UTILIZATION UV TUBELAMP AS A PRACTICAL AND ECONOMIC ALTERNATIVE DISINFECTANT FOR HOUSEHOLD DRINKING WATER SUPPLY

BY :

ALGAMAR, KALIMARDIN

DR. ING, DEA, DIPL. S.E, IR. ITB

SENIOR LECTURER ITN-ITB CENTER INDONESIA

HEAD OF LABORATORY OF ENVIRONMENTAL ENGINEERING ITB

BANDUNG JULY 1989

ABSTRACT

The epidemic outbreak of water-borne diseases is still occuring frequently, both in the rural, as well as in the urban areas in Indonesia.

The quality of drinking water should satisfy the physical, chemical, and bacteriological standards for drinking water. Clean water from a treatment plant is not safe to drink because it might not be of satisfactory microbiological sanitary quality, hence it should undergo a disinfection process.

With the invention of the ultraviolet lamp, effective disinfection of clean water can be accomplished with a relatively short radiation time and economically cheap in the operation cost. Hence a supply of potable water of satisfactory sanitary quality can be expected, which will improve the level of public health.

INTRODUCTION

Supply of potable water is one of the most essential human needs for his living. With no water to drink, not any single human being or a community can stay alive, and it is very hard to imagine a clean and healthy environment without water.

The more the supply of water, satisfactory in quality, quantity, as well as continuity, the more rapid is the improvement and development of community health.

The natural availability of water, having different qualities and from different sources, will greatly depend on the condition and characteristics of the respectic raw water source. On the other hand, its utilization by man requires a certain level of quality for safe consumption, for the many water uses.

Treatment will improve water quality to make the water potable. There are a number of technologies applicable for this purpose, ranging from the very simple to the more advanced.

Clear water might not always be potable, the bacteriological sanitary quality is often not satisfactory. To make the clear water potable, certain requirements are needed so that using the water is not a detriment to human's helth.

DRINKING WATER IN INDONESIA

For practical reasons, people in Indonesia tend to use the deep groundwater source, since generally the water is of standard quality, both chemically and physically.

Groundwater resources in Indonesia, particularly along the volcanic mountain range from North Sumatra, Jawa, Nusa Tenggara Barat, Nusa Tenggara Timur to Sulawesi are generally of satisfactory physical and chemical qualities, however, most frequently the bacteriological quality is poor.

Although people are using treated water from the community water treatment plants, however, contamination occur quite frequently in the distribution system. Hence for safety reasons, the water should undergo another treatment before use. A practical disinfection equipment will be the answer for good supply of drinking water.

Apart from that, to support tourism development, these equipments for water desinfection could be installed in the vicinity of the tourism destination area, or at other places needing practical water supply with aesthetic considerations, such as offices and shopping centres.

The following notes are based on laboratory investigations conducted at the Water and Microbiology Laboratory of the Department of Environmental Engineering of the Institute of Technologi Bandung, and the laboratory of the PDAM (The Bandung Water Supply Company/Enterprise) Badaksinga in Bandung. Field testing is conducted at the filtration unit of the PDAM Badaksinga.

In general, water used for drinking water should meet following requirements[1,2] :

- Physical properties : turbidity, temperature. color, odor and taste, all should not exceed the recommended tolarable level.
- Water turbidity is due to the concentration of organic and inorganic matters in the water, such as mud and other waste material.

- Chemical properties : the water should not contain any toxic chemicals, or constituents detrimental to the water treatment installation units and household appliances.
- Bacteriological properties : the water should be free of pathogenic microbes.

Standards for drinking water in Indonesia is stipulated in the *PERMENKES RI No. 10/BIRHUKMAS/I/1975*. A range of treating methods can be carried out to improve water quality to meet the standard requirements, from the very simple technologies to the complex ones. Discussion in this paper will be stressed on the bacteriological parameter of the treatment.

