Surveillance, Monitoring, WQ Design
Safe Drinking Water Supply - WSP

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Climate Change & Implications for Water Resources & Nutrition Security

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National Environmental Engineering Research Institute

The Major Issue

Survival of Life on Earth depends on 3 Natural Resources

Air - We can live for ~ **5 minutes** without air
25000L (~16 kg) @Breathing rate of 22000/day

Water - We can live for ~ **5 days** without water
Normal consumption 2 – 5 kg per day

Food - We can live for ~ **5 weeks** without food
Normal consumption 1-2 kg per day

Lead →0.3 mg/L (**300000µg/m³**) in water considered **harmful** but only **1.5 µg/m³** in air is **deadly** harmful

Air, Water & Food must forever constitute the survival bases of human and other populations. We will pay for them whatever they cost in Time, Money and Effort. Without them we die.

WATER makes up

60% of Body

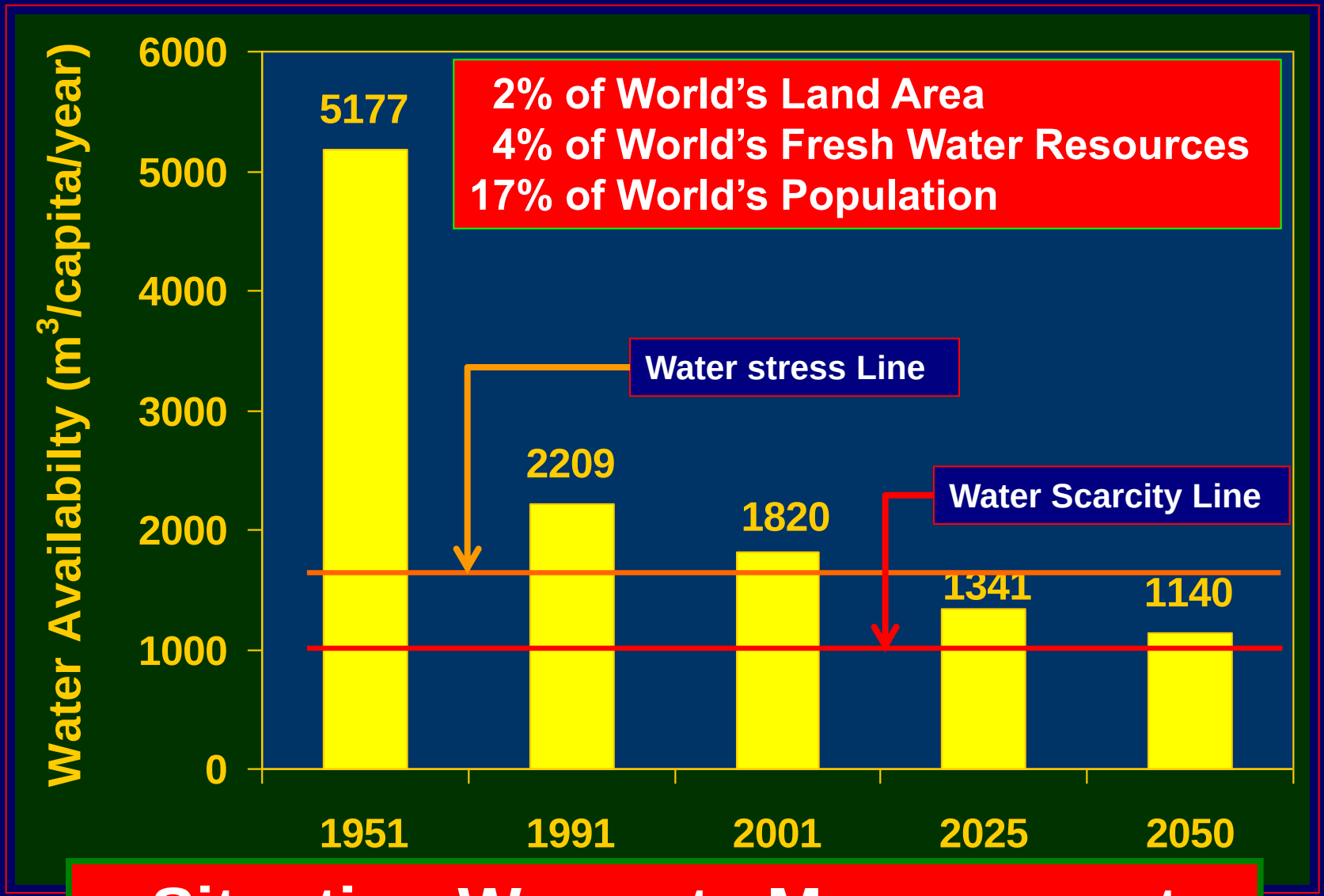
70% of Brain

80% of Blood

THEIR IMPORTANCE

- Not Manufactured
- Limited Assimilative Capacity
- Limited Supportive Capacity

Per Capita Water Availability (National Avg)



