Uranium partitioning during water treatment processes

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Outlines

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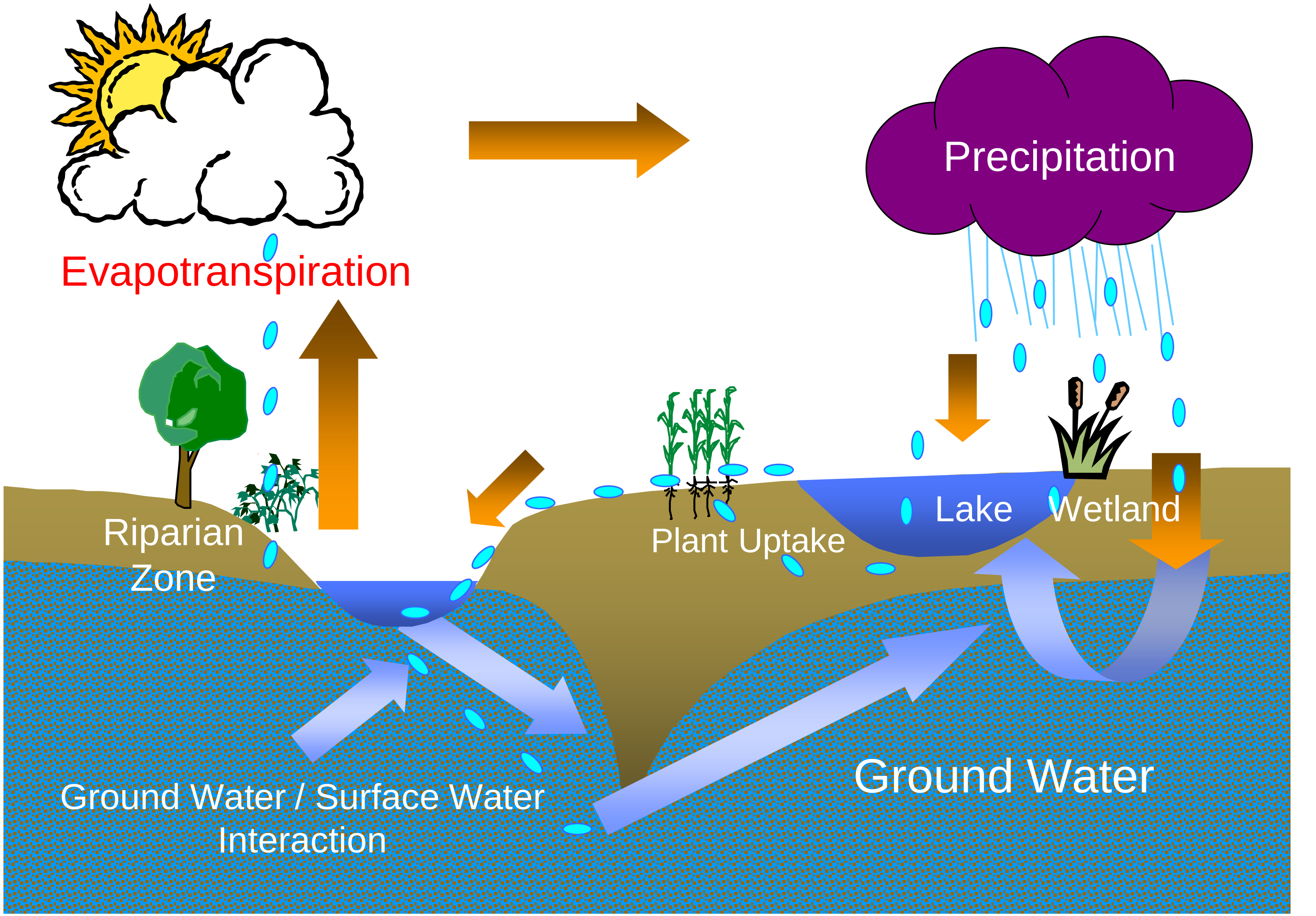
- Aim of Work
- Drinking Water Purification
- Experimental work
- Results and discussion
- conclusions