The following formula implies for natural water resources, deep and shallow groundwater, surface water fetched from rivers, lakes, sea water and other water sources[4,5] :

$H_2O + X$

Where *X* is the biotic and abiotic factors. The biotic factors in water are :

1. *Bacteri*
2. *Fungi*
3. *Micro-algae*
4. *Protozoa*
5. *Virus.*

Photogenic microbies of greatest concern in the water body are the following :

a. *Salmonella*, causing typhoic diseases

b. *Shigella*, causing bacilarry and intestinal diseases

c. *Vibrio*, causing cholera

d. *Ascaris*, causing helminthic diseases, and others.

The water might also contain dengerous toxic microbes such as :

a. Anaerobic microbies, for example *Clostridium*

b. Aerobic microbies, for example *Pseudomones*, *Salmonella*, *Staphylococcus*, etc.

The presence of pathogenic microbes in the water can be detected from the approximation of bacterial count, usually the coli bacteria.

The presence of coli bacteria in substances for human daily consumption (water, food, etc) is not expected since it indicates that the water has been contaminated by fecal material, coli bacteris is known to be present in the faeces of human being and the other warm blood animals.

DISINFECTION PROCESS WITH THE USE OF UV RADIATION

Disinfection is a measure undertaken to kill the pathogenic bacteria present in water. Disinfection is not the same as sterilization. There are 3 disinfection methods, namely :

1. Heat treatment, boiling the water, usually for small volumes. Ultra High Temperature (UHT) treatment is usually implemented for canned food & beverages.

2. Chemical treatment, with the addition of chemicals. Usually the chemicals used for treatment are[1,4,5] :

   a. Oxidizing agents : chlorine, iodine, ozone, permanganate ($KMNO_4$)

   b. Metal ions :

   c. Strong acid & bases

3. Radiation treatment, using the ultra violet radiation and usually implemented in the food and beverage industries. The ultraviolet light has a wavelength between 400 nm to 0,6 nm (1 nm = 10^{-9} m). The waves are produced from the atoms and molecules of electric light. The ultraviolet energy is about equal to the energy for chemical reaction, hence influencing the chemical properties. The sun is resourceful for ultraviolet radiation, this is why our skin will get darker when exposed to sunlight. The ultraviolet will also interact with the atoms in the upper atmosphere, causing the layer (up to 90 km above the earth) to be in an ionized condition.

Basically, there are four classes of ultraviolet light,[3] namely:

a. Blue black light, causing certain objects to sparkle.
b. Erythemal, causing abnormal redness of the skin, to aid in the formation of vitamine D in the body.
c. Bactericidal, lighly potential to kill bacteria.
d. Ozone producers.

The ultraviolet light at a wavelength about 253,7 nm has an effective killing effect towards microorganisms (bacteria, algae, spores and virus). Energy demand to inhibit 90% growth of a colory of microorganisms varies between 1.300 - 20.000 u watt-sec/cm^2, from the ultraviolet light.

This does not mean that the ultraviolet light at shorter or longer wavelengths has no bactericidal or growth inhibiting effect. It has, however less effective since most of the energy produced by the ultraviolet radiotion at a wavelength < 200 nm are absorbed by oxygent to produce ozone.

The natural source for ultraviolet light is the sun, radiating all spectra of ultraviolet light, whereas only those having wavelength > 290 nm will reach the earth surface, because most of the ultraviolet light having wavelenght < 290 nm are absorbed by oxygen and ozone of the stratosphere, and so is the infrared rays (which has a significantly high heating effect) at a certain wavelength.

Artificial ultraviolet light is produced by a lamp containing vaporized mercury, either with high or low pressure. Usually the ultraviolet light radiated by the lamp is having a wavelength of 253.7 nm. For other uses such as sun lamp ; imitated photosynthesis, then florence flask made of quartz is used as glass-tube for the lamp to produce ultraviolet light with longer wavelengths.

Considering the properties of the ultraviolet light and both the natural and artificial resources, ultraviolet light is highly promising to be used as disinfectant.

The use of sun radiation at a wavelength of > 290 nm will need a relatively longer time because the bactericidal effect of the light with a wavelength of > 290 nm will be less compared to the artificial light at 253.7 nm wavelength from the UV-TL (UltraViolet TubeLamp).

