Three Day Online Training
On
"Groundwater Quality and Stable Isotope Characterization for Salinity "
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Spatial and Temporal Analysis of Groundwater Quality Data

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"Groundwater will be the enduring gauge of this generations intelligence in water and land management"

.....Australian Groundwater School, Adelaide

Organic Micro Pollutants in Water

Frequency of occurrence of OMPs: high, medium & low relevance

Atrazine	Paracetamol	N,N-Dimethylsulfamide
Desethylatrazine	Primidone	Bentazone
Desisopropylatrazine	Sulfamethoxazole	Triclosan
Simazine	Iohexol	Gemifibrozil
Diuron	Iopromide	Diazepam
1-H-Benzotriazole	Iomeprol	Loratadine
Tolytriazole	Diatrizoate	Ranitidine
Linuron	Iopamidol	Theophylline
Terbutryn	Diclofenac	Acetamipride
Ametryn	Naproxen	Clothianidine
Phenazone	Phenobarbital	Gabapentin
Atenolol	Ibuprofen	Sulfadiazine
Carbamazepine	Clofibric acid	Sucralose
Cotinine	Isoproturon	Acesulfame
Trimethoprim	Ciprofloxacin	Saccharin
Carbofuran	Chlorothiazide	Sodium cyclamate
Propanil	Metformin	Aspartame
Caffeine	Chloramphenicol	N,N-Dimethylsulfamide

Requested by D.YADAV

Monitoring planning

- Why ?
- Where ?
- What ?
- When ?
- How often ?

- Results obtained from such monitoring should be regularly reviewed to decide if any changes in the programme are necessary

Stages of the monitoring process

- Sample taking
- Transportation to the laboratory
- Sample pretreatment
- Analysis proper
- Data storage and communication

- The data that comes out of the sequence of operations must still be related to the initial quality of water

Philosophy

- Keep it simple
- Think first, sample later
- Samples can be obtained fairly easily, what comes next is much more difficult
- Often data are buried in computers, never to be used again
- Try to set up a conceptual model first

Philosophy …

- Map the area with the main sources of pollution
- Sample, monitor, investigate
- Communicate data to the decision makers

Two approaches

- Fixed networks
- Synoptic studies

Disciplines involved

- Geography
- Chemistry
- (micro)biology
- Statistics
- Hydrology – conditions of flow are more important to understand the quality of water

Why monitoring ?

- Process control
- Curiosity
- Compliance with the standards
- Detection of trends
- Modelling
- Early warning – fish monitors

Objectives of Monitoring

1. Assess the impact of activities by man upon the quality of water and its suitability for intended use
2. Determine the quality of water, in its natural state, which might be available to meet future needs
3. Keep under observation the sources and pathways of specified substances
4. Determine the trend of water quality at representative stations

- **Impact Stations (1) – situated in water bodies where there is at least one major use of water or which are greatly affected by man's activities.**

- **Baseline Stations (2) – located in an area where no direct diffuse or point sources of pollution are likely to be found.**

- **Impact or baseline station (3) – depending upon whether the hazardous substance is of artificial or natural origin.**

- **Trend Stations (4) – set up specially to assess the trends of water quality.**

Where ?

- Where changes are occurring
- Depends on the goal:
  - Trends > well mixed
  - Compliance > at intake or in effluent
- Not necessarily at bridges – bridges are ideal for traffic but not for sampling, although convenient

Water Quality Characterization Domestic Water Supply

1. Colour, odour, taste
2. Organic content: COD, BOD, TOC, Phenols, hydrocarbons
3. Carcinogens and toxic compounds, insecticides, pesticides, detergents
4. Turbidity, salinity
5. Alkalinity, pH
6. Total hardness, Ca, Mg, Fe, Si., etc.
7. Pathogenic organisms, total bacterial count (37^{o}C), E. coli count, plankton count

Water Quality Characterization Agricultural Irrigation

1. Salinity
2. SAR (Na-Ca-Mg content)
3. RSC (CO_3-HCO_3-Ca-Mg content)
4. Boron
5. Alkalinity, pH
6. Pesticides, growth regulators, etc.
7. Persistent synthetic chemicals (e.g., polyethylene derivatives, asphalt sprays, etc.)
8. Pathogenic organisms

Water Quality Characterization
Fish, shellfish, wildlife and recreation

1. Colour, odour
2. Toxic compounds
3. Turbidity, floating matter, sludge deposits, salinity
4. Temperature
5. Dissolved oxygen, BOD
6. Alkalinity, pH
7. Pathogenic organisms, plankton count
8. Nitrogen, phosphorous, etc. (inorganic nutrients which support algae blooms and other undesirable aquatic growth)

Water Quality Characterization Watering of livestock

1. Salinity
2. Toxic compounds
3. Pathogenic organisms
4. Plankton count

Industrial Characterization

Industry	Quality Parameters
Pulp and Paper Mill	Colour Suspended solids Chromium BOD Phenols COD Solids pH Total coliform

Industrial Characterization …

Industry	Quality Parameters
Steel Rolling Mill	Suspended solids NH_4-N Phosphorous Cyanide Nickel Iron Zinc Phenols pH

Industrial Characterization …

Industry	Quality Parameters
Sugar Mill	Colour Suspended solids BOD NH_4-N Solids Alkalinity pH Total coliform

When ?

