Sustainable waste water treatment & reuse option for commercial and residential buildings

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Objective

- The main objective of this paper is to provide guidelines for designing waste water treatment plants for commercial and residential buildings
- Based on the analytical studies conducted on the samples collected from the kitchen line of Dar Al-Hekma University.
- It also aims to create awareness among public for the reuse of treated waste water in flush tanks, gardening and landscaping.

Need of this Study

- Demand for water is increasing due to increase in the population as well as per capita water consumption of water.
- The Arab news, quoting Prof. Mirza Barjees Baig- a Canadian professor at KSU's department of agricultural extension and rural society, reported that the average water consumption in the Kingdom is double the world average.
- It was also further reported that 'Water consumption (by households) exceeds eight million cubic meters per day, and it is an unprecedented record ever for Saudi Arabia.
- On average, the daily per capita consumption of water in the Kingdom is about 265 liters".
- Thereby it is the right time to set up waste water treatment plant in commercial and residential buildings and to meet the demand.

Collection of Sample

- Our samples are collected at different times of the day from kitchen line of our university
- It is assumed that they are of same nature and are collected manually and randomly.
- The point of collection, date, hour and time is recorded.
- Our samples are mainly grey water generated from kitchen and the minimum volume is 1 liter.
- The reason for not examining black water is it involves lot of chemicals and tests which needs investment of more time and cost.
- The samples are stored, preserved and tested as per the specifications mentioned in the guide manual for water and waste water analysis for hydrology project II-Ministry of water resources, Gov. India

Tests conducted on the sample

- The following tests are conducted in the sample to find
  - PH value
  - Alkalinity
  - Total solids
  - Total dissolved solids
  - Total suspended solids
  - Total hardness
  - Conductivity
  - Chloride
  - Dissolved oxygen
  - Biological oxygen demand

Preservation of Sample [1]

- Samples are collected in glass bottles and pH value is measured immediately
- Samples are collected in 250 ml glass bottles and refrigerated if not analyzed immediately for alkalinity and chloride.
- Samples are collected in glass bottles and analyzed immediately for total dissolved solids and total solids
- Two samples are collected in BOD bottles of 300 mL capacity to test the dissolved oxygen. The bottles should over flow before putting stoppers. Out of two samples, one is analyzed immediately and other one is incubated for 3 days at 27.5^0 and analyzed.
- Samples are collected in glass bottles and pH is adjusted to two or less by adding H_2SO_4 for hardness.

TEST	METHOD / EQUIPMENT	MODEL NUMBER
PH	PH METER WITH COMBINED GLASS ELECTRODE	DENVER INSTRUMENT MODEL 215
ALKALINITY	TITRATION METHOD [1]	---
TOTAL SOLIDS	EVAPORATION AND DRYING IN ELECTRICALLY TEMPERATURE CONTROLLED OVEN [1]	HERAEUS MODEL T_6 FROM KEDRO LAB PRODUCTS
TOTAL DISSOLVED SOLIDS (TDS)	TDS METER [1]	HANNA INSTRUMENT MODEL NO. HI 98312
DISSOLVED OXYGEN BOD	WINKLER METHOD WITH AZIDE MODIFICATION [1,7]	----
TOTAL HARDNESS	EDTA TITRATION METHOD [1]	HANNA INSTRUMENT MODEL NO. HI 98312
CONDUCTIVITY	EC METER	HANNA INSTRUMENT MODEL NO. HI 98312
CHLORIDE	ARGENTOMETRIC METHOD [1]	

pH and ALKALINITY

- PH
  - PH meter is calibrated using laboratory supplied buffers of PH= 4 (HACH) and pH =7 (Panreac) . Usual precautions are taken while calibrating and the pH value is **7.7**
- Alkalinity
  - It is estimated by titrating 50cm^3 of grey water sample . No colour change with phenolphthalein , with methyl orange it gives yellow colour. It is titrated against standardized H_2SO_4 .(H_2SO_4 is standardized against Na_2 CO_3 of same concentration)
  - 0.02 N OR 0.01 M H_2SO_4 is prepared by diluting the appropriate volume of standardized sulfuric acid.
  - All solutions are prepared in CO_2 free distilled water.
  - Also potentiometric titration is carried out to bring pH to 4.5 using calibrated pH meter

