Water treatment plants are designed to treat water of specific raw water quality to drinking water quality standards at the outlet to the works.

To achieve this various unit processes are employed, each having a specific purpose that is considered critical to the overall process efficiency.
WATER TREATMENT PROCESS

1. **Abstraction**
   Raw water is abstracted from a raw water source such as a river, Dam or lake and transferred to the plant by a canal and/or gravity pipeline by pumping depending on the process.

2. **Coagulation**
   Suspended particles are removed from the raw water through the addition of suitable chemicals.
   - **Flocculants**
   The suspended particles clump together to form heavier visible particles called flocs.

3. **Sedimentation**
   The flocs settle in specially designed tanks, also engineered to reduce sludge.

4. **Stabilization**
   The water flows into carbonation bays, where it is stabilized by bubbling carbon dioxide gas or suitable chemical to correct the pH.

- Removal of suspended matter and some metals
- Reduce scaling or corrosion potential
WATER TREATMENT PROCESS

5 Filtration
The water passes into the filter houses, where it flows through rapid gravity sand filter beds. The remaining suspended particles are removed at this stage.

6 Primary disinfection
The water leaving the purification works is disinfected with chlorine to kill any remaining microorganisms, bacteria and viruses.

7 pumping final product
The final product is then pumped to the booster sites.

8 Secondary disinfection
Chlorine and ammonia are added at the booster pumping station to form monochloramine, which protects the water against bacteria. The water is then distributed to the consumer.

Online Laboratories
The online laboratories measure pH, conductivity, turbidity and chlorine on a continuous basis on all outgoing mains to ensure compliance to SANS 241.
Rand Water Treatment Technology

• Treatment objectives
  • Remove suspended matter
  • Eliminate pathogens
  • Remove potentially harmful chemicals
  • Adjust pH
  • Produce a product that is aesthetically pleasing and safe for lifelong consumption

• Quality of the source water allows for the use of conventional treatment processes at both primary treatment plants
  • Relatively inexpensive processes
  • Allow for full compliance to all parameters of the South African drinking water standard and World Health Organization guidelines

• Multi-barrier approach to ensure microbiological quality
  • Elevated pH
  • Filtration
  • Primary and secondary disinfection
Reported Removals of *Cryptosporidium* Oocysts by Physical-Chemical Water Treatment Processes (Bench, Pilot and Field Studies) - *courtesy of Mark D. Sobsey*

<table>
<thead>
<tr>
<th>Process</th>
<th>Log$_{10}$ Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarification by:</td>
<td></td>
</tr>
<tr>
<td>Coagulation flocculation-sedimentation or Flotation</td>
<td>&lt;1 - 2.6</td>
</tr>
<tr>
<td>Rapid Filtration (pre-coagulated)</td>
<td>1.5 - &gt;4.0</td>
</tr>
<tr>
<td>Both Processes</td>
<td>&lt;2.5 - &gt;6.6</td>
</tr>
<tr>
<td>Slow Sand Filtration</td>
<td>&gt;3.7</td>
</tr>
<tr>
<td>Diatomaceous Earth Filtration</td>
<td>&gt;4.0</td>
</tr>
<tr>
<td>Coagulation + Microfiltration</td>
<td>&gt;6.0</td>
</tr>
<tr>
<td>Ultrafiltration</td>
<td>&gt;6.0</td>
</tr>
</tbody>
</table>
Acceptable Water Quality

- Must be safe for lifelong consumption
- Free of pathogenic organisms
- Not contain any chemical or radioactive substances deleterious to health
- Must be palatable (taste, odour) and aesthetically appealing (clear)
- Be chemically stable
Target Drinking Water Quality

PURE WATER

Deficiency Diseases Possible

Toxic Diseases Possible

Pollution

Recommended Limit
Negligible Risk Limit
Low Risk Limit

Range of acceptable water quality

TOXIC OR BENEFICIAL AMOUNT?

Source: PL Kempster et al
Importance of Treatment

World Health Organization
“The potential health consequences of microbial contamination are such that its control must always be of paramount importance and must never be compromised.”