- **Depends on the variability**:
  - Systematic
  - Random
- **Examples**:
  - Colis in swimming pool (in morning hours no colis but evening hours much colis)

When …

- **Examples:**
  - Diurnal variations of oxygen (if algae is present we may measure 120% oxygen in day time and only about 70% in night)
  - Industries starts producing sewage in day
  - People produces more sewage in day than night

When …

- **Examples**:
  - Water quality problems are more critical in dry season because of low flows
  - Because of dilution water quality problems are not pronounced in wet season
  - Wet seasons are important for erosion studies

How often ?

- The precision increases with $\sqrt{n}$

  n is the number of samples

Compare

- Rivers
- Lakes
- Groundwater

- The quality of water in various water bodies is rarely if ever constant in time but subject to change. Variations are caused by changes in the quantity of any of the input to the water body

Results

Result = Average + Noise

(Systematic + Random)

Results …

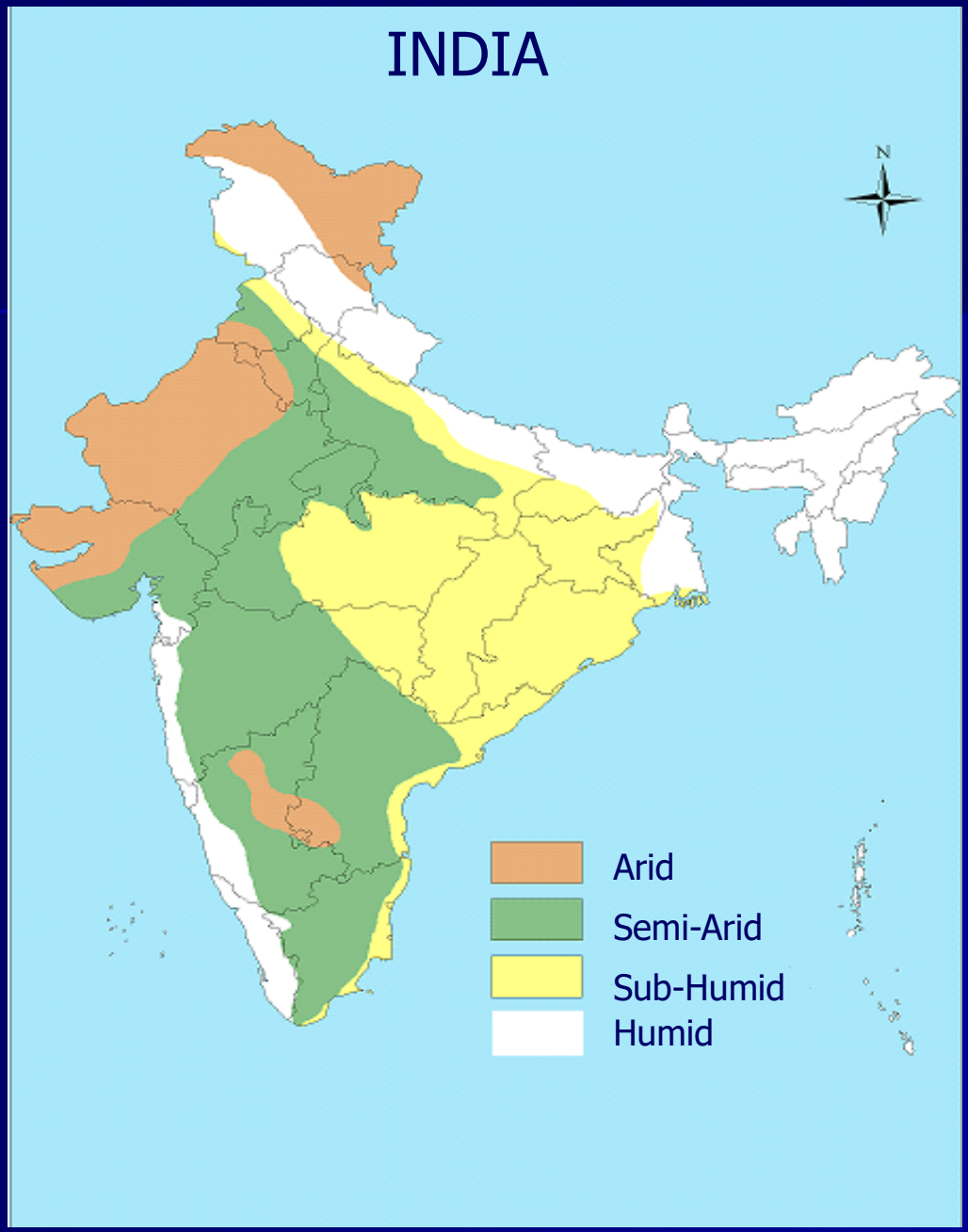
- Relationships
- Correlation/association
  - Scatter plots
  - Correlation coefficients (r = 0.01-0.99)
- Regression (line)
- Transformations

Water Quality Issues

- Water Scarcity
- Oxygen Depletion
- Pollution due to Urbanization
- Non-Point Source Pollution
- Eutrophication
- Salinity
- Natural contaminants
- Pathogenic Pollution
- Ecological Health

Water Scarcity

- Un-even distribution of rainfall
- Increasing demand of water for agricultural, industrial and domestic activities


INDIA
N
Arid
Semi-Arid
Sub-Humid
Humid

Non Point Source Pollution

- Agricultural activities (nutrients, pesticides etc.)
- Open defecation in fields
- Bathing and Washing activities

Eutrophication

- Discharge of domestic waste water
- Agricultural runoff
- Industrial effluents

Salinity

- Leaching of salts build-up in agricultural areas under intense irrigation
- Industrial effluents with high dissolved solids
- Increased use of chemicals in agriculture