Situation Warrants Management

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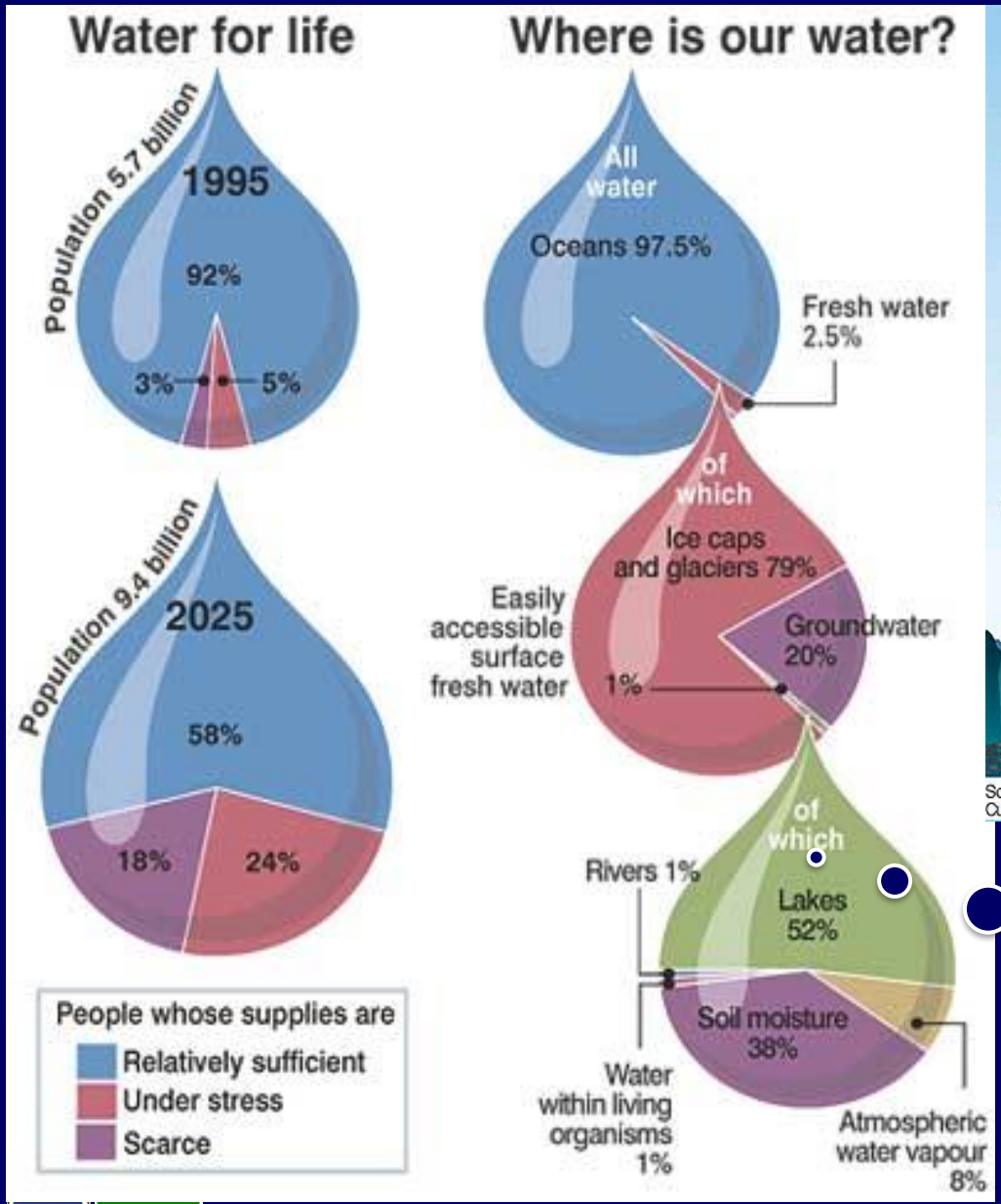
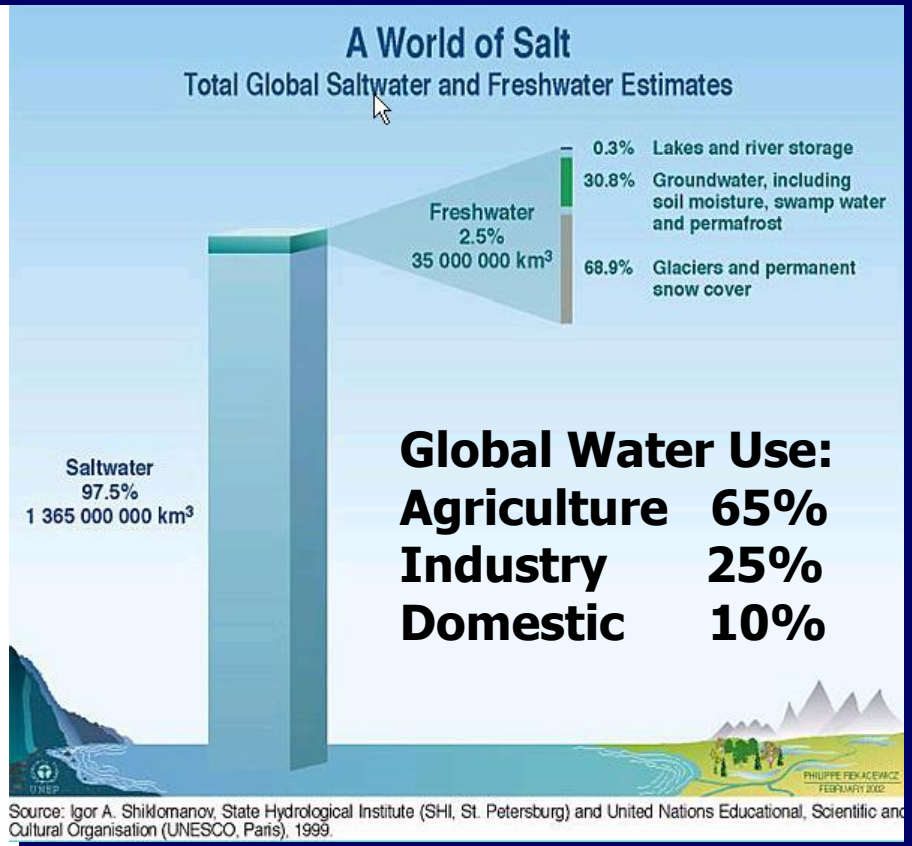
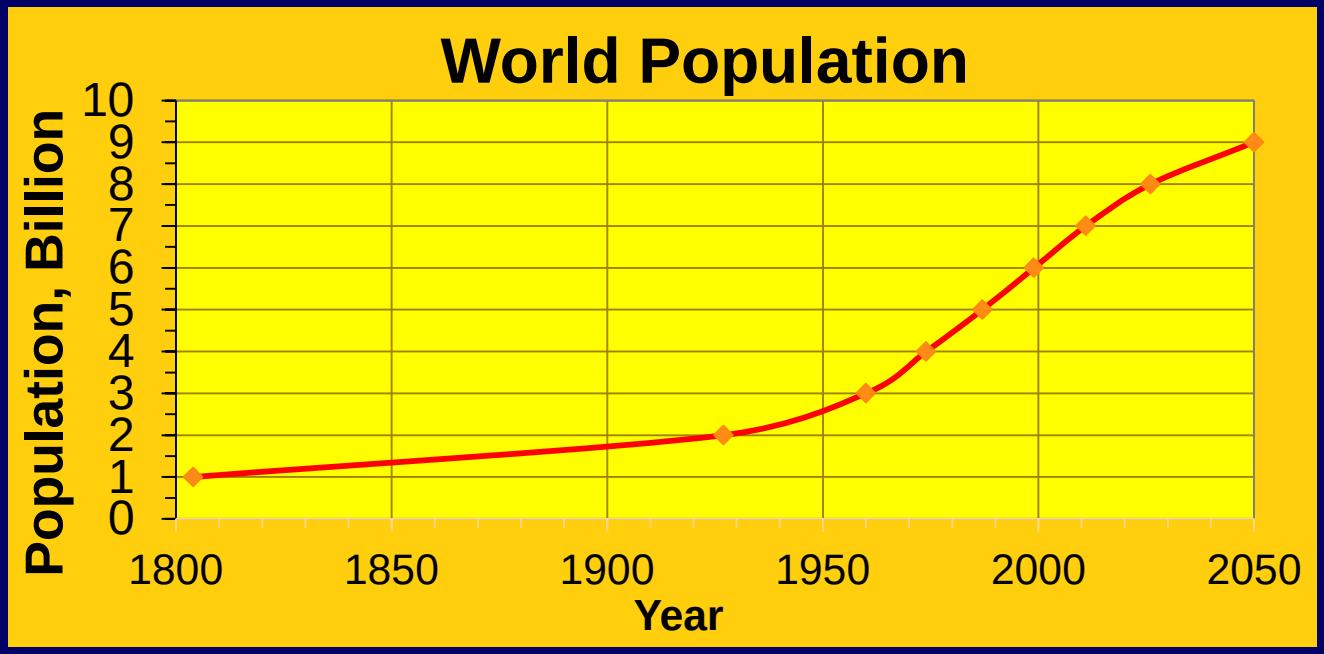
Water is in atmosphere, on & below surface – **WATER CYCLE**
In nature it is in seas, oceans, rivers, lakes, springs, reservoirs & under ground





Fresh water available is only 0.78%



Estimated:

Fresh water availability: 9000 BCM (5190 used currently) (1120/605)

Current Water usage: 10% Dom, 25% Ind, 65% Agri (5/12/83)

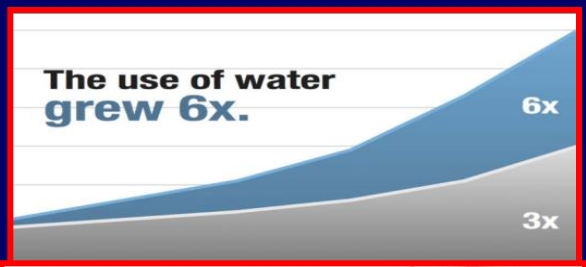
By 2050:

Domestic: 1.30 Million MLD (10%) @150 lpcd (

Industrial: 3.25 Million MLD (25%)

Agriculture: 8.45 Million MLD (65%)

Total: 13.00 Million MLD (13000 BCM)



1 in 5
don't have access
to safe drinking water.

