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Development of RO Units for Treatment of High Sulfur Groundwater

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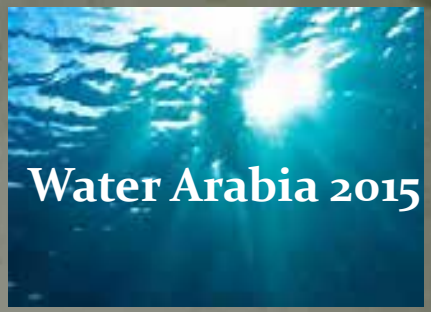
Objective:

to strengthen the relationship between industry and academic institutions, while at the same time solving technological and organisational problems of the business sector.

Outlines



- Introduction
- Methods of treatment of high sulfur groundwater
- Case Study
- Conclusion
- Acknowledgements

Introduction

- Underground water is one of the main water recourses in many countries.
- Sulfur is most commonly found in groundwater characterized by relatively low concentrations of dissolved oxygen and by a pH less than 6.0 (relatively acidic).
- Sulfur or hydrogen sulfide (H_2S) is a gas formed by the decay of organic matter in presence of bacteria.
- It will consume sulfate oxygen, after depleting oxygen, leaving bi-sulfide ions to combine with hydrogen to form aqueous H_2S

- The taste and odor threshold for hydrogen sulfide in water has been estimated to be as low as 0.05 ppm.

- Concentration of H_2S around 1 ppm gives the water a musty or swampy odor, while A 1-2 ppm gives water a rotten egg odor

- Hydrogen sulfide corrode plumbing metals (iron, steel, copper, brass) and exposed metals parts in washing machines and other water-using appliance.

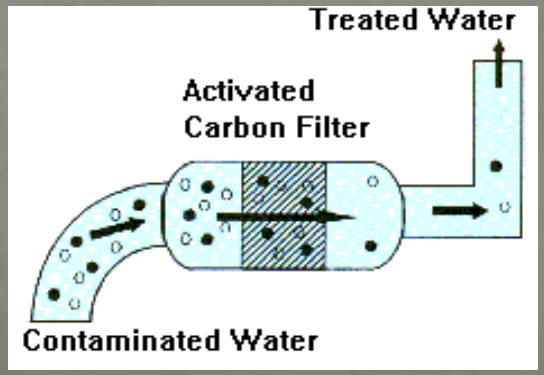
- From a public health standpoint, Adverse physical effects are from inhalation, not ingestion, and don't normally occur until the H_2S reaches levels around 2 to 50 mg/L.
- Ingestion of sulphides through drinking water can result in stomach discomfort, nausea and vomiting
- The Immediate Dangerous to Life and Health (IDLH) level for hydrogen sulfide is 300 mg/L.
- In drinking water systems, total sulfide is primarily composed of H_2S and HS^-
- At a pH equal to 7.0 for instance, approximately 56% of the total sulfide is H_2S while 44% is present as HS^-

Methods of removal H_2S from ground water

- 1- Catalytic Carbon process
- 2- Aeration process
- 3- Chlorination process
- 4- Manganese greensand filter