Natural Contaminants

- Fluoride
- Arsenic, Selinium
- Nitrate
- Iron

Fluorosis

- An estimated 62 million people in 17 States are affected with dental, skeletal and/or non-skeletal fluorosis in India
- Extent of fluoride contamination: 1.0 - 48.0 mg/L.
- The control of the fluoride contamination in ground water is difficult
- However, some artificial recharge and/or rainwater harvesting techniques improve the quality of groundwater by dilution

Pathogenic Pollution

- Water borne diseases are the most important water quality issues in India
- Inadequate arrangement for transport and treatment of wastewater

Ecological Health

- Large area in our aquatic environment support rare species and ecologically very sensitive

Ground Water Contaminants

- Nitrate – Blue baby disease
- Pathogens – Bacteria and virus causes water borne diseases such as typhoid, cholera, dysentery, polio and hepatitis
- Toxic Metals – Arsenic, selenium, lead, mercury, cadmium, copper, chromium, nickel, etc.
- Organic compounds – Pesticides, Phenols, Hydrocarbons, PCBs, etc.

Use Based Classification

Designated best use	Quality class	Criteria
Drinking water source without conventional treatment but with chlorination	A	pH: 6.5 to 8.5 DO: 6 mg/L or more BOD: 2 mg/L or less Total coliform MPN/100 ml: 50

Use Based Classification…

Designated best use	Quality class	Criteria
Outdoor bathing (organized)	B	pH:6.5 to 8.5 DO: 5 mg/L or more BOD: 3 mg/L or less Total coliform MPN/100 ml: 500

Use Based Classification…

Designated best use	Quality class	Criteria
Drinking water source with conventional treatment	C	pH: 6.5 to 8.5 DO: 4 mg/L or more BOD: 3 mg/L or less Total coliform MPN/100 ml: 5000

Use Based Classification…

Designated best use	Quality class	Criteria
Propagation of wildlife and fisheries	D	pH: 6.5 to 8.5 DO: 4 mg/L or more Free ammonia: 1.2 mg/L

Use Based Classification…

Designated best use	Quality class	Criteria
Irrigation, industrial cooling, and controlled waste disposal	E	pH: 6.5 to 8.5 EC: 2250 mS/cm SAR (max): 26 B: 2 mg/L

Salt water intrusion and its estimation

The two important factors to be considered for any event of sea water intrusion are

- proximity of the sea and low altitude

Revelle(1941), Simpson(1946), Scholler(1959), Walton(1970), Stein and Kumhansi (1988), Rosenthal (1987), Rightmor et al (1974), Back and Zoetl (1975)

-have studied the sea water intrusion using the following ratios

TA/TH,
Ca/Cl,
Na/(Ca+Mg)
Index

Na/Cl,
Mg/Cl,
Cl -(Na+K):Cl

Cl/SO4,
Cl/(CO3+HCO3)
BEI (Base Exchange

Specific values of the ratios to show or indicate possible sea water contamination

TA/TH	< 1	Excess of hardness over alkalinity
Mg/Ca	> 0.9	Sea water contamination
Na/Cl	> 0.86	Sea water contamination
Cl/(CO3+HCO3)	< 0.5	Uncontaminated or fresh
	0.5 – 2.8	Slightly contaminated
	> 2.8	Severely contaminated
SO4/Cl	> 0.2	Sea water contamination
Na/(Ca+Mg)	> 0.97	Sea water contamination
Cl-(Na+K): Cl (Base Ion Exchange)	+ Values	Indicate the cation process i.e. water contamination
	- Values	Indicate the release of alkalies from the aquifer materials i.e. no sea water contamination

Saline Groundwater

Saline groundwater

- is generally referring to any groundwater containing more than 1000mg/l TDS

Classification of Saline Groundwater (after Carroll)

Water type	Total Dissolved Solids, mg/l
Fresh water	0-1000
Brackish water	1000-10,000
Saline water	10,000-100,000
Brine	>100,000

Rapid advances in desalinization techniques suggest that

-it may be a potentially important water supply source where shortages are imminent

-industrial use of saline groundwater for cooling purposes

Changes in Chemical Composition

- **As ground water moves under ground**
  - it tends to develop a chemical equilibrium by chemical reactions with its environment
- **Chemical precipitation**
  - may remove ions in solution by forming insoluble compounds
- **Precipitation of $CaCO_3$ and release of dissolved CO_2**
  - may result from a decrease in pressure and /or an increase in temperature
- **Ion exchange**
  - involves replacement of ions adsorbed on the surface of the fine grained material in aquifers by ions in solution
- **Exchange involves principally cations (Na, Ca & Mg)**
  - the process is known as base or cation exchange

- **Base exchange**

  - naturally softens and produce ground water having a quality other than a simple mixture of the two source waters

  - causes changes in the physical properties of soils

- **When high sodium water applied to a soil the number of sodium ions combine with the soil increases, while an equivalent quantity of Ca or other ions is displaced**

  - causes deflocculation and reduction of permeability

- **When adding gypsum($CaSo_4$) to a soil**

  - by base exchange the soil texture and drainability can be improved

- **Chemical reduction of oxidised sulphur ions to sulphate or to sulphide state**

