and to a greater extent in surface water.

Standards of Water for Human Consumption:

Drinking water for human beings should contain some level of minerals(TDS), but these levels should not be excessive. The standard that applies to India is the BIS 10500-1991 standard .

This standard used the WHO standard as the basis and has been amended subsequently to take into account the fact that over exploitation of ground water which has the largest share of water supplied for human use has deteriorated to such an extent that the crucial parameters such as TDS, hardness, Chlorides, etc usually exceed the desirable levels substantially.

Consequently, a higher permissible limit has been specified. Water used for drinking becomes unpalatable when the TDS level is above 500 mg/l, but lack of any better source enables people consuming such water to get used to its taste.

The BIS standard applies to the purity level acceptable for human beings to drink. For practically all industrial and some commercial uses, the purity levels required are very much higher and in most cases demand water with virtually no residual dissolved solids at all.

BIS 10500 STANDARD FOR DRINKING WATER-1991

Essential Characteristics

Characteristic	Requirement.(desirable)	Permissible limit
1. Color-Hazen units,	maximum 5	25
2. Odor	Unobjectionable	Unobjectionable
3. Taste	Agreeable	Agreeable
4. Turbidity,Ntu,	Max 5	10
5. pH value	6.5 to 8.5	No relaxation
6. Total Hardness,max mg/l as CaCo3	300	600
7. Iron as Fe,max mg/l	0.3	1.0
8. Chlorides as Cl,max mg/l	250	1000
9. Residual free Chlorine as Cl, min 0.2		- -

Desirable Characteristics

10. Dissolved Solids, mg/l,	max 500	2000
11. Calcium as Ca, mg/l,	max 75	200
12. Copper as Cu, mg/l,	max 0.05	1.5
13. Manganese as Mn, mg/l,	max 0.10	0.3
14. Sulphate as So4,mg/l,	max 200	400
15. Nitrate as No3,mg/l,	max 45	100
16. Fluoride as F, mg/l,	max 1.5	1.9
17. Phenolic compounds, mg/lit,	max 0.001	0.002
18. Mercury as Hg, mg/lit	max 0.001	No relaxation
19. Cadmium as Cd, mg/lit ,	max 0.01	No relaxation
20. Selenium as Se, mg/lit,	max 0.01	No relaxation
21. Arsenic as As, mg/lit,	max 0.01	No relaxation
22. Cyanide as Cn, mg/lit,	max 0.05	No relaxation
23. Lead as Pb, mg/lit,	max 0.05	No relaxation

24. Zinc as Zn, mg/lit,	max 5.0	No relaxation
25. Anionic detergents, mg/lit,	max 0.2	1.0
26. Chromium as Cr, mg/lit,	max 0.05	No relaxation
27. Polynuclear Hydro carbons	--	--
28. Mineral oil, mg/lit ,	max 0.01	0.03
29. Pesticides, mg/lit,	max Absent	0.001
30. Alkalinity, mg/lit ,	max 200	600
31. Aluminum as Al, mg/lit,	max 0.03	0.2
32. Boron as B, mg/lit,	max 1.0	5.0

Bacteriological standards:

For water entering a distribution system- Coliform count in any sample of 100 ml should be zero(0).

b) For water in a distribution system – (i) E Coli count in 100 ml of any sample must be zero (0).

(ii)Coliform organisms should not be more than 10 per 100 ml in any sample.

(iii) Coliform organisms should not be present in 100 ml of any two consecutive samples or more than 5% of the samples collected for the year.

Parameters	USEPA	WHO	ISI	ICMR	CPCB
pH (mg/l)	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.2	6.5-8.5
Turbidity NTU	-	-	10	25	10
Conductivity (mg/l)	-	-	-	-	2000
Alkalinity (mg/l)	-	-	-	-	600
Total hardness (mg/l)	-	500	300	600	600
Iron *mg/l)	-	0.1	0.3	1.0	1.0
Chlorides (mg/l)	250	200	250	1000	1000
Nitrate (mg/l)	-	-	45	100	100
Sulfate (mg/l)	-	-	150	400	400
Residual (mg/l) free Chlorine	-	-	0.2	-	-
Calcium (mg/l)	-	75	75	200	200
Magnesium (mg/l)	-	50	30	-	100
Copper (mg/l)	1.3	1.0	0.05	1.5	1.5
Fluoride (mg/l)	4.0	1.5	0.6-1.2	1.5	1.5
Mercury (mg/l)	0.002	0.001	0.001	0.001	No relaxation
Cadmium (mg/l)	0.005	0.005	0.01	0.01	No relaxation
Selenium (mg/l)	0.05	0.01	-	-	No relaxation
Arsenic (mg/l)	0.05	0.05	0.05	0.05	No relaxation
Lead (mg/l)	-	0.05	0.10	0.05	No relaxation
Zinc (mg/l)	-	5.0	5.0	0.10	15.0
Chromium (mg/l)	0.1	-	0.05	-	No relaxation
E. coli (MPN/100 ml)	-	-	-	-	No relaxation

Water quality standards-WHO

Drinking water

- **Key facts**
- In 2015, 71% of the global population (5.2 billion people) used a safely managed drinking-water service – that is, one located on premises, available when needed, and free from contamination.
- 89% of the global population (6.5 billion people) used at least a basic service. A basic service is an improved drinking-water source within a round trip of 30 minutes to collect water.
- 844 million people lack even a basic drinking-water service, including 159 million people who are dependent on surface water.
- Globally, at least 2 billion people use a drinking water source contaminated with faeces.
- Contaminated water can transmit diseases such diarrhoea, cholera, dysentery, typhoid, and polio. Contaminated drinking water is estimated to cause 502 000 diarrhoeal deaths each year.
- By 2025, half of the world's population will be living in water-stressed areas.
- In low- and middle-income countries, 38% of health care facilities lack an improved water source, 19% do not have improved sanitation, and 35% lack water and soap for handwashing.

- Safe and readily available water is important for public health, whether it is used for drinking, domestic use, food production or recreational purposes. Improved water supply and sanitation, and better management of water resources, can boost countries' economic growth and can contribute greatly to poverty reduction.
- In 2010, the UN General Assembly explicitly recognized the human right to water and sanitation. Everyone has the right to sufficient, continuous, safe, acceptable, physically accessible, and affordable water for personal and domestic use.