Calculation of Total Alkalinity

- Total alkalinity (mg $CaCO_3$ /L) = Volume of H_2SO_4 required to reach pH 4.5 x 1000 / ml of sample

  = 2.2 x 1000 /50 = **44mg $CaCO_3$ / litre**

- Phenolphthalein alkalinity = 0
- As phenolphthalein alkalinity is zero therefore alkalinity is not due to OH^- and CO_3^{-2} [1]
- The total alkalinity is due to HCO_3^{-1} as the methyl orange indicator works with the sample. The total alkalinity is 44 mg of $CaCO_3^{-2}$ /litre
- $HCO3^{-1}$ in mg = mg of $CaCO_3^{-2}$ /L X 1.22 = 53.68 mg of HCO_3^{-1} /litre
- Molar concentration of HCO_3^{-1} = mg /L of HCO_3^{-1} / 61000

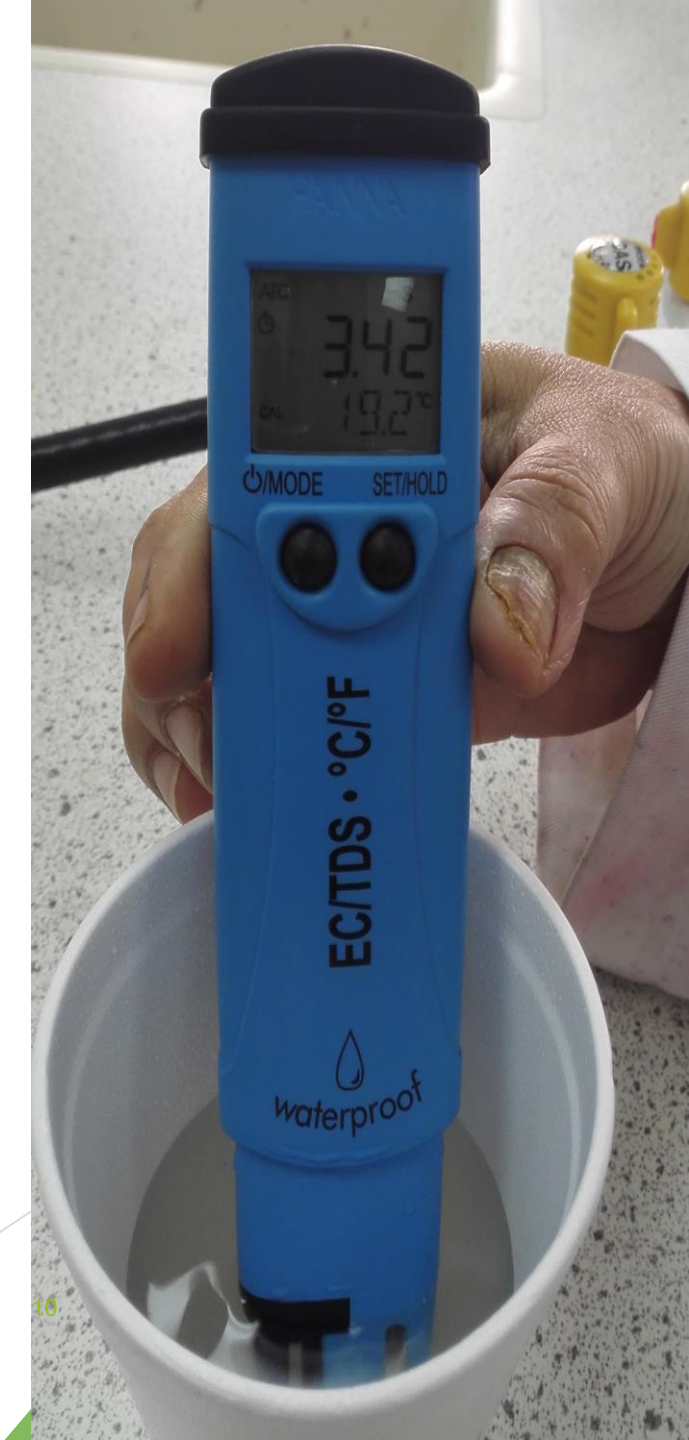
  = 8.8 X 10^{-4} mol/litre

Total Solids and Total Dissolved Solids

- 50 cm^3 of grey water sample is evaporated and dried in electrical temperature controlled oven at 103 -104 ^{0}C for 24 hrs.
- Total solids = $(W_2 - W_1)$ x 1000 / ml of sample
  - W_1 = weight of evaporating dish
  - W_2 = weight of dish with evaporated sample
- Total solids = 0.2 g x 1000 / 50 ml = **4 g/litre**

