Water and Power Saving
By Recycling & Reuse of Domestic Water

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Abstract:

Many investigations were published for domestic wastewater treatment, using biological processes to convert the finely divided and dissolved organic matter into flocculent settable solids that can be removed in sedimentation tanks.

These processes are employed in conjunction with the physical and chemical processes. More and more complex processes are used to remove contaminates to protect the environment. The treated water then discharged to seas, rivers or reused in irrigation system and cleaning streets.

No investigations were directed to reuse the treated water to save the domestic water supply itself.

In the present paper a report will be given on research that has been conducted on saving water consumption for domestic use by about 25 % of the typical rates of water used for public supplies. Using recycling process for water used in showers, bathtubs and wash basins **ONLY** to supply the water-closet tanks, bidets and urinals **ONLY**.

Only and only if the pipe networks, for domestic water supply and drainage systems for buildings, are redesigned.

1.Introduction:

Water is considered the most important basic element for man, animal and plant life. It is 2/3 of the body weight. It is essential for plants to make their own food. Water is considered the international solvent for organic and inorganic matters. It's used for irrigation, transportation, industrial, power generation projects……etc.

Water plays an important rule in weather and climate. No one can be a life in the absence of water.

Due to that great importance, the highly organized sanitary services of today have reached a degree of development in the history of modern civilization.

Water resources are limited and domestic demands increased due to the exponential increase in population. So it can be side that the only way is through water saving , recycling and reusing that can be achieved by redesigning water supply and drainage domestic systems.

Sanitary, chemistry, mechanical, public health engineers and other professionals in related area must cooperate to save our life on the earth. Also there are no solutions without political solutions.

2.Objectives:

This paper is considered as a solution for water saving and reusing the domestic water specially in towns. Not only saving in water supply but also saving in power and total cost (running and initial).

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The question here, is why domestic water?

The answer is for the following reasons:

1- Domestic use is about 40% of the consumption rate in any country against 35% for industrial and commercial use, 15% for public use (irrigation, cleaning streets, fire, …..etc.) and 10% water losses and wastes.
2- Increasing the consumption rate from town to town, for example the rate in lit/day/person in a town like New York 1000 lit/day/person., in Shekagoo 800 lit/day/person and in Alex. Egypt 200 lit/day/person.
3- Domestic consumption rate changes according to man activity and requirements form time to time:
    - Seasonal changes:
      In summer the consumption rate is 120% to 160% of the average consumption rate/day/person during the whole year, while in winter it reaches to 70%.
    - Daily changes:
      The water consumption rate changes from one day to another not only in the same season but also in the same week. It may increases to 140% or decreases to 60% of the average consumption rate.
    - Hourly changes:
      Water consumption changes by day and night. It increases by day and decreases dramatically until it reaches its minimum by night.

For these reasons one can conclude the importance of increasing research and study for water domestic use. The researches must conducted to save any droplet of water.

This paper will help sanitary engineers to save not only a droplet of water but about 25% of the average consumption rate.