According to the U.N., a child dies
from a water-related disease
every 15 seconds.

It's been said,
we're going to
run out of water
before we run out of oil.

1 in 3 people
lack access to
adequate sanitation.

25 million refugees
were displaced
by contaminated
rivers last year.

The average American
uses about 160 gallons.

Due to over-pumping,
the groundwater in several
countries is almost gone.

Depleted aquifers lead to
cutbacks in grain harvests…

…which lead to more food
shortages and higher prices.

Millions of people in the
world live on less than
3 gallons each day.

That's more than were
forced to flee from war zones.

Our water problem is fast becoming a hunger problem.

Water Quality Issues & Challenge

- 1.2 billion people per force drink contaminated / dirty water daily?
- Water borne disease is by far the worst killer, particularly children?
- Diarrhea & related diseases are responsible for > 25% of all child deaths (0-5 age group). India loses an estimated 2,500 children every day to diarrheal diseases?
- About 21% of all communicable diseases and >11% of all diseases in India are water-borne (typhoid, polio, hepatitis A & E, leptospirosis, diarrhea and other intestinal diseases) – Poor bacterial quality?
- Poor bacterial water quality and increasing incidence of natural contaminants (F, As, NO_3) pose a continual challenge to supply of safe drinking water.

Situation Warrants Management

The Himalayan Times, November 21, 2007

Waterborne diseases kill 13,000 kids a year

Himalayan News Service

Kathmandu, November 19

Over 13,000 children die of waterborne diseases in Nepal every year. The root cause of these casualties, equivalent to 65 plane crashes, is lack of toilets in the homes of these children.

"As many as 13,000 children die every year in our country because of waterborne diseases. These deaths can be curbed by building a toilet in every household. The government and non-governmental organisations have not made enough efforts towards this end," said Umesh Pandey, coordinator of the Nepal chapter of the Water Supply and Sanitation Collaborative Council.

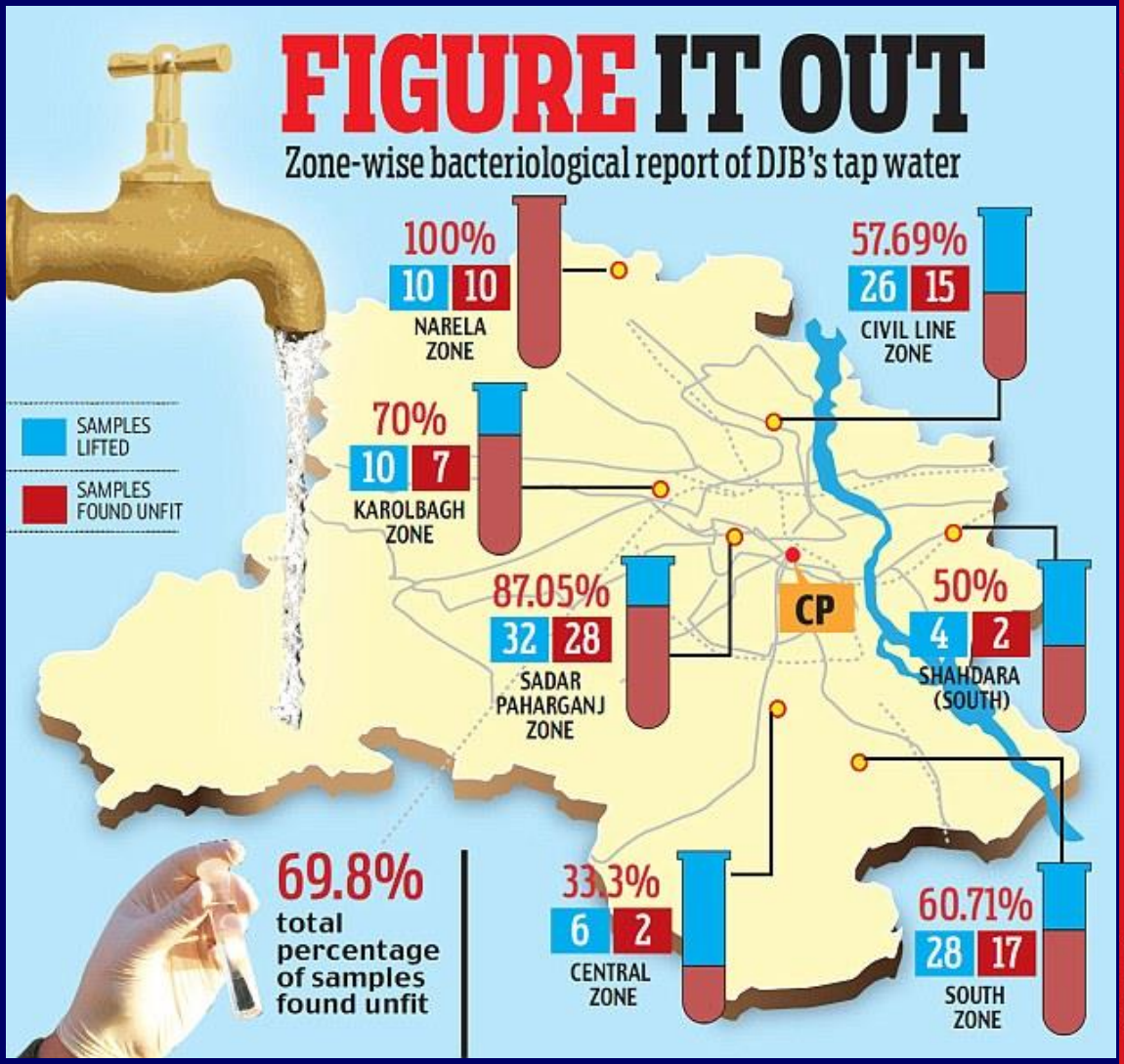
He was addressing an interaction organised to mark the World Toilet Day (WTD). The practice of celebrating the WTD started from Singapore in 2001.

We keep dreaming of cutting to half the number of people, who lack basic sanitation, by 2015, but we don't pay attention to small things that can make a difference, he said. Citing government data, he said only 49 per cent of total schools in the country have toilets.

Senior comedian Madan Krishna Shrestha said infrastructure building and awareness campaign should go side by side.

