# Cost Analysis of Water Purification Methods in India

Anand M. Sharan[1,*] and Sarita Sharan[2]

[1]*Department of Mechanical Engineering, Memorial University of Newfoundland, St. John's, Newfoundland, Canada A1B 3X5*

[2]*Medical Superintendent, Coal India Ltd, Singrauli, Up, India*

**Abstract:** In this work, cost analysis of commonly used RO method, Ultra-Violet method and the new Pressure Cooker method is performed. These methods studied here relate to the production of potable water which meets the World Health Organization (WHO) standards. The advantages of the use of the Pressure Cooker method over the two other methods for undeveloped countries are explained.

The results show that not only the Pressure Cooker method is most economical but also is very versatile as far as its use in rural India or other under-developed countries are concerned.

**Keywords:** Cost comparison of water purification methods, pressure cooker method, reverse osmosis method, ultra-violet method, potable water.

## 1. INTRODUCTION

Potable water is water that has been either treated/cleaned or filtered and meets established drinking water standards. It is assumed that it is reasonably free of harmful bacteria and contaminants and considered safe to drink or use in cooking. Example of potable water is that supplied by municipal water systems where water has been treated by chlorine or passed through Ultra-Violet (UV) rays or water purified by Reverse Osmosis (RO) method [1].

The safety and accessibility of drinking water are major concerns throughout the world. Health risks may arise from consumption of water contaminated with infectious agents, toxic chemicals and radiological hazards. Improving access to safe drinking water can result in tangible improvements to health [2].

Assurance of drinking water safety is a foundation for prevention and control of water borne diseases like cholera, typhoid, dysentery, hepatitis and most importantly diarrhea.

Much of ill health which affects people especially in developing countries can be traced to lack of safe and wholesome water. In 1981, the 34th World Health Assembly in a resolution emphasized that safe drinking water is basic element of primary health care which is the key to attainment of health for all.

Amongst the poor and especially in developing countries, diarrhea is a major killer. In 1998, diarrhea was estimated to have killed 2.2 million people, most of whom were under 5 years of age [3]. Each year there are approximately 4 billion cases of diarrhea world-wide [4].

In view of the above, this paper aims at giving a simple, safe and economical solution for the developing countries by providing, at first a method for purification of drinking water, and then costs involved in using this method and other commonly used methods [5]. These alternate methods are Reverse Osmosis (RO) method and Ultra-Violet (UV) method. Unfortunately, the latter two methods require electricity which many may not have, for the purpose of water purification.

For those who do not have electricity, these water purifying machines are not viable options.

The method in [5] uses a pressure cooker to boil water until one hears the first whistle then the water is allowed to cool naturally without opening the cover (cooling under pressure) until it reaches room temperature. So, in this method there are two steps - heating and cooling. While heating, thermal energy is supplied which has associated cost where fuel is consumed. The cooling step is free of cost. In this process, one speeds up the process of boiling water due to the use of pressure cooker and consequently, the energy consumption is a fraction of conventional boiling of water. In the cooling process, the energy taken up in converting water to steam in step 1, is recovered because here, the steam is not allowed to escape. By slowing down cooling, the temperature of

*Address correspondence to this author at the Memorial University of Newfoundland, QEII Library Electronic Resources and Serials, St. JohnÂ¹s, NL, A1B 3Y1, Canada; Tel: 709-864-8930; Fax: 709-864-4042;
E-mail: asharan@mun.ca

E-ISSN: 2410-3624/15 

water which rises to 121°C in step 1 remains higher than 60°C, the pasteurization temperature for a long time thereby saving energy (in ordinary boiling of water for drinking it is heated for longer time).

Here, for the purpose of heating, one may use any type of fuel such as natural gas, kerosene, coal, wood, dried leaves etc. i.e. whatever is readily available as opposed to electricity required in the RO or UV methods.

## 2. COST ANALYSIS OF RO, ULTRA-VIOLET (UV) AND PRESSURE COOKER METHODS OF WATER PURIFUICATION

Water purification with ultraviolet (UV) light is one of the most efficient sanitary methods for eliminating viruses and bacteria from drinking water. The purification includes deactivation of all pathogenic waterborne bacteria and viruses, and also crypto-sporidium cysts.

In reverse osmosis (RO), one uses a semi-permeable membrane. In this method, an applied pressure is used to overcome osmotic pressure.

In the Pressure Cooker method, water is boiled at 1 atmosphere gauge pressure where the boiling point of water is elevated to 121°C from 100°C and then the water is allowed to cool under natural conditions with the lid and the weight continued in the same position while being heated This enables the steam generated to condense to water thereby recovering the latent heat of water and by preventing steam from leaving - the thermal efficiency of the process is increased thereby minimizing the fuel requirement or cost.