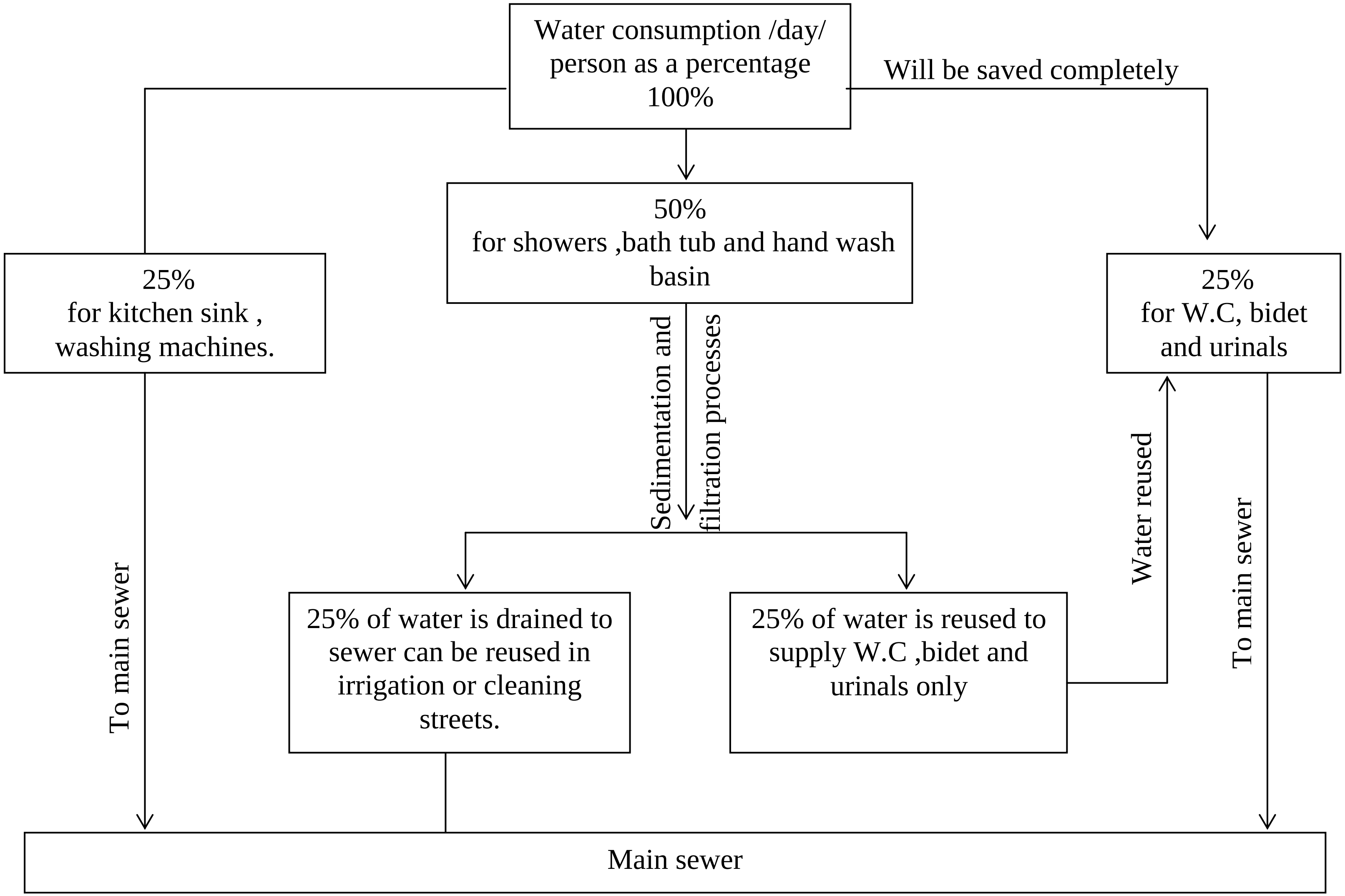
Referring to the previous studies and researches in the related area we can tabulate the following rates for different sanitary appliances:

Type	%age of water consumption / day	Notes
Water closet	15%	Will be saved
Urinals, Bidets	10%	Will be saved
Hand wash basin	8%	Will be recycled
Showers	15%	Will be recycled
Bath Tub	27%	Will be recycled
Kitchen sink, dishwashers and automatic washing machines	25%	Direct to main sewer

The sum of the percentages of water consumption /day/person used in w.cs, urinals and bidets are about 25%. This percentage will be saved. It is 250 lit/day/person in a town like New York and 50 lit/day/person in Alexandria, Egypt, according to the consumption rates that mentioned before.

