A Proposed Solution for The Bottle Water Problem Through System Engineering

A SE initiative to reduce the plastic bottled water consumption in Los Angeles South Bay Area

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System Engineering Leadership program with focus on Mechanical Engineering Integrative Project
A Solution Proposal for The Bottle Water Problem Through SE

Agenda:

I. Introduction
II. Analysis of the bottled water problem
III. Current State of tap & bottled water quality
IV. Current State of drinking water treatment
V. Alternatives for the solution of the bottled water problem
VI. System Engineering approach for the bottled water problem solution
VII. Analysis of Results
VIII. Summary and Conclusions
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Introduction

- Plastic, one of a new generation of polluting agents, has become one of the worst causes of environmental contamination.

- A great percentage of the plastic production is currently used for bottling water.

- Bottled water consumption has radically grown in the past few years, creating a severe effect on the environment.

- This project will analyze the bottled water problem in depth and review several possible solutions to the problem.

- The Project Goal is to present a solution to the bottled water problem using System Engineering fundamentals and tools.
A Solution Proposal for The Bottle Water Problem Through SE Analysis of the Existing Problem

- Perrier & Evian started marketing of bottled water in 1977.
- 1989 the plastics industry introduced Polyethylene Terephthalate (PET), an invention that changed the world.
- Today, most plastic water bottles are made of PET – 30% of the world’s PET goes into plastic bottles*.
- 40% of the bottled water comes from tap water*
- Coca Cola and Pepsi process tap water into bottled water using processes like reverse osmosis (RO)

In 2011, 50 billion water bottles were sold in the US alone. Americans spent more money last year on bottled water than on iPods or movie tickets: $15 Billion!!!*

That number is not easy to visualize. Putting it another way, Americans consumed over 1,500 bottles every second*
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Analysis of the Existing Problem (Cont)

- **Effect of bottled water on the environment**
  - Only 15% of plastic water bottles are recycled & the rest goes into landfills or ends up in the ocean*
  - Almost all water bottles come from virgin plastic, not recycled material
  - Water bottles that end in landfills can take up to 1000 years to biodegrade
  - Incinerating used bottles produces toxic byproducts that leak into the ground
  - Much of the unrecycled plastic that does not end up in landfills ends up in oceans creating the “Great Pacific Garbage Patch”

*Please see references for data source 5.
• Marine animals like mammals and birds mistake the plastic for food. Plastic will eventually photodegrade, breaking up into smaller and smaller bits.

• The negative impact on the marine food chain is pushed further down, so that virtually all the marine life ends up consuming plastics, even when they are very tiny.

• In some places, bits of plastic outnumber plankton 7:1*

• Bottled water industry has a huge carbon footprint, during the making and the distribution. Using up to millions of barrels of crude oil.
A Solution Proposal for The Bottle Water Problem Through System SE Analysis of the Existing Problem (Cont)

What is being done to reduce consumption?

- More than 90 universities, such Loyola Chicago, Brown and Harvard have banned or restricted the sale of bottled water. Loyola is installing 35 bottle refill stations.

- The town of Concord, Massachusetts recently became the first US city to ban the sale of bottled water.

- London authorities have paired up with Thames Water to launch a water station program that aims to reduce the city's use of bottled water. Customers will pay up to 20p (roughly 30 cents USD) for 500 ml of water*.

- Many countries are starting initiatives to reduce the bottled water consumption; nevertheless, the efforts are minimum compared to the severity of the problem.

- Unfortunately, the U.S, one of the largest offenders, is doing very little to attack the bottled water consumption problem.

*Please see references for data source 7
A Solution Proposal for The Bottle Water Problem Through SE

Current State of Tap & Bottled Water Quality

Tap Water Quality

• In 1974 the United State Congress created a law to protect health by regulating the nation’s public drinking water supply.

• The Environmental Protection Agency (EPA) is the government agency responsible for enforcing these regulations.

• There are two types EPA Standards:
  • Primary standards protect the public health by limiting the levels of specific contaminants in the water (i.e: microbial, chemical carcinogens and chemical non-carcinogens).

  • Secondary standards are recommended guidelines for contaminants whose effects are mostly cosmetic or aesthetic, like odor, taste, color.

  • A third category of contaminants are unregulated, for which there are no standards.
A Solution Proposal for The Bottle Water Problem Through System SE
Analysis of the Existing Problem (Cont)

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Current State of Tap & Bottled Water Quality (Cont)

Tap Water Quality (cont.)

Most tap water in the United States is perfectly healthful, although the chlorination affects the taste.