  -occurs frequently in ground water

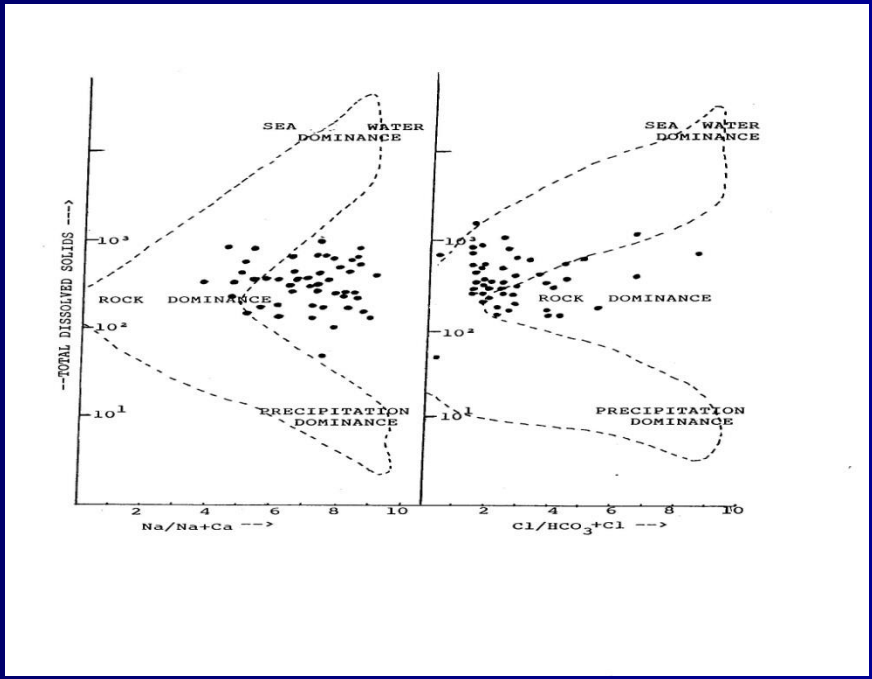
- **waters experiencing sulphate reduction**

  -have high HCO_3 and CO_2 contents and contain hydrogen sulphide

- The equilibrium achieved by various chemical reactions
  - tends to produce a quality that remains stable with time because of the slow movement of ground water and its long residence time with a given geological formation
- Quality variations are more noticeable
  - in shallow aquifers where seasonal variations in recharge and discharge create corresponding fluctuations in salinity

Gibbs diagram 1970

- is being used to know the factors controlling the groundwater chemistry



General

- Sample Collection, Analysis Accuracy and Accuracy Checks
- Single Well data Interpretation
- Many wells data Interpretation
- Utility of Water (for various purposes)
- Correlation between Water Quality Parameters
- Correlation between Water Quality Data and Geological/hydrological units

Interpretation Techniques

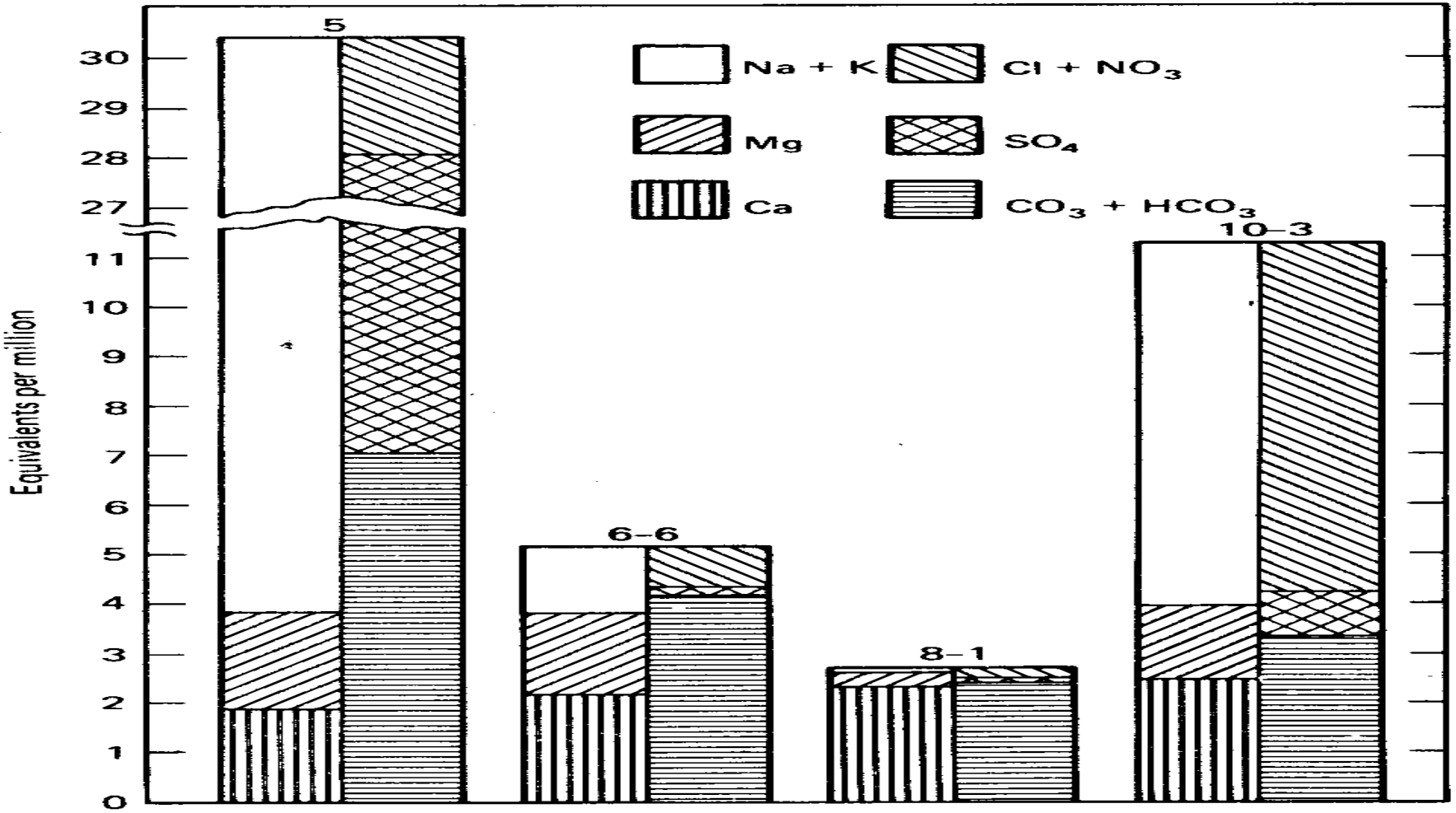
- Inspection of Data
- Simple Comparisons
- Statistical Analysis/Time series analysis
- Preparation of Graphs (Scatter Plot/Time Series Plots/Bar charts etc)
- Few samples and large number of samples