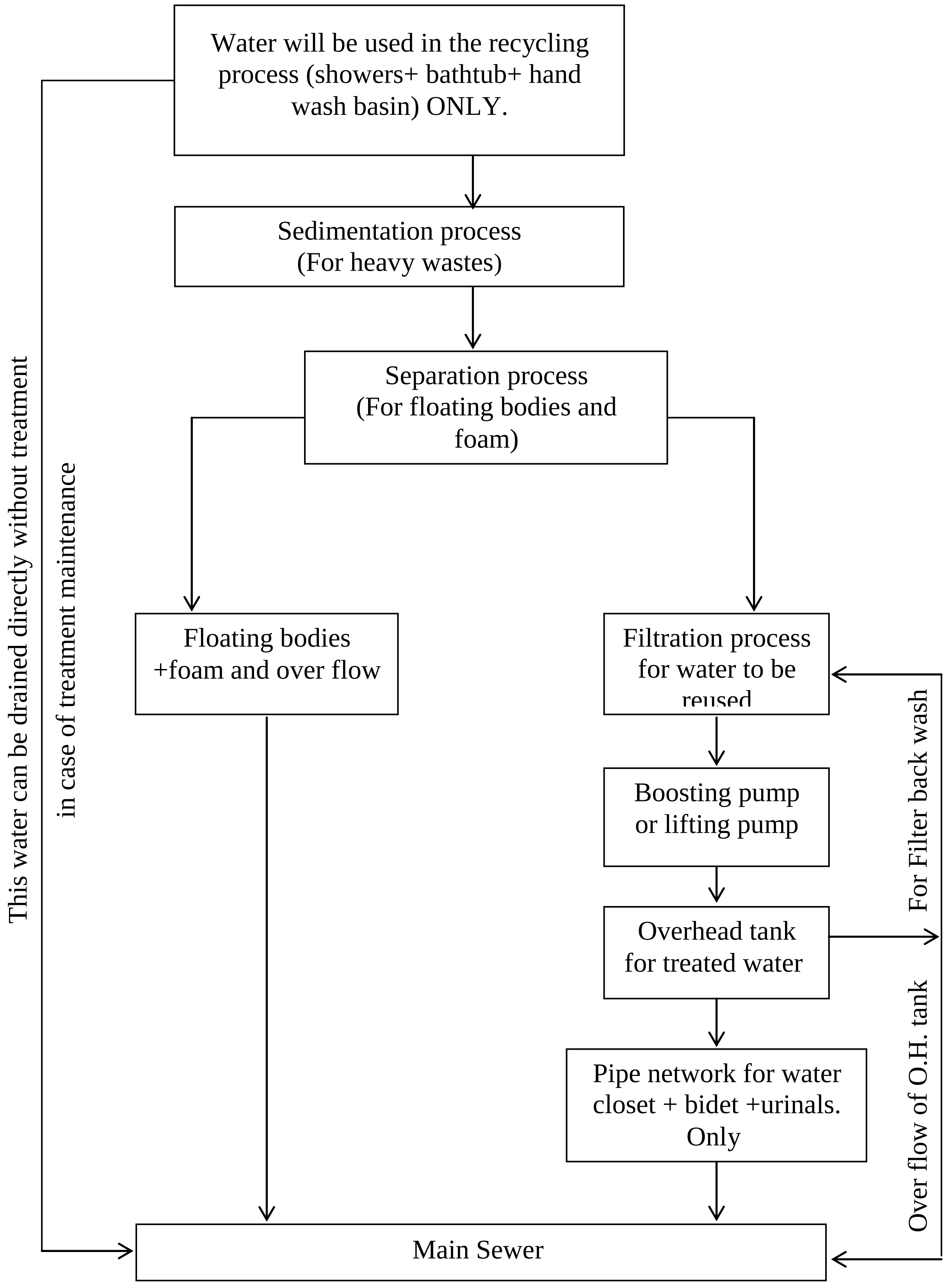
This research saves the water supplied to water- closet, urinal and bidet in houses, hotels, clubs, factories …..and others in towns and modern countries. This amount is about 25% of daily consumption as mentioned. This can be achieved by recycling and reusing the drainage water of showers, bathtubs and hand wash basins **ONLY.** The sum of the percentage rates used in showers, bathtubs and hand wash basins is about 50% of the total water consumption /day. This means that we can reuse fifty percent of this drainage water to supply w.c., urinal and bidet after a simplest, easiest and cheapest sedimentation and filtration processes. The shower, bathtub and hand wash water has a small amount of heavy solids, light or floating solids and foam which can be separated easily by any well known methods for sedimentation, scraping and filtration processes also redesign water supply and drainage systems for buildings and houses.