With the availability of the UV-TL, the radiation time can be cut down. Optimal use of the lamp in water, placed in a small tube for effective radiation. The ultraviolet light will be absorbed, depending on the depth of penetration, the physical and chemical properties of the water. The absoebed energy is expressed by :

$P_a = 1 - \exp(-k.l)$

$P_a = (I_o - I)/I_o$

P_a = absorbed energy

k = extinction constant (0,02 - 0,3)/cm ; (0,02/cm for clear distilled water)

l = depth of penetration (cm)

The apparatus has a form of a tube covering the whole length of the lamp for optimum use of its total surface area. A narrow tube is preferred, for effective irradiation.

This instrument for disinfection is made of PVC pipes. The selection of the material is based on considerations of its capabilities of isolating the ultraviolet light emitted by the lamp in place for safety measures, as well as it is easily available in the market.

A valve is placed in the inlet and outlet end inside the radiating tube, made of the same material (PVC). These valves are useful for flow control, keeping a constant laminar flow and prevent turbulence. Taking into considerations the ease of use, small size and availability, the Hoofman clamp is used for control of the valves. The size is adjusted to water demand (2 l/person/day). The collection tank is also made of PVC, covered with a lid to prevent contamination. The tank is placed on a stand, made of wood, steel, fibre-glass, or other material. It's function is to support the whole disinfecting apparatus and the purified water in the collection tank.

The following is a comparison of cost of two different disinfection processes, the heat treatment and the ultraviolet radiation.

- Assured water demand = 2 l/person/day.
- Total demand of household (7 person) = 14 l/day.

A. Heat Treatment Using Kerosene.

- Kerosene needed to boil 14 l of water = 0,5 l.
- Price of kerosene/l = Rp. 200,00
- Investment on equipment = Rp. 7.500,00
- Depreciation cost/year = Rp. 2.500,00

* *Operation cost/year :*

- Kerosene = 0,5 x 360 x Rp. 200,00 = Rp. 36.000,00
- Maintenance cost = Rp. 1.500,00
- Depreciation (30 %/year) = Rp. 2.500,00

Rp. 40.000,00

* *Operation cost/household/day = Rp. 111,11*

Some time is also needed to cool the water before use.

B. Ultraviolet Radiation

- Productivity = (60 - 90) l/hour
- Use of electricity = (15 - 25) watts.
- Time needed to treat 14 l of water = 14 minutes
- Preheating the apparatus = 4 minutes
- Use of electricity = 0.025 KWH x 18/60 (hour) = 0.0075 KWH
- Cost of electricity = Rp. 75.00/KWH
- Investment on equipment = Rp. 50.000,00
- Effective machine life = 95% = 300 hours
- Depreciation cost/year = Rp. 15.000,00
- Operation cost/year =
- Electricity = 0.0075 x 75 x 360 = Rp. 202,50
- Depreciation = Rp. 15.000,00
- Maintenance = Rp. 2.500,00

Rp. 17.202.50

** Operation cost/household/day = Rp. 48,78*

Note : (1 US.$ = Rp. 1.775)

Another advantage is the water being ready for use, with a special taste of freshness and more natural.

CONCLUSIONS

Field testing and laboratory analysis had gives satisfactorily results as viewed from the aspect of drinking water quality improvement. This offers another alternative for disinfection, quite effective and practical for houshold drinking water supply.

The following conclusion are draw :

- The lamp produces ultraviolet radiation, with a wavelength of 253.7 nm, and is able to kill pathogenic microorganisms in the water in a relatively short time (minimum retention time at 90 l/hour discharge is 76 seconds).
- Productivity is 90 l/hour, with the capacity of reducing the parameter for coliform from > 2400 MPN (MPN = Most Probability Number) to 0.
- Analysis of the disinfected water has proved an improvement bacteriologically so that the water can be drank safely and tasted cool and fresh without any changes in chloride content considering the use of PVC as the material for the radiating tube, less so a change in the pH and temperature.

