CANADIAN BOTTLED WATER INDUSTRY - TECHNOLOGICAL, ECONOMIC AND ENVIRONMENTAL PERSPECTIVES

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Canadian Bottled Water Industry - Technological, Economic and Environmental Perspectives

By

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Dedicated to my parents Ziaur Rahman Ansari and Kaniz Fatima for their love, affection and invaluable sacrifice throughout my life and all my teachers who taught me to sail in life.

Abstract

This study presents an assessment of global freshwater resources, water supply and demand and safe drinking water issues with a focus on Canada in general and Newfoundland and Labrador in particular. Therefore, providing adequate freshwater to meet basic human needs must be done within the sustainable development policy, with proper planning and integrated approach considering environmental, ecological, socio-economic, and political factors. It examines innovative water treatment technologies like, filtration process, ozonation and ultra violet (UV) radiation for water bottling development. A water quality analysis for nutrient minerals for major global bottled water brands are discussed in the light of World Health Organization (WHO) requirements.

The study also evaluates an integrated water bottling system and environmental impact on the Gisborne Lake watershed area in Newfoundland and Labrador. This study also presents three scenarios of the transportation systems for bottled water export (i) by shuttle service to the United States (ii) by Suez vessels to the United States and (iii) by a modified Very Large Crude oil Carrier (VLCC) vessel to the Gulf countries specially to port facilities in Saudi Arabia, on their way back, from the proposed Newfoundland and Labrador Refining Corporation (NLRC) at Southern Head, Arnold's Cove region in the Placentia Bay, Newfoundland and Labrador, Canada.

The study presents the feasibility for bottled water industry, environmental cost and explores the viability of the export of bottled water from Newfoundland and Labrador, to global markets. There seems to be considerable potential for bottled water export for Canada particularly for the economic development of Newfoundland and Labrador. The transportation cost for bottled water to the United States and the port facilities in the Gulf countries are about 2.0 to 7.0 cents per liter from Newfoundland and Labrador, which are not as high as is usually speculated and seems quite feasible, if planned properly.

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I wish to greatly acknowledge the continued support, guidance and encouragement of my supervisor Dr. Tahir Husain, who in addition to guiding me on this thesis also shared enormous insight on various important aspects in the last three decades. Thus, I owe Dr. Husain immensely for his time and contribution in shaping my career.

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Nomenclature

ABWA	Asian Bottled Water Association
AWWA	American Water Works Association
BAF	Bunker Adjustment Factor
BC	Building Cost
BMC	Beverage Marketing Corporation
CBWA	Canadian Bottled Water Association
D	Depreciation
DAF	Dissolve Air Filtration
EC	Total Electricity Cost
EH	Annual Effective Operation Hours
EIS	Equipment Imbalance Surcharge
EUC	Total Energy Used
FEU	Fourty Foot Equivalent Unit
GIS	Geographical Information Systems
GMP	Good Manufacturing Practice
IBWA	International Bottled Water Association
IC	Total Investment Cost
IMO	International Maritime Organization
IR	Annual Interest Rate
MARPOL	International Convention for the Prevention of Pollution from Ship
MF	Micro-filtration
MGD	Million Gallons Per Day
MWCO	Molecular Weight Cutoff
NF	Nano-filtration
NLRC	Newfoundland and Labrador Refining Corporation
NSF	National Sanitation Foundation
PAI	Population Action International
TPC	Total Plant Cost
PC	Unit Cost of Efficiency
PET	Poly Ethylene Tetra

PKC	Packaging Cost
RBC	Total Cost of Raw Material
RC	Price of Raw Material
RFR	Required Freight Rate
RO	Reverse Osmosis
SWC	Total Source Water Cost
TDS	Total Dissolved Solids
TI	Total Interest
TEU	Twenty Foot Equivalent Unit
UF	Ultra-filtration
ULCC	Ultra Large Crude Oil Carrier
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational Scientific Organization
USEPA	United States Environment Protection Agency
USFDA	United States Food and Drug Administration
UV	Ultraviolet Radiation
VB	Volume of Water in a Bottle
VLCC	Very Large Crude Oil Carrier
VR	Volume of Water in Rinsing
WB	Volume of Bottle Raw Material
WHO	World Health Organization
WRA	Water Resource Atlas of Newfoundland and Labrador
WRI	World Resource Institute
WTO	World Trade Organization

Chapter I

INTRODUCTION

1.1 Background

Global freshwater resources are under stress, water quality is deteriorating and water resources are depleting due to climate change, population growth and poor water management practices. It is estimated that 3% freshwater resources are available but only 1% of the total world's water are available for human consumption (Gleick, 2001).