FIGURE IT OUT

Zone-wise bacteriological report of DJB's tap water



http://www.dailymail.co.uk/indiahome/indianews/article-2155484/Study-finds-70-water-Delhi-unfit-consumption.html

HEALTH WOES

- The contamination shows presence of coliform bacteria or E.coli in Delhi's water. This bacteria is responsible for gastrointestinal infections that can result in typhoid, cholera, gastroenteritis or jaundice
- Posh areas of south Delhi and Karol Bagh are the worst affected
- About 60 per cent of Delhi residents consume water supplied by the Delhi Jal Board. The rest get water from pumps or tankers
- Drinking water sources in Delhi are contaminated by sewage overflow, septic tanks, leaking sewer lines, sludge and untreated waste water

- Pipes supplying water to many areas of Delhi are old and have cracks

THE WAY OUT

HOME REMEDIES

- Boil water to kill disease-causing bacteria and other germs

- Sterilise water chemically. Household chlorine bleach can be used
- Store water in a clean container and make sure if it is a metal container, it has not corroded

CHLORINATION

- The use of chlorine in water eliminates almost all germs that cause waterborne diseases. If your water comes from a private well, overhead tank or water tanker, chlorination is an effective way to purify it

- Chlorine can be added to water by way of bleaching powder, chlorine tablets and liquids. A four gram tablet purifies 2,000 litres of water

ISO 9001 DNV REGISTERED FIRM नीरी NEERI

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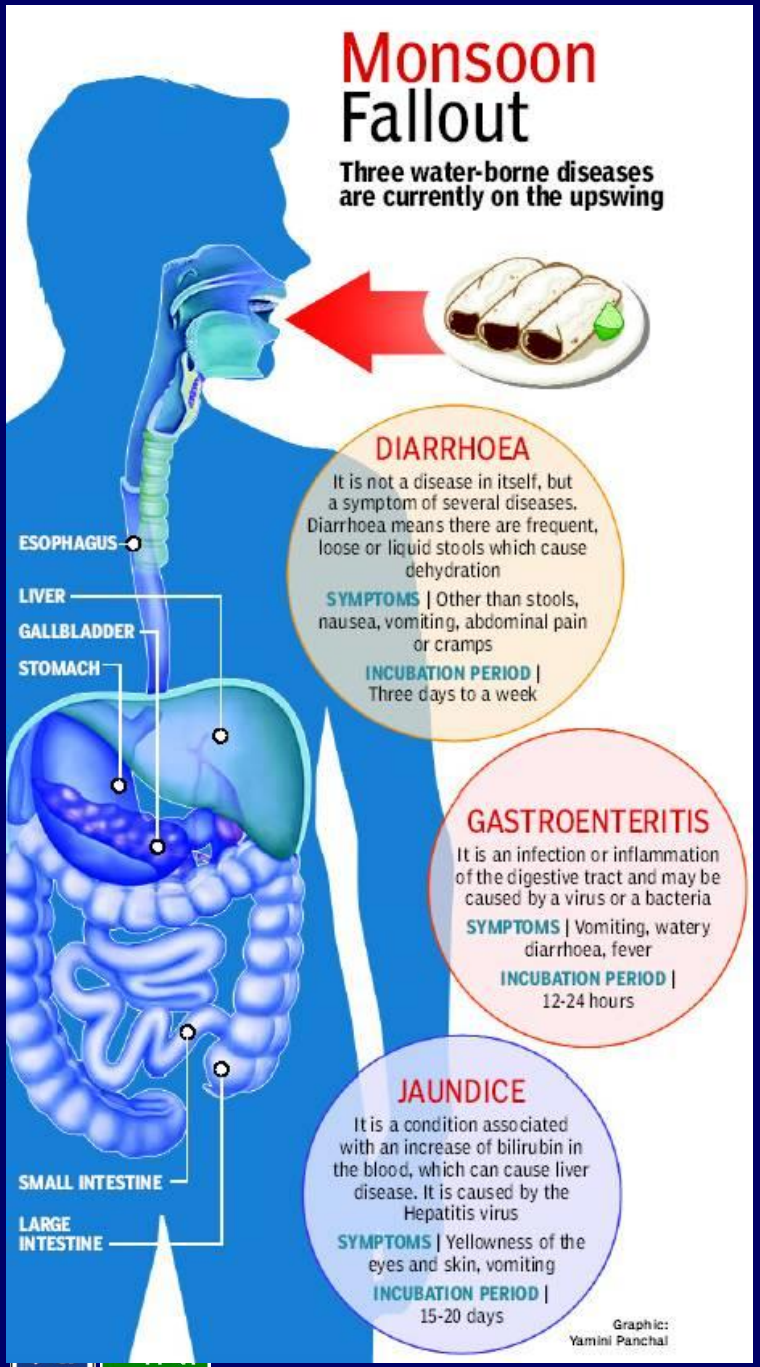


ADVISORIES

- Drink boiled water Avoid ice
- Avoid roadside food
- Do not eat fruits which have been cut open for a long time
- Strictly maintain personal hygiene
- Avoid eating heavy or spicy food
- Rest well
- Avoid self medication; visit a doctor if a stomach ache, loose motions or vomiting persist for more than a day
- If your water supply is turbid or smelly, complain to your nearest ward office immediately
- Add chlorine tablets to your water in the meantime


(K·M·C)

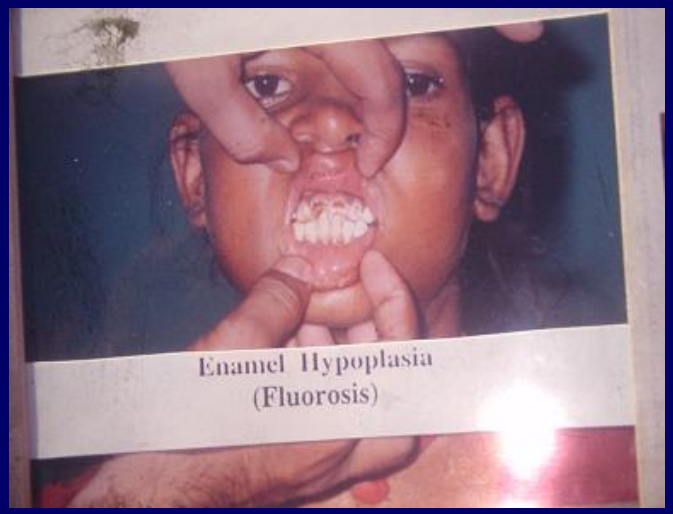

KILIMANJARO
KILIMANJARO



Arsenic affected patients from West Bengal. Photo: SOES



Dental Fluorosis



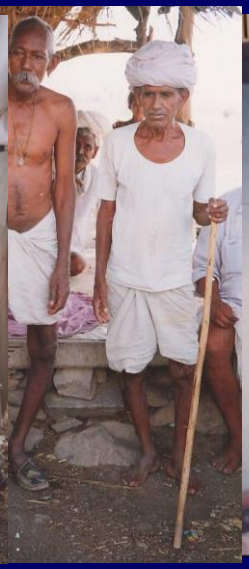
Affects the Teeth

- Discoloration
- Delayed eruption
- Chipping of edges
- Pitting
- Enamel Hypoplasia










Skeletal Fluorosis

Affects Bones and Joints:

- Heel pain
- Painful and restricted joint movements
- Deformities in Limbs, *and in very severe cases*
- Patient may develop a Hunch back and Paralysis

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Water Safety: Historically

- Development of Public Water Supplies assumed greater importance with the progressive increase in urbanisation.
- Potentially great advantages → Convenience, health benefits deriving from washing & cleaning.
- Risk to health → Large No. of people if contamination occurs.
- Substantiated by recorded outbreaks of diseases → Outbreaks of cholera in European cities in the 19th century.
- 1st proof of PWS as source of infection → Studies by J.Snow in 1850s.

At that time, water was supplied to London by a number of small companies. S&V Co. obtained its water from the Thames at Batter sea, WL Co. obtained its water from Thames but a considerable distance upstream, above the major sources of pollution from human sewage. Pipes of both companies were laid in the streets with houses connected to one or other source of supply.

Snow's analysis showed striking results: houses served by Lambeth Co. had a lower incidence & those served by S&V Co. had a very high incidence.

Snow concluded → water supply route transmitted cholera agent.