- Total dissolved solids (TDS) is measured using TDS/ EC meter at 25.6 ^{0}C and it is 0.13 ppt (parts per thousand) which is equal to 0.13 g/litre
- Suspended solids = Total solid –TDS [1]

  = 4 - 0.13 = **3.87 g /litre**



Total Hardness by EDTA titration method

- Hardness of water is caused by mixture of cations and anions. Generally total hardness is concentration of Ca^{+2} and Mg^{+2} ions and it is expressed in terms of $CaCO_3$ in mg/L [2]
- It is discussed as carbonate (temporary) and non-carbonate (permanent)
- The hardness is determined by EDTA by using buffer of pH = 10 and Eriochrome black T indicator, which forms wine red complex with Ca^{+2} and Mg^{+2} ions and blue complex with EDTA
- EDTA is standardized against calcium ion solution
  - 1 ml of this solution = 1 mg of $CaCO_3$
- A reagent blank is also carried out with redistilled water

Calculation of Total Hardness

Titration of sample :

- Volume of EDTA required by 25 $cm^3$of grey water sample = 5.5 cm^3
- Volume of EDTA required by 25 cm^3 of reagent blank = 2 cm^3
- Volume of EDTA reacted with Ca^{+2} and Mg^{2+} ions of water sample =3.5 cm^3

Standardization of EDTA:

- 25 cm^3 of Ca^{2+} ions solution needs 27.3 cm^3 of EDTA , 1.092 cm^3 of EDTA = 1cm^3 of calcium ion solution
- 3.5 cm^3 of EDTA solution is equivalent to 3.21 mg of $CaCO_3$ in 25cm^3 of grey water sample.
- In 1000cm^3 or 1L contains **128.4 mg of $CaCO_3$**

Calculation of carbonate and non-carbonate hardness

- In the tested sample it is found that total hardness is numerically greater than total alkalinity expressed as $CaCO_3$ so the amount of hardness equivalent to alkalinity and it is the carbonate hardness
- The amount of hardness in excess of total alkalinity is expressed as calcium carbonate is non-carbonate hardness [1]
- Total hardness = 128.4 mg $CaCO_3$ /litre
- Total alkalinity = **44 mg $CaCO_3$ /litre** = carbonate hardness
- Non-carbonate hardness = Total hardness – carbonate hardness

  (permanent HD) = **84.4 mg /litre**

Conductivity

- It is measured by EC meter and it was found as:

  0.26 ms/cm =166mg/L

Chloride by Argentometric method

- Chloride in grey water is estimated by titrating the sample in slightly alkaline conditions against standardized $AgNO_3$
- Yellow colour of potassium chromate changes to red precipitate as Ag_2CrO_4 is formed
- $AgNO_3$ is standardized against 0.014 M NaCl
- Calculation:
- Standardization:

1 ml of $AgNO_3$ = 0.5 mg of Cl^{-1}

Molarity of standardized $AgNO_3$ is 0.0137

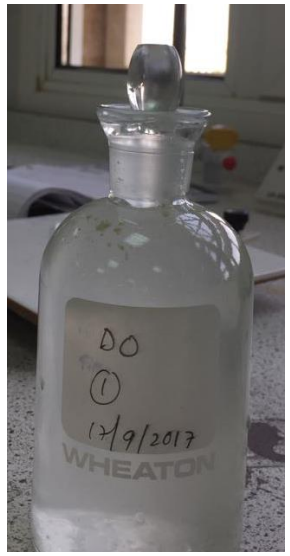
- Sample:

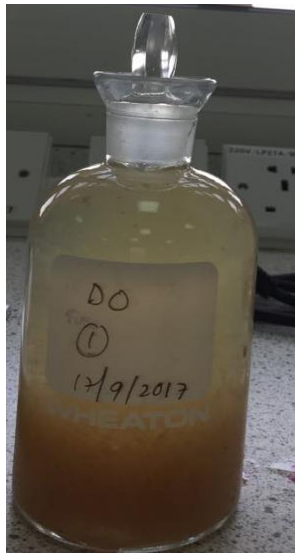
Volume of $AgNO_3$ required by 50 cm^3 of sample = 5.0cm^3 =2.46 mg/50cm^3

- Chloride in 1litre grey water sample = 49.2 mg

Dissolved oxygen (The Winkler method with azide modification)

- The dissolved oxygen (DO) level shows the changes caused by aerobic bacteria. Some metal ions are oxidized to higher oxidation state and may dissolve them. DO is the pollution level indicator.
- The method used [1,4,7] is based on reaction of $MnSO_4$ with NaOH to form $Mn(OH)_2$, which is oxidized from +2 to +4 and precipitates out as brown solid of hydrated manganese hydroxide. The precipitate dissolves in con H_2SO_4.