In many developing countries, inefficient water management practices are considered to be the major contributing factor in the deterioration of water quality and disparity in water supply and demand (Rahman and Husain, 2001). It is estimated that 166 million people in 18 countries are facing water scarcity and almost 11 additional countries with 270 million people are in the group of water stressed countries. The Middle East and North Africa (MENA) regions are facing most serious water availability problem. The United Nations Environment Programme (UNEP) concludes that "two of every three people will live in water stressed regions by 2025" (Christen, 2000). According to the United Nations Educational Scientific

Organization (UNESCO) "around 2.7 billion people are likely to face water shortages by 2025 if effective measures are not taken to conserve water resources." The International Council for Scientific Committee ranks the water shortages as the most pressing environmental issue of the 21st century (Christen, 2000).

Falkenmark (1989) categorizes countries on the basis of the availability of renewable freshwater resources on per capita basis and classifies them as:

- Limited water problem countries — Countries having more than 10,000 m^3 per capita per year renewable water resources.
- General water problem countries — Countries having water availability between 1,670 to 10,000 m^3 per person per year renewable water resources.
- Water Stressed Countries — Countries having water availability between 1000 to 1,670 m^3 per person per year renewable water resources.
- Chronic Water Scarcity Countries — Countries having water availability between 500 and 1,000 m^3 per person per year renewable water resources.
- Beyond "water barrier" countries — Countries having less than 500 m^3 per person per year renewable water resources.

Water scarcity in some countries have increased by several folds in the last two three decades. According to the estimate, more than 1 billion people do not have access to safe drinking water. The current level of water consumption and the effects of ecosystems degradation may further deplete water resources for the future generations (Cosgrove and Rijsberman, 2000).

International Year of Freshwater in 2003 focused on the safe drinking water availability and sustainable water resources management. For the governments, safe drinking water has become one of the priority areas.

Public water supply systems, in developing countries, are often inadequate to provide safe drinking water, and as a result there is a big gap in water supply and demand. Due to lack of availability of safe drinking water for a large population, commercial alternatives for drinking water are emerging. The emergence of bottled water industry is one of the most significant development in addressing the safe drinking water demand and supply imbalance. There are two important factors influencing the development of bottled water industry:

- Limited availability of safe drinking water, and
- Growing awareness among people to safeguard their health using bottled water.

Bottled water industry targets both of these factors and as a result there is a growing belief among people that bottled water is a safe alternative supply for drinking purposes. Since the demand for bottled water has increased significantly in the last decade, the bottled water industries are mushrooming throughout the world. At present, bottled water market for ten (10) selected countries have increased from 78.7

billion liters in 2000 to 121.9 billion liters in 2005. In the United States sales of bottled water have increased from 19.6 billion liters in 2001 to 31.25 billion liters in 2006. Asia is one of the fastest growing bottled water market, with 14% compound annual growth observed during the year 2006. In Canada, production and market of bottled water have reached 2,076 million liters in 2005. Canadian bottled water export was 222 million liters and import was 52.8 million liters (Beverage Marketing Corporation, 2006).

The province of Newfoundland and Labrador has large quantities of freshwater resources, which can be used for developing bottled water industries for both local consumption as well as exports. The development of bottled water industry in Newfoundland and Labrador will not only provide a better source for safe drinking water for the local population but also contribute to the economic development. A technical and economic feasibility analysis for the bottled water industry in the province is fundamental to the development of industries and offering bottled water export potential.

1.2 Objectives

The main objectives of this research are as follows:

- To describe global water supply and demand situation and discuss safe drinking water supply and demand scenario in the world.
- To assess and analyze possible alternatives to address safe drinking water supply and demand.

- To discuss state-of-the-art water treatment and water bottling technologies for bottled water production.
- To statically analyze quality of bottled water and examine its use as drinking alternative.
- To assess the economic and environmental feasibility of bottled water industry in Newfoundland and Labrador.
- To assess the economic feasibility of the bottled water export.

1.3 Organization of Thesis

This study consists of nine chapters:

- Chapter I is the introduction of the thesis describing the background, objectives, and organization of the thesis.