Interpretation Techniques

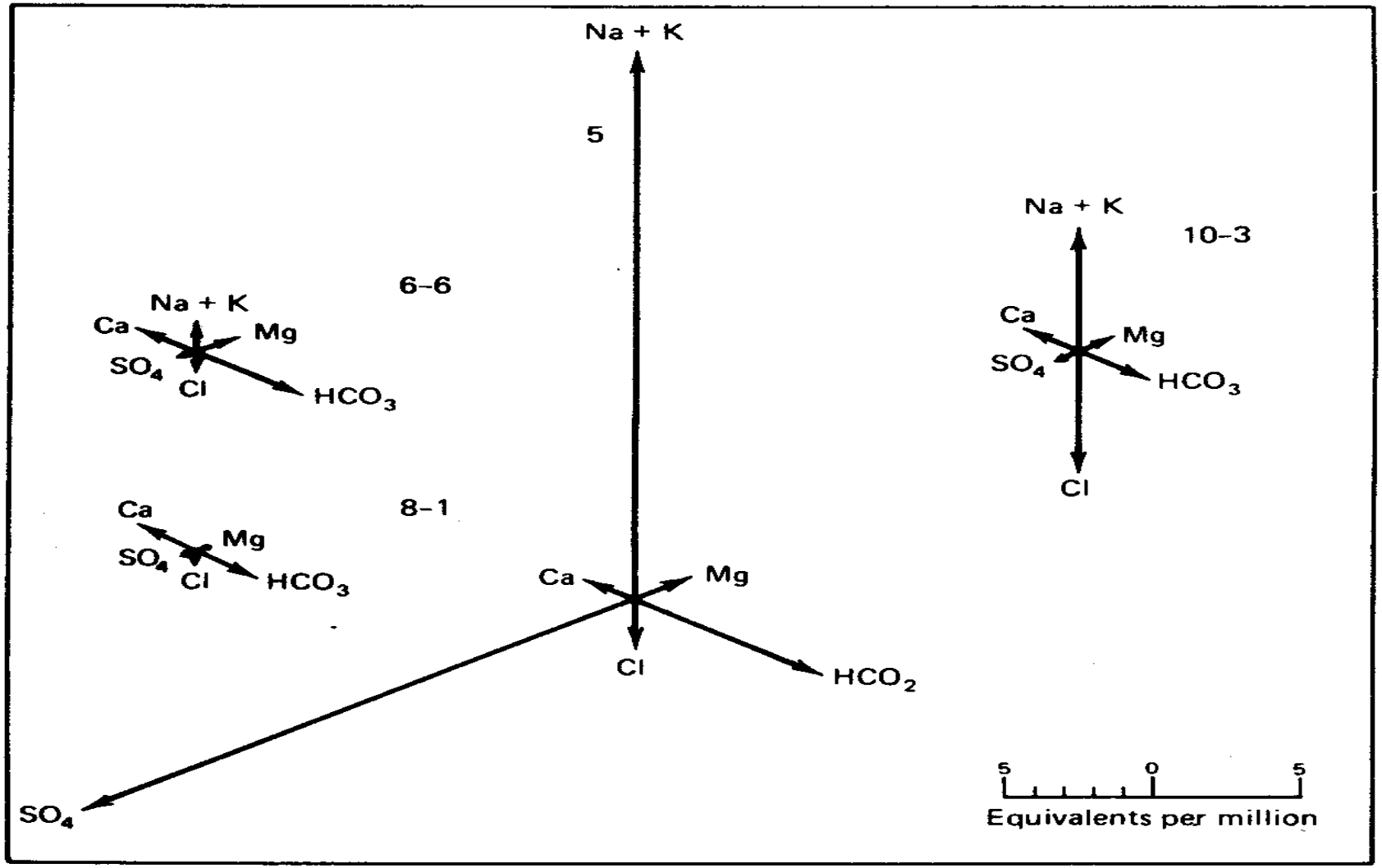
Classification/Interpretation of Water Quality using Standard Graphs

- Vertical Bar Diagrams
- Radiating Vectors
- Stiff Diagrams
- Circular Diagrams
- Trilinear Diagrams
- Durov's Classification
- Gibbs Diagram
- U. S. Salinity Laboratory Diagram
- Wilcox's Diagram