Water Safety: Historically

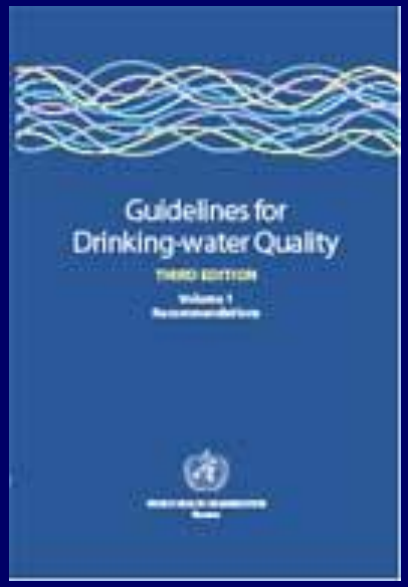
- It is recognised that the key to microbiologically safe drinking water is the exclusion of fecal contamination.
- Outbreaks of cholera and typhoid in the 19th and the early 20th centuries led to the wide-spread use of filtration to treat water supplies followed by the gradual introduction of the use of chlorine, usually on an intermittent basis, from 1910 onwards.
- The Croydon typhoid outbreak in 1937 led to continuous chlorination of water being used almost universally on PWS.

Today, most PWS contain disinfectant, normally chlorine, at a low level at consumer's tap to protect against contamination, which may occur if integrity of distribution system is breached *(e.g.* through pipe burst or cross contamination).

Traditional Approach- Limitations

- Relies heavily on end product testing
- Wide range of parameters that could be monitored
- Not technically feasible
- E coli, coliforms – do not correlate well with risks from protozoa & virus
- **Promotes reactive management – corrective actions are initiated after monitoring reveals that water quality is unsatisfactory** ***(people may have fallen ill)***
- Monitoring uninformative about the exact nature, location & timing of problem

3rd Edition of WHO Guidelines on DWQ



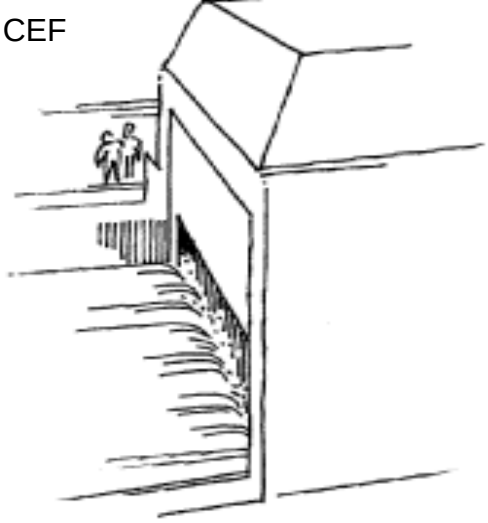
- WHO updated its 'Guidelines for DWQ' in Sep. 2004
- Departure from previous editions
- Main focus no longer on monitoring DWQ at the tap but rather on a comprehensive analysis of supply systems
- Less emphasis on analysis of water quality
- Place emphasis on risk assessment & risk mgmt
  (Needs good design, construction, O&M)

"The most effective means of consistently ensuring safety of a DWS is through the use of a comprehensive ***risk assesment & risk mgmt*** *approach that encompases all steps in water supply from* ***catchment to consumer****. In these Guidelines, such approaches are called* ***water safety plans****"*