- Chapter II contains the review of global water supply and demand situation, focuses on the Canadian water supply and demand, water supply and demand in Newfoundland and Labrador, water quality and safe drinking water.
- Chapter III focuses on the literature review on the water treatment and water bottling technologies.

- Chapter IV includes discussion on the bottled water industry including an overview of the world bottled water demand and Canadian bottled water industry, regulatory framework, bottled water market, and potential for bottled water export.

- Chapter V presents bottled water quality analysis based on the literature research from various international bottled water brands.

- Chapter VI examines the prospect of bottled water production, analysis of potential water supply sources, water treatment systems for bottled water production in Newfoundland and Labrador.

- Chapter VII discusses the transportation system for bottled water export including transportation cost to the United States and Saudi Arabia.

- Chapter VIII presents cost and benefit analysis for the bottled water industry in Newfoundland and Labrador.

- Chapter IX provides conclusions and recommendations on the safe drinking water issues, and potential for bottled water industry in Newfoundland and Labrador.

Chapter II

WATER SUPPLY AND DEMAND

2.1 Introduction

Global, national and regional perspective for the variety of reasons indicated earlier, the global freshwater resources are depleting at an alarming rate. Nearly 166 million people in 18 countries are confronted with severe water scarcity, in addition to 11 countries with 270 million inhabitants who are also believed to be in the water stressed group. According to United Nations population projections, the water scarcity will continue to increase in future due to climate change and increase in population growth in the world (Gleick, 2001).

This chapter discusses (i) an overview of global, Canadian, Newfoundland and Labrador and Middle East and African freshwater resources, (ii) the global, Canadian, Newfoundland and Labrador freshwater supply and demand, (iii) the freshwater consumption and withdrawal, (iv) issues related to the water quality, causes of water contamination, and diseases caused by water contamination, and (v) the emergence of bottled water industry as one of the fastest growing industries in the world.

2.2 Freshwater Resources in the World

As indicated earlier, the global freshwater resources are under stress globally due to climatic changes, imbalance in hydrologic cycles, and population growth. The scarcity of freshwater is also becoming a major cause of conflicts in many countries that share the natural water resources. According to the United Nations Population Projection estimates, the water scarcity will increase more than five times of its present level in the next 50 years. Given the extent of current water scarcity, as well as future demand projections, evolving a feasible solution to meet freshwater demand – a basic human need, is extremely challenging. In many developing countries, inefficient water management practices are contributing to the deterioration of water quality and also growing water demand and supply gaps (Rahman and Husain, 2000).

Freshwater stocks are estimated about 35 million km^3 or 2.5% of the global water reservoir. A large part of freshwater (24 million km^3 or 68.7%) is in the ice form and permanent snow cover in the Antarctic and Arctic regions. The main sources of freshwater for human consumption are lakes and rivers that contain about 90,000 km^3 of water, or just 0.26% of total global freshwater reserves, as detailed in Table 2.1 (Shiklomanov and Gleick, 1993). Artificial lakes and reservoirs are significant in terms of water resources and in the river flow control systems.

Table 2.1: Global Water Resources

Water Reserves	Distribution Area (10^3 km^2)	Volume (10^3 m^3)	Percentage of Total Water (%)	Freshwater Reserves (10^3 m^3)
World Ocean	361,300	1,338,000	96.5	–
Ground water	134,800			
Freshwater		23,400		30.1
Soil Moisture		10,530		0.05
Glacier & Snow Cover	16,227	24,064	1.74	68.7
Antarctic	13,980	21,600		61.7
Greenland	1,802	2,340		6.68
Arctic Island	226	83.5		0.24
Mountainous Regions	224	40.6		0.12
Ground ice/ Permafrost	21,000	300.0	0.022	0.86
Water Reserves in Lakes	2058.7	176.4	0.013	–
Fresh	1236.4	91.0	0.007	0.26
Saline	822.3	85.4	0.006	
Swamp Water	2682.6	11.47	0.0008	0.03
River Flows	148,800	2.12	0.0002	0.006
Biological Water	510,000	1.12	0.0001	0.003
Atmospheric Water	510,000	12.9	0.001	0.04
Total Water Reserves	510,000	1,385,984.0	100.0	–
Total Freshwater Reserves	148,800	35,029.0	2.53	100.0

Source: Shiklomanov, 1993

The freshwater lake areas of the world are about 1.5 million km^2. The basic data on the 28 largest freshwater lakes of the world, with an area of more than 5,000 km^2 are presented in the Table 2.2.