3- flow chart for water recycling and reuse:



Flow chart (1)

4-Water Recycling Processes:



Flow Chart (2)

5. Redesign for Water Supply and Drainage Systems of Buildings:

5.1.Water Supply System:

Nowadays it is usual to supply bathrooms (showers- bathtub- hand wash basin urinal - bidet- water closet), kitchens, washing machines and drinking water by fresh and clean water through the water main pipe network if its pressure is enough. If water main pipe network pressure is not enough there are two solutions:

* The first one is using a booster pump for feeding the building’s network specially in higher buildings and feeding in this case will be directly to the building supply network.

* The second one is using a lifting pump to lift water to an overhead tank or tanks-depending on water storage volume needed and consumption- then the overhead tank or tanks supply the building network for different sanitary appliances.

This pipe network for water supply will be redesigned according to the new concept in the present research. (See figure 2)

The new design for water supply will be divided into two pipe networks:

- **The first one: Fresh andclean water supply :**
  Bath rooms (Shower, bathtub and wash basin **ONLY**), kitchens and drinking water will be supplied directly from the water main pipe network for fresh and clean water if the pressure is enough or using booster pump or lifting pump and overhead tanks if the pressure of water main pipe network is not enough for direct feeding.
- **The second one: Recycled water supply (Treated water) :**
  The water closet, bidet and urinals **ONLY** will be supplied by the recycled water from shower, bathtub and hand wash basin **ONLY** after treatment (sedimentation and filtration processes). The second pipe network for the recycled water is fed directly through a boosting pump or indirectly through a lifting pump and an overhead tank.

5.2.Water Drainage System:

The traditional system, now known as the **two – pipe system**. One vertical pipe is used for wastes of shower, bathtub, wash basin, kitchen, washing machine and dishwasher ending with gulley then directed to manhole. The second vertical one is used for wastes of w.c., bidet and urinals directly to manhole.

The new design for wastewater drainage system will be of **three-pipes** :

- **The first one:**
  It will be used for shower, bathtub and hand wash basin wastewater **ONLY.** This water will be recycled and reused to supply w.c., bidet and urinal **ONLY** after treatment. Wastewater from this vertical pipe will be directed to sedimentation and filtration unit.
- **The second one:**
  It will be used for kitchen, washing machine and dishwasher. The wastewater of this pipe will be directed to gulley then to manhole without treatment as described in the two pipe system.
- **The third one:**
  It will be used for drainage of w.c., bidet and urinal. The wastes of this pipe will be drained to manhole directly as followed in the two - pipe system.

6. Description of Sedimentation and Filtration Unit:

As mentioned before the wastewater of shower, bathtub and hand wash basin only will be reused to save 25% of the average daily consumption. This wastewater will be recycled to supply the w.c., bidet and urinal only through a separate pipe network. Wastewater for shower, bathtub and hand wash basin contain small amounts of heavy solids which can be settled easily in the sedimentation tank (see fig.1).

The floating and light solid can be scraped through a surface weir skimmer. After sedimentation for heavy solids and scraping of floating bodies and foam, water is directed to filtration tank to separate any suspended solids. The filtration tank is closed coupled to sedimentation tank. Water flows through two layers of filter media, sand and gravel respectively. In the bottom of the filtration tank there is a drainage system, consists of a main pipe and laterals made of porous material or pipes containing a very fine longitudinal or circumferential slots to have a very efficient filtration process. These laterals, sand and gravel can be cleaned to have more filtration efficiency from time to time by a back wash process. Clean water is fed in the opposite direction through the main pipe exists on the filter bottom is enough to direct dirties to manhole.

Clean water-after sedimentation and filtration-is directed to treated water sump (collected tank). A pump lifts water form the sump to supply the pipe network for w.c., bidet and urinals directly or lifting it to an overhead tank or tanks above the building then to the pipe network.