Parameter	WHO Guideline value
Faecal coliform or E. coli	Not detectable in a 100 mL sample
Aluminium	0.2 mg/L*
Arsenic	0.01 mg/L
Ammonia	1.5 mg/L*
Cadmium	0.003 mg/L
Arsenic	0.01 mg/L
Chloride	250 mg/L*
Colour	15TCU*
Copper	2 mg/L
Fluoride	1.5 mg/L
Hydrogen Sulphide	0.05 mg/L*
Iron	0.3 mg/L*
Lead	0.01 mg/L
Manganese	0.1 mg/L*
Nitrate	10 mg/L
Sodium	200 mg/L*
Sulphate	250 mg/L*
Turbidity	5 NTU*
Total dissolved solids	1000 mg/L*
Zinc	3 mg/L*

*May not be toxic but could result in consumer complaints

A positive test for *E. coli* or faecal coliform organisms in drinking water indicates the need for immediate remedial action and additional measurements. As soon as possible,

ACTS FOR WATER POLLUTION PREVENTION AND CONTROL

- The Water (Prevention and Control of Pollution) Act was enacted in 1974 to provide for the prevention and control of water pollution, and for the maintaining or restoring of wholesomeness of water in the country. The Act was amended in 1988.
- The Water (Prevention and Control of Pollution) Cess Act was enacted in 1977, to provide for the levy and collection of a cess on water consumed by persons operating and carrying on certain types of industrial activities.
- This cess is collected with a view to augment the resources of the Central Board and the State Boards for the prevention and control of water pollution constituted under the Water (Prevention and Control of Pollution) Act, 1974. The Act was last amended in 2003.

- **Acts**
- No.6 of 1974, [23/3/1974] - The Water (Prevention and Control of Pollution) Act, 1974, amended 1988
- No.36 of 1977, [7/12/1977] - The Water (Prevention and Control of Pollution) Cess Act, 1977, amended 1992 ,
- No. 19 of 2003, [17/3/2003] - The Water (Prevention and Control of Pollution) Cess (Amendment) Act, 2003.

RULES

- Rules
- G.S.R.860(E), [30/11/2012] - The Central Pollution Control Board (Qualifications and other Terms and Conditions of Service of Chairman) (Amendment) Rules, 2012.
- G.S.R.840(E), [22/11/2012] - The Central Pollution Control Board (Member-Secretary, Terms and Conditions of Service and Recruitment) Rules, 2012.
- G.S.R.830(E), [24/11/2011] - The Water (Prevention and Control of Pollution) Amendment Rules, 2011.
- G.S.R.378(E), [24/7/1978] - The Water (Prevention and Control of Pollution) Cess Rules, 1978
- G.S.R.58(E), [27/2/1975] - The Water (Prevention and Control of Pollution) Rules, 1975 [PDF](8.14 MB)
- Central Board for the Prevention and Control of Water Pollution (Procedure for Transaction of Business) Rules, 1975 amended 1976

The Environment (Protection) Act, 1986

- This Act has been enacted in 1986 with an aim to protect and improve the environment, thereby preventing the hazards, which could be faced by human beings, plants, living creatures and property.This act extends to whole of India.The act consists of 4 chapters and 26 Sections.
- Chapter-l

This act defines the following terms in a whole-some manner- environment, environmental pollution, hazardous substances etc.,

- Chapter-II

It deals with the general power of the central government to take measures in order to protect and improve the environment.

This chapter further deals with appointment of officers, their power to function and to give directions. This chapter provides the standards of quality for air, water and soil, the maximum allowable concentration of various pollutants, the procedure and restriction on handling hazardous waste and on the location of industries have been described.

- Chapter -III

It deals with the Prevention and control of Environmental pollution.

It stresses that the emission of any type of waste must not exceed the standards, the chapter also explains the power of state and central pollution control board authorities to enter and inspect any industry at any time. They are also eligible to collect the sample and check the methodology followed in the concerned industry. The samples can be transported to the respective laboratory and can be analyzed by the government analyst, following which the company may be punished with penalty when they fail to adhere to the standards.

- Penalty

Imprisonment to five years with a fine which may extend upto One Lakh Rupees or it may extend to Rupees 5000 for every day.

- Chapter- IV

It deals with various titles, which includes that the legal action must be taken, in good faith. It further stresses the submission of related information, reports and returns. According to this chapter the central government can also formulate rules for carrying out this act and these rules must be laid before parliament for its validity.

The Water (Prevention and Control of Pollution) Act, 1974

- This Act has been framed and enacted in the parliament in the year 1974 to prevent and control water pollution with an aim to protect and restore the wholesomeness or purity of water. In this period the boards were formed to check pollution and they were assigned with particular function.This Act consists of 8 chapter and-64 sections.
- **Chapter-I**

This chapter explains the terms such as board, central state board, member, outlet sewer sewage effluent, trade effluent, stream and pollution.

- **Chapter II**

It elaborates about the constitution of central board, state board, committees, terms and conditions of service of members, meeting of the board. It also explains about delegation of powers to chairman, member secretary, officers and other employees of the board.

- **Chapter III**

It deals with the constitution, composition and the special provision of joint board. For eg. A Joint board for the river Cauvery includes officials from Karnataka, Tamilnadu and Pondicherry along with the Central board officials.

- **Chapter IV**

This chapter deals with the functions of central board, state board and their powers to give directions to concerned authorities.

- **Chapter V**

It explains the power of state government to collect samples of effluent, analyse in government laboratory and publish the results. In the basis of the result they may restrict the outlets and discharges into stream or well.

- **Chapter VI**

It deals with the maintenance of funds of central and state board, budgets, annual report submission, account and auditing.

- **Chapter-VII**

This elaborates about the penalty in case of offences committed by companies.

- Punishment:

Imprisonment for not less than one year and six months but which may extend to 6 years with fine. In case of failure, an additional fine Rs.5000/will be imposed for every day.In such case the names of the offenders may be even published.

- **Chapter VIII**

It explains about the central and state water laboratories, analysts, reports of the analysts, protection and action in good faith and about the power of central and state government to formulate the rules.

The Water (Prevention and Control of Pollution) Cess Act, 1977

- The Water (Prevention and Control of Pollution) Cess Act, 1977 aims to provide for the levy and collection of a cess on water consumed by persons carrying on certain industries and by local authorities, with a view to augment the resources of the Central Board and the State Boards for the prevention and control of water pollution constituted under the Water (Prevention and Control of Pollution) Act, 1974.
- **Water Pollution Cess Act, 1977**
- **According to this Act, anyone consuming water has to pay certain amount of cess depending on:**
- 1. Whether the industry is using water for industrial cooling, spraying in mine pits or boilers feed,
- 2. In processing, whereby water gets polluted and pollutants are easily biodegradable.
- 3. In processing whereby water gets polluted and the pollutants are not easily bio-degradable and are toxic.
- Those industries that had installed a suitable treatment plant for the treatment of industrial effluents can get a rebate of 70 per cent on the cess payable.