Figure **1** shows a water filtering machine as well as a pressure cooker where water is heated after it is filtered. Figures **2** and **3** show RO as well as an ultra violet machines.


**Figure 1:** Pressure cooker and water filtering machine.

**Figure 2:** Pressure cooker and ultra-violet machine.

**Figure 3:** RO machine and a pressure cooker.

In Table **1** the cost of heating 1 and 15 litres of water are arrived at based on heat required by burning Liquefied Petroleum Gas (LPG) which is available in India contained in cylinders. For the cost determination of per kilogram of LPG one can refer to [6-9], The cost comparisons are done based on the consumption of 15 litres of potable water.

In Table **2**, various costs involved in the RO method are discussed. The life-span of this machine is considered to be 10 years. In this table, in row 2, the cost of the machine [10, 11] shown is 18000 rupees. This machine is financed through loan taken at 11.9% interest to be paid over 5 years. Next to the machine cost is the maintenance cost of 1800 rupees in the first year and this changes in the subsequent years due to inflation at 7.8% per annum. In the next column is the

**Table 1: Calculation of Cost of Heating One Litre of Water from 20°C to 121°C**

| Item | Value | Comments |
|---|---|---|
| Heating value of lpg | 46100 kj/kg | |
| Specific heat of water | 4.187 kj/kg °k | |
| Initial temperature of water | 20° c | Room temperature |
| Final temperature of water | 121° c | Boiling point of water under 1 atmosphere gauge pressure due to the weight of the pressure cooker |
| Energy required to heat one litre of water | 1 x 4.187 x (121-20) = 422.079 kj | Mass x specific heat x increase in temperature |
| Energy consumption | 0.00915527 kg of lpg | |
| Mass of lpg in a cylinder | 14.2 kg | |
| Price of 1 cylinder | Rs 425 | |
| Price of lpg | Rs 29.93 /kg | |
| Price for heating 1 litre | 29.93 x 0.009155727 = 0.27 rs | |
| Price of heating 15 litre | 4.11 rs | |

**Table 2: Calculation of Various Costs if RO Machine is Used**

| Year | Ro machine | Repair and maintenance | Initial modification cost | Electricity | Total cost |
|---|---|---|---|---|---|
| Cost | 18000 | 1800 | 1000 | 160 | |
| 1 | 4794 | 1800 | 1000 | 160 | 7754 |
| 2 | 4794 | 1942 | | 173 | 6909 |
| 3 | 4794 | 2096 | | 186 | 7076 |
| 4 | 4794 | 2261 | | 201 | 7256 |
| 5 | 4794 | 2440 | | 217 | 7451 |
| 6 | 0 | 2633 | | 234 | 2867 |
| 7 | 0 | 2841 | | 252 | 3093 |
| 8 | 0 | 3065 | | 272 | 3337 |
| 9 | 0 | 3307 | | 294 | 3601 |
| 10 | 0 | 3568 | | 317 | 3886 |
| **Total cost over 10 years** | | | | | 53229 |

**Table 3: Calculation of Various Costs if Ultra-Violet Machine is Used**

| Year | Ultra-Violet Machine | Electricity | Initial Existing Modification Cost | Repair and Maintennce | Total Cost |
|---|---|---|---|---|---|
| | 9000 | 160 | 1000 | 900 | 11060 |
| 1 | 2397 | 160 | 1000 | 900 | 4458 |
| 2 | 2397 | 173 | | 971 | 3543 |
| 3 | 2397 | 186 | | 1048 | 3634 |
| 4 | 2397 | 201 | | 1131 | 3733 |
| 5 | 2397 | 217 | | 1220 | 3839 |
| 6 | 0 | 234 | | 1316 | 1556 |
| 7 | 0 | 252 | | 1420 | 1680 |
| 8 | 0 | 272 | | 1532 | 1813 |
| 9 | 0 | 294 | | 1654 | 1956 |
| 10 | 0 | 317 | | 1784 | 2111 |
| **Total cost over 10 years** | | | | | **28323** |

initial modification cost in the existing water supply of a dwelling. It is a onetime cost. The next item is the cost of electricity calculated based on 0.5 Amperes of current at 220 Volts where the cost of 1 unit (1000 Watt-hour) is taken as 6 rupees. This cost is subject to inflation as discussed earlier. The last column shows the total yearly payment.

The total payment over 10 years shown at the bottom of the last column is Rs 53,229.