Contd.,

Dissolved oxygen

- Mn^{+4} oxidizes I^{-1} to iodine which is estimated by iodometric titration
- $MnSO_4$ and alkali-iodide azide reagents are added to sample collected by dipping the pipette in it and then 1 ml of concentrated H_2SO_4
- 201 mL of this sample is titrated against standardized $Na_2S_2O_3$ using starch indicator
- 201 ml of sample is used to recover loss which is equal to 200 ml of original sample

Reactions

- $MnSO_4 + 2\ NaOH \longrightarrow Mn(OH)_2 + Na_2SO_4$
- $2Mn(OH)_2 + O_2 \longrightarrow 2\ MnO\ (OH)_{2\ S}$

  brown ppt
- $MnO\ (OH)_2 + 2\ H_2SO_4 + 3\ H_2O \longrightarrow Mn(SO_4)_2 + 6H_2O$
- $Mn(SO_4)_2 + 2KI \longrightarrow MnSO_4 + I_2 + K_2SO_4$
- $2Na_2S_2O_3 + I_2 \longrightarrow Na_2S_4O_6 + 2\ NaI$

Calculation of Dissolved Oxygen

- 1 ml of 0.025 N $Na_2S_2O_3$ = 0.2 mg of O_2
- DO in mg /litre = 0.2 X1000 X 0.025 X Volume of $Na_2S_2O_3$ / ml of sample
- Initial DO_0 (zero day) with 98% dilution

= 0.2 X1000 X 0.025 X 10.4 / 200 = 0.26 mg/litre

For 98 % dilution DO_0 = 0.26 /.02 = 13 mg/litre

- DO_5 after incubation(3 days at 27.5^0C) with 98% dilution

= 0.2 X1000 X 0.025 X 2.2 / 200 = 0.055 mg/litre

For 98 % dilution DO_5 = 0.055 /.02 = 2.75 mg/litre

Calculation of BOD [7]

- BOD of sample is the difference between the initial DO and DO after incubation.

- BOD = DO_0 - DO_5
- = 13 – 2.75 mg/litre
- = 10.25 mg/litre

Comparison of our results with standard values [3]

Constituents	Strong	Medium	Weak	Our Test result
Alkalinity as $caco_3$[1]	200	100	50	44
Total solids as g/litre	1.2	0.7	0.35	4
Total Dissolved Solids as g/litre	0.85	0.5	0.25	0.13
Suspended solids as g/litre	0.35	0.2	0.1	3.87
Total Hardness as mg $caco_3$/litre	180	120	60	128
BOD mg/litre [1,7]	300	200	100	10.8
Chloride mg/litre	100	50	30	49.2