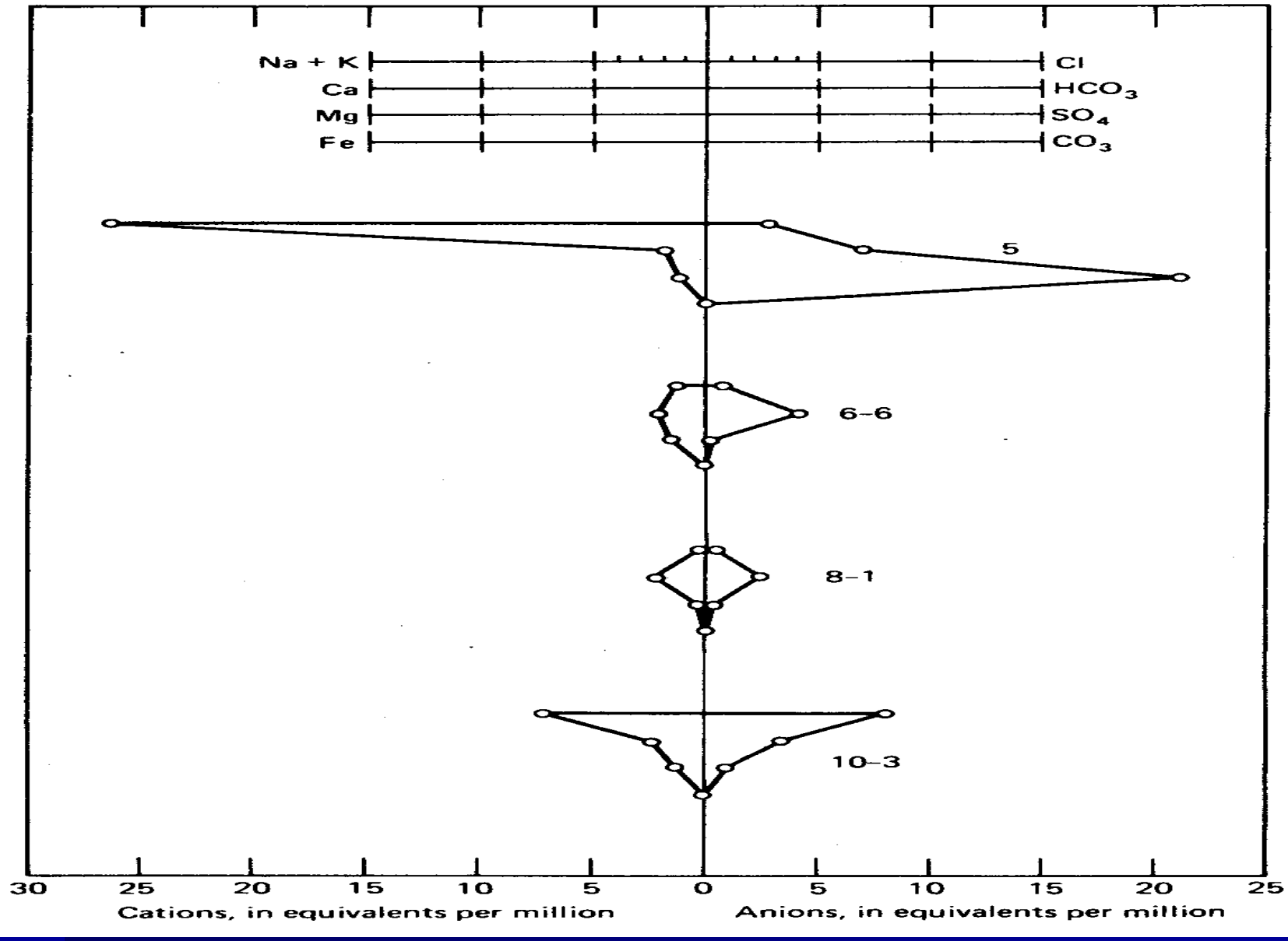
Vertical Bar Diagrams....