**Table 4: Calculation of Various Costs if Pressure Cooker is Used**

| Year | Lpg (rs 0.27 per Litre) | Pressure Cooker and Filtering Machine | Repair and Maintenance | Total |
|---|---|---|---|---|
| | 1471 | 554 | 300 | |
| 1 | 1471 | 554 | 300 | 2325 |
| 2 | 1527 | 554 | 324 | 2405 |
| 3 | 1584 | 554 | 349 | 2487 |
| 4 | 1640 | | 377 | 2017 |
| 5 | 1697 | | 407 | 2103 |
| 6 | 1753 | | 439 | 2192 |
| 7 | 1810 | | 473 | 2283 |
| 8 | 1866 | | 511 | 2377 |
| 9 | 1923 | | 551 | 2474 |
| 10 | 1979 | | 595 | 2574 |
| **Total payments over 10 years** | 17250 | | | 23239 |

Similar cost analysis for the ultra- violet method is shown in Table **3**. The total payment in this case is Rs 28,323.

Next, the details of the cost breakdown for the Pressure Cooker method are shown in Table **4**. Here, the second column shows the cost of LPG for heating 15 liters of water. The cost variation of LPG cylinder over 10 years is calculated by extrapolating the cost since the Year 2004 to the present. The second row in the third column shows the total cost of a pressure cooker and a water filtering machine shown in Figure **1**. This is purchased by taking a loan at the interest rate of 11.9% over three years. The last column shows the total yearly payments. The bottom row in the last column shows that the total payment in this case would be Rs. 23,239, the most economical amongst all the three methods.

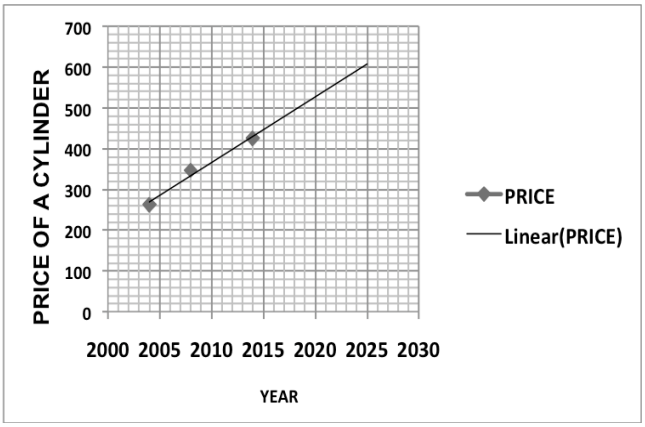



**Figure 4:** Projected cost of the price of a cylinder.

Figure **5** shows the payment variations of all the three methods over ten years. In this figure, the cost in the RO method drops sharply after the 5 years as the financing payments of acquiring the machines come to an end. Similar is the case in the ultra violet method. In the Pressure Cooker method this drop takes place after 3 years. Since, the fuel cost is the main component in this method, this cost rises based on Figure **4** as the cost of the fuel increases.

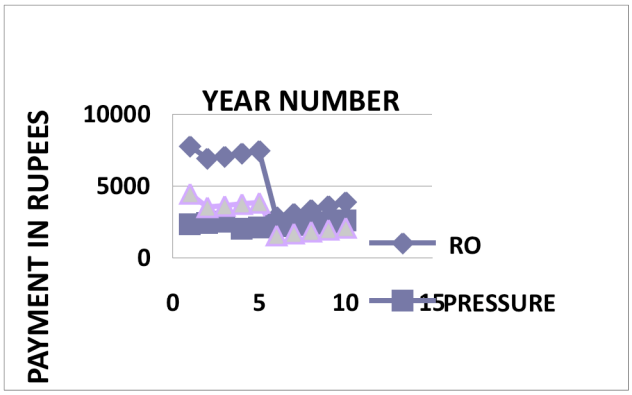
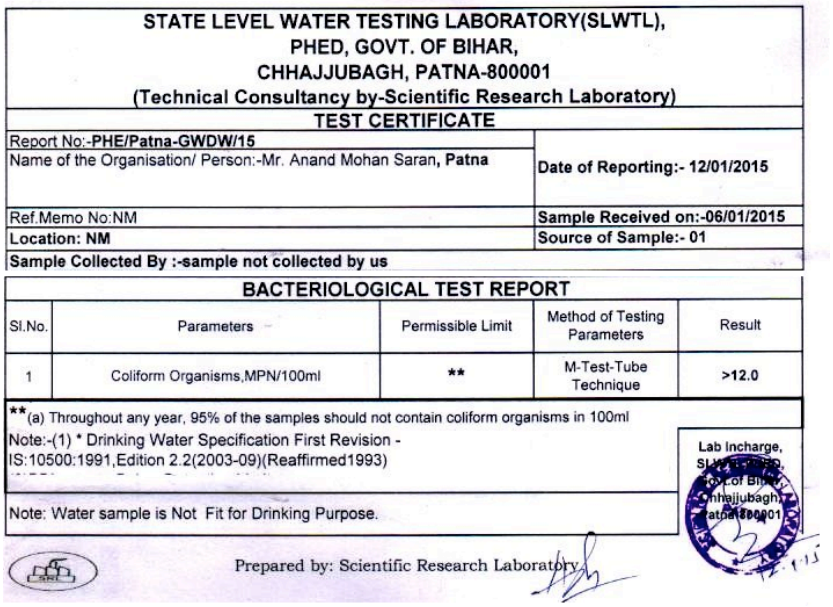