Sampling Results

During the past year, we have taken hundreds of water samples in order to determine the presence of any radioactive, biological, inorganic, volatile organic, or synthetic organic contaminants. The table below shows only those contaminants that were detected in the water. Although all of the substances listed here are under the Maximum Contaminant Level (MCL), we feel it is important that you know exactly what was detected and how much of the substance was present in the water.

A constituent is any naturally occurring or man-made substance found in drinking water. The U.S. EPA and the California EPA establish the list of constituents that require testing and the frequency of such tests. MWD, Distribution System, and chemicals of interest results are from calendar year 2011. Ground water results are from 2009-2011. The state requires us to monitor for certain substances less than once per year because the concentrations of these substances do not change frequently. In these cases, the most recent sample data is included.

<table>
<thead>
<tr>
<th>REGULATED SUBSTANCES</th>
<th>City of Torrance Ground Water</th>
<th>MWD Surface Water</th>
<th>Monitored in the Distribution System</th>
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</thead>
<tbody>
<tr>
<td><strong>UNIT OF MEASUREMENT</strong></td>
<td><strong>MCL</strong></td>
<td><strong>P90</strong></td>
<td><strong>AMOUNT DETECTED</strong></td>
</tr>
<tr>
<td>Aluminum (ppm)</td>
<td>0.5</td>
<td>0.6</td>
<td>NA</td>
</tr>
<tr>
<td>Bromate (ppb)</td>
<td>10</td>
<td>0.1</td>
<td>NA</td>
</tr>
<tr>
<td>Chloramines (ppm)</td>
<td>4.0 (as CI2)</td>
<td>4 (as CI2)</td>
<td>NA</td>
</tr>
<tr>
<td>Fluoride (ppm)</td>
<td>1.0</td>
<td>1</td>
<td>0.16</td>
</tr>
<tr>
<td>Hafnium (ppb)</td>
<td>60</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Nitrate (as nitrogen) (ppm)</td>
<td>45</td>
<td>45</td>
<td>ND</td>
</tr>
<tr>
<td>TTHMs (Total Trihalomethanes) (ppb)</td>
<td>80</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Uranium (pCi/L)</td>
<td>20</td>
<td>0.43</td>
<td>NA</td>
</tr>
</tbody>
</table>

City of Torrance Water Quality Report for 2011 – Reports are available to the public
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Current State of Tap & Bottled Water Quality (Cont)

• Bottled Water Quality

• One of the arguments for bottled water is that it has a better taste, is safer and more healthful. Is this true?

• A study conducted from 2004 to 2008 by the National Resources Defense Council concluded, "there is no assurance that just because water comes out of a bottle, it is any cleaner or safer than water from the tap."

• Tap water is regulated by the EPA, but bottled water is overseen by the FDA, which has only one inspector. Therefore the industry does the inspecting.

• It should not be assumed that bottled water is any safer than tap water. But that just further supports the need for a low-cost system to provide the public with clean, safe, good-tasting water. There is clearly a problem -- and clearly there needs to be a solution.
## Current State of Tap & Bottled Water Quality (Cont)

- **Major Regulatory Gaps on bottled water**

<table>
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<tr>
<th>TAP WATER</th>
<th>BOTTLED WATER</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ City tap water can have no confirmed E. coli or fecal coliform bacteria</td>
<td>✗ FDA bottled water rules include no such prohibition.</td>
</tr>
<tr>
<td>✓ City tap water from surface water must be filtered and disinfected</td>
<td>✗ There are no federal filtration or disinfection requirements for bottled water.</td>
</tr>
<tr>
<td>✓ Big-city tap water must be tested 100 or more times a month.</td>
<td>✗ Bottled water plants must test for coliform bacteria just once a week.</td>
</tr>
<tr>
<td>✓ Repeated high levels of bacteria in tap water combined with a lack of disinfectant can trigger a violation for cities.</td>
<td>✗ But not for water bottlers.</td>
</tr>
<tr>
<td>✓ Any violation of tap-water standards is grounds for enforcement</td>
<td>✗ But bottled water in violation of standards can still be sold if it is labeled as &quot;containing excessive chemicals&quot; or &quot;excessive bacteria&quot;.</td>
</tr>
<tr>
<td>✓ Cities generally must test at least once a quarter for many chemical</td>
<td>✗ Water bottlers generally must test only annually.</td>
</tr>
</tbody>
</table>
Current State of Tap & Bottled Water Quality (Cont)

- Major Regulatory Gaps on bottled water

EWG research*, including analysis of 96 bottled waters purchased in California, and personal communication with bottled water companies.