Death Rate for Typhoid Fever
United States, 1900-1960

The Multi Barrier Approach

- A broader perspective to potable water production
- Looking at the widest range of “preventive” or “control measures” from catchment to tap in order to protect public health
- Approach to risk management of the safety of drinking water
- Creating barriers that needs to be managed throughout the entire drinking value chain
## Multi-barrier approach in German water supply (Sturm, 2006)

<table>
<thead>
<tr>
<th>1st Barrier</th>
<th>2nd Barrier</th>
<th>3rd Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resource Protection</strong></td>
<td><strong>Water Supply</strong></td>
<td><strong>Distribution System</strong></td>
</tr>
<tr>
<td>- Groundwater Protection Areas</td>
<td>- DVGW System of technical standards</td>
<td>- Materials in contact with drinking water:</td>
</tr>
<tr>
<td>- Catchment Area Management</td>
<td>- Abstraction</td>
<td>- carefully tested &amp; chosen</td>
</tr>
<tr>
<td>- Surveillance &amp; Control</td>
<td>- Storage</td>
<td>- careful maintenance</td>
</tr>
<tr>
<td></td>
<td>- Transport</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Distribution</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Management</td>
<td></td>
</tr>
</tbody>
</table>

with modifications adapted from Castell-Exner 2001
Determination of Treatment Requirements

- Formulating an optimum treatment approach is complex

- Selection of treatment technology and process configuration requires a holistic approach which depends on (amongst others):
  - Source characteristics
  - Exact nature of contamination
  - Technology combinations
  - Existing infrastructure
  - Impact on other unit processes
  - Secondary impacts on water quality
  - Volumes to be treated (full or partial)
  - Target water quality (SANS 241 or specific parameters)
  - Technology life cycle costs
  - Commodity price fluctuations
  - Waste disposal implications and costs
Points where operational limits are required

- Intakes
- Treatment chemicals
- Chemical dosing
- Coagulation
- Flocculation
- Sedimentation
- Stabilization
- Filtration
- Disinfection
Process Capability Assessments

Monitoring and assessment

- Plant audits which are conducted to identify factors that may adversely impact on the ability of unit processes to achieve optimal performance
- Both visual inspection and contaminant removal efficiencies are used
Road Map for Process Audit

1. Kick-off meeting
2. Plant Tour
3. Administration data
4. Design data
5. Operations data
6. Maintenance data
7. Performance data

- Conduct performance assessment
- Evaluation of major Units
- Interviews
- Exit meeting

Determine if the plant current treatment processes meet performance goals.
Functional / Behavioral Skill requirements

Auditor capabilities

- Water treatment processes
- Water quality standards
- Instrumentation and control
- Water chemistry
- Safety
- Process design
- Maintenance
- Sampling
- Laboratory testing
- Interview skills
- “People” Skills
Visual Inspection

Coagulation/Flocculation
- Floc characteristics
- Floc settling
- Floc formation (formed or not, size)
- Floc breakage at outlet
- Scum accumulation
- Deposits in flocculators
- Algal growth

Sedimentation
- Effects of turbulence
- Is scour high?
- Floating water treatment residue
- Floc carryover excessive or not
- Algae growth
- Scum accumulation

Filtration
- Algae growth
- Mud ball formation
- Media cracking
- Coating of filter sand with mud

Backwashing
- Carryover of sand
- Are mud balls still there?
- Start ups occur on dirty sand, etc
<table>
<thead>
<tr>
<th>Process</th>
<th>Measured Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coagulation/Flocculation</td>
<td>• Mixing efficiencies – G values</td>
</tr>
<tr>
<td></td>
<td>• Optimum dosages of chemicals (jar tests records)</td>
</tr>
<tr>
<td></td>
<td>• Alkalinity</td>
</tr>
<tr>
<td></td>
<td>• pH</td>
</tr>
<tr>
<td>Sedimentation</td>
<td>• pH</td>
</tr>
<tr>
<td></td>
<td>• Turbidity</td>
</tr>
<tr>
<td></td>
<td>• Alkalinity</td>
</tr>
<tr>
<td>Stabilization</td>
<td>• pH</td>
</tr>
<tr>
<td></td>
<td>• Turbidity</td>
</tr>
<tr>
<td></td>
<td>• Alkalinity</td>
</tr>
<tr>
<td>Filtration</td>
<td>• pH</td>
</tr>
<tr>
<td></td>
<td>• Turbidity</td>
</tr>
<tr>
<td></td>
<td>• Particle size</td>
</tr>
<tr>
<td>Disinfection</td>
<td>• Turbidity</td>
</tr>
<tr>
<td></td>
<td>• Alkalinity</td>
</tr>
<tr>
<td></td>
<td>• pH</td>
</tr>
<tr>
<td></td>
<td>• Conductivity</td>
</tr>
<tr>
<td></td>
<td>• Residual chlorine</td>
</tr>
<tr>
<td></td>
<td>• Corrosion Index (e.g. Calcium Carbonate Precipitation Potential (CCPP), mg/l as CaCO₃)</td>
</tr>
</tbody>
</table>
Water Quality Threats in the Source Waters