- **Section 2** of the Act defines: (a) ''Local authorities'' to mean any municipal corporation or a municipal council or a cantonment board or any other body, entrusted with the duty of supplying water under the law by or under which it is constituted.(b) ''Industry'' – to include any operation or process, or treatment and disposal system, which consumes water or discharges sewage effluent or trade effluent but does not include any hydel power unit.
- **Section 3:**The Act provides that the State Pollution Control Boards and Committees shall levy and collect Cess from persons carrying on any industry and from all local authorities for the purposes of and utilization under the Water (Prevention and Control of Pollution) Act 1974.The Cess shall be assessed on the basis of water consumed by the person or local authority and would also include supply of water.
- **Section 4:**
- Provides for the affixing of Meters and prescribes that for measuring the quantity of water, used by any person or any industry or by local authorities, the persons liable to pay cess should install water meters of such standards and at such positions as may be prescribed. If this is not done then the Central Government (presently the duty of the State Boards) shall install the same and recover the costs from the concerned industry or local authority.

- **Section 5:**
- Of the Act lays down that every person liable to pay cess shall have to submit cess returns in the proforma and periodicity as prescribed for this purpose. If the said cess return is not submitted then the Assessing authority shall send a notice requiring the person concerned to submit the said returns before such dates as may be prescribed for this purpose.
- **Section 6:**
- Under section-6, the authority or the officer to whom the return has been furnished, shall after making enquiry and satisfying himself that the particulars stated in the returns are correct, assess the amount of cess payable by the concerned person or industry or local authority and issue necessary cess assessment orders.

- **Section 7:**
- Of the Act makes a provision for a rebate of 25% of the cess payable, if the person or authority liable to pay cess installs any plant for the treatment of effluents .
- **Section8:**
- Under section-9, any officer or authority of the state government, duly empowered on this behalf can enter any premises or any industry at any reasonable time for carrying out the functions as according to this Act including the testing of the correctness of the meters affixed .
- **Section 9:**
- Under section-10, if any person or authority fails to pay the amount of cess to the State Government, within the date specified in the order, then they have to pay an interest of two percent for every month or part of a month on the amount payable by them to the State Government.

Acts and Rules

- **Act**- Act is the law that is passed by the legislature. It is also called statute. However, most laws are not complete code in themselves, i.e. certain provisions as to their application or enforcement etc are deliberately left out by the legislature. That is where rules come into picture.
- **Rule**-Rules help govern a law. They are secondary in nature, in the sense they don't have independent existence of their own. They are made to make the parent Act work. The rules provide for the details that have not been provided for in the Act, however Rules by no means can go beyond the power conferred by the Act, or extend the same.

The Water (Prevention and Control of Pollution) Cess Rules, 1978

- -In exercise of the powers conferred by section 17 of the Water (Prevention and Control of Pollution) Cess Act, 1977 (36 of 1977), the Central Government hereby makes the following rules namely:-
- (a) These rules may be called the Water (Prevention and Control of Pollution) Cess Rules, 1978; (b) They shall come into force on the date of their publication in the official Gazette;
- **Section 2** of the Act defines: (a) ''Local authorities'' to mean any municipal corporation or a municipal council or a cantonment board or any other body, entrusted with the duty of supplying water under the law by or under which it is constituted.(b) ''Industry'' – to include any operation or process, or treatment and disposal system, which consumes water or discharges sewage effluent or trade effluent but does not include any hydel power unit.
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- **Section 7:**
- Of the Act makes a provision for a rebate of 25% of the cess payable, if the person or authority liable to pay cess installs any plant for the treatment of effluents .
- **Section 8:**
- Rebate. Where a consumer installs any plant for the treatment of sewage or trade effluent, such consumer shall be entitled to the rebate under section 7 on and from the expiry of fifteen days from the date on which such plant is successfully commissioned and so long as it functions successfully.
- **Section 9:**
- Under section-9, any officer or authority of the state government, duly empowered on this behalf can enter any premises or any industry at any reasonable time for carrying out the functions as according to this Act including the testing of the correctness of the meters affixed .
- **Section 9:**
- Under section-10, if any person or authority fails to pay the amount of cess to the State Government, within the date specified in the order, then they have to pay an interest of two percent for every month or part of a month on the amount payable by them to the State Government.

Water quality index

WQI

- Accurate information on the quality of water is inevitable to form a public policy and to implement the water quality improvement programmes.
- Water quality index (WQI) provides information about water quality in a single value. WQI is commonly used for the detection and evaluation of water pollution and may be defined as a reflection of composite influence of different quality parameters on the overall quality of water (Horton, 1965).
- WQI indices are broadly classified into two types, they are physico-chemical and biological indices. The physico-chemical indices are based on the values of various physico-chemical parameters in a water sample, while biological indices are derived from the biological information.

- WQI CALCULATION Calculation of WQI was carried out in this work by Horton’s method.
- The WQI is calculated by using the expression given in Equation
- WQI =E qn Wn / E Wn (7.1)
- Where, qn = Quality rating of n th water quality parameter.
- Wn= Unit weight of n th water quality parameter.

- Quality rating (q_n)
- The quality rating (q_n) is calculated using the expression given in Equation
- $q_n = [(V_n – V_{id}) / (S_n - V_{id})] \times 100$
- Where, V_n = Estimated value of nth water quality parameter at a given sample location.
- V_{id} = Ideal value for n th parameter in pure water. (V_{id} for pH = 7 and 0 for all other parameters)
- S_n = Standard permissible value of n th water quality parameter.

- Unit weight
- The unit weight (Wn) is calculated using the expression given in Equation
- Wn = k / Sn
- Where, Sn = Standard permissible value of n th water quality parameter.
- k = Constant of proportionality and it is calculated by using the expression given in Equation
- k = [1 / (E 1/ Sn=1,2,..n)]

- WQI AND STATUS
- The ranges of WQI, the corresponding status of water quality and their possible use are summarized in Table
- WQI and corresponding water quality status

S.No	WQI	Status	Possible usages
1	0 – 25	Excellent	Drinking, Irrigation and Industrial
2	25 – 50	Good	Domestic, Irrigaion and industrial
3	51 -75	Fair	Irrigation and Industrial
4	76 – 100	Poor	Irrigation
5	101 -150	Very Poor	Restricted use for Irrigation
6	Above 150	Unfit for Drinking	Proper treatment required before use.