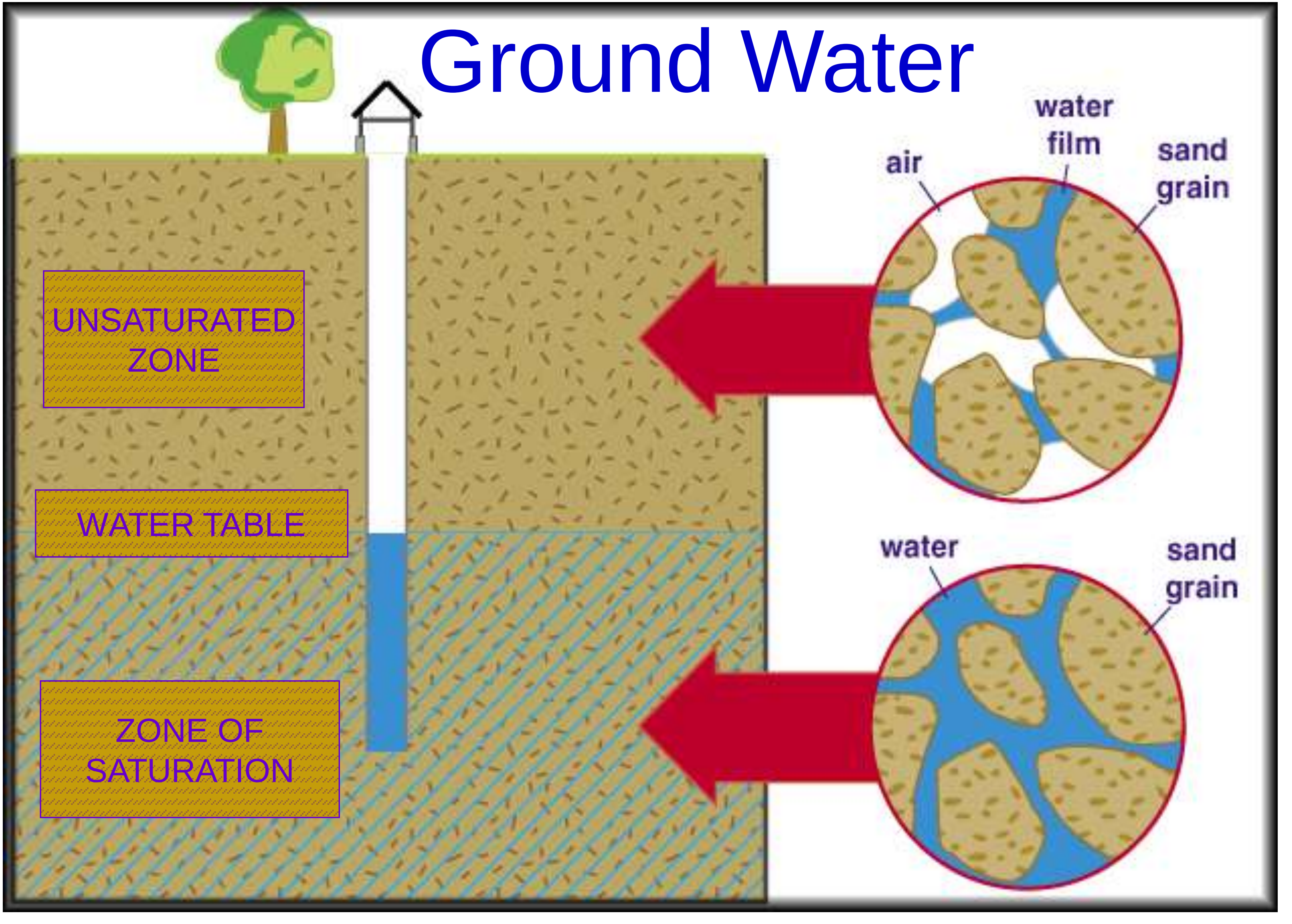
Introduction

- Generally, the occurrence of radionuclides in the underground water is meanly due to the leaching of the salts from the bed-rocks.
- Uranium is mobilized from rock by the weathering of uraninte (UO_2).
- The action of surface water and groundwater causes oxidative dissolution of uraninite to soluble uranyl ion (UO_2^{2+}).
- Worldwide from 27 000 to 32 000 t uranium are released from igneous, shale, sandstone rocks annually by weathering and natural erosion (Eriksson 1960; Bowen 1966; environment Canada 1983; CCME 2007).



Evapotranspiration
Precipitation
Riparian Zone
Plant Uptake
Lake
Wetland
Ground Water / Surface Water Interaction
Ground Water

Ground Water



Why is Groundwater Important?