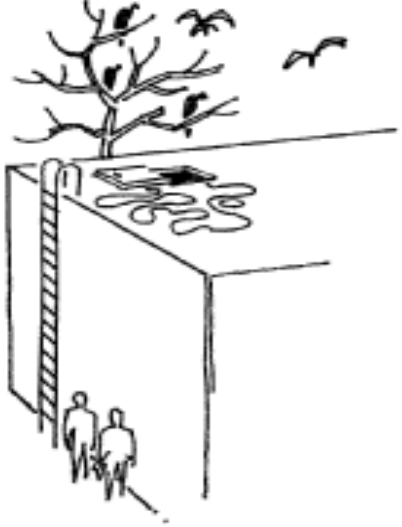
– DWQG Ch-4

*slide courtesy of Dr. Samuel Godfrey, UNICEF

Source Catchment Contamination



Water Treatment



Poorly Maintained Service Reservoir

Supply Main Intersecting Open Sewer

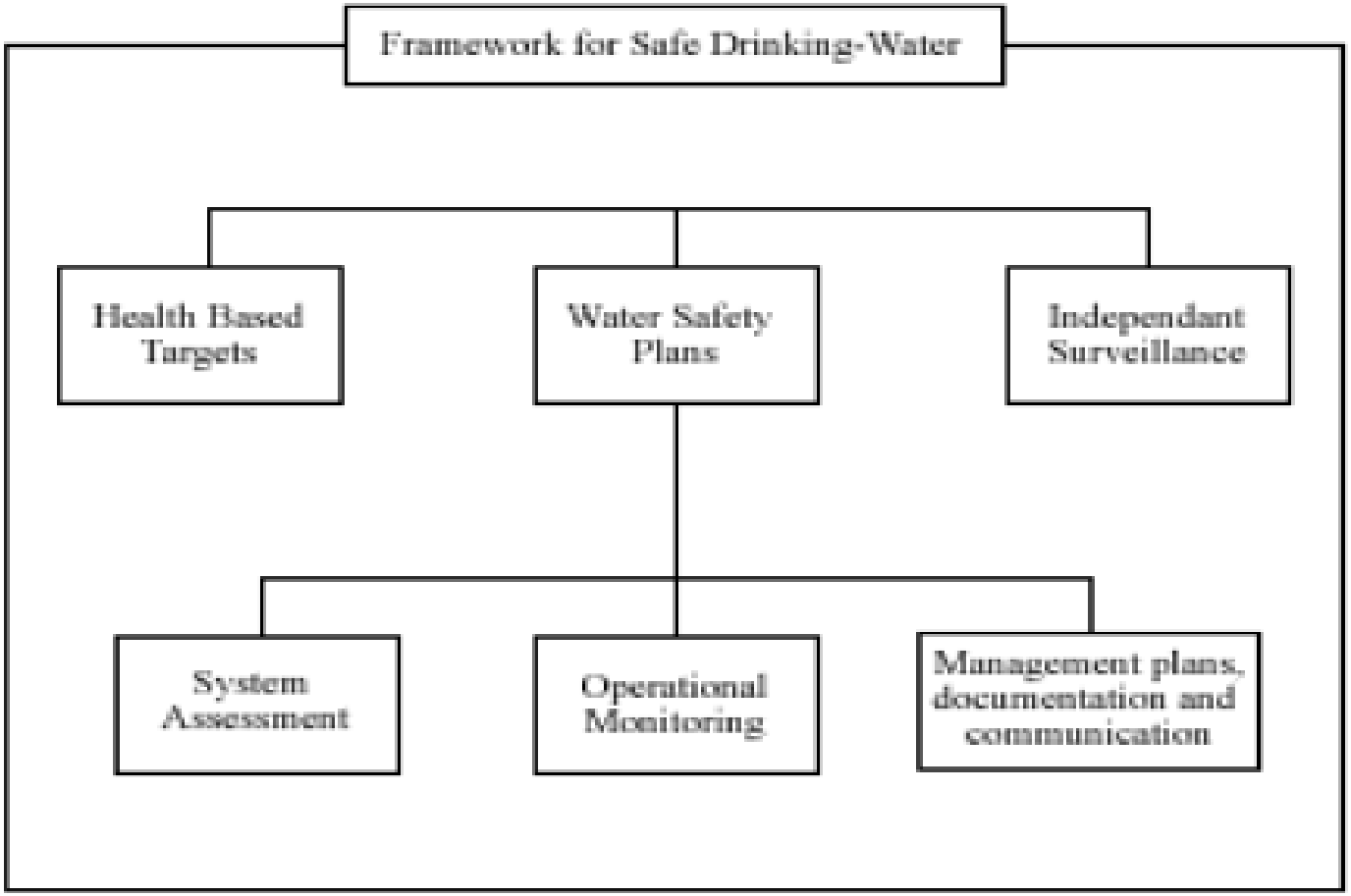
Leaking Valve Box

Unhygienic Standpipe Collection

WHO Water Safety: Framework

Three key elements

1. Health-based targets 2. Water Safety Plans 3. Surveillance



Water Safety Plans

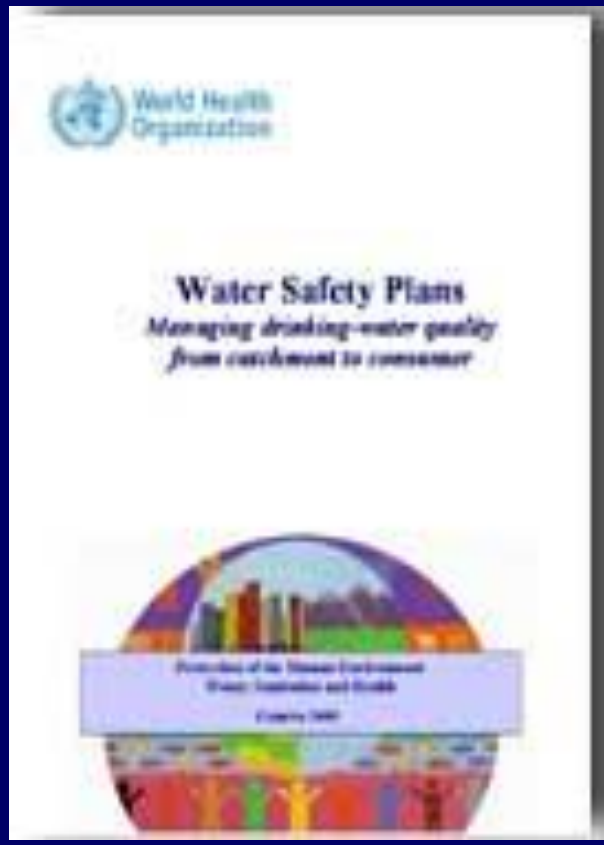
Approach

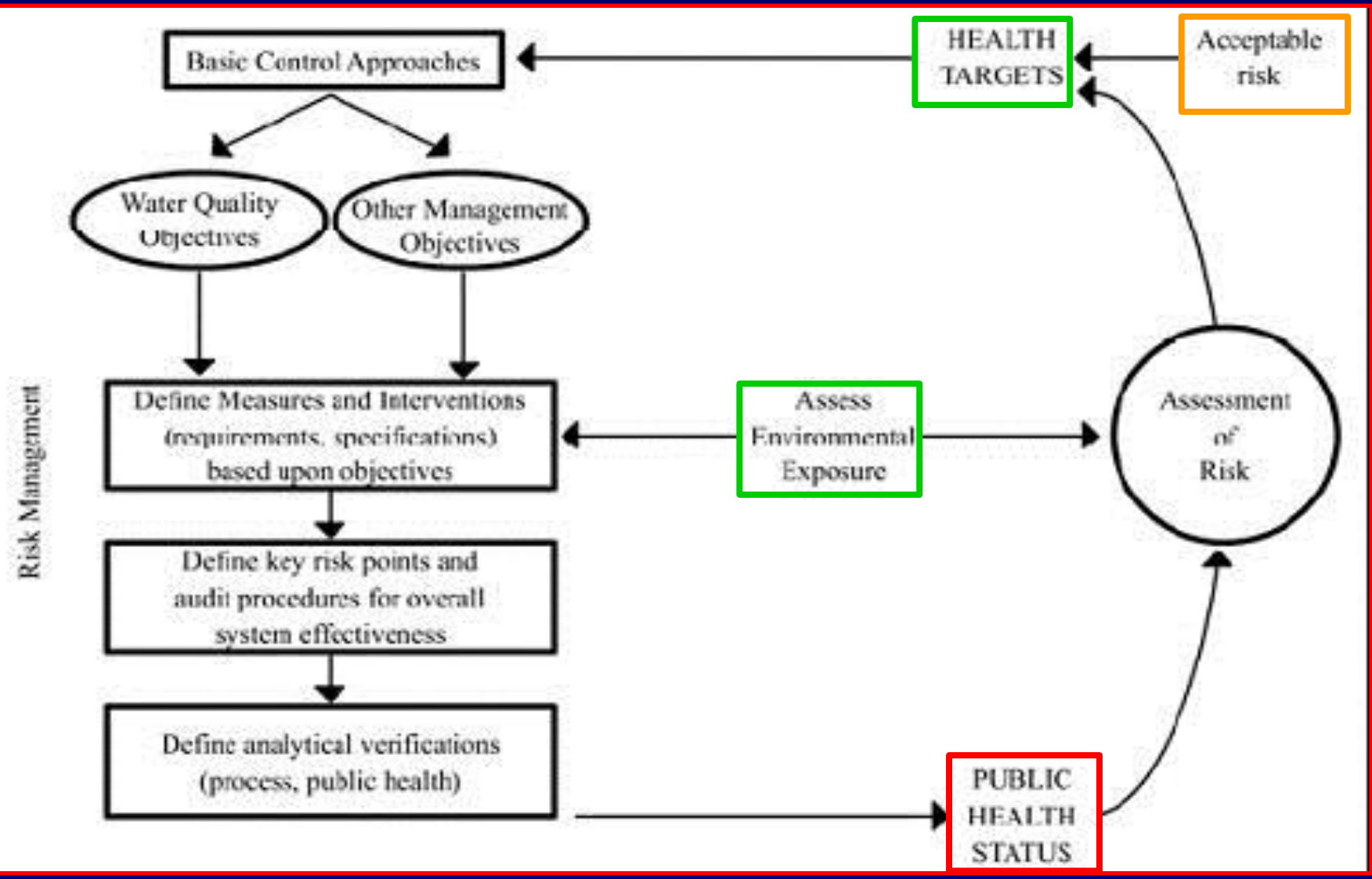
- Developed by the water industry, international experts, and WHO
- Designed to assess risks and identify ways in which risks can be managed
- Based on HACCP model

5 key steps for water safety

- Health based targets **(Health Sector)**
- System assessment **(WS Agency)**
- Operational monitoring of the control measures in the supply chain **(WS Agency)**
- Management plans **(WS Agency)**
- A system of independent surveillance that verifies that the above are operating properly

(Basis of Regulation)





Iterative Framework encompasses assessment of public health concerns, risk assessment, establishing health-based targets & risk management.

Feeding into this cycle is the determination of environmental exposure & estimation of what constitutes acceptable risk.

1. **Water Safety:** Health-based targets

- **Health based targets provide a basis for identifying safety requirements and are of four types:**
  - ✓ **Health outcome** (using either risk assessment or epidemiology to define reductions in risk of disease or recorded disease);
  - ✓ **Water quality** (specified concentrations of substances in water that are considered to be of low or no risk to health or acceptability);
  - ✓ **Performance** (targets for quantifiable reductions in the concentrations of microbes and chemicals in water, usually through treatment processes but sometimes through source protection measures); **and**
  - ✓ **Specified technology** (targets that establish the type of technology that can be used; or specify design requirements for technologies; or that specify particular processes for treatment works).