*Please see references for data source.
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Current State of Drinking Water Treatment

There are two organizations providing independent certification for water purification devices,

(1) National Sanitation Foundation (NSF)
(2) The Water Quality Association (WQA).

Two important terms related to water treatment:

- Water purification: The act of cleaning by getting rid of impurities
- Water Disinfection: Killing or removal of microorganisms by direct exposure to chemical or physical agents or processes.

The most popular water treatment systems are:

- Reverse Osmosis (RO)
- Water Filter
  - Sediment Filters
  - Ceramic Filters
  - Activated Carbon Filters (AC)
  - Granular Activated Carbon (GAC)
  - Solid Block Activated Carbon (SBAC)
- Ozonation
Alternatives for the solution of the bottled water problem

- List of potential candidates investigated in this project to resolve the bottled water problem:

1. Ban the use of plastic bottled water

2. Improving the recycle process around the country – to ensure no plastic bottles become an environmental issue.

3. Promote the use of tap water – marketing tap water the same way bottled water companies market bottled water.

4. Use biodegradable water bottles - made from more environmental friendly sources different than plastics.

5. Design a system to continue the distribution of the bottled water, but eliminating the plastic element from the system.

After analyzing all possible options, this project selected option (5) as the most optimal solution to resolve the problem.
A Solution Proposal for The Bottle Water Problem Through SE
System Engineering approach for the bottled water problem solution

- The following SE approaches will be implemented:
  - System Architecting
  - Model Design (prototype)
  - Network Planning (South Bay Area)
  - System approach to control Network

**System Architecting:**
- Architecting is a discipline for planning and building system structures.
- For this project, the architecture will be defined in three areas:
  - The bottled Solution
  - The water quality solution
  - The system solution.

- Heuristics generally come in two forms.
  - The first is descriptive => What is the situation – “The Plastic Bottled Water Problem”
  - The second one is prescriptive => What to do about it – “Design a system to reduce (or eliminate) the bottled water consumption”

The more succinct and even humorous the heuristic, the more easy it is remembered.
As Rechtin says “the simplest solution is usually the correct one”*

*Please see references for data source 15
A Solution Proposal for The Bottle Water Problem Through SE
System Engineering approach for the bottled water problem solution (cont.)

- The System Architecture: The proposed system architecture approach for the solution of the plastic bottled water problem

![Flowchart Diagram]

End User to Provide

NO

Keeping the Bottle for the solution?

YES

Reengineering of bottled water concept

Home redesign

Bottles Solution

The Bottled Water Problem

Provide a High Quality water Solution

Device System Design

Water Treatment Prototype

Quality Solution

System Implementation

Network Design South Bay Cities

System Maintenance

The system Network
The Bottle Solution:

- Bottled water will not be eliminated from the proposed system - it will be reengineered. Per the heuristic approach, the simplest solution for this project is to keep the bottle in the solution. This bottle will be called: **POWACO (Portable Water Container)**

Distribution: POWACO will be distributed throughout major retailers and supermarkets sponsored by the cities.
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System Engineering approach for the bottled water problem solution (Cont.)

Design of the System: In order to create this new system, the "V" chart will be used as a roadmap that guides the design of the system based on SE fundamentals.
A Solution Proposal for the Bottle Water Problem Through SE System Engineering approach for the bottled water problem solution (Cont.)

✓ Pre-Phase A - System Architect
✓ Phase A: Concept Development – System Definition: The system is defined as “A system to provide high quality and good tasting drinking water using a bottle element that is portable and convenient, but eliminates the use of plastic.”
✓ Phase B: Design Part I – Interfacing Technology – High-Tech Water filtration system

✓ System “1” selected (first filter): Sediment Filter – This type of filter removes suspended sediments (or turbidity).

System “2” selected (second filter): GAC Filter GAC filter will primarily be used for aesthetic water treatment.

System “3” selected (third filter): RO membrane – RO membrane will use the technology of RO process to prevent many contaminants from passing by trapping them.

✓ System “4” selected (fourth filter): SBAC Filter – SBAC provides a larger surface area for adsorption than Granular Activated Carbon (GAC) for better contaminant reduction.

✓ System “5” selected: Ozonation – 99% percent of all bacteria in drinking water can be killed with ozone water treatments. This process will be carried out by an electric discharge field as the ozone generator.
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System Engineering approach for the bottled water problem solution

Design of the System (cont)
Phase B: Design Part I – Interfacing Technology: The final design has been architected. This system will be named: POWADI (Potable Water Dispenser).