- Groundwater supplies:
  - 75% of drinking water in Europe
  - 51% in the US
  - 32% in Asia
  - 29% in Latin America

Groundwater Pollution

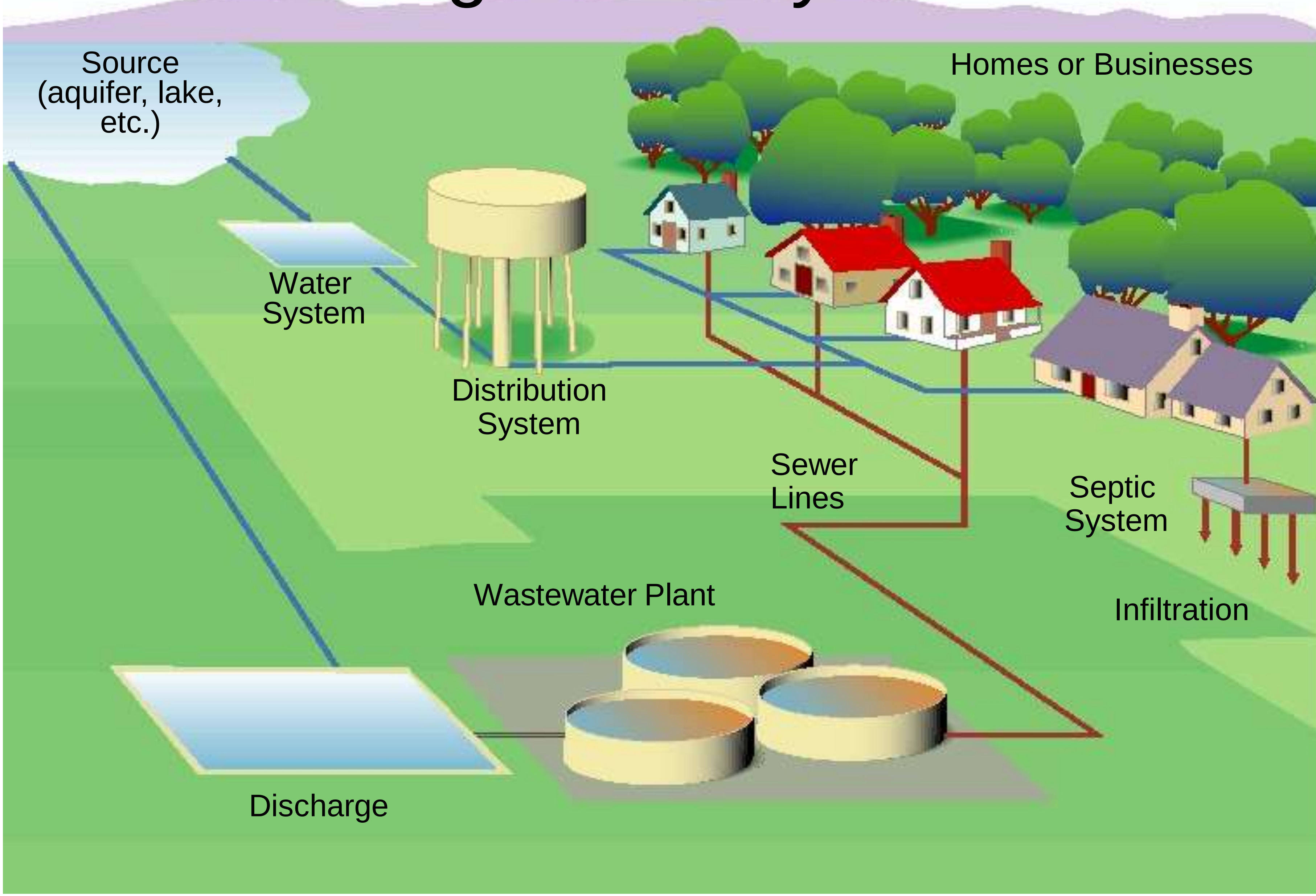
- Groundwater pollution comes from:
  - Storage lagoons
  - Septic tanks
  - Landfills
  - Hazardous waste dumps
  - Deep injection wells
  - Stored gasoline, oil, solvents, and hazardous wastes underground – can corrode and leak
- Pollutants in drinking water = high risk health problems
  - Contamination with petrochemicals (gasoline and oil)
  - Organic solvents (TCE)
  - Pesticides
  - Arsenic
  - Lead
  - Fluoride
- Groundwater cannot clean itself of degradable wastes as flowing surface water can because it flows so slowly, has much smaller amounts of decomposing bacteria, and has cold temperatures that slow down the chemical reactions that decompose waste

Sources of Contamination

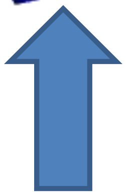
Sources of Drinking Water

- Surface water
- Ground water
- Ground water under the direct influence of surface water
- Desalinated sea water
- Rain water

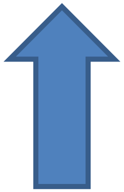
The Drinking Water Cycle



Uranium health effects and risk



Radioactive



Heavy metal

US Environmental Protection Agency (EPA) has classified uranium as a confirmed human carcinogen (group A).