The great lakes in the North America form one of the largest lake systems in the world. The largest lake in volume, Lake Baikal in former Soviet Union has approximately 25% of global freshwater resources (Shiklomanov, 1993). United

States, the former Soviet Union and Canada have the largest number of reservoirs and approximately half of the world's reservoir volume (Shiklomanov, 1998).

Table 2.2: Selected World Freshwater Lakes

Lake	Area (km^2)	Volume (km^3)	Depth (m)	Continent
Superior	82680	11600	406	North America
Victoria	69,000	2700	92	Africa
Huron	59800	3580	299	North America
Michigan	58100	4680	281	North America
Tanganyika	32900	18900	1435	Africa
Nyasa	30900	7725	706	Africa
Great Bear	30200	1010	137	North America
Great Slave	27200	1070	156	North America
Erie	25700	545	64	North America
Winnipeg	24600	127	19	North America
Ontario	19000	1710	236	North America
Ladoga	17700	908	230	Europe
Chad	16600	44.4	12	Africa
Tonle Sap	10000	40	12	Asia
Nicaragua	8430	108	70	North America
Titicaca	8110	710	230	South America
Athabasca	7990	110	60	North America
Vanern	5550	180	100	Europe
Zaisan	5510	53	8.5	Asia
Winnipegosis	5470	16	12	North America
Albert	5100	64	57	Africa
Mweru	5100	32	15	Africa

Source: Shiklomanov, 1993

Many countries have long range plans for developing water reservoirs, the volume is expected to reach 7000-7500 km^3 by the end of last century as shown in the Table 2.3. The water capacity of rivers and stream network depends on the climatic factors, geologic structures and severity of terrain.

Table 2.3: Selected World Reservoirs (km^3)

Countries	1971-1980	1981-1990	1991-1996	Total
North America	339.0	176.9	34.7	1692.1
Central & South America	251.5	349.1	236.1	971.5
Europe	103.6	49.3	2.7	645.0
Asia	484.1	321.5	221.6	1980.4
Africa	173.7	56.6	9.8	1000.7
Australia/New Zealand	42.4	5.9	0.3	94.8
Totals	1394.3	959.9	505.2	6384.5
Average Annual Addition	139.4	95.9	84.2	

Source: Shiklomanov, 1993

River water systems, has a significant contribution to the global water resources. Water storage in lakes is fully renewed in seventeen (17) years, however, in rivers it takes only sixteen (16) days (Shiklomanov, 1998). In the assessment of freshwater resources generally two criteria are used - static freshwater and renewable freshwater resources.

Renewed volume is generally measured as volume per unit of time per year (m/s, km/yr), which consists of regional runoff, and the inflow of ground water into the river network. The Amazon is the world's largest river with more than 15% of annual global runoff. Table 2.4 presents world's largest rivers average runoff volume with more than 200 km^3, which forms approximately 40% of global runoff (Shiklomanov, 1993).

Table 2.4: Selected World's Largest Rivers

River	Average Runoff (km^3)	Area of Basin (10^3 km^2)	Length (km)	Continent
Amazon	6930	6915	6280	South America
Congo	1460	3820	4370	Africa
Ganges & Brahmaputra	1400	1730	3000	Asia
Yangzijiang	995	1800	5520	Asia
Orinoco	914	1000	2740	South America
Parana	725	2970	4700	South America
Yenisei	610	2580	3490	Asia
Mississippi	580	3220	5985	North America
Lena	532	2490	4400	Asia
Mekong	510	810	4500	Asia
Irrawaddy	486	410	2300	Asia
St. Lawrence	439	1290	3060	North America
Chutsyan	363	437	2130	Asia
Amur	355	1855	2820	Asia
Mackenzie	350	1800	4240	North America
Niger	320	2090	4160	Africa
Columbia	267	669	1950	North America
Magdalena	260	260	1530	South America
Volga	254	1360	3350	Europe
Indus	220	960	3180	Asia
Danube	214	817	2860	Europe
Yukon	207	852	3000	North America
Nile	202	2870	6670	Africa

Source: Shiklomanov, 1993

World Resources Institute (WRI) 1996 as well as the Population Action International (PAI) Study (1993) have provided the quantities of renewable water resources for most of the countries. These projections indicate per capita water availability based on demographic forecasts between the years 1990 and 2025.