1-Catalytic Carbon process

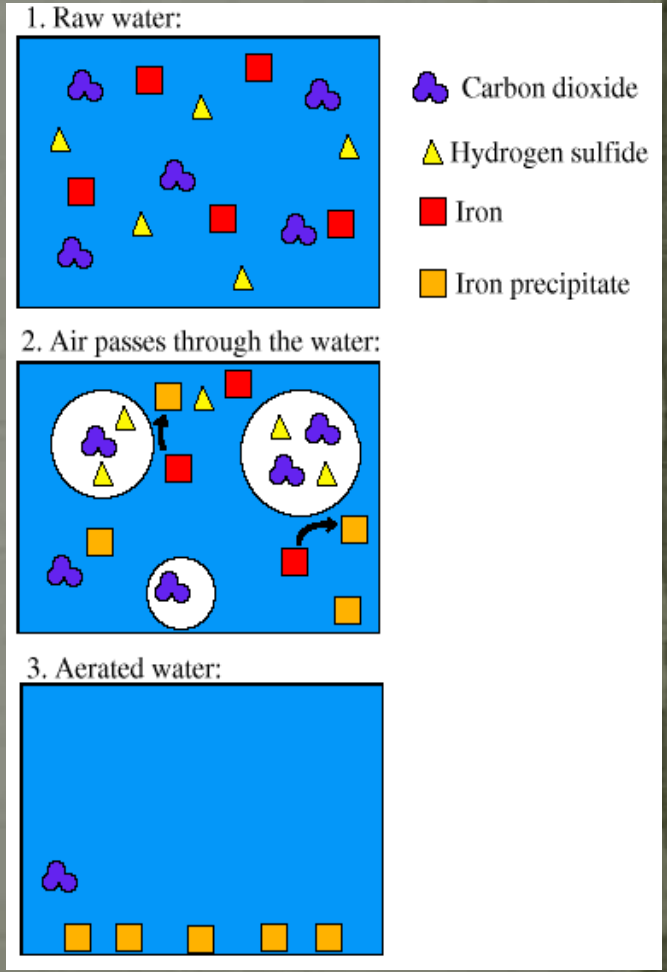
- Catalytic carbon is activated carbon with a modified carbon surface.
- activated carbon filtration removes very small amounts of hydrogen sulfide, generally concentrations below 0.3 mg/l.
- Once the filter is saturated, the activated carbon must be replaced, not regenerated.
- As a result, activated carbon is not effective for removing moderate or high concentrations of hydrogen sulfide in drinking water.



2-Aeration process

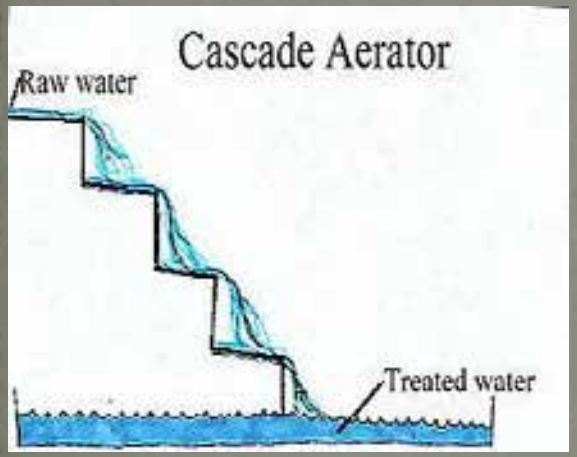
- Hydrogen sulfide is physically removed by agitating the water via bubbling or cascading and then separating or "stripping" the hydrogen sulfide in a container.

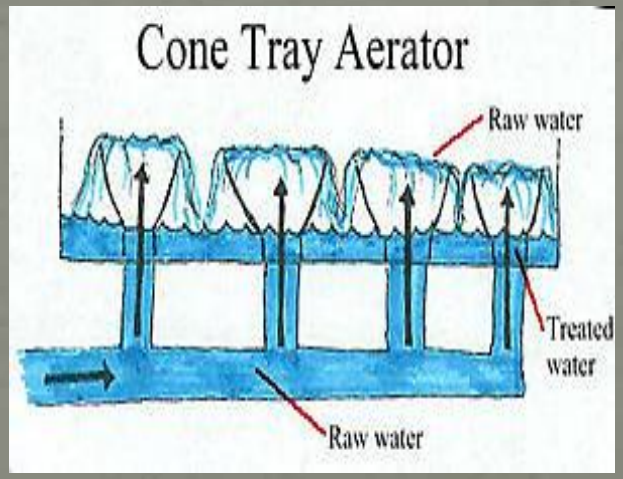
- The undesired hydrogen sulfide is removed as a volatile gas by venting it into a waste pipe or to the outdoors.