Maximum acceptable level of U in drinking water

- EPA has suggested that only zero tolerance is a safe acceptable limit for the carcinogenic risk from uranium and finalized a realistic regulation levels as maximum contaminant level (MCL) of 30 $\mu g.L^{-1}$,
- Canada proposed interim maximum acceptable level (IMAC) of 20 $\mu g.L^{-1}$, and
- World Health Organization (WHO) strictly recommended a reference level of 2 $\mu g.L^{-1}$(Kim et al. 2004).

Several factors control the concentration of uranium in water;

- **the uranium concentration in the aquifer rock,**
- **the partial pressure of carbon dioxide, and the presence of oxygen**
- **complexing agents in the aquifer.**

Also the characteristics (physical and chemical) of water mainly determine its capacity to dissolve, carry or deposit elements are

- **pH,**
- **temperature,**
- **redox potential,**
- **concentration and properties of dissolved salts,**
- **flow rate and residence time (Pontius 2000; Shabana and Al-Hobiab 1999).**

- **The uranyl ion (UO_2^{2+}) forms stable salts and complexes with many commonly occurring anions in aquatic environment.**
- **The chemical speciation of uranium ions in aqueous solution is quit complex because of the many possibilities of complexing reactions with most other ions**
- **Uranium may be precipitated as insoluble UO_2 or adsorbed by clays and hydrous metal oxides.**

Aim of the work

- shading more light on the variation of uranium concentrations through the water purification and treatment processes and
- Studying the relationship between uranium and the physical and chemical properties (pH, EC, major anions and cations) of water during treatment.

Main water treatment steps

Input water derives from 18 drilled wells, 500-600 m depth, in a circle of 10 km^2 area.

Pre-chlorination

Aeration

Phase 1

pH adjustment, Coagulation-flocculation

Filtration (sand filter) *

Phase 2

Reverse Osmosis (RO) *

Phase 3

Post-chlorination

produces 10^5 m^3/d

•Chemical reagents include; chlorine, Sulfate, polyelectrolyte, lime.

•Back wash of sand filter and RO reject are pumped to 6 evaporation ponds

Experimental work

• Sampling: Water samples; input- after aeration, after filtration (sand filter), sludge tank, reverse osmosis permit, reverse osmosis reject, output water and two samples from the evaporation ponds. Water samples were collected in 5 L capacity polyethylene containers, and transferred and kept in darkness for preservation,

•Uranium concentrations, $\mu g.L^{-1}$, were measured using PerkinElmer model ELAN-9000 ICP-MS,

• Water physical and chemical properties such as pH, EC (electric conductivity, $dS.cm^{-1}$), major cations (Ca, Mg and K) and major anions (CO_3, HCO_3, Cl and SO_4) were determine using standard methods (Al-Omran 1987)

Cont.: Experimental work

The variation percentage of uranium concentration in water samples relative to input water were calculated using the following equation:

$$\Delta = (C - C') \times 100/C$$

Where: C; uranium concentration in input water

C'; uranium concentration in the sample

Positive and negative percentages mean uranium decontamination and increment of uranium concentration, respectively (Jimenez 2002)

Results and discussion

Uranium concentrations ($\mu g.L^{-1}$) and activity concentrations ($mBq.L^{-1}$) in water samples and variation ratio.

Samples	Uranium		▲
	µg/ L	mBq/L	
Input	4.0	49	0
After Filtration	4.1	51	-2
Sludge tank	4.2	52	-5
R.O. Permit	0.06	0.74	99
R.O. Reject	15.7	195	-293
Output	0.17	2	96
Evaporation P-1	8.3	103	-108
Evaporation P-2	35.1	435	-778

- Uranium concentration was not changed before the reverse osmosis process, only variation percentage of -2 % after filtration.

- Uranium removal percentage by reverse osmosis process was 99 % while the increment of uranium in reverse osmosis reject water was very close to 300 %.