**Figure 5:** Payments involved in the three methods.

## 3. DISCUSSIONS ON EXPERIMENTAL RESULTS OF WATER PURIFICATION IN THE PRESSURE COOKER METHOD

Experiments were performed by collecting samples of water from the mid-stream of the Ganga River at Patna on January 5, 2015. The water was filled in the pressure cooker and heated until the first steam whistle was heard. After this, water was cooled in air with the lid and the weight on. After cooling, it was sent for chemical and bacteriological analysis. The results of analysis of the collected sample from the Ganga River are shown in Table **5** and those obtained after heating in a pressure cooker are given in Table **6**.

**Table 5: Results of the Sample from Ganga River at Patna**



STATE LEVEL WATER TESTING LABORATORY(SLWTL),
PHED, GOVT. OF BIHAR,
CHHAJJUBAGH, PATNA-800001
(Technical Consultancy by-Scientific Research Laboratory)

TEST CERTIFICATE

| | |
|---|---|
| Report No:-PHE/Patna-GWDW/15 | |
| Name of the Organisation/ Person:-Mr. Anand Mohan Saran, Patna | Date of Reporting:- 12/01/2015 |
| Ref.Memo No:NM | Sample Received on:-06/01/2015 |
| Location: NM | Source of Sample:- 01 |
| Sample Collected By :-sample not collected by us | |

BACTERIOLOGICAL TEST REPORT

| Sl.No. | Parameters | Permissible Limit | Method of Testing Parameters | Result |
|---|---|---|---|---|
| 1 | Coliform Organisms,MPN/100ml | ** | M-Test-Tube Technique | >12.0 |

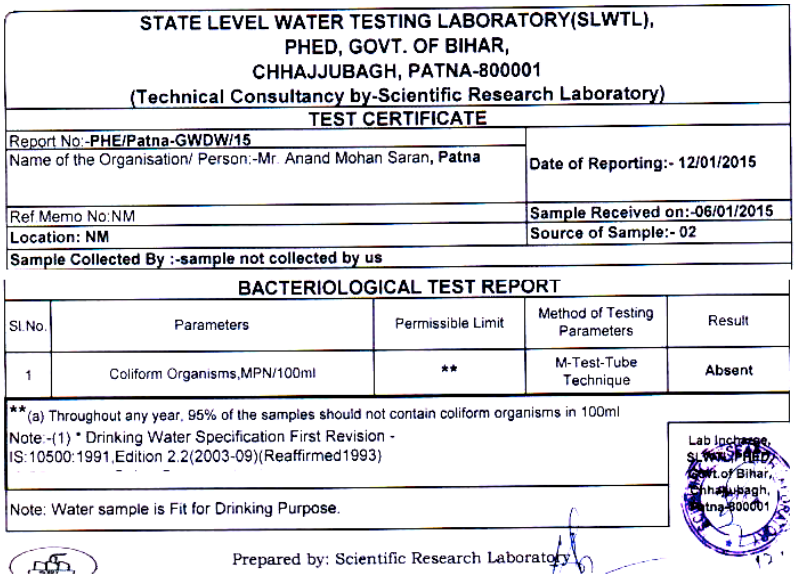
**(a) Throughout any year, 95% of the samples should not contain coliform organisms in 100ml
Note:-(1) * Drinking Water Specification First Revision - IS:10500:1991,Edition 2.2(2003-09)(Reaffirmed1993)

Lab Incharge, SLWTL, PHED, Govt.of Bihar, Chhajjubagh, Patna-800001

Note: Water sample is Not Fit for Drinking Purpose.