RECOMMENDATIONS

Improving the drinking water quality should be exerted for the advancement of science and technology in Indonesia which will also improve the health and socio-economic condition of the people, hence this disinfection apparatus should be modified and developed further.

oooOOooo

SAMPLE/NUMBER	PRESUMTIVE TEST						CONFIRMATIVE TEST			Media Fesal Cfm			J.P.T. (M.P.N.)	Sisa Chl (mg/l) / Chl Residual mg/l)	pH
	24 Jam/hars. 1			48 Jam/28 hrs.			Media Total Cfm								
	10 ml	1 ml	0,1 ml	10 ml	1 ml	0,1 ml	10 ml	1 ml	0,1 ml	10 ml	1 ml	0,1 ml			
Raw Water	3/3	3/3	3/3	3/3	3/3	3/3	+3	+3	+3	+3	+3	+3	> 2400		
Desinfector UV I	0/3	0/3	0/3	0/3	0/3	0/3	neg	neg	neg	neg	neg	neg	0		
Desinfector UV II	0/3	0/3	0/3	0/3	0/3	0/3	neg	neg	neg	neg	neg	neg	0		
Desinfector UV III	0/3	0/3	0/3	1/3	1/3	0/3	neg	neg	neg	neg	neg	neg	0		
Desinfector UV IV	0/3	0/3	1/3	0/3	0/3	1/3	neg	neg	neg	neg	neg	neg	0		
Raw Water	3/3	3/3	3/3	3/3	3/3	3/3	+3	+3	+3	+3	+3	+3	> 2400		6,9
Desinfector UV I	0/3	0/3	0/3	0/3	0/3	0/3	neg	neg	neg	neg	neg	neg	0		6,9
Desinfector UV II	0/3	0/3	0/3	0/3	0/3	0/3	neg	neg	neg	neg	neg	neg	0		6,9

Note : J.P.T = Jumlah Perkiraan Terdekat
M.P.N = Most Probable Number
Cfm = Coliform
Chl = Chlor

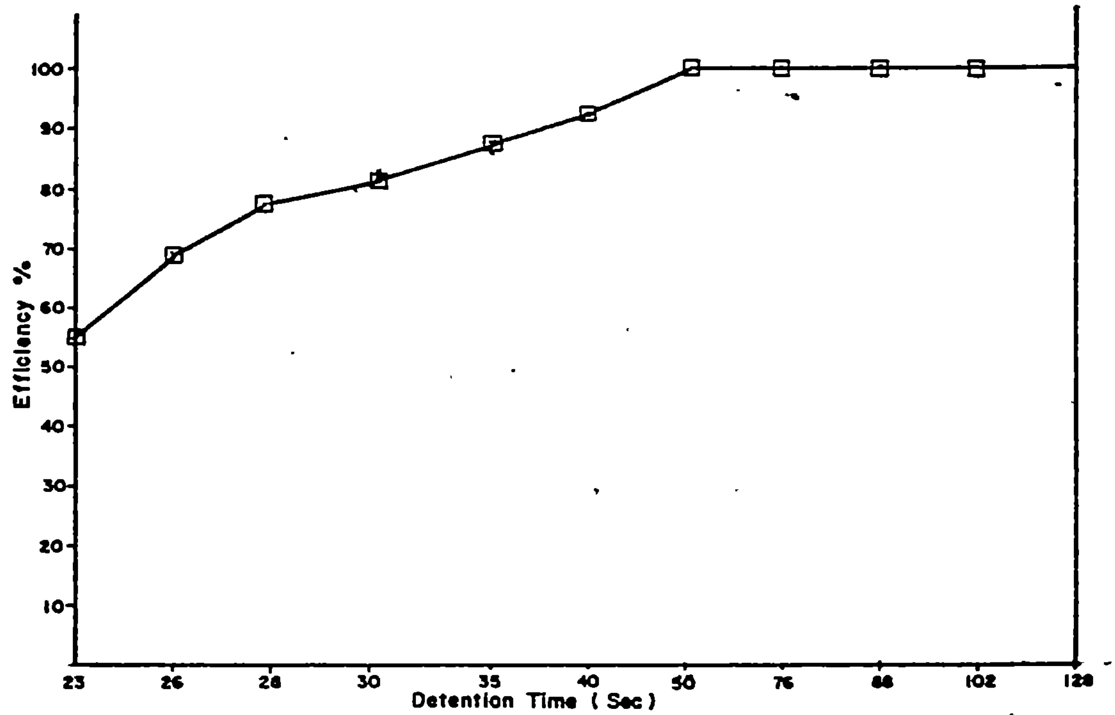
Source : Laboratory of Environmental Engineering ITB, 1989.