2.2.1 Freshwater Resources in Canada

The Canadian economic development and transportation is greatly influenced by the Canadian waters particularly rivers and lakes. Canada has approximately 20% of the world's freshwater resources. Canadian rivers annually discharge approximately 9 % of the world's renewable water. Canadian lakes cover approximately 7.6 % of the Canadian landmass, and approximately 2% of perennial snow (Environment Canada, 2000).

As presented in Table 2.5, the Mackenzie River is more than 4000 km long and is the largest river of Canada. The annual discharge of Mackenzie River is 312 billion cubic meters of water into the Arctic Ocean (WRA,1992). Great Bear Lake on the Northwest Territories is the world's ninth largest lake in terms of area.

Table 2.5: Rivers in Canada

Name of the Rivers	Length (kilometers) approx.
Mackenzie	4200 – 4300
St. Lawrence	3000 – 3001
Nelson	2600
Churchill	1600
Peace	1500
Fraser	1400
North Saskatchewan	1300
Ottawa	1250
Athabasca	1200
Yukon	1150
Liard	1100
Assiniboine	1050
Severn	1000
Albany	1000

Source: Environment Canada, 2000

The St. Lawrence – Great Lakes drainage basin is the largest in Southern Canada.

St. Lawrence river annually discharges 319 billion cubic meters of water (WRA,1992). There are 41 rivers in Canada having lengths from 673 km to 4241 km, and 22 lakes encompassing areas ranging from 2247 sq. km to 821000 sq. km. Some of the major lakes in Canada are listed in the Table 2.6.

Table 2.6: Lakes in Canada

Name of Lakes	Lake Area in km^2x1000 (Approximately)
Huron, Ontario	40.0
Great Bear, N.W.T.	31.5
Superior, Ontario	30.0
Great Slave, N.W.T.	28.5
Winnipeg, Manitoba	24.5
Erie, Ontario	13.0
Ontario, Ontario	10.0
Athabasca, Sask.	8.0
Reindeer, Sask. / Manitoba	7.0
Smallwood Reservoir, Nfld.	6.5
Netilling, N.W.T.	6.0
Winnipegosis, Man.	5.5
Nipigon, Ont.	5.0
Manitoba, Man.	4.8
Lake of the Wood, Ont./Man.	3.2
Melville, Newfoundland	3.0

Source: Environment Canada, 2000

The Northwest Territories and Nunavut cover about 34% of landmass and approximately 18 % of its area is covered with lakes. The average annual runoff produced within these two territories is 18 % of the total runoff in Canada (Eaton, 1994).

2.2.2 Freshwater Resources in Newfoundland and Labrador

The province of Newfoundland - Labrador Province with about half a million people, is the most easterly part of Canada. It covers an area of 405,720 square kilometers.

The area of the Newfoundland Island is 111,390 square kilometers (27% of the province) and Labrador is 294,330 square kilometers (73% of the province). The distance from the southern limit to the northern tip of the province is nearly 1,500 kilometers. The province's island part, Newfoundland, is situated in the Gulf of St. Lawrence while Labrador is situated on the northeastern part of Canada. The province has vast natural resources including lakes and ponds (WRA, 1992).

The surface water is the main source of drinking water in the province. Approximately 71% of the population use surface water for domestic and municipal uses, and remaining 29% uses groundwater. Smallwood Reservoir, 3640 square kilometers on the Churchill River in Labrador, is the largest water body in the province. In Newfoundland the largest water body is Grand Lake with a surface area of 354 square kilometers. The sizes of water bodies in the province are shown in the Figure 2.1 (Environment Canada, 2000; WRA, 1992).

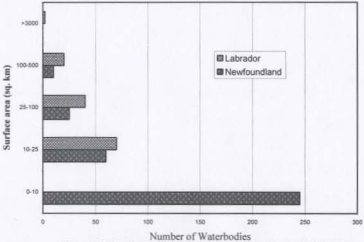

Figure 2.1. Distribution of water bodies in Newfoundland and Labrador

Source: WRI, 1992

Exploits River is estimated to have an annual run-off of about 8.5 billion cubic meters.

2.3 Freshwater Supply and Demand in the World

The consumption of water in the world is determined by three main factors:

- Population
- Economic Development
- Climatic and Geophysical Factors

A glance at the world's population indicates that it is growing at an alarming rate and has already exceeded 6,300 million. According to the forecasts it is expected to exceed 9,000 million by the turn of the century (PAI, 2003). It is predicted that the per capita water supply in the world will decline significantly due to population growth (Shiklomanov, 1993).