- Water quality indices provide a way to distill thousands of records of environmental data into meaningful values that indicate the health of water resources and create a yardstick for measuring and assessing water quality.
- In general, water quality indices incorporate data from multiple water quality parameters into a mathematical equation that rates the health of a stream with a single number.
- That number is placed on a relative scale that rates the water quality in categories ranging from very bad to excellent.

- A Water Quality Index (WQI) is a numerical expression that represents the overall quality of water based on various physical, chemical, and biological parameters. It provides a simple and standardized way to assess and communicate the quality of water for different uses, such as drinking, recreational, or ecological purposes. The index typically combines multiple water quality parameters into a single value, facilitating comparisons between different water bodies or monitoring trends over time.
- The calculation of a Water Quality Index involves several steps:
- Selection of Parameters: The first step in calculating a WQI is to select the parameters that will be included in the index. These parameters may include physical characteristics (e.g., temperature, turbidity), chemical constituents (e.g., pH, dissolved oxygen, nutrients), and biological indicators (e.g., fecal coliform bacteria, aquatic macroinvertebrates).
- Normalization of Parameters: Each water quality parameter is normalized to a common scale, typically ranging from 0 to 100, where 0 represents the worst possible quality and 100 represents the best quality. Normalization ensures that parameters with different units and measurement scales can be combined into a single index.
- Normalized Value = (Observed Value / Standard Value) * 100

- Weighting of Parameters: Some parameters may be more important than others in assessing water quality for a specific use. Therefore, each parameter may be assigned a weight or importance factor based on its significance to the overall quality of water. For example, parameters related to human health or regulatory standards may be given higher weights than parameters with less immediate impact.

- Calculation of Sub-Indices: Sub-indices are calculated for each parameter by multiplying the normalized value of the parameter by its corresponding weight. The sub-indices represent the contribution of each parameter to the overall water quality.
- Sub-Index for Parameter i = (Normalized Value of Parameter i) * (Weight of Parameter i)

- Aggregation of Sub-Indices: The sub-indices are then aggregated to calculate the overall Water Quality Index. This is typically done by summing the weighted sub-indices or using a weighted average formula. The resulting value represents the overall quality of water for the specific set of parameters and weights chosen.
- WQI = Σ(Sub-Index for all Parameters)

- Alternatively, the WQI can be calculated using a geometric mean formula, particularly when dealing with multiple parameters. In this case, the sub-indices are multiplied together, and then the nth root of the product is taken, where n is the total number of parameters.
- WQI = (Sub-Index1 * Sub-Index2 * ... * Sub-Indexn)^(1/n)
- Interpretation of Results: The final Water Quality Index value can be interpreted using predefined categories or thresholds to classify water quality into different levels, such as excellent, good, fair, poor, or very poor. These categories provide a qualitative assessment of water quality and can help stakeholders understand the implications of the index value for different uses of water.
- Here's an example of how a Water Quality Index might be calculated for a hypothetical river:
- Suppose we select four parameters for inclusion in the index: dissolved oxygen (DO), biochemical oxygen demand (BOD), pH, and fecal coliform bacteria (FCB). We assign weights to each parameter based on its importance: DO (0.3), BOD (0.2), pH (0.3), and FCB (0.2).

- Next, we collect water quality data from sampling sites along the river and calculate the normalized values for each parameter, ranging from 0 to 100. For example:

- DO: 8 mg/L (normalized to 80)
- BOD: 4 mg/L (normalized to 60)
- pH: 7.5 (normalized to 75)
- FCB: 1000 MPN/100mL (normalized to 40)
- Then, we calculate the sub-indices for each parameter by multiplying the normalized value by its corresponding weight:

- Sub-index for DO = 80 * 0.3 = 24
- Sub-index for BOD = 60 * 0.2 = 12
- Sub-index for pH = 75 * 0.3 = 22.5
- Sub-index for FCB = 40 * 0.2 = 8