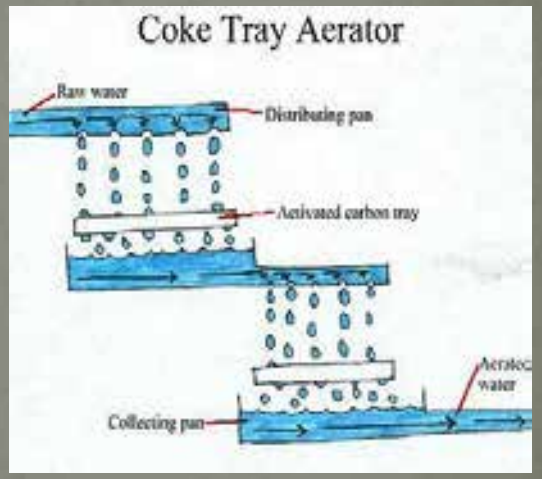


- They are several types of aeration systems:
- These types include conventional (free fall), forced draft, or packed tower aeration.

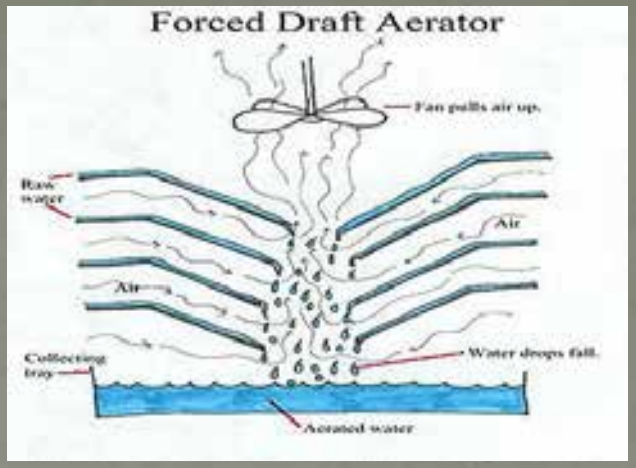
- In conventional type (free fall), water is sprayed into a nonpressurized storage tank.



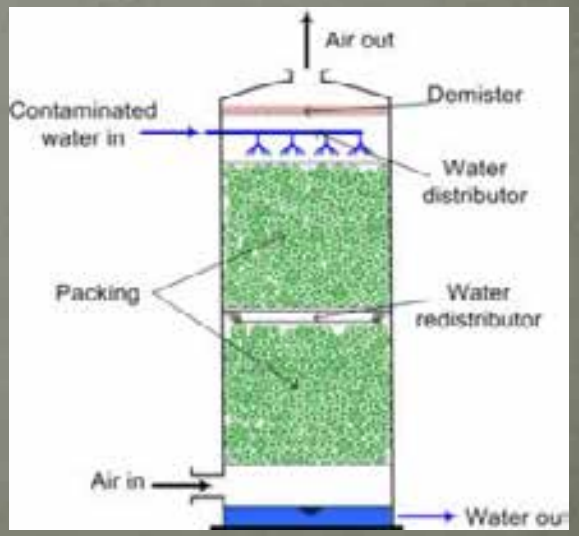




- In a forced draft, compressed air is injected into the water system.



- The last type of Aeration is the packed tower aeration, The water is sprayed over a packing material with a counter current process with the pumped air.



- The air then must be removed from the water to prevent knocking or air-blocks in the system and to reduce the corrosion potential caused by dissolved oxygen

- Aeration is most effective when hydrogen sulfide concentrations are lower than 2.0 mg/l.

- At higher concentrations, this method may not remove the entire offensive odor unless the air is used to oxidize hydrogen sulfide chemically into solid sulfur, which is then filtered.

Chlorination process

- This method is used if the water pH is in the range 6-8.
- Chlorine is administered as sodium hypochlorite, which reacts with sulfide, hydrogen sulfide, and bisulfide to form compounds that do not cause foul taste or odors in drinking water.
- It is usually recommended for water that contains hydrogen sulfide with concentration up to 75 ppm.
- The process also effectively removes iron and manganese that can occur in association with hydrogen sulfide

Manganese greensand filter

- A manganese greensand filter has a special coating that oxidizes hydrogen sulfide gas to solid sulfur particles, which are filtered.
- When all of the manganese oxide is consumed, the greensand is regenerated with potassium permanganate.
- It is usually recommended for water that contains less than 6.0 mg/l H_2S.

- More details found in:

S. Edwards, R. Alharthi and A.E. Ghaly, **Removal of Hydrogen Sulphide from Water,** American Journal of Environmental Sciences 7 (4) (2011), 295-305.