7. Filter Design and Construction:

The filter used in our case will be of a low rate sand filter for the following advantages:

1- **Easy design, easy construction and of a lower initial cost:**
The simple design of the slow sand filter makes it easy to use local materials-concrete or bricks- and local skills. The cost of imported materials and equipment may be kept to almost negligible proportions. These factors make design and construction for the filtration unit easy using available materials.

2- **Flexible operation and minimum operational cost (running cost):**
The cost of operation lies almost wholly in the cleaning of the filter-beds which may be carried out either mechanically or manually. In developing countries labor is readily available and latter method will be used.

3- **Quality of the treated water is reasonable :**
The water quality obtained from low rate sand filter is of reasonable quality. Turbidity not more than 15 NTU [33]. So no chemicals are need for excessive treatment or during operation. No need for higher quality since this water will be reused in w.cs, bidets and urinals.

4- **Long time intervals between two successive maintenance operations:**
The time between two successive maintenance operations are from 20 to 60 days or more [33].So we can say that maintenance is less than other types of filtration. In additional to the back wash facility to reduce maintenance and make the time between two successive maintenance operations be longer.

5- **No restrictions for the unit position:**
The filtration unit can constructed either under ground or over ground if there is any problem due under ground water table level. In case surface unit flow levels must be taken into consideration.

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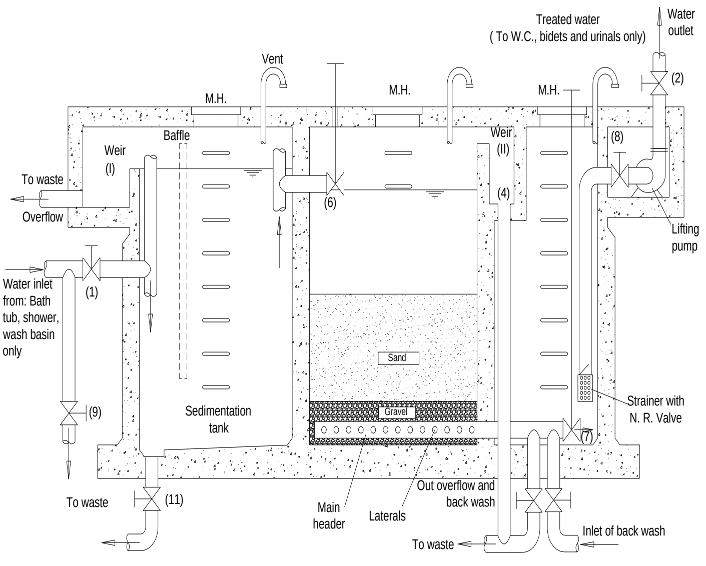


1) Water inlet control valve
2) Water outlet control valve
3) Water inlet for back wash
4) Overflow
5) Drain valve
6) Water inlet control valve to sand filter
7) Water inlet control valve to sump
8) Pump's suction valve
9) By-pass control valve
10) Strainer and non-return valve
11) Drain valve

Fig.(1): Schematic drawing of sedimentation and filtration unit.

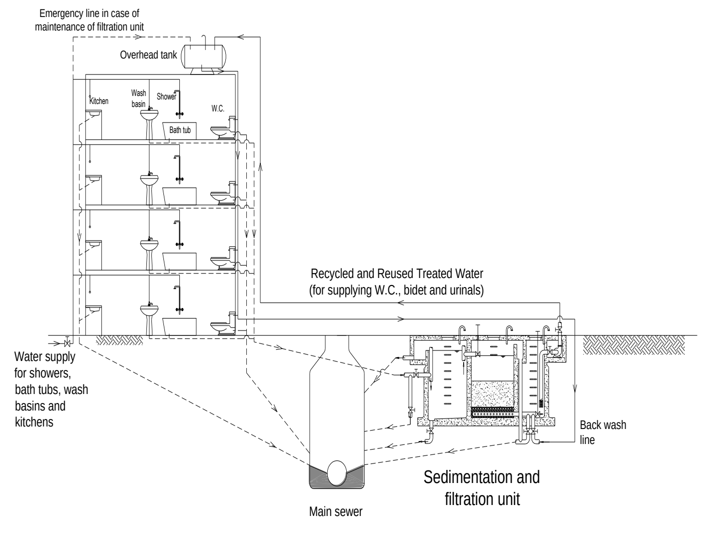


Fig.(2): Schematic diagram for the suggested water supply and drainage system.