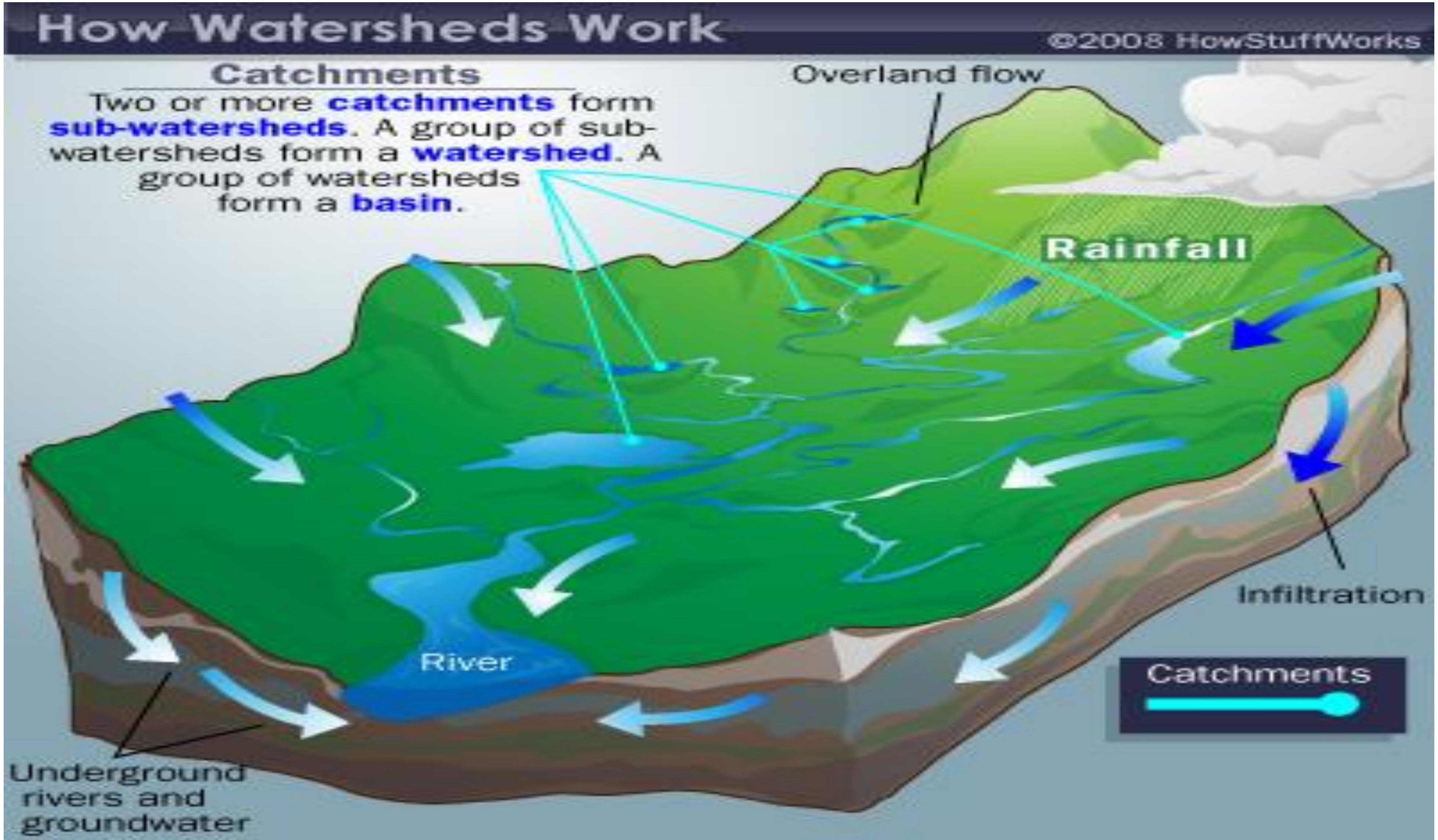
- Finally, we aggregate the sub-indices to calculate the overall Water Quality Index:
- WQI = Sub-index for DO + Sub-index for BOD + Sub-index for pH + Sub-index for FCB
- = 24 + 12 + 22.5 + 8
- = 66.5
- Based on predefined categories or thresholds, we interpret the Water Quality Index value of 66.5 to classify the water quality of the river as "good."
- In summary, the Water Quality Index provides a comprehensive and standardized method for assessing the overall quality of water based on multiple parameters, enabling stakeholders to make informed decisions regarding water management, protection, and conservation.

Water shed management

What is a Watershed?

- Every body of water (e.g., rivers, lakes, ponds, streams, and estuaries) has a watershed. The watershed is the area of land that drains or sheds water into a specific receiving waterbody, such as a lake or a river.
- As rainwater or melted snow runs downhill in the watershed, it collects and transports sediment and other materials and deposits them into the receiving waterbody.
- **Purpose of watershed**
- A watershed is an area of land that drains rain **water** or snow into one location such as a stream, lake or wetland. These **water** bodies supply our drinking **water**, **water** for agriculture and manufacturing, offer opportunities for recreation and provide habitat to numerous plants and animals.

watershed



How Watersheds Work
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Catchments
Two or more catchments form sub-watersheds. A group of sub-watersheds form a watershed. A group of watersheds form a basin.
Overland flow
Rainfall
Infiltration
River
Catchments
Underground rivers and groundwater

What is Watershed Management?

- Watershed management is a term used to describe the process of implementing land use practices and water management practices to protect and improve the quality of the water and other natural resources within a watershed by managing the use of those land and water resources in a comprehensive manner.
- **What is Watershed Management Planning?**
- Watershed management planning is a process that results in a plan or a blueprint of how to best protect and improve the water quality and other natural resources in a watershed. Very often, watershed boundaries extend over political boundaries into adjacent municipalities and/or states. That is why a comprehensive planning process that involves all affected municipalities located in the watershed is essential to successful watershed management.

- **Why is watershed management important?**
- Runoff from rainwater or snowmelt can contribute significant amounts of pollution into the lake or river. Watershed management helps to control pollution of the water and other natural resources in the watershed by identifying the different kinds of pollution present in the watershed and how those pollutants are transported, and recommending ways to reduce or eliminate those pollution sources.
- All activities that occur within a watershed will somehow affect that watershed's natural resources and water quality. New land development, runoff from already-developed areas, agricultural activities, and household activities such as gardening/lawn care, septic system use/maintenance, water diversion and car maintenance all can affect the quality of the resources within a watershed.
- Watershed management planning comprehensively identifies those activities that affect the health of the watershed and makes recommendations to properly address them so that adverse impacts from pollution are reduced.

PRINCIPLE FACTORS INFLUENCING WATERSHED OPERATIONS

A. Physiography
B. Soil and Geology
C. Land use
D. Climatological and meteorological information
E. Design peak runoff rate and
F. Socio – economic factors

A. PHYSIOGRAPHY

Size:

Small watershed with an area not exceeding 4000ha should be taken as "basic natural planning unit" for maintenance.

Shape:

Time of conservation is more for a long & narrow watershed, resulting in lower runoff rates than square – shaped watersheds of the same size.

Drainage morphometry:

Several parameters like "drainage density", "bifurcation ration", "stream order", "drainage pattern " etc., characterize the basin morphometry.

B. SOIL AND GEOLOGY:

Soil and geology of a watershed determine the runoff and sedimentation potential of a watershed and ground water recharge.

C. LAND USE:

A detailed land use planning to use the watershed in fullest potential and capabilities must be formulated.

D. CLIMATOLOGICAL AND METEOROLOGICAL INFORMATION:

It includes not only precipitation, but also speaks about the time of precipitation, duration, intensity along with the temperature, evaporation, sunshine hours etc.

E. DESIGN PEAK RUNOFF RATE:

Designing of peak runoff rate is very essential for soil and water conservation of a watershed area.

F. SOCIO – ECONOMIC FACTORS:

The ultimate objective of a water development programme is to increase and stabilize socio – economic condition of local people.