Final Design Process Architecture
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System Engineering approach for the bottled water problem solution

- Design of the System:
  - Phase B: Design Part I – Interfacing Technology (Cont)
    - Touch-Screen (Instruction/command panel):
      - End user Input
      - Bottle Size Identification System
      - Payment
      - Water Filtration/Bottles Filling System
      - Finished Good removal from system
  - Additional Components:
    - Contact Number
    - Water Quality Report
    - Water Filtration Treatment Information

Water Filling Prices

- System trays for Individual and multiple bottles)
- Water Filling Prices: $0.30, $0.20, $0.15, $0.10, $0.05

This Logo belongs to “Green Leaf Collective (GLC), used in this project only for presentation proposes.
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System Engineering approach for the bottled water problem solution

Design of the System:
Phase B: Design Part 1 –
Interfacing-Technology (Cont)

Two different models are proposed in this project:

✓ HV Model: For “High Volume” demand. This model will be designed to support large volume demand.

✓ LV Model: For “Low Volume” demand. This model will be designed for low demand volume (HV smaller scale).

Both models will be able to support high-transited areas - the main difference is the volume of water to be dispensed during each usage.

This Logo belongs to “Green Leaf Collective (GLC), used in this project only for presentation proposes.
Design of the System:

**Phase C: Manufacturing Analysis:** This project recommends having the L.A South Bay Cities as the main sponsors of the POWADI system.

- **Strategy proposed** Have cities paired up with the POWADI manufacturers to execute the making of the system. In order to establish the best partnership, competitive project bidding is suggested.

- **Phase D: System Network Design - Network Definition:** The POWADI Network is defined as the number of units to be installed around the South Bay cities as well as the point of sales of the POWACOs.

- POWADI HV model would be installed at each supermarket and major retailer such as Costco, Target, CVS, Walgreens, supermarkets, etc.

- POWADI LV, would be installed in Schools, Libraries, Malls, government offices, Downtown and Pier areas.
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System Engineering approach for the bottled water problem solution

Redondo Beach
POWADI HV Model Network

Total POWADI HV Model = 22 units
POWACO Points of Sales = 20 points
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System Engineering approach for the bottled water problem solution

Redondo Beach
POWADI LV Model Network

Schools 132 units
Public Libraries 2 units
Mall 3 units
Downtown & Pier 5 units
Government Offices 5 units

Total POWADI LV Model = 147 units
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Design of the System:

Phase D(2) – System Implementation
Taking a Project Management System approach, the following techniques will be applied to review the implementation of this system:

(1) System Evaluation
(2) Functional Ownership Analysis
(3) System Risk Analysis

(1) System Evaluation Pros and Cons of the POWADI System:

Pros of POWADI:
✓ Provides incentives for the reduction of plastic bottle consumption
✓ Provides high quality water with a great taste. It guarantees water free of chemicals and bacteria.
✓ Network provides the availability and accessibility of the service.
✓ The POWADI system uses, as its main source, tap water which is regulated by the EPA at a higher standard than FDA which regulates bottled water.
✓ Lowers costs – price of bottles and filling will be noticeably lower compared to current bottled water.
✓ Creates Environmental consciousness in citizens where the system will be implemented. POWADIs in the school districts will help raise awareness for future generations.
A Solution Proposal for The Bottle Water Problem Through SE System Engineering approach for the bottled water problem solution

Design of the System:
Phase D(2) – System Implementation (Cont.)

(1) System Evaluation Pros and Cons of the POWADI System (Cont):
Cons of POWADI:
- POWACOs will need to be purchased by consumers in order to use the system. This will be one of the major drawbacks; nonetheless, this is the only way to avoid the usage of plastic bottles in the system.

- POWACO's bottles will require cleaning & sanitization; this can be seen as a major disadvantage by users of plastic bottles who are used to disposing of the plastic container. However, clear instructions of how to clean and sanitize bottles will be provided.

(2) Functional Ownership
á Partnership:
   - South Bay cities - POWACO Manufacture
   - South Bay cities - POWADI Manufacture.

á Relationship:
   - POWACO Manufacture - POWADI Manufacture.

á Responsibilities:
   ➤ South Bay Cities - marketing and sponsorship of the system
   ➤ POWADI Manufacturer: production, installation, maintenance and consumer support.
   ➤ POWACO Manufacturer: production, distribution, replenishment (through demand analysis), and customer support.
A Solution Proposal for The Bottle Water Problem Through SE System Engineering approach for the bottled water problem solution

Design of the System:
Phase D(2) – System Implementation (Cont.)