2. Water Safety: WSP

- A WSP as an improved risk management tool designed to ensure the delivery of safe drinking water. It identifies:
  - ✓ the hazards that the water supply is exposed to & the level of risk associated with each;
  - ✓ how each hazard will be controlled;
  - ✓ how the means of control will be monitored;
  - ✓ how the operator can tell if control has been lost;
  - ✓ what actions are required to restore control; and
  - ✓ how the effectiveness of the whole system can be verified.
- By developing WSP, system managers & operators will gain a thorough understanding of their system and the risks that must be managed. This knowledge can then be used to develop operational plans and identify key priorities for action.
- Development of WSP will also identify what additional training and capacity-building initiatives are required to support and improve the performance of the water supplier in meeting the water safety targets.

Water Safety: WSP

The development of a WSP involves:

- preventing contamination of source waters;
- treating water to reduce or remove contamination in order that water safety targets are met, and
- preventing re-contamination during storage, distribution & handling.

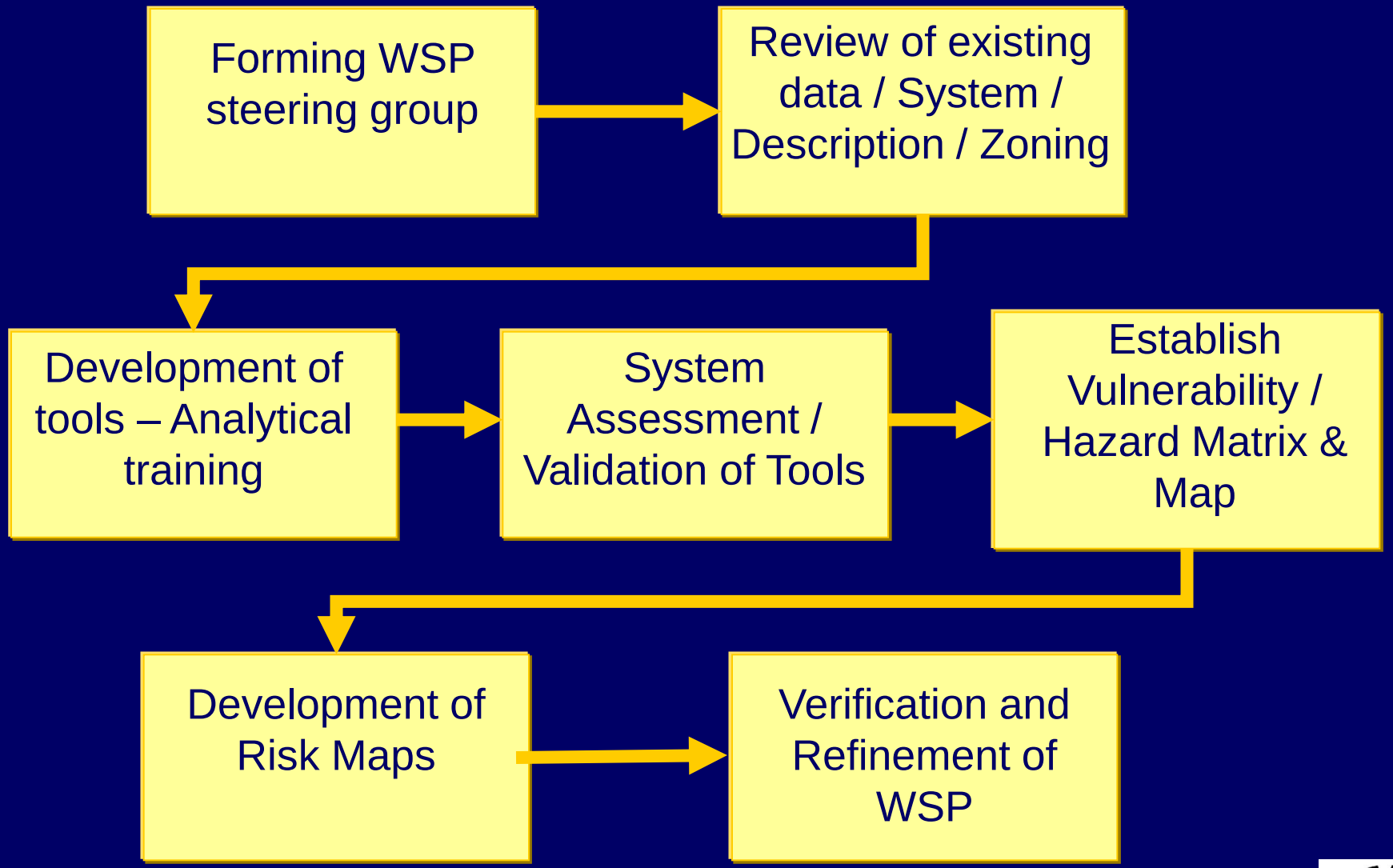
In order to do this, the water supplier needs to:

- assemble a team;
- identify where contamination could arise & how it could be controlled;
- validate the methods employed to control hazards;
- establish a monitoring system to check that safe water is consistently supplied and corrective actions taken; and
- periodically verify that WSP is achieving the performance required to meet the water safety targets.

3. **Water Safety:** Surveillance

- Process of WQ testing, inspection & audit undertaken to verify that safe drinking water is supplied.
- To protect public health through the identification of inadequacies & timely implementation of action to control risks in supply of adequate quantity of water of desirable quality at affordable cost.
- It is preferred that surveillance is undertaken by an agency not involved in water supply provision, but in practice this is often difficult in rural areas of developing countries.
- Most urban water suppliers themselves undertake surveillance, a condition that is likely to continue for some time.
- Surveillance : Monitoring **: :** Audit : QA-QC

Steps for Development of WSP



Risk Variable Definition

Data requirements for *hazards can be divided into*

- *hazardous environments and*
- *hazard source.*

The hazard source would include areas of high faecal loading (i.e. areas of high population density) and *hazard environment as areas of* increased potential occurrence of hazard source (e.g. sewered zones, areas with on-site sanitation or low-lying areas).

Low-lying areas are of particular importance due to the

- probability of cross contamination of water mains
  - ✓ from onsite sanitation and/or sewers,
  - ✓ through leaching of contaminants in water logged areas

- potential for back-siphonage where intermittence A/O leaks occur.

Risk Assessment in Distribution System

- **Aim of risk assessment in WDS is to evaluate the static risk and sanitary integrity of the entire distribution network**
- **Vulnerability of the pipe infrastructure to breakage, leakage, intermittence is evaluated**
- **The status of physical state of the infrastructure such as age, material, diameter and length of the pipes determine the vulnerability of distribution network to hazard events**

Approach to Risk Estimation

- HACCP (General – Food Packaging)
- IRA-WDS (USEPA)
- SANMAN (UNICEF)

Risk Assessment Model (RAM)

The approach involves identification of *source* ***pathway-receptor relationships*** to identify **specific risk variables** that result in an increase in potential ***hazardous microbial contaminants*** entering the system at identified points of ***vulnerability****.*

Conceptually, risk is defined as:

RISK = HAZARD + VULNERABILITY

where, HAZARD = specific biological, chemical and physical agent that cause adverse health effect &

VULNERABILITY = susceptibility of pipe to a hazard event

RAM combines the outputs from CIM and PCA by using appropriate weights to generate a risk score for each pipe.

$$RI = (w_h * HA_k) + (w_h * VU_k) \qquad k = 1, 2, \ldots NC$$

where *RI* - risk index; W_h - weight for hazard agent; W_V - weight for vulnerability of water pipe