Methods of watershed management

- Watershed management basically refers to the efficient management and conservation of surface and groundwater resources. It involves the prevention of runoff and storage and recharge of groundwater through various methods like percolation tanks, recharge wells, etc. The methods of watershed management are:
- Contour bund
- Bench terracing
- Microcatchments for sloping lands
- Check dam
- Percolation pond
- Stone Barriers

- Watershed management is crucial for conserving water resources, preventing soil erosion, and promoting sustainable land use practices. Here are explanations for each of the methods listed:
- 1. Contour bunds: Contour bunds are structures built along the contours of sloping land to reduce soil erosion and retain water. They consist of embankments made of soil or stone, built perpendicular to the slope, which helps to slow down the flow of water, allowing it to infiltrate into the soil rather than causing erosion.
- 2. Bench terracing: Bench terracing involves constructing series of steps or terraces along the slope of the land. These terraces help to reduce the speed of water runoff, prevent soil erosion, and promote water infiltration. Bench terracing also provides flat areas for cultivation, thereby maximizing land use efficiency.
- 3. Microcatchments for sloping lands: Microcatchments are small-scale water harvesting structures designed to capture and retain rainwater in areas with sloping terrain. They typically consist of small embankments or bunds constructed along the contour lines to collect runoff water, which can then be used for irrigation or groundwater recharge.
- 4. Check dams: Check dams are small structures built across gullies or small streams to slow down the flow of water, reduce erosion, and promote groundwater recharge. They are typically constructed using materials such as rocks, stones, or concrete, and help to retain sediment and nutrients, thereby improving water quality downstream.

- 5. Percolation ponds: Percolation ponds, also known as recharge basins or infiltration basins, are depressions or excavated areas designed to capture and store surface runoff or stormwater. These ponds allow water to percolate slowly into the soil, replenishing groundwater aquifers and helping to maintain base flow in streams and rivers.

- 6. Stone barriers: Stone barriers are structures built using rocks or stones to slow down the flow of water, reduce soil erosion, and promote water infiltration. They are often constructed across small channels or swales to create small dams or embankments that help to retain sediment and moisture.

- Each of these methods plays a vital role in watershed management by helping to conserve water, prevent soil erosion, and promote sustainable land use practices, thereby contributing to the overall health and resilience of ecosystems within the watershed.

What are some key steps in watershed management?

- Comprehensive watershed plans should first identify the characteristics of the watershed and inventory the watershed’s natural resources. It is important to establish a baseline of the overall nature and quality of the watershed in order to plan properly for the improvement of the resources in the watershed and to actually measure those improvements.
- The first steps in watershed management planning are to:
- Delineate and map the watershed’s boundaries and the smaller drainage basins within the watershed;
- Inventory and map the resources in the watershed;
- Inventory and map the natural and manmade drainage systems in the watershed;
- Inventory and map land use and land cover;
- Inventory and map soils;
- Identify areas of erosion, including stream banks and construction sites;
- Identify the quality of water resources in the watershed as a baseline; and
- Inventory and map pollution sources, both point sources (such as industrial discharge pipes) and nonpoint sources (such as municipal stormwater systems, failing septic systems, illicit discharges).
- Watershed plans should establish clear goals, visions, and actions to be taken.

- **Examples of opportunities to reduce pollution and address other wide-ranging environmental issues include:**
- Infrastructure improvements. More frequent maintenance of municipal stormwater systems or improving or replacing inadequate stormwater treatment systems, identifying and eliminating illicit (i.e., non-stormwater) connections to municipal stormwater systems;
- Reducing paved areas and other impervious cover, especially adjacent to waterbodies and wetlands. Zoning and subdivision regulations can be revised to address issues such as reducing lot coverage/impervious cover, reducing roadway widths, encouraging cluster and low impact development, limiting land disturbance such as grading and clearing, and increasing development setbacks from resources;
- Identifying appropriate areas for open space acquisition, greenways planning, and the establishment of vegetated buffers along waterbodies and wetland areas;
- Establishing sewer avoidance areas to limit development;
- Increasing inspections and maintenance of existing septic system and encouraging repairs to failing systems;

- Identifying other appropriate housekeeping practices for homeowners and landowners (encouraging the use of vegetated buffers adjacent to waterbodies and wetlands, reducing lawn areas and the amount of fertilizers and chemicals applied to them, recommending washing cars over lawns instead of driveways so rinse water can drain into the lawn and not run-off into storm drains, etc.);
- Identifying resource and wildlife habitat restoration priorities;
- Increasing and promoting public access and greenways and identifying areas where it is appropriate to do so; and
- Identifying and evaluating opportunities for nonstructural flood protection efforts;
- Improving waste management, pollution prevention, and recycling efforts at municipal facilities and businesses within the watershed.
- The degree of public education and participation in the planning process can greatly influence the success of watershed management.

The Triple Benefits of a Healthy Watershed

- Water is essential for our future. A healthy watershed provides the triple benefits of human, ecological and economic health. The goal of watershed management is to properly balance and manage this resource.
- **Ecological Health**
- A healthy watershed functions as a complete ecological system promoting the health of all living organisms and landscapes within the watershed. A healthy, intact watershed minimizes the impacts of flooding and erosion and serves to filter sediments and contaminants so they do not reach our streams, lakes, and groundwater.
- **Economic Health**
- An abundant supply of clean water is essential for a vibrant economy. Homes, farms, municipalities and businesses all need an ample supply of clean water to operate effectively. Clean water allows municipalities, businesses, agricultural producers, and industries to operate more cost effectively, saving money for taxpayers and consumers. Healthy rivers, lakes, wetlands and natural spaces are foundations for recreation and tourism.

- **Human Health**
- Life requires a safe daily supply of water. But water is far more than that: clean surface and ground water is essential to support our high quality of life and the social aspects of our communities. Clean rivers, lakes and streams provide many healthy recreational opportunities including swimming, boating, and fishing.

Kothapally Watershed in Andhra Pradesh, Southern India

- Kothapally watershed is located at 170 22' N latitude, 780 07' E longitude and about 550 meters AMSL altitude in Ranga Reddy district, Andhra Pradesh, India. This watershed is part of the Musi sub-basin of the Krishna river basin, and situated approximately at 25 km upstream of Osman Sagar reservoir.
- Soil has been classified as Vertisols with shallow soil depth (10 to 90 cm ranges) and has medium to low water holding capacity. The average landholding per household is about 1.4 ha. Average crop yield was less than 1 ton/ha therefore Kothapally was characterized by low productivity, low income, and low employment with high incidence of poverty in year 1999 and before.
- ICRISAT, consortium with local partners (government agencies and NGOs) started watershed development program in Kothapally village from year 1999 onwards. Integrated watershed management approach was used. Soil and water conservation, both in-situ and ex-situ practices were made in watershed. Integrated nutrient and pest management approach adopted. Efforts were put in direction of increasing crop productivity.
- Good variety of seeds and fertilizer were made available in village and helped farmers in selecting right cropping pattern according to their soils. Water balance of Kothapally watershed shows that after doing such interventions, groundwater recharge has increased from 7 to 32 %, outflow reduced from 37 to 9 % of total rainfall. Crop yields increased by 2 to 5 times in monsoon season and irrigation potential increased from 13 % to 31 % compared to pre-development stage.
- Survey suggest that average household income in Kothapally watershed is greater than 50 % compare to adjoining locations where watershed interventions were not been made. This program has significantly increased crop productivity, reduced poverty and increased employment opportunity and has become the site for learning to the farmers, researchers and policy makers. K