CHEMICAL ASPECTS

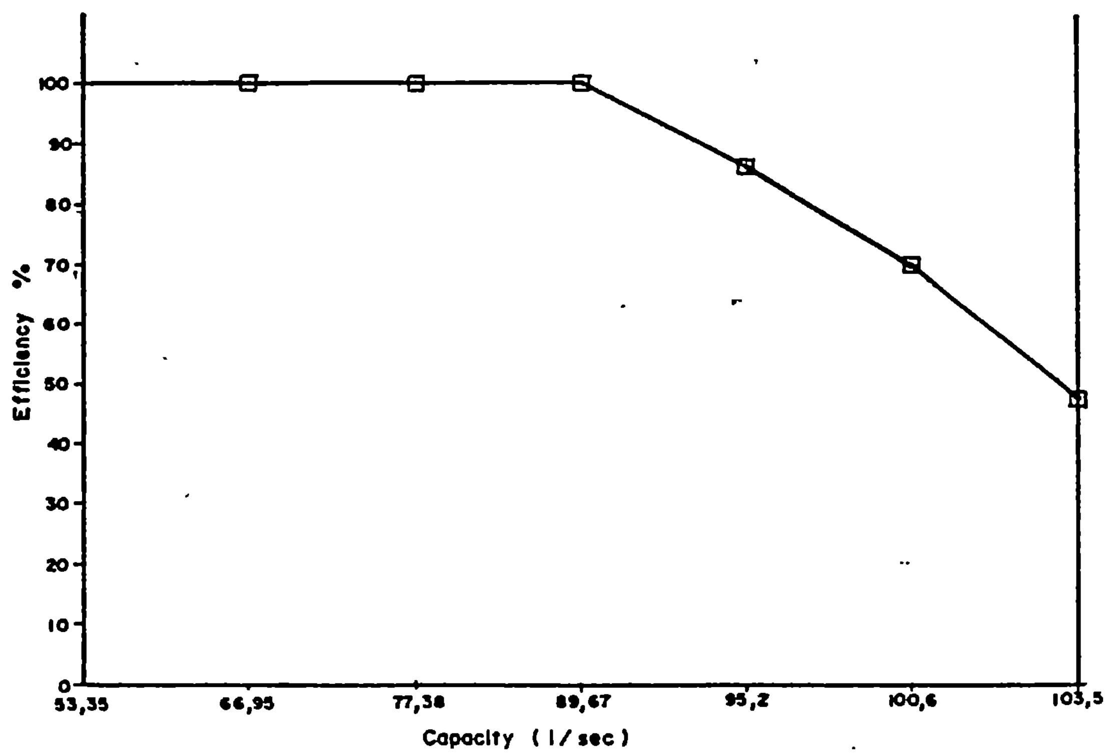
parameters	Raw Water	After U.V
pH	6,9	6,9
Cl	20,97 mg/l	21,46 mg/l