- Reverse osmosis is one of the few water treatment methods which can be applied for simultaneous removal of U, Ra, Pb, Po and water salinity, i.e. water is almost completely demineralized (Huikuri et al 1998).

- Uranium variation percentage (removal) was 96% for the final treated water. The decrease in uranium removal percentage from that of reverse osmosis step (99%) could be due to the presence of uranium in the reagents used and/or to the dissolution of uranium associated with colloids and other substances, during water treatment processes (Jimenez 2002).

- Uranium concentrations in evaporation ponds enhanced due to evaporation process where the variation percentages were – 108 % and - 778 % and it will increase more by evaporation.

- It is expected that uranium and other radionuclides will be accumulated to reach very high concentrations in evaporation ponds. This situation should be considered very carefully to prevent the contamination of the surrounding environment.

Physical and chemical **properties** of water samples

Ser. No.	Samples	pH	EC (dS/cm)	Major cations (meq/L)				Major Anions (meq/L)			
				Ca	Mg	Na	K	CO3	HCO3	Cl	SO4
1	Input (after airation)	8.3	1.2	6	4	4	0.15	1.3	1.5	7	3
2	After sand filter	8.3	1.1	5	3	4	0.15	1.3	1.0	8	4
3	From sludge tank	8.2	1.1	6	4	4	0.15	1.3	2	7	4
4	Revers Osmosis permit	8.4	0.22	1	0.59	0.84	0.1	6	0.5		2
5	Revers Osmosis reject	8.5	1.7	10	6	13	0.27	1.3	3	18	8
6	Output	7.9	0.32	1.5	0.89	1.9	0.13	3	1.2	4	2
7	Evaporation bond-1	8.3	5	26	16	26	0.63	1.3	3	36	18
8	Evaporation bond-2	7.6	17	66	39	106	1.9	1.3	1.5	138	40

- pH values ranged from 7.6 to 8.5 where U and most heavy elements are increasingly adsorbed on oxides, clays and other silicates. The adsorbed fraction may be very close to 100 % above pH 7.

- It was reported that uranium concentrations enhanced in all water that has been purified within the acidic pH (<7) (Jimeneze 2002).

- It obvious that the reverse osmosis process remove not only U but also other anions and cations with variation concentration percentages more than 400% for Ca, Mg and Na, about 200 % for HCO_3^-, and about 50 % for K^+.

Correlations between uranium concentration and physical and chemical properties of water samples

	U	*Δ*	*pH*	*EC*	*Ca*	*Mg*	*Na*	*K*	*CO_3*	*HCO_3*	*Cl*	*SO_4*
U	1											
Δ	-1	1										
pH	-0.56	0.55	1									
EC	0.93	-0.92	-0.72	1								
Ca	0.93	-0.93	-0.68	1.0	1							
Mg	0.93	-0.93	-0.68	1.0	1	1						
Na	0.94	-0.94	-0.73	1.0	0.99	1	1					
K	0.93	-0.93	-0.73	1.0	0.99	1	1.0	1				
CO_3	-0.39	0.43	0.14	-0.3	-0.33	-0.3	-0.27	-0.27	1			
HCO_3	0.32	-0.31	0.25	0.1	0.18	0.2	0.09	0.11	-0.63	1		
Cl	0.94	-0.94	-0.71	1.0	0.99	1	1.0	1.00	-0.25	-0.03	1	
SO_4	0.92	-0.92	-0.66	1.0	1.0	1	0.98	0.99	-0.31	0.20	0.98	1

- There are strong correlation (correlation coefficient) between uranium concentrations and EC (0.93), Ca (0.93), Mg (0.93), Na (0.94), Cl (0.94) and SO_4 (0.92).

- The correlation is good (-0.56) with pH values and weak with CO_3 (-0.39) and HCO_3 (0.32).

- The strong correlation could be explained due to the demineralization of water during treatment processes especially during reverse osmosis process or due to the chemical behavior of uranium. For example, uranium can form soluble complexes in most underground waters with chloride, sulfate and under oxidizing conditions with carbonate which keep uranium in solution (Shabana and Al-Hobiab 1999).

Conclusions

- Drinking water treatment is very essential to remove many contaminants such as radionuclides.
- Reverse osmosis is very effective in removing radionuclides, heavy metals and other element but it de-minerlizes water.
- Drinking water purification residuals should be carefully considered for their possible environmental risks.

Thank you