Case studies

Dr.M.Vasanthy

Water borne Problems

- **What is Itai-itai Disease?**
- Itai-itai disease was the first documented occurrence of mass cadmium poisoning in the world.
- It occurred in 1950 in Toyama Prefecture in Japan. However, the first time the disease was reported here was in 1912.
- Toyama Prefecture was at the time the leading industrial prefecture on the Japan sea coast.
- Itai-itai disease literally translates to “ouch-ouch” disease, named for the painful screams of its victims.

- Cadmium poisoning is a serious example of the toxicity of some metals in the body.
- In the body cadmium has no constructive function, meaning it serves no biological function except as a toxin.
- Cadmium is highly toxic even at low doses. Some of the effects of acute cadmium exposure are flu-like symptoms, fever, chills, muscle aches.
- These flu-like symptoms are referred to as “The Cadmium Blues”. More serious exposure to cadmium has much more detrimental effects.
- Any significant amount of cadmium taken up by the body immediately poisons the liver and kidneys.
- Proximal Renal Tubular Dysfunction occurs when significant amounts of cadmium are ingested, meaning the kidneys lose their ability to remove acid from the blood.
- A side effect of this is Gout, most likely contributing to much of the pain endured by victims of Itai-itai. The kidney damage caused by cadmium is irreversible.
- Serious damage is also inflicted upon the bones in a victim of Itai-itai. Cadmium poisoning leads to osteomalacia (softening of the bones) and osteoporosis (loss of bone mass and weakness).
- In extreme cases of this a person with Itai-itai can sustain bone fractures from their body weight alone. Cadmium is also a carcinogen.

- **Why Did Itai-itai Disease Even Occur?**
- Mining was prevalent in the Toyama Prefecture of Japan starting around the year 710.
- After WWI, new mining technology arriving from Europe made the Kamioka Mines in Toyama among the most productive in the world.
- Starting all the way back in 1910 cadmium was being released in significant quantities into the Jinzu River in Toyama.
- This was a major problem because the cadmium in the water killed all the fish, as it was the major source for irrigation for the surrounding paddy fields, as well as drinking water. I
- In 1912 the first documented case of the disease emerged. This was only two years after the cadmium had shown up in large quantities in the river. This means that there was a lot of cadmium present. It was reported that over 200 elderly women living in the Jinzu Valley in the 1940s being mothers of multiple children were disabled by the disease. This was on top of a reported 65 deaths of women thanks to Itai-itai.

Why cadmium was absorbed so quickly?

- The key actually lies in a close relative of cadmium, namely in zinc. Zinc and cadmium share an uptake pathway in the body. So, cadmium which is very similar to zinc in reactivity, is taken up by the zinc uptake protein in the body unknowingly. And it seems like it's taken up in large quantities, very quickly.

Minamata disease

- Minamata village came into being in 1889, during the Meiji period, with the introduction of the cities, towns and villages system.
- Although the village produced salt on the tidal flats, with only 2,325 homesand a population of 12,040, Minamata was no more that a small farming and fishing village.
- NipponNitrogen Fertilizer Corporation, the predecessor of Chisso Corporation, was established in 1908.
- Thereafter, Minamata developed in parallel with the company's growth. Minamata was designated a town in 1912, when a railroad connection and other infrastructure were laiddown.
- Emerging from the devastation of war, Minamata became a city in 1949, and took an important steptoward modernity. The population reached a peak of 50,461 persons in 1956, when the city boundaries were redrawn to encompass Kugino village. Minamata City took on the aspect of one of only a handful of modern, industrial cities in Kumamoto Prefecture.

- The area around Minamata Bay in the Yatsushiro Sea of Kumamoto Prefecture was a beautiful and fertile sea blessed with a natural fish reef. It was also a spawning site for many species of fish.However, in the 1950s, strange phenomena appeared in the bay.
- Shellfish began to die, fish floated on the surface of the water, seaweed failed to grow, and cats died in strange ways. On Apri1 21, 1956, a child from Tsukinoura, in Minamata City, Kumamoto Prefecture was admitted,with severe complaints such as the inability to talk, walk and eat, to the Shin Nippon Chisso Fertilizer Co., Ltd. Minamata Factory hospital (hereafter called Chisso Hospital). The present name of the company is Chisso Corporation. (hereafter called Chisso).
- Following that, three patients were admitted to the hospital with similar symptoms. On May l of the same year, Dr. Hajime Hosokawa, Director General of the hospital, reported to Minamata Public Health Center (Head: Dr. Hasuo Ito) that four patients were in the hospital showing cerebral symptoms with an unknown cause.

- The day of official recognition of Minamata disease had come. In the days of the official recognition, people were afraid of this strange disease, as they thought it might be infectious.
- After official recognition of the first patients, a survey by the Minamata Public Health Center,Minamata City, Minamata Medical Association, Chisso Hospital and Minamata Municipal Hospital,confirmed the existence of other patients with the same condition.
- Fifty-four cases were confirmed,including seventeen deaths, since the outbreak in December 1953 and a child diagnosed with cerebral paralysis was certified as a congenital Minamata disease patient (the first official recognition of a congenital Minamata disease patient) in November 1962.
- As the investigation into the cause took a long time, the outbreak of Minamata disease continued and expanded along the Yatsushiro Sea coast.