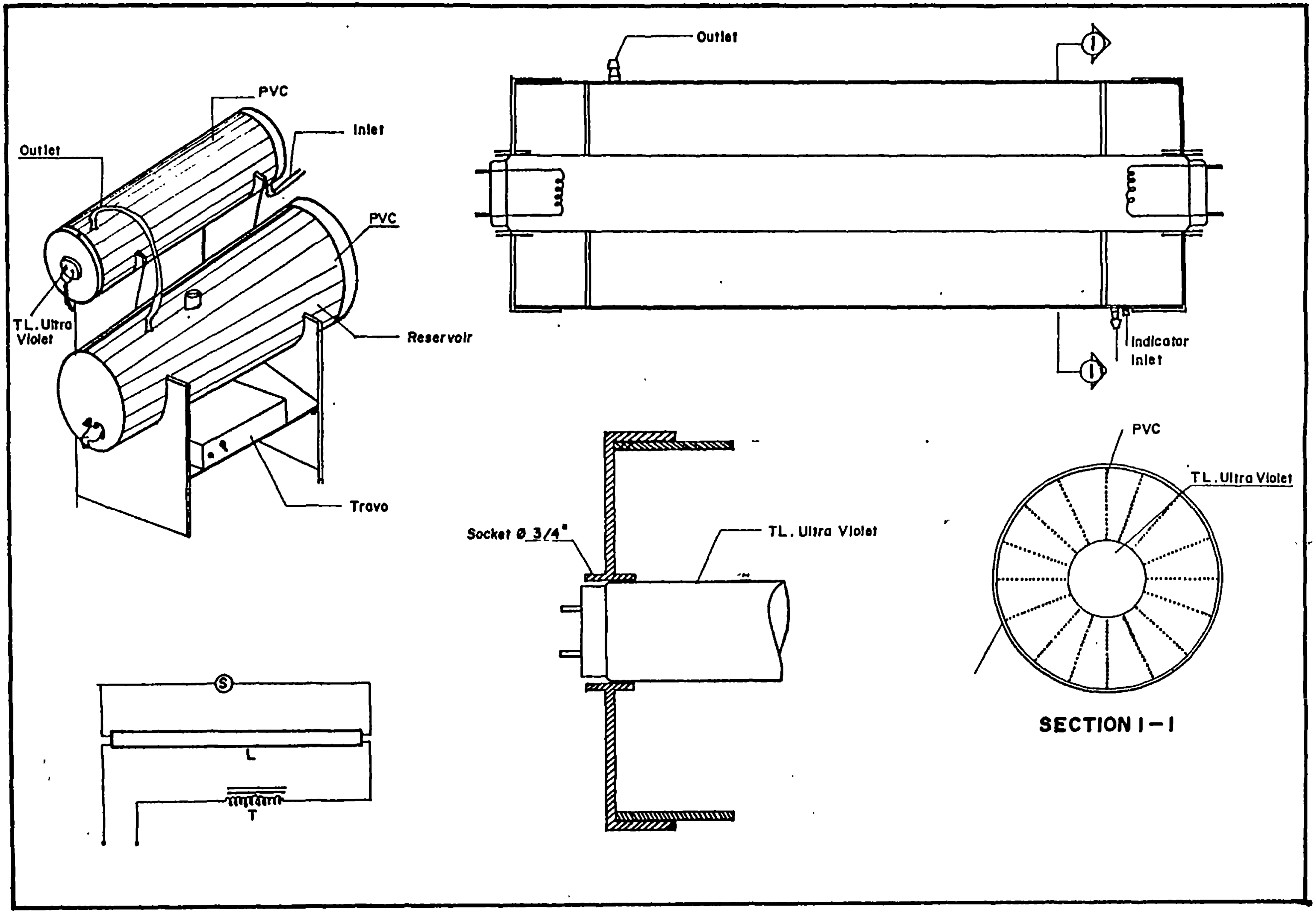
Source : Laboratory of Environmental
Engineering ITB, 1989.

CURVE : 1
CORELATION BETWEEN DETENTION TIME AND EFFICIENCY



CURVE . 2
CORELATION BETWEEN CAPACITY AND EFFICIENCY




PVC
Inlet
Outlet
PVC
TL. Ultra Violet
Reservoir
Travo
Outlet
Indicator
Inlet
PVC
TL. Ultra Violet
Socket Ø 3/4"
TL. Ultra Violet
S
L
T
SECTION I – I

REFERENCES

1. Babbit, H.E, J.J. Dolland, and J.L. Cleasby, Water Supply Engineering, 6 th edition, Mr Graw Hill Co.Ltd.. New York 1962.
2. Fair, G.M., and J.C. Geyer, Water and Wastewater Engineering. John Wiley and Sons, Inc, USA, 1968.
3. Kaufman, John E, and others, Lighting Handbook, IES. 5 th Edition, 1972.
4. Walker, Roger., Water Supply Treatment and Distribution. Prentice Hall, Inc. Englewood Cliffs, New Jersey 07632, USA, 1978.
5. Sawyer, C.N., and P.L. Mr Carty, Chemistry for Sanitary Engineers, Second edition, Mc Graw Hill Book Co. Ltd., Kogakusha Co. Ltd., 1968.