As noted in the Table 2.7, with 20% run-off volumes Brazil occupies the first place in the world in terms of water resources, followed closely by the former Soviet Union has second place with runoff volume approximately 10.6%, China (5.7%), Canada (5.6 %), the United States (4.4%), and India (3.8 %)(Shiklomanov,1993).

Table 2.7: Water Availability in Selected Countries (1980s)

Country	Area (10^3 km^2)	Population (10^6)	Total Runoff (10^3 m^3)	Percentage of Global Runoff
Brazil	8512	129.9	9230	20.7
USSR	22274	275	4740	10.6
China	9561	1024	2550	5.7
Canada	9976	24.9	2470	5.6
India	3288	718	1680	3.8
United States	9363	234.2	1940	4.4
Norway	324	4.1	405	0.9
France	544	54.6	183	0.4
Finland	337	4.9	110	0.2
World Total	134,800	4,665	44,500	100

Source: Shiklomanov, 1993

The water withdrawals and water consumption in a region is directly influenced by its population, industrial development, irrigation system and reservoir water losses due to evaporation (Shiklomanov, 1993). Water consumption in Asia, Africa and South America, where irrigation determines 70-90 % of total water withdrawals, depends on the accuracy of irrigated areas (Shiklomanov, 1993). Table 2.8 shows renewable water resources and water availability by continent.

Table 2.8: Renewable Water Resources and Water Availability

Continent	Area (million km^2)	Population (million) 1995	Maximum Water Resources (10^3m^3)	Water Availability (10^3 m^3/year)	
				Per km^2	Per capita
Europe	10.46	685	3410	277	4.23
North & Central America	24.3	453	8917	324	17.4
Africa	30.1	708	5082	134	5.72
Asia	43.5	3445	15008	311	3.92
South America	17.9	315	14350	672	38.2
Australia & Oceania	8.95	29	2843	264	82.2
The World	135.21	5635	44712	317	7.6

Source: Shiklomanov, 1998

As observed in the Table 2.8, Africa and the Middle East are facing severe water shortage. The poor water supply in the region is causing major restraint for socio-economic development. United Nations Environmental Program (UNEP) predicts, that two of every three people will live in water stressed region by the year 2025 (Christen, 2000).

The current water status in selected countries of the world is shown in Table 2.9 and 2.10. Annual available freshwater resources in South Africa, 50 billion cubic meters renewable resources once distributed to 44 million inhabitants will be less than 1000 m^3 per person per year, which is much lower than the minimum required for sustainability (Falkenmark, 1989). Although, Asia has the largest water resources, it has the lowest per capita availability because of its large population.

Table 2.9: Annual Renewable Freshwater Resources and Withdrawal - I

Countries	Renewable (km^3/yr)	Withdrawal (km^3/yr)	Per Capita Withdrawal (m^3/yr)
Former Soviet Union			
Russia	4498.0	77.10	527
Kazakhstan	109.6	33.67	1989
Ukraine	139.5	25.99	512
Uzbekistan	50.4	58.05	2320
Asia			
China	2829.6	525.46	412
India	1907.8	500.00	497
Indonesia	2838.0	74.35	350
Japan	430.0	91.40	723
Malaysia	580.0	12.73	571
Thailand	409.9	33.13	548
Oceania			
Australia	398.0	17.80	945
New Zealand	397.0	2.00	532
Papua New Guinea	801.0	0.10	21

Source: Gleick, 2001

The adequate renewable water resources supplies are concentrated in six countries of the world, which includes Brazil, Canada, China, India, Russia and the United States. More than 40% of total annual river runoff originates from these countries. Five large river systems: Amazon, Ganges & Brahmaputra, Congo, Yangtze, and Orinoko constitute 27% of the world's water resources, while River Amazon, the world's greatest river alone contributes 16% of annual global river runoff (Shiklomanov, 2000).

Table 2.10: Annual Renewable Freshwater Resources and Withdrawal - II

Countries	Renewable (10^3 m^3/year)	Withdrawal (10^3 m^3/year)	Per Capita Withdrawal (m^3/yr)
North America			
Canada	2901.0	43.89	1431
United States	2478.0	469.00	1688
South America			
Argentina	994.0	27.60	745
Brazil	6950.0	36.47	216
Chile	468.0	16.80	1104
Columbia	1070.0	5.34	137
Venezuela	1317.0	4.10	170
Mexico	357.4	77.62	785

Source: Gleick, 2001

Water resources planning during 20th century has been based on projections of population, per-capita water demand, agricultural production, and the levels of economic development. Shiklomanov and Markova have published current and projected water consumption by region for agricultural, industrial, and municipal sectors as well as water lost from reservoir evaporation (Shiklomanov 1993).