Summarizing

Treatment type	H_2S concentration	Comments
Carbon filter	< 1 ppm	**Requires regular replacements**
Aeration	< 2 ppm	**Requires sizeable equipment placed a way from residence.**
Manganese green sand filter	<6 ppm	**Systems requires regeneration of oxidizing media.**
Chlorination systems	**<75 ppm**	**Upper cost range assumes removal**

Case study -WENFAC unit

- Water Equipment National Factory (WENFAC) is one of Jordanian water treatment companies established 1999.
- WENFAC usually builds up RO unit to desalinate underground water for irrigation application (banana and date).
- The TDS value for underground water is in the range of 4000 to 5000 ppm, while the required TDS value lower than 700ppm
- The main parts of the unit are feed pump, sand filter, cartridge filter, antiscalant, and RO system.

Typical RO Units

Water source

Pump

Sand Filter

Cartridge Filter

Pumps for antiscalant

Concentrated water

Cleaned water

%75-70

RO System

Motivation -Sulfur problem

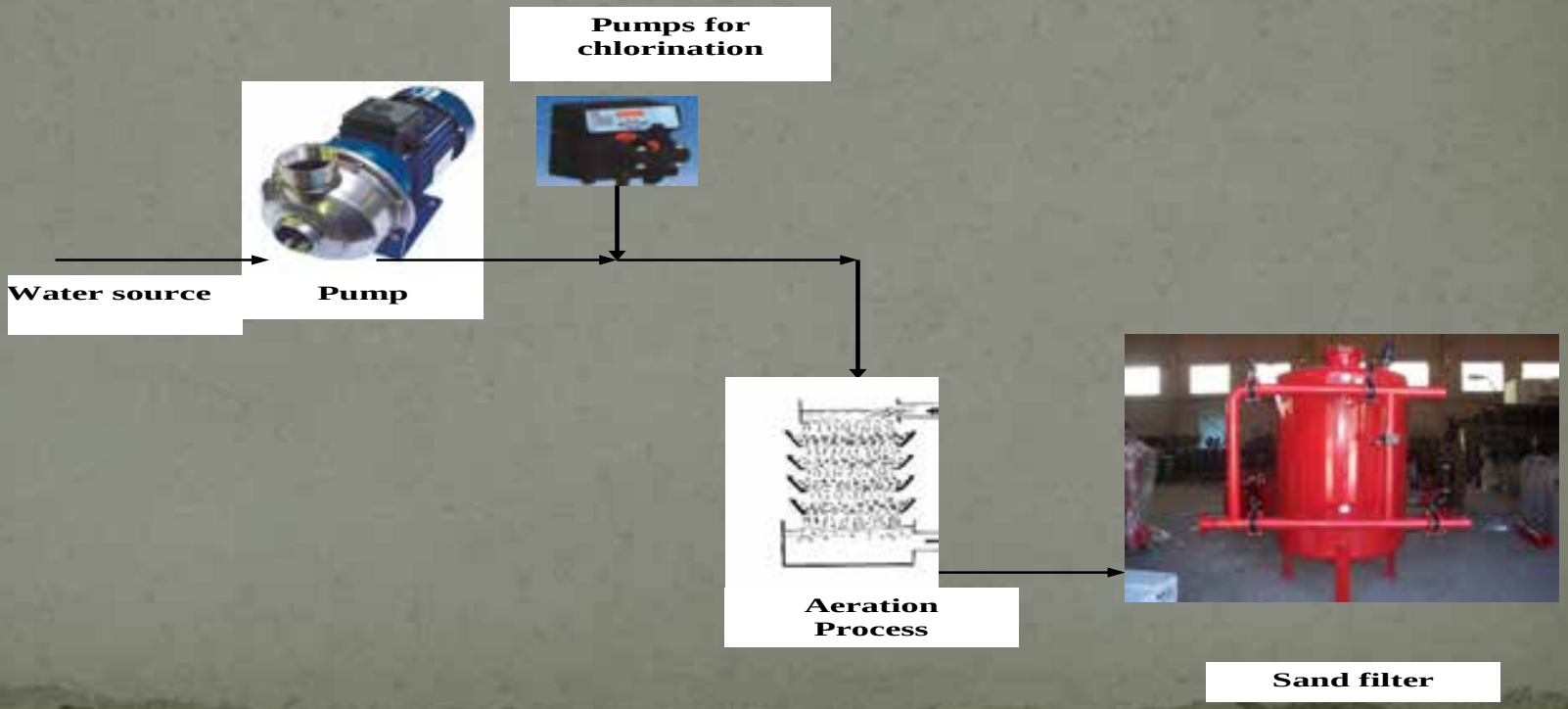
- One of the WENFAC customers complained about the sulfur content in his ground water. He felt the sulfur as a rotten egg smell in his well.
- He asked WENFAC to install a RO unit to treat a ground water with relatively high concentration of sulfur.
- This contaminant will destroy his plants (banana, date).
- WENFAC didn't deal with this issue in the previous time.
- Therefore, they need to modify their RO unit to decrease the concentration of sulfur from the ground water with suitable prices (customer request).