7.1. Essential Parts of a Slow Sand Filter:

1- Water reservoir (sedimentation tank).
2- Filter media.
3- Filter bottom and under-drainage system.
4- Filter box, containing (1), (2), (3) above.
5- Filter control system (flow and direction control).

7.2.Design Criteria:

Before design to obtain the size of a filter required, there are many important points must be determined, which are of a great importance when we design a slow sand filter:

1- Calculate the average flow rate/person form the average flow rate of water supply which differ from town to town as mentioned before. Also it changes form season to another, from week to week but also from one hour to another …….. So the average flow rate/person must be determined.
2- Determine the building and total number of persons in that building (NOTE: more than one building can served by one filter unit depending on the number of occupation in that area).
3- Calculate the total average flow rate /day of the building or buildings in cooperation in one filter (The total average flow rate /day = No. of persons * average flow rate /person).
4- Calculate the working hours.
5- Calculate the average flow rate/hr.
6- Calculate the average flow rate/hr of the water to be filtered (water from showers- bathtubs-hand wash basins only).This water is about 50% of the total flow rate/hr. So the average flow rate/hr entering the filter can be determined (Q_{avr}).
7- Assuming laminar flow inside the filter and that the average flow velocity between 0.1-0.2 m/s [7],[33].
8- After calculating (Q_{avr}) and V_{avr} substitute in continuity equation:

$$\mathbf{Q_{avr} = A * V_{avr}}$$

The cross sectional (A) can be determined.

9- The height of filter media must be taken into consideration according to grains size and the suggested number of layers for the filter media taking the media porosity and resistance into account.

7.3. Elements' design of a Slow Sand Filter :

7.3.1. Sedimentation Tank:

Sedimentation tank can be constructed from local materials-concrete or bricks with non porous cement coating layer (watertight) as mentioned before.
The cross sectional area can be calculated by calculating the average flow rate (Q_{avr}) entering the filter and assuming average flow velocity in the range 0.1and 0.2 m/hr as mentioned, the cross sectional area is obtained in m^2 .

So the tank dimensions and shape square or rectangle can be obtained. Tank location under or above ground surface can be determined according to site facilities, while tank depth can be determined after design of filter box containing filter media (will be obtained later in detail).

7.3.2. Filter Box:

The filter box can be constructed from local materials-concrete or bricks with non porous cement coating layer (watertight) as sedimentation tank.

The filter contain media (gravel and sand), under drainage system and filter control system. It can be selected and determined as follows:

7.3.2.1.Gravel layers:

The gravel layers for slow sand filters should have at least four layers of appropriate depth and of successively grain size to prevent the intrusion of the filter media and to obtain a reasonable filtration quality. The layers must be located in succession to avoid any disturbance inside the filter as followed [7]:

Layers	Grain size	Layer depth
The first layer(upper layer)	0.7-1.4mm	6cm
The second layer	2-4mm	6cm
The third layer	4-12mm	6cm
The fourth layer(lower layer)	18-36mm	12cm

So the total gravel depth is about 30 cm.