(3) Risk Analysis:
☑ Equipment Failure – Will drive unreliability
  ✔ Risk Mitigation: Proper Equipment Set-up & Maintenance

☒ POWACO OOS (Out of Stock) – Consumer will not be motivated to use system
  ✔ Risk Mitigation: Proper replenishment thru demand & supply analysis

Phase E – System Verification & Deployment
  ✔ Verification:
    ☑ Filtration System – Validate “High Quality & Good Taste” Claim
    ☑ Capacity – Can demand volumes be supported?
    ☑ Process Cycle Time – Is the system fast enough to support expected traffic?
  ✔ Deployment (Launch):
    ☑ Once the system has been validated, it can now be launched into the market.
    ☑ POWADI HV and LV Networks will need to be created.
    ☑ Technical requirements at each location need to be reviewed to guarantee POWADI(s) proper Installation & Operation.
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System Engineering approach for the bottled water problem solution

Design of the System:
Phase E(2) – System Life Cycle & Maintenance
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System Engineering approach for the bottled water problem solution

Design of the System:
Phase E(2) – System Life Cycle & Maintenance (Cont.)

POWADI Maintenance

✓ Monthly (check-up) – During this maintenance session, technicians will verify that equipment is working properly and a sample of water will be taken for lab testing.

✓ Quarterly (Filter replacement) – As POWADI will use four different filters; they will need to be replaced. During this maintenance session, technicians will replace all parts that need substitution.

✓ Annually (Software updates) – As POWADI equipment uses touch screens for operation, a software update is recommended to ensure optimization.
A Solution Proposal for The Bottle Water Problem Through SE

Analysis of Results:

✓ Results of Bottled Water Research:

- 30% of the world PET is goes into plastic bottles.
- In 2011, 50 billion water bottles were sold in the US alone (1,500 every second)
- Only 15% of plastic water bottles are recycled. The rest goes into landfills or ends up in the ocean.
- The Great Pacific Garbage Patch is a the result of debris trapped in the dead zone, most of the debris is plastics.
- Water bottles photodegrade but it is more of disintegration, the plastic breaking down into smaller pieces, so all the marine life ends up consuming plastics.

✓ System Engineering approach to resolve problem:

- Through System Architecture the solution was identified in three areas:
  - A new bottled concept => POWACO
  - A Water Treatment system => POWADI
  - A Network solution => South Bay City POWADI HV & LV Network
- The design of the system was accomplished using SE “V” chart as a roadmap. Several phases were developed to create an optimal system that provided an effective solution to the bottled water problem.
Summary & Conclusions

- Bottled water has become a terrible habit by not only millions, but billions of people.

- Detailed research of the existing problem was completed (from internet sources). The results provided validation of the data and statement of environmentalists that have fought for years to eradicate the plastic bottle production and consumption.

- System Architecture, the "V" chart design roadmap and Project Management of System were the SE approaches used to develop a solution to the problem.

- This paper presents a solution that will, hopefully, change some small communities in Los Angeles, setting an example for other cities.

- This project can lead to a discussion for resolving a problem that affects the entire world with a negative impact on the environment and human health.

It is not too late to make a big change and ensure a better world to future generations.
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<table>
<thead>
<tr>
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<tbody>
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<td>(47)</td>
<td>History by America Beverage association <a href="http://www.ameribev.org/about-aba/history/">http://www.ameribev.org/about-aba/history/</a></td>
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<td>(50)</td>
<td>The Use of Phosphates For Potable Water Treatment by The Phosphate Forum of the Americas <a href="http://www.phosphatesfacts.org/pdfs/Potable%20Water%20Treatment.pdf">http://www.phosphatesfacts.org/pdfs/Potable%20Water%20Treatment.pdf</a></td>
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<td>Ion Exchange Water Softening by Water sustainability the University of Arizona <a href="http://web.sahra.arizona.edu/programs/akyw/ion.html">http://web.sahra.arizona.edu/programs/akyw/ion.html</a></td>
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<td>(55)</td>
<td>Ultraviolet Light by wellness product <a href="http://www.frequencyrising.com/water_ultraviolet.htm">http://www.frequencyrising.com/water_ultraviolet.htm</a></td>
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</table>
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(70) SW300 System The preferred solution for high volume and demand by Streamline water
http://www.streamlinewater.com/sw300

(71) PW1R Bottleless Cooler by Onesourcewater http://drinkcleantogreen.com/pw1r-bottleless-cooler


(75) http://ourweed.com/green-leaf-collective-glcl/ - Source for Logo used on the POWADI and POWACO