Flow chart for GIS based Risk Assessment

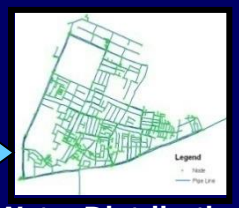
Role of GIS

Capture, store, analyze, manipulate & display spatial data

Nodes, Lines, and polygons for Water Distribution System Open drains and Canals foul water bodies, & sewer network

Pressure zone

Preparation of Thematic Maps

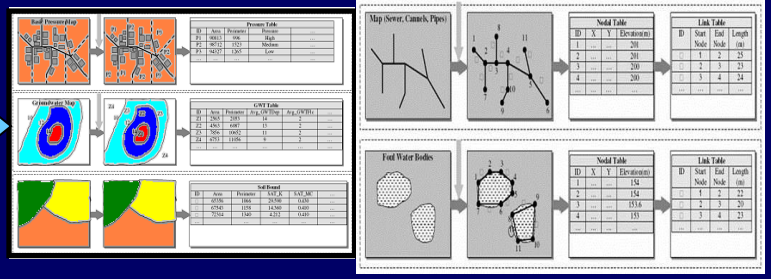


Water Distribution System

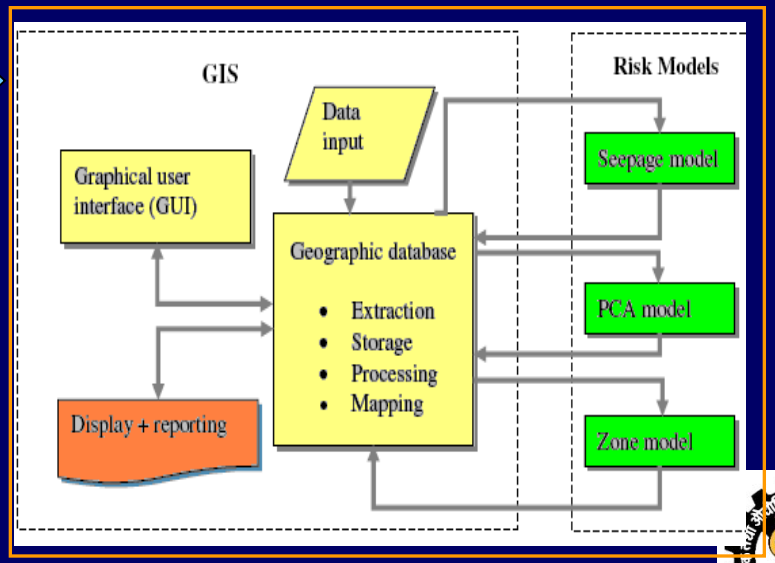
Sewer network

Contour Map

Preparation of Attribute Data for Shapefiles



Integration of GIS with Mathematical Models



IRA-WDS Outputs

Decision making

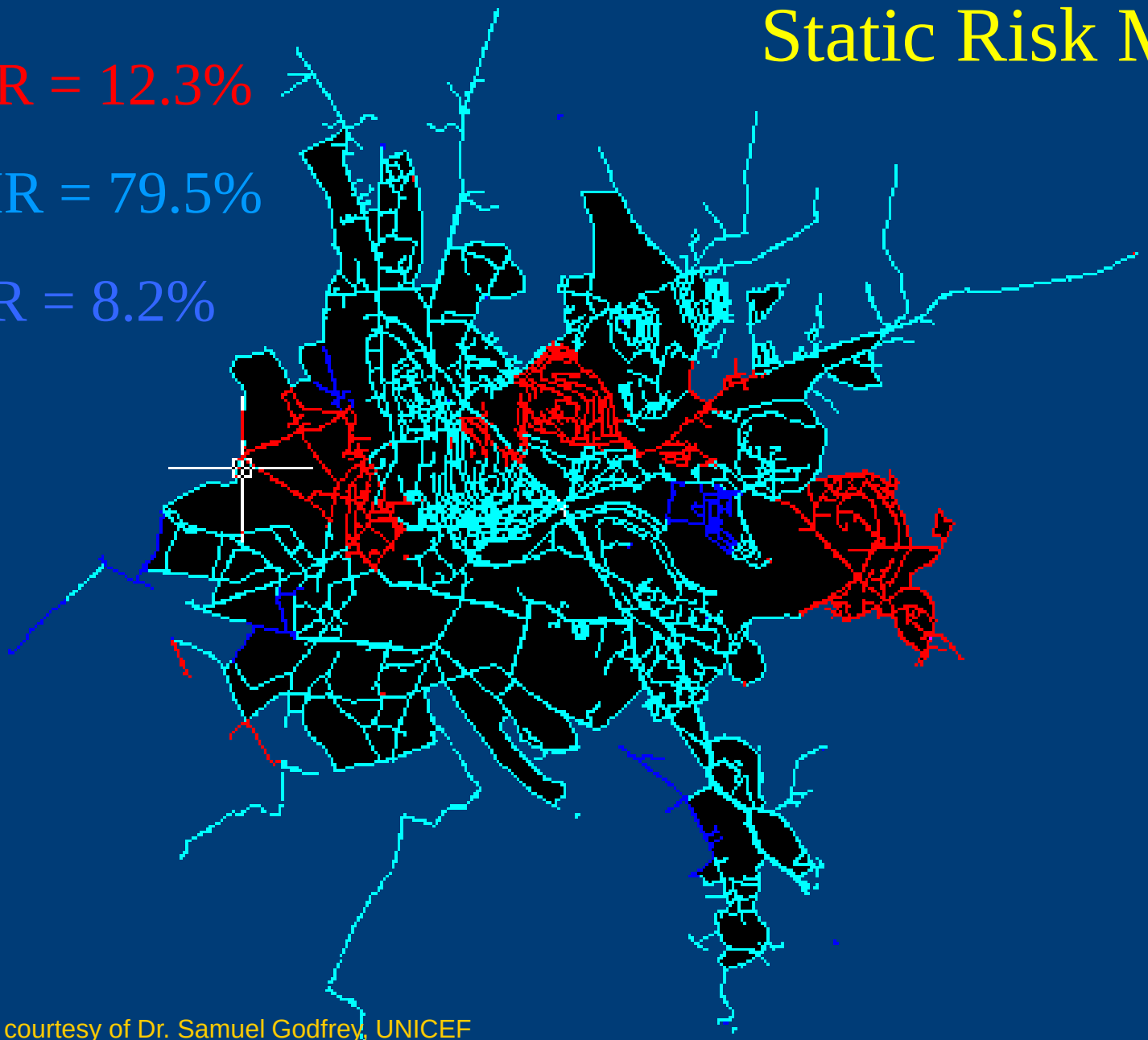
RISK

Static Risk Map

HR = 12.3%

MR = 79.5%

LR = 8.2%



*map courtesy of Dr. Samuel Godfrey, UNICEF

Attractive Features of WSP

- WSP enables systematic & detailed assessment and prioritization of hazards & operational monitoring of barriers or control measures
- Demonstration of application of best practices to secure water safety to public health bodies and regulators
- Provides for an organized & structured system to minimize chances of failure through oversight or lapse of management
- Increase the consistency with which safe water is supplied
- Provides contingency plans to respond to system failure or unforeseeable hazardous event
- Avoid limitations of relying on end point testing as means of water safety controls
- Potential for significant improvement in asset management, marketing of services to new & existing customers of improved product
- Benefits realized from delivering a more consistent water quality and safety through quality assurance systems


Thank you for listening!