Prepared by: Scientific Research Laboratory

**Table 6: Results of the Sample from Ganga River at Patna after One Whistle**



STATE LEVEL WATER TESTING LABORATORY(SLWTL),
PHED, GOVT. OF BIHAR,
CHHAJJUBAGH, PATNA-800001
(Technical Consultancy by-Scientific Research Laboratory)

TEST CERTIFICATE

| | |
|---|---|
| Report No:-PHE/Patna-GWDW/15 | |
| Name of the Organisation/ Person:-Mr. Anand Mohan Saran, Patna | Date of Reporting:- 12/01/2015 |
| Ref.Memo No:NM | Sample Received on:-06/01/2015 |
| Location: NM | Source of Sample:- 02 |
| Sample Collected By :-sample not collected by us | |

BACTERIOLOGICAL TEST REPORT

| Sl.No. | Parameters | Permissible Limit | Method of Testing Parameters | Result |
|---|---|---|---|---|
| 1 | Coliform Organisms,MPN/100ml | ** | M-Test-Tube Technique | Absent |

**(a) Throughout any year, 95% of the samples should not contain coliform organisms in 100ml
Note:-(1) * Drinking Water Specification First Revision - IS:10500:1991,Edition 2.2(2003-09)(Reaffirmed1993)

Lab Incharge, SLWTL, PHED, Govt.of Bihar, Chhajjubagh, Patna-800001

Note: Water sample is Fit for Drinking Purpose.

Prepared by: Scientific Research Laboratory

The last row in the Table **5** shows that the Ganga water is not fit for drinking as the water quality index is greater than 12(last column and second row from the bottom). The acceptable range is between 0 to 10.

On the other hand, the Table **6** shows the absence of any bacteria- thus fit for drinking.

Finally, the Pressure Cooker method is very simple as it can be used in situations where there is no electricity supply. Vast areas of India do not have stable electricity supply as well as servicing facility needed for maintenance of RO and UV machines.

Fourthly, Pressure Cooker method is simple and the components used for purification are portable. Many people do not stay at a place for long as they work on different projects. Thus, they can very easily carry the water filtering machine and the pressure cooker wherever they move to.

## 4. CONCLUSIONS

In this work, at first, the detailed cost analysis of the three water purification methods was carried out. In this analysis it was determined that the Pressure Cooker method is the most economical.

Next, the effectiveness of the Pressure Cooker was further shown by performing chemical and bacteriological analysis of collected water sample from the Ganga River at Patna and after treating this water through a heating process described above. It is also concluded here that this method is very effective as all the bacteria were eliminated.

Thirdly, it can be stated that the Pressure Cooker method is very versatile as it can be used in situations where there is no electricity supply and fourthly, this method is simple and the components used for purification are portable, Unlike the two other accepted and commonly used methods (RO and UV) of water purification.

## REFERENCES

[1] WHO Drinking Water. www.who.int/topics/drinking-water/en/.

[2] WHO/Drinking Water quality. www.who.int/water-sanitationhealth/dwg.

[3] Park K. Park's Textbook of Preventive and Social Medicine, 19th edition. Banarsidas Bhanot Publishers: Jabalpur, India, 567.

[4] WHO: Waterborne Disease is World's Leading Killer, http://www.voanews.com/content/a-13-2005-03-17-voa34-67381152/274768.html.

[5] Sharan AM. Economical and Reliable Method of Water Purification", Asian Journal of Water, Environment and Pollution 2014; 11(3): 71-81.

[6] TABLE-India's petrol, diesel, kerosene and LPG prices, http://in.reuters.com/article/2010/02/04/india-fuel-prices-idINSGE6130E720100204.

[7] LPG subsidy fixed at Rs 568, price to change after March, http://indianexpress.com/article/business/business-others/lpg-subsidy-fixed-at-rs-568-price-to-change-after-march/.

[8] Non-subsidized LPG price cut by Rs 113/cylinder, jet fuel price slashed by 4.1%, http://timesofindia.indiatimes.com/business/india-business/Non- subsidized-LPG-price-cut-by-Rs-113/cylinder-jet-fuel-price-slashed-by-4-1/articleshow/45334637.cms.

[9] Liquefied petroleum gas, http://en.wikipedia.org/wiki/Liquefied_petroleum_gas.

[10] The Engineering Toolbox, http://www.engineeringtoolbox.com/water-thermal-properties-d_162.html

[11] Flipkart.com, http://www.flipkart.com/home-store?otracker=hp_nmenu_home-kitchen.

Received on 09-06-2015 Accepted on 31-07-2015 Published on 31-12-2015

DOI: http://dx.doi.org/10.15377/2410-3624.2015.02.02.1