- Microbiological (bacteria, viruses and protozoa)
- Eutrophication (algae)
- Organic Matter (NOM and SOM)
- Heavy Metals and Radioactive Compounds
- Salinity

Eutrophication (algae)
Water Quality Threats in Source Waters

- **Biological**
  - Pathogenic micro-organisms
  - Problematic algae

- **Eutrophication**
  - Enrichment of water with nutrients
  - Algal blooms
Water Quality Threats

- **Organic matter**
  - Natural organic matter (NOM)
  - Synthetic organic matter (SOM)
    - Pesticides
    - Pharmaceuticals and personal care products
    - Industrial solvents and detergents

- **Salinity**

- **Heavy metals**

- **Radioactivity**
Technology Requirements for Excessive Increase in Pollutants

<table>
<thead>
<tr>
<th>Technology</th>
<th>Pollution Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-chlorination or pre-ozonation</td>
<td>Micro Eutro Org</td>
</tr>
<tr>
<td>Enhanced coagulation</td>
<td>Org</td>
</tr>
<tr>
<td>Powdered activated carbon</td>
<td>Org Metals</td>
</tr>
<tr>
<td>Granular activated carbon</td>
<td>Org Metals</td>
</tr>
<tr>
<td>Dissolved air flotation</td>
<td>Eutro</td>
</tr>
<tr>
<td>Ozone/advanced oxidation</td>
<td>Micro Eutro Org Metals</td>
</tr>
<tr>
<td>Ultraviolet light</td>
<td>Micro Org</td>
</tr>
<tr>
<td>Membranes</td>
<td>Micro Org Metals Salinity</td>
</tr>
<tr>
<td>Ion-exchange</td>
<td>Org Metals Salinity</td>
</tr>
<tr>
<td>Distillation processes</td>
<td>Salinity</td>
</tr>
</tbody>
</table>
Tolerance for Metal and Salinity Increases

Current Bulk Water Supply as a Percentage of SANS 241

- Conductivity
- Total Dissolved Solids
- Antimony
- Arsenic
- Cadmium
- Chromium - total
- Cobalt
- Cyanide - recoverable
- Lead
- Mercury
- Nickel
- Selenium
- Vanadium
- Aluminium
- Ammonia
- Calcium
- Chloride
- Copper
- Fluoride
- Iron
- Magnesium
- Manganese
- Nitrate and nitrite
- Potassium
- Sodium
- Sulphate
- Zinc

Legend:
- % of SANS 241
- Tolerable Increase
Advanced Treatment Technology

- Advanced treatment technology is already employed at Rand Water in special cases
- Barrage Treatment Plant
  - Separate system treating a more eutrophied source
  - Granular activated carbon for organic compound removal
  - Ultraviolet light for additional disinfection
- Zuurbekom Wells *(note: currently not operational)*
  - Potential for contamination by human/animal waste
  - Ultraviolet light to inactivate pathogenic protozoa
- Ongoing research on alternate and advanced treatment technologies
Future Treatment Technology Considerations

- The future water quality of the Vaal Dam is uncertain.
- In a worst case scenario of excessive and uncontrolled pollution, the following treatment technologies may be required:

<table>
<thead>
<tr>
<th>Organic matter</th>
<th>Eutrophication</th>
<th>High turbidity</th>
<th>Salinity</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAC</td>
<td>Pre- and/or intermediate oxidation</td>
<td>Microfiltration</td>
<td>Reverse osmosis</td>
</tr>
<tr>
<td>PAC</td>
<td></td>
<td>Ultrafiltration</td>
<td>Electrodialysis (ED/EDR)</td>
</tr>
<tr>
<td>IX resins</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AOX</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Questions?