Gleick (1996) argues that water demand projections are based on the current trend in water consumption. The researcher maintains that the planning process should be based on the water demand projections and an anticipated water supply. The projections for the water withdrawal and water consumption for the year 2000 based on regions are summarized in the Table 2.11 and Table 2.12.

Table 2.11: Water Withdrawal and Consumption (2000)

Region	Withdrawals and Consumptive Use (10^6 m^3/year)	
Europe	404	158
Asia	2160	1433
USSR	533	286
Africa	289	201
North America	946	434
South America	293	165
Oceania	35	22.5
Total	4660	2700

Source: Gleick, 1996

The water withdrawal for human consumption in 1990 was 3,500 km^3 and water consumption was about 2,100 km^3. The remaining 1,400 km^3 are returned to rivers and lakes. In the WRI projection, global withdrawals were expected to rise 2% to 3% percent annually.

Shiklomanov (1998) used population and economic factors as main considerations for the detailed water demand assessments. He refines his water demand assessment and provides a comprehensive analysis for water resources for the different regions of the world. Asia due to its population has the largest water demand. Gleick (1996) points out that decrease in the overall water consumption is possible by improving water re-use. Global water supply and demand are presented in Table 2.12.

Table 2.12: Global Water Supply and Demand (million m^3/year)

Continent	Estimates 1995	Projected Forecast 2025
Europe		
Withdrawal	455	559
Consumption	187	256
North America		
Withdrawal	686	786
Consumption	238	269
Africa		
Withdrawal	219	337
Consumption	160	220
Asia		
Withdrawal	2231	3254
Consumption	1565	1876
South America		
Withdrawal	167	260
Consumption	97.7	120
Australia & Oceania		
Withdrawal	30.4	39.5
Consumption	97.7	22.3
Total		
Withdrawal	**3788**	**5235**
Consumption	**2265**	**2764**

Source: Shiklomanov 2000

2.3.1 Freshwater Supply and Demand in Canada

Canada's per capita demand for water is about 326 liters per person per day (CBWA, 1998). As detailed in Table 2.13, in many industries, such as steel, pulp and paper production, technical advancements have contributed to an eco-efficiency approach, which has significantly decreased the water use. For example, the water recirculation in a steel plant located on the St. Lawrence River in Quebec was able to realize a 36 percent reduction in the total volume of water used.

Table 2.13: Water Intake in Canadian Regions (million m^3/ year)

Region	Thermal Power	Manufacturing	Municipal	Agriculture	Regional Total
Atlantic	2126	601	356	15	3175
Quebec	1005	1616	1703	100	4498
Ontario	23095	3457	1660	186	28485
Prairies	2025	447	685	3014	6221
British Columbia	106	1161	698	676	2716
National Total	28357	7282	5102	3991	45096
Percent of total	63.0	16.0	11.0	9.0	100.0

Source: Environment Canada, 2000

2.3.2 Water Supply and Demand in Middle East and North Africa

Middle East and North Africa (MENA) is facing severe water shortage. It is estimated that about 5 % of the world's population has less than 1 % of all the renewable freshwater in the region. As shown in the Table 2.14 more than half of the population in MENA has less than 1,000 cubic meter renewable water resources annually on per capita basis, which is the lowest in the world. The per-capita availability of water in the region dropped to 1,250 m^3 a year in 1996 from 3,300 m^3 in 1960. Also, when comparing the world per capita average renewal water resources of 7,700 m^3, MENA's per capita renewable water resources of 1,000 m^3 falls far behind the world's average. In addition, more than 70% people in MENA share less than 2,000 m^3 water annually on per capita basis (Al-Qurashi and Husain, 2001).