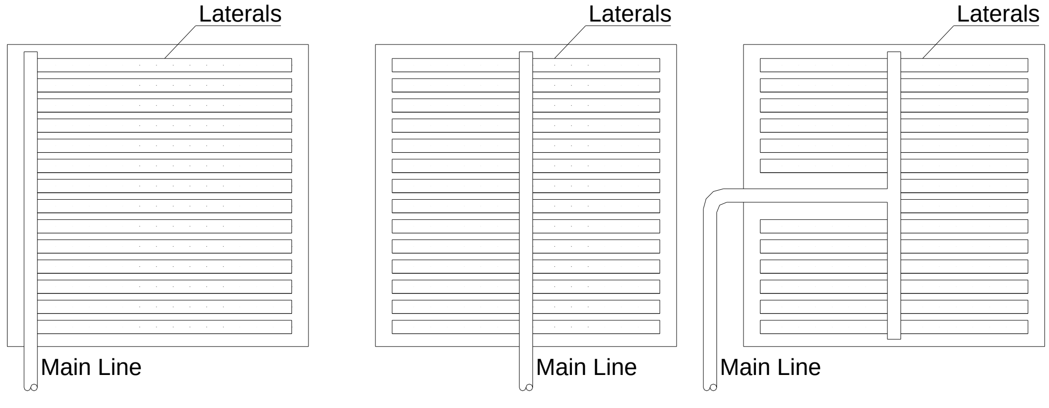
7.3.2.2.Sand layer:

The recommended height for sand layer in this type of filters [7] ranges between 1 m and 1.5 m and having an effective grain size 0.3 mm to obtain a higher filtration efficiency .

7.3.2.3. Filter Drainage System:

The under drainage system, through unseen, plays an important role to obtain a higher filter efficiency. It serves the dual purpose of supporting the filter medium and of providing an unobstructed passageway for the treated water to leave the underside of the filter.

The simplest form of under – drainage system consists of a system of main and lateral drains. The lateral drains consist of porous or perforated pipes from P.V.C (Polyvinylchloride) covered with gravel layers those are mentioned in section 7.3.2.1.



The Common Arrangements For the Main Drain of Slow Sand Filter

From the pervious studies, the filter box containing media and drainage system must have a sufficient depth to accommodate the constitute parts just described.

In the example given, the internal depth of the filter box would be the sum of the following depths starting from the top :

- Feed board above water……………………………0.30m
- Water depth above sand……………………………1.25m
- Sand (filter medium)……………………………….1.25m
- Four-gravel layer support…………………………..0.3m

…………

- **Sum…………………………………………… 3.1m**

Other conditions may call for depth 2.5m-4m.

The filter box should be watertight, to prevent loss of treated water.

The cross sectional area of the filter box can be calculated from the continuity equation:

$$\mathbf{Q_{avr} = A * V_{avr}}$$

Assuming an average flow velocity (0.1-0.2m/hr) and calculating the average discharge (m^3/hr) as mentioned before we can obtain the cross sectional area.

7.3.2.4. Filter Controls:

To be certain that the filter will operate successfully in accordance with the calculated hydraulic characteristics already described. It is important that the pipe work, valves and devices used to regulate the operation of the filter should be planed and calculated with the same care. Control valves and pipe work are very important during normal operation as well as during maintenance, back wash and overflow.

Basically, means must be available to

1. Deliver raw water in sedimentation tank (reservoir).
2. Availability to divert the raw water partially or totally to main sewer in case of maintenance of sedimentation and filtration unit is a must using a by pass line.
3. Availability to direct water over flow for both sedimentation tank and filter box directly to main sewer.
4. Remove scum and floating matter from sedimentation tank through a weir connected directly to the main sewer.
5. Availability to drain off and maintain the sedimentation tank through a control valves.
6. Lower the level within the bed.
7. Control the rate of filtration using control valves at inlet and outlet.
8. Covey the filtered treated water to water sump.
9. Back wash facility to minimize hydraulic resistance and increase filter efficiency.
10. Drain off both filter box and sump of filtered water during maintenance is essential.
11. Availability to supply the W.C., bidet and urinal with fresh water using emergency line in case of shortage of treated water or during maintenance for the sedimentation and filtration unit.
12. Protect pump from dry running or loss of priming in case of water level drop for any reason.