Investigated water analysis

Test	Results
pH	7.16
TDS (ppm)	3150
Sodium (Na^+) (ppm)	370
Iron, Fe^{3+} (ppm)	0.14
Silica, SiO_2 (ppm)	124
Total Sulfur (ppm)	2.23
Turbidity (NTU)	1.88

Modified RO unit

- Another pretreatment step was suggested for the treatment process including chlorination and aeration processes.
- The chlorination (low concentration) was injected directly to underground water line followed by aeration process.



Free fall Aerator

- Simple Free fall Aerator was chosen (low price).
- The Aerator consists of simple vertical layers of wood with dimensions of 1 m x 1m with 3 m high.
- The space between each two vertical layers is 10 cm.
- The aeration is only open from the top where the feed water is fallen down through the aeration.

- All sides of the aeration were built by concrete
- The chlorination is injected to the water line before the aeration process.
- The effluent of the Aeration process will be collected in the underground concrete tank which represents feed stream to the main RO unit

- Then, the investigated underground water will be pumped to the normal RO unit to decease both silica and TDS.

Top view of the suggest free fall aeration

Feed water falls down through free fall Aeration

Side view of the free fall Aeration

Effluent stream of the aeration process

Permeate collected in the lake

Results

Sample position	total sulfur (mg/L)	% sulfur removal	Silica (mg/L)	% silica removal	Turbidity (NTU)
Feed	2.23	-	80.5	-	1.88
After chlorination process	1.86	17	71.5	11%	1.30
After aeration process	0.82	63	-		1.08
After RO	-	-	1.81	98%	0.80

Conclusion

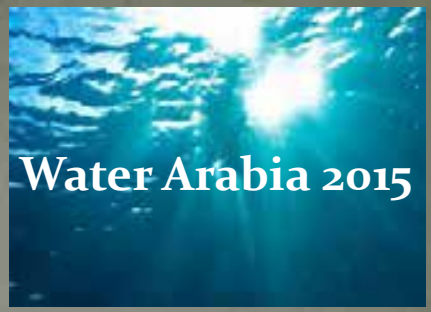
- A simple cheap aeration system was added to RO unit to treat underground water contains relatively high sulfur concentration (2.23 mg/L).
- The system consists of wood layers with size of (1m x 1m) and height of 3m. The distance between two layers is 10 cm.
- Chlorination was injected before the aeration system to kill the bacteria, treat the silica, and help in treating the sulfur in the ground water.

- The new system gave an accepted results as the concentration of total sulfur decrease to 0.82 mg/L with medium percentage removal of 63%.

- More studies (details) are required to increase the sulfur removal.

Acknowledgement

- The author thanks
- the faculty for factory program (FFF), Jordan for sponsoring this work
- WENFAC Company for supporting to achieve this studying and for their warm cooperation.



- ***Development of RO Units for Treatment of High Sulfur Groundwater***

Thank You
Any Questions

Different methods

- 1- Ion exchange:

Ion-exchange resin adsorbs H_2S until the resin is exhausted with H_2S. Then the resin should be regenerated with a salt, such as sodium chloride, before further treatment can occur