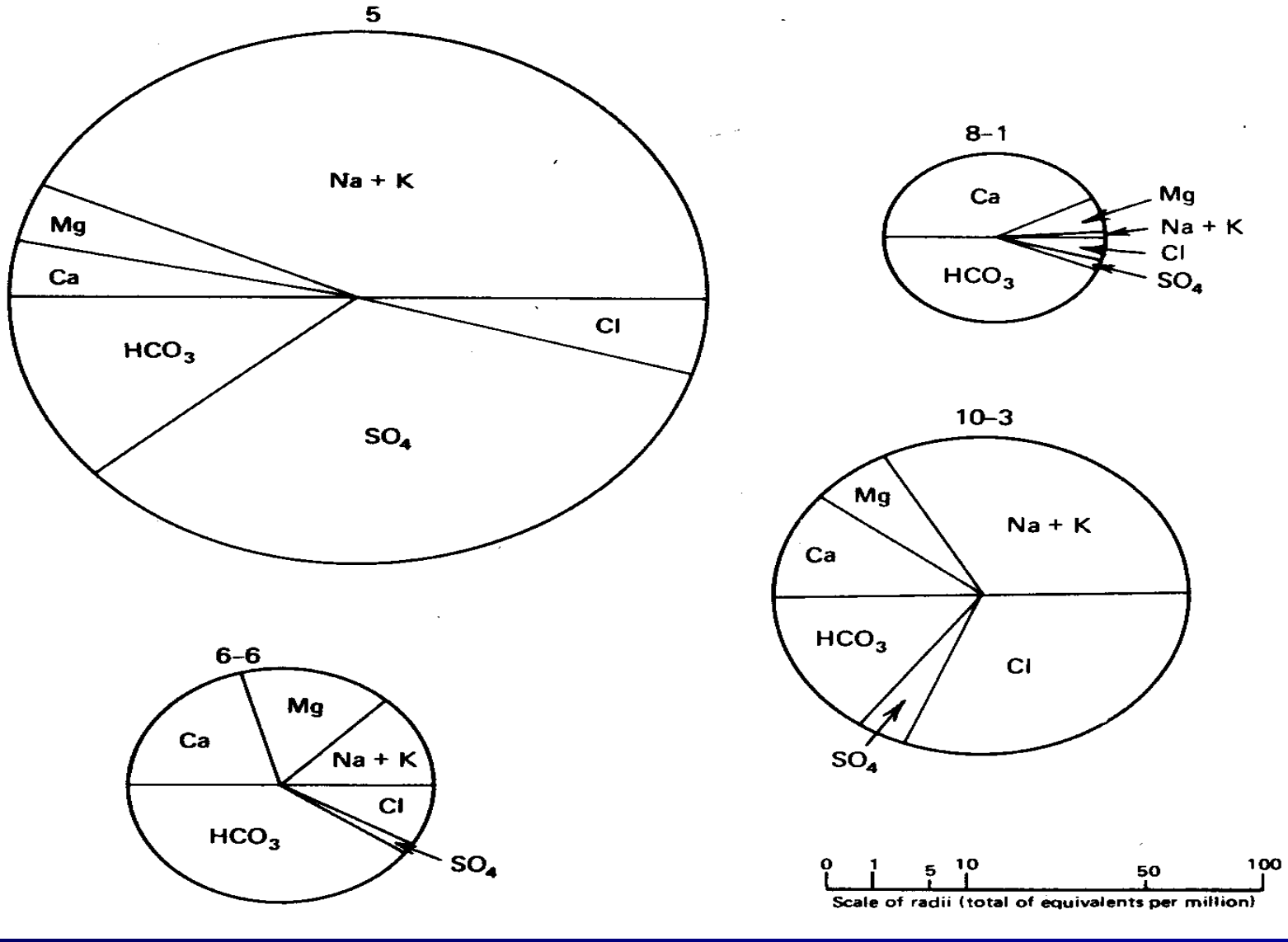
Radiating Vectors....



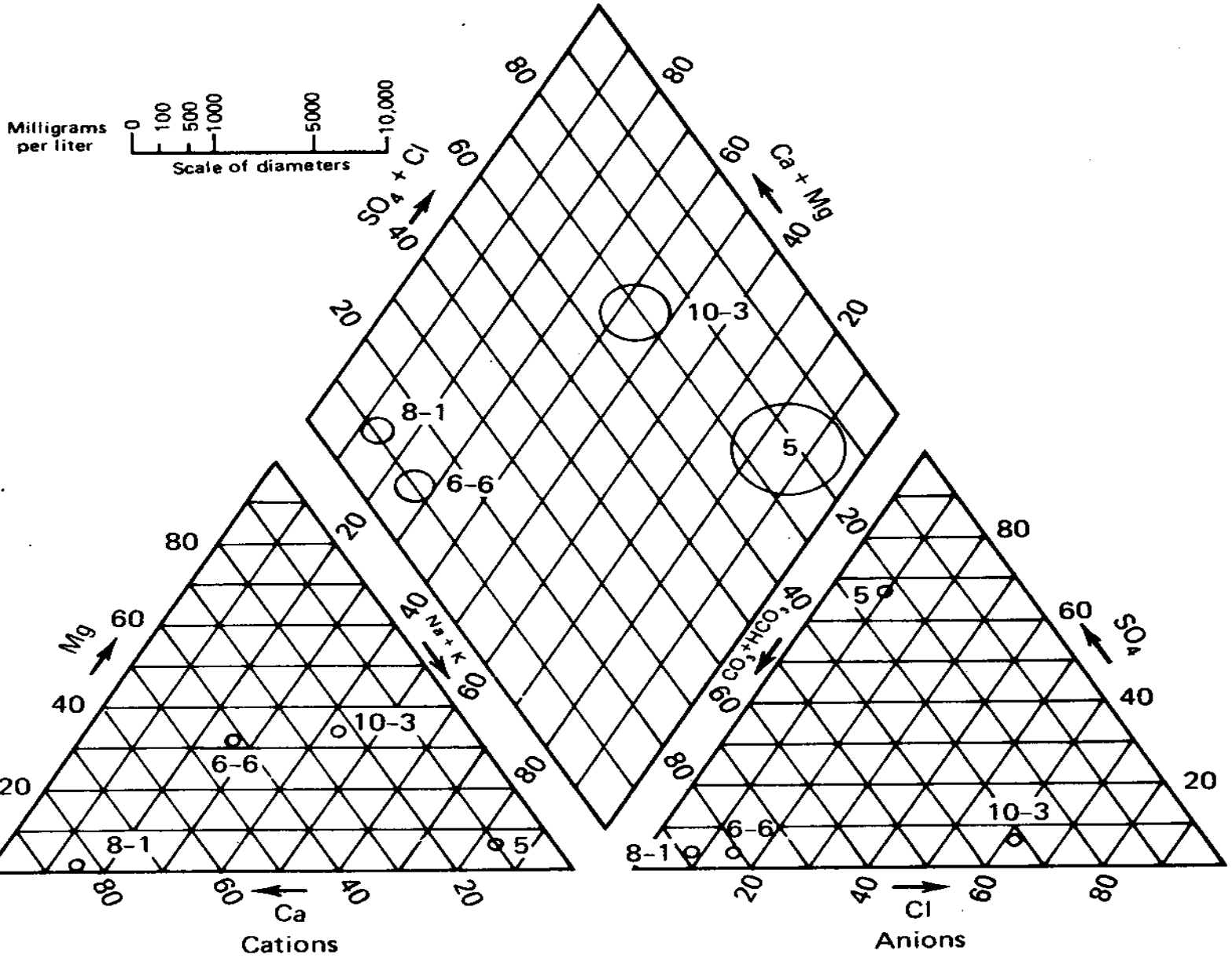
Stiff Diagrams (Pattern Diagrams)