Minamata disease

- A form of poisoning, Minamata disease is a disease of the central nervous system, caused by the consumption of fish and shellfish contaminated with methyl mercury compounds discharged into the environment as factory waste etc. and then accumulating in the marine life.
- There have also been cases of Congenital Minamata disease, in which victims were born with a condition resembling cerebral palsy. This form of the disease is methyl mercury poisoning of the fetus via the placenta,caused when the mother consumes contaminated seafood during pregnancy.
- Minamata disease is not an infectious disease transferred by air or food, neither is it genetically inherited.
- The first recognized outbreaks occurred around Minamata Bay, in Kumamoto Prefecture, in 1956.
- Brought about by environmental pollution, the damage to health wrought by Minamata disease and the accompanying destruction of the natural environment, is in terms of the scale of damage and the unimaginable gravity of its repercussions, a pollution disaster unprecedented in human history.Niigata Minamata Disease broke out in Niigata Prefecture in 1965

Symptoms and treatment of Minamata disease

- The symptoms of Minamata disease include sensory disorders in the distal portion of the four extremities (loss of sensation in the hands and feet), ataxia (difficulty coordinating movement ofhands and feet), concentric constriction of the visual field (narrowing of the field of vision), hearing impairment, disequilibrium (impairment of faculties for maintaining balance), speech impediments (speech becomes slurred and unclear), tremors (trembling of the hands and feet), and disorder of the ocular movement (eye movement becomes erratic).
- In very severe cases, victims fall into a state of madness, lose consciousness, and may even die. In relatively mild cases, the condition is barely distinguishable from other ailments such as headache, chronic fatigue, and a generalised inability todistinguish taste and smell
- Causative treatments, involving patients taking medicines to force methyl mercury to be excreted from the body, are applied in the initial stages. However, a fundamental cure for Minamata disease has not yet been found. The main treatments involve the temporary relief of symptoms (symptomatic therapy), and rehabilitation (physiotherapy and occupational therapy)

Fukoshima Nuclear disaster

- On the 11th of March, 2011, a magnitude 9.0 earthquake hit Northern Japan. This so-called Tōhoku earthquake led to a tsunami on the Eastern coast of Northern Japan, leading to further destruction. More than 15.000 people died as a direct result of the earthquake and tsunami, more than 500.000 had to be evacuated.
- The Fukushima Daiichi nuclear power plant was severely damaged by the quake and the tsunami.
- With no electricity to power the cooling systems, water inside the reactors began to boil off, causing meltdowns of the uranium fuel rods inside of reactor cores 1 to 3.
- TEPCO, the company responsible for the plant, began to vent steam from the reactors in order to relieve pressure and prevent a giant explosion. This steam carried radioactive particles out to the Pacific Ocean.

- Since it became evident that a nuclear meltdown was possibly taking place in the reactor cores, a 20 km zone around the power plant (with an area of about 600 km2) was declared an evacuation zone and a total of 200,000 people were forced to leave their homes.
- While evacuations were commencing, multiple explosions destroyed reactor 1, 2 and 3 and caused a fire of the spent fuel pond of reactor 4.
- To cool off the cores, TEPCO took the controversial decision to pump seawater into the reactor. This could not prevent the temperatures from rising even further, as the nuclear fuel rods were left partially uncovered.
- According to TEPCO, all fuel rods in reactor 1 melted, a well as 57% of the fuel rods in reactor 2 and 63% of those in reactor 3.3 Also, as a result, massive amounts of radioactively contaminated water flowed into the groundwater and back into the ocean.
- On March 25th, people living in the 30 km radius were asked to voluntarily evacuate their homes and leave the contaminated areas. On April 12th, the Fukushima nuclear meltdowns were categorized as a level 7 nuclear accident – the highest level on the International Nuclear Event Scale (INES), which had previously only been reached by the Chernobyl disaster.

- The four large explosions, the fire of the spent fuel pond, smoke, evaporation of sea-water used for cooling and deliberate venting of the pressurized reactors all caused the emission of radioactive isotopes into the atmosphere.
- Measurements of radioactivity taken outside of the power plant reached a maximum of 10.85 mSv/h, or about 38,000 times the normal background radiation.
- Further deliberate venting of block 2 and 3 on March 16th led to additional air-borne releases of radioactivity in similar magnitudes.
- Radioactivity doses around the plant a week after the earthquake reached levels of up to 1,930 µSv/h – more than 6,000 times normal background radiation.

- A study by the Norwegian Institute for Air Research (NILU) found that around 16,700 PBq of xenon133 (250% of the amount released at Chernobyl) were emitted by the Fukushima power plant between March12th and 19th.
- This constitutes the largest release of radioactive Xenon in history. Xenon-133 is a radioactive gas with a half-life of 5.2 days, which emits beta- and gamma-radiation and cause harm upon inhalation.
- Additionally, the NILU study found that 35.8 PBq of caesium-137 (42% of the amount released at Chernobyl) were emitted by the Fukushima power plant between March 12th and 19th .
- Their study found that radioactive emissions were first measured right after the earthquake and before the tsunami struck the plant, showing that the quake itself had already caused substantial damage to the reactors.
- The NILU report also suggests that the fire in the spent fuel pond of reactor may have been the major contributor of airborne emissions, since emissions decreased significantly after the fire had been brought under control.
- In its report to the IAEA, the Japanese government states that the total amount of fission products released into the atmosphere amounts to 840 PBq, a number even higher than previous estimates.

- 70,000 people remained in more than 870 km2 of highly contaminated land outside of the evacuation zone, where they were exposed to an external radioactivity 100 times higher than the normal background radiation in the first year after the catastrophe.
- • The risk of developing cancer and other radiation-induced diseases increased proportionally to the amount of radioactive exposure. There is no lower threshold, as even the slightest amount of radioactivity can cause harmful tissue damage and genetic mutations.
- • Radioactive contamination has been detected in all kinds of fruits and vegetables grown in the affected regions as well as in meat of animals grazing on contaminated land. Radioactivity has also been detected in milk, tea and tap water, even in the Tokyo Metropolitan area. Eating just 500g of contaminated vegetables can cause internal exposure to more than 100 times the normal annual amount of radioactive food content for adults and more than 200 times for children.
- • Fish and seafood caught in the North Pacific are highly contaminated, with a clear accumulation of radioactivity in animals higher up the food-chain in the months after the disaster. Washout and bioaccumulation will continue to cause radioactive contamination of marine animals for many years.

- Children are most severely affected by radioactivity, as their bodies have a higher sensibility and as their natural habits expose them to greater dosage. Raising the permissible radioactive dose level to 20 mSv per year and withholding iodine tablets has led to a high exposure of children in Fukushima prefecture.
- It is too early and too little data exists in order to estimate the extent of health effects caused by the nuclear disaster. Large-scale epidemiological studies are required in order to determine the effect and the extent of health consequences for the population.
- It is important that this research is performed by independent groups not associated with the nuclear industry, such as TEPCO, JAEA, the IAEA or affiliated organizations.
- Claims by scientists affiliated with the nuclear industry that no health effects are to be expected are unscientific and immoral.