8. Miscellaneous operation:

Referring to flow chart (2) and figure (1) for sedimentation &filtration unit. Waste water (raw water) from shower, bathtub and hand wash basin ONLY are recycled and treated according to the following steps:

1. The waste water (from showers, bathtubs and hand wash basins ONLY) is directed to the vertical drainage pipe then to sedimentation & filtration unit. In this case valves1, 6, 7, 8 and 2 are opened, while valaes9, 3, 5 and 11 are closed.
2. Water flows to sedimentation tank through the control valve (1). In this tank a large amount of heavy solids can be settled. The light solids, floating bodies and foam on water surface of the same tank can be drained through the surface weir skimmer (I) in additional to water over flow directly to main sewer.
3. Water containing suspended solids then pass through the control valve (6) direct to filter box.
4. Water flow through the low sand filter containing sand, gravel and drainage bed to water sump through the control valve (7).
5. Treated water collected in water sump that can be lifted by a pump through a strainer containing N.R.V. (10). The pump direct the treated water to the vertical pipe supplying W.C, bidet and urinal pipe net work or to the over head tank to supply pipe net work for W.C, bidet and urinal according to the suggested design for the piping system.
6. To improve the filter efficiency a clean water can be supplied from the over head tank to the control valve (3) used for back wash only. In case of back wash process valves (6) and (7) must be closed before performing the back wash operation. Water flows in the opposite direction from bottom to top passing through gravel layers then sand layer. Dirties and suspensions are directed to weir (II) then to pipe (4) and finally to main sewer.
7. In case of unit maintenance valves (3) and (7) must be closed while valve (5) is opened. Water flow through valve (5) direct to main sewer.
8. In case of draining of water sump, valves (5) and (7) must be opened to direct water to the main sewer.
9. In case of pump maintenance valves (2) and (8) must be closed, then dismal ling the pump for repair and maintenance.
10. In case of maintenance of the whole unit valve (1) is closed while valve (9) is opened to direct wastewater to the main sewer. Figure (2) shows a schematic diagram for the suggested water supply and drainage systems.
11. In case of shortage of treated water during maintenance the over head tank can be supplied by a fresh and clean water line from water main to avoid shortage of water supply for W.C., bidet and urinal, See figure (2).
12. Use valve (11) to drain the sedimentation tank.

NOTE:

In some towns the toilet may contain W.C. and bidet or W.C. only or a group of W.Cs. and urinals (public W.Cs. in hotels, clubs, schools, university, factories ….etc.)

9. Conclusions:

Waste water recycling for showers bathtubs and hand wash basins ONLY and reuse of the treated water to supply a separate piping net work for W.C., bidet and urinals helps in :

1. Saving 25% from the main water supply or less according to the appliances used according to the design.
2. Saving the same percentage or less used to clean streets, irrigation or fire fighting if the treated water from the filtration units is collected.
3. Saving 25% of chemicals used in water treatment for water main supply since chemicals consumption is directly proportional to water rates supplied.
4. saving 25% of the pumping power in the main stations since pumping power is proportional to water rates.
5. Saving the fixed cost: pumping power and piping since the main water supply rates are reduced by 25%. So water pipe lines for water main can be designed at a lower discharge for new towns. The discharge is proportional to the pipe diameter to the power two (Continuity equation)

$$\mathbf{Q = Л/4\ d^2 * V_{avr}}$$

6. Saving the running cost (operating and maintenance……etc.). That's due to reduction in pumping power:

$$\mathbf{Power = w * Q * H / c * \zeta}$$
$$\mathbf{Power\ \alpha\ Q}$$

7. Saving effort, time and money for treatment, maintenance and chemicals …etc.
8. The most important benefit is water saving to save our life on our earth.

10.Recommendations:

1. Sanitary engineers have to redesign the piping net work for water supply and drainage for buildings to save each water droplet.
2. The percentage of water saving may be more or less 25% of the water consumption rates according to appliances used in each building, but we have gain in any case.
3. In case of shortage of treated water obtained from the filtration unit we can supply the toilets form the main water supply of fresh water in additional to the available treated water obtained from the filtration unit.

NOTE: The mixing can be done in the over head tank of the building.

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