Circular Diagrams..

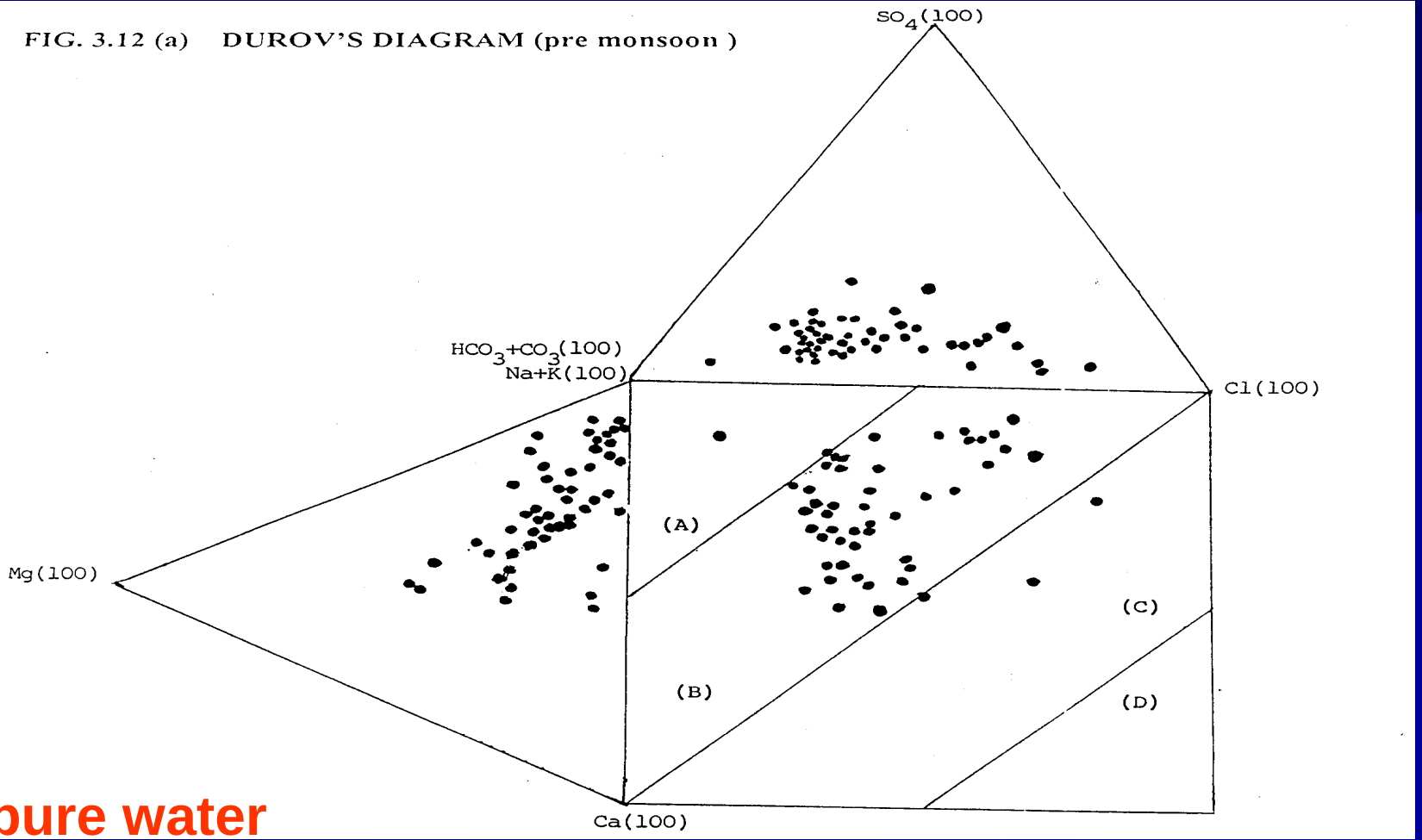


Pipers Trilinear Diagrams.....



Durov's Classification .....

FIG. 3.12 (a) DUROV'S DIAGRAM (pre monsoon)



A is pure water
B is no contamination
C is moderate quality
D is high contamination of Na & Cl

When large number of samples are to be evaluated (for reducing the Data volume without loosing single data point

Statistical Techniques

- Q-mode Hierarchical Cluster Analysis (HCA)
- K-Means Cluster analysis (KMC)
- Fuzzy K Means Clustering (FKM)
- Principal component Analysis (PCA)
- Geostatistics

Interpretation

- Suitability
- Seasonal changes

- Contamination type
- Quantification

- Spatial extent
- Sources of contamination

- Correlation with geologic and anthropogenic activities


Thank You..