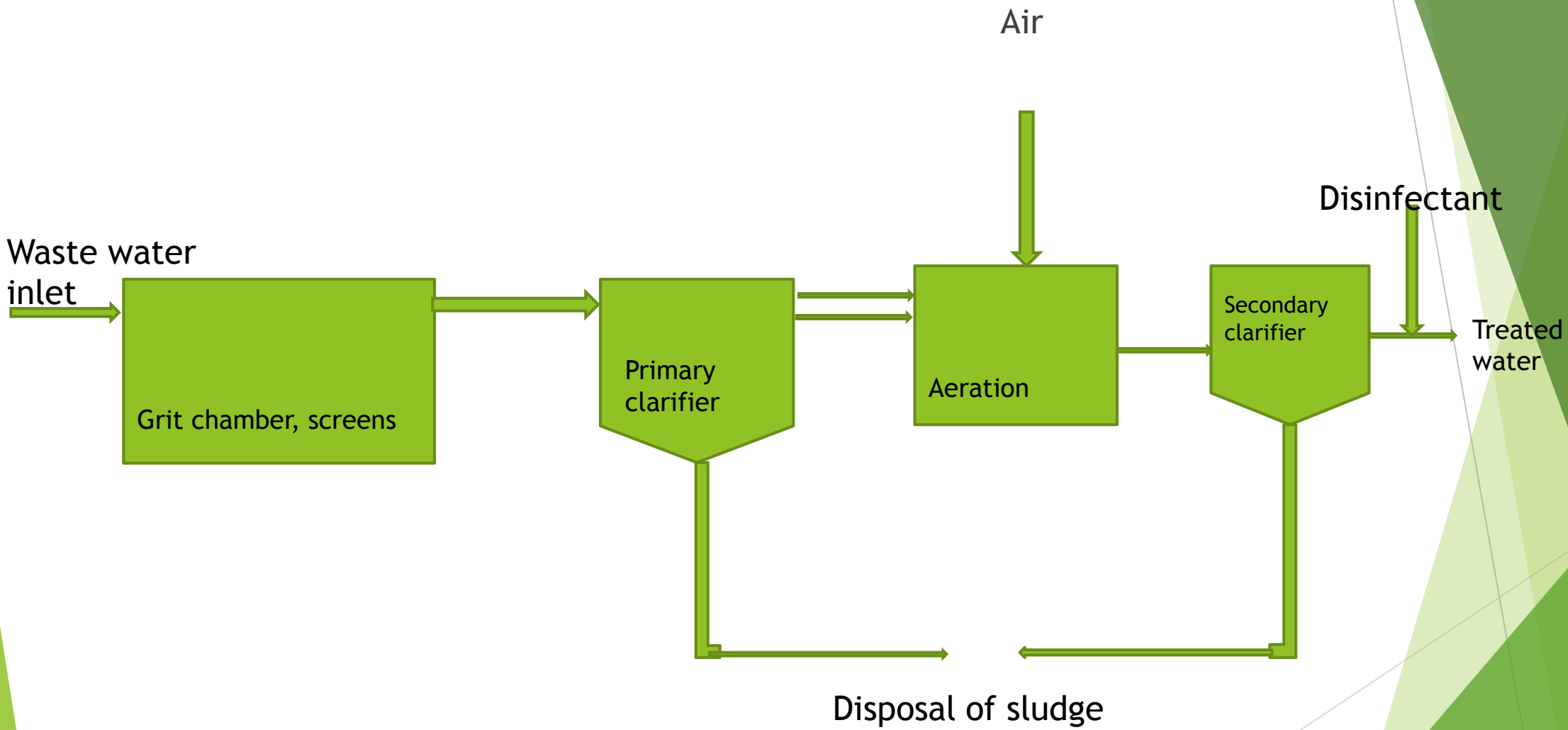
Conclusion from our test results

From our test results the following results are concluded

- The waste water generated from our university was

  weakly alkaline (from pH value)
- It shows the Alkalinity was due to HCO_3^{-1}
- The degree of hardness was slightly higher than medium
- The sample contains both carbonate and noncarbonated hardness
- Suspended solids were strong and dissolved solids were weak
- Chloride was medium
- BOD was weak for our samples

Schematic View of Treatment Process [6]



Treatment Process

- Floatation Units – Installed already in our university removes oil and grease
- Screening - Removes the floating matter
- Grit Chamber – Removes food waste
- Primary clarifier – Removes a portion of suspended solids
- Secondary clarifier – Removes biodegradable organics and suspended solids
- Disinfectant is injected to the pipeline
- The sludge settles at the bottom of the primary and secondary clarifier will be disposed or can be used as manure.

Design Recommendations

- Segregation of waste water as grey water and black water by using separate piping services for grey water and black water.
- For storage it is suggested that grey and black water are stored in separate septic tanks.
- In this paper, it is decided to reuse the water for toilet flush and for landscaping/gardening
- Also from the result found till date , it is recommended that the grey water generated from our university requires only two stages of treatment : primary and secondary treatment which requires four tanks : Grit Chamber, Primary clarifier, Aeration tank and secondary clarifier.

Future Work

- Quantitative test will be carried out on more parameters in order to improve the design of STP and the water grade
- Number of collection points and the samples will be increase
- Waste water samples will be collected from kitchen line of residential buildings
- Designing the size of the tanks depends on the quantity of the water generated/treated.

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