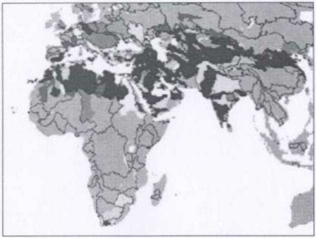

Figure 2.1: Water Scarcity in Middle East and Africa (MENA)
Adapted from Watersheds of the World, 2006

Gelick (1996) points out that the basic water requirement for human needs excluding water required to grow food is approximately 50 liters per person per day. In the year 1955 only Bahrain and Qatar were among "beyond water barrier" countries. It is, however, predicted that by the year 2025, other middle east countries including Jordan, Qatar, Saudi Arabia, United Arab Emirates, and Yemen will have per capita yearly renewable water resources below 300 cubic meter.

According to Population Action International (PAI) forecast total population of the world is likely to increase from 5.7 billion in 1995 to 9.4 billion in 2025. Due to the population growth and economic development, the world with relative sufficiency of water will reduce from 92% in 1995 to 58% by 2050.

Table 2.14: Comparative Evaluation of World Water Resources

Regions	Per capita renewable water resources per year (m^3)	Percentage of population with less than 1000 m^3 of water per person per year	Percentage Population between 1000 to 2000m^3 of water per person per year
Sub-Saharan Africa	7,100	8.0	16.0
East Asia and Pacific	5,300	< 10	6.0
South Africa	4,200	0.0	0.0
Eastern Europe and former USSR	11,400	3.0	19.0
Other Europe	4,600	6.0	15.0
Middle East and North Africa	1,000	53.0	18.0
Latin America and the Caribbean	23,900	< 10	4.0
Canada and USA	19,400	0.0	0.0
World	7,700	4.0	8.0

(Al-Qurashi and Husain, 2001)

In 1995, world population with water stress was estimated to be 5%, which is predicted to increase up to 24% by the year 2050. The water scarcity in the world will increase to 18% in 2050 compared to 3% in 1995 (Al-Qurashi and Husain, 2001).

In the water scarcity statistics presented in the Table 2.15, water consumption has been ranked from highest to lowest. Table 2.16 presents water consumption in the countries for domestic, agricultural, and industrial sectors. The countries are ranked according to their consumption and renewable of water per person based on the data collected from Food and Agriculture Organization (FAO) and Population Action International (PAI). A comparison of these ranks reveal considerable disparity in the supply and demand of water among the listed countries.

In the Middle East, Saudi Arabia is ranked number 3 from the consumption point of view and ranks number 9 from the supply point of view. United Arab Emirates (UAE) ranks number 4 for per capita water consumption. However, based on the renewable water availability, UAE has the lowest per capita water availability in the region (PAI Analysis). In Qatar, the per capita consumption of water is much higher and ranks 7 (Table 2.16) compared to per capita availability of water resources (Al-Qurashi and Husain, 2001).

Table 2.15: Water Scarcity Countries in the World Based on UN Analysis

Countries	Renewable Water 10^3m^3/ year	1995		2025	
		Population x 1000	m^3 per person per year	Population x 1000	m^3 per person per year
Malta	30	367	82	395-448	67-76
Qatar	50	548	91	739-819	61-68
Kuwait	161	1691	95	2647-3160	51-60
Libya	600	5407	111	12422-13359	45-48
Bahrain	90	557	162	795-928	97-113
Singapore	599	3227	180	3939-4397	136-152
Barbados	50	261	192	276-311	161-181
UAE	489	2210	221	3098-3496	139-157
Saudi Arabia	4550	18255	249	40916-43531	105-111
Jordan	1710	5373	318	11375-12414	138-150
Yemen	5199	15027	346	36535-42307	123-142
Israel	2148	5525	389	7183-8744	246-299
Tunisia	3900	8987	434	12323-14618	267-316
Algeria	14800	28109	527	43374-50615	292-341
Brundi	3597	6064	594	11986-13209	273-300
Cape Verde	300	386	777	630-727	413-476
Oman	1929	2207	874	6044-6943	278-319
Egypt	58874	62096	936	87577-103979	559-663

Source: Al-Qurashi and Husain, 2001

PAI has carried out a detailed analysis on the renewable water resources, population increase, and per capita availability of water in the world. Table 2.16 represents international scenario in terms of water consumption. The statistics published by PAI is updated from time to time and is considered to be the most reliable. Based on the recent statistics, PAI, the Middle East and the North African region has been found under the category of "beyond water barrier" with water availability less than 500 m^3/person/day.

Table 2.16: Water Consumption in Middle East

	Water Consumption in million cubic meter per year			
	Domestic	Agriculture	Industrial	Total
Countries	10^3m^3/yr	10^3m^3/yr	10^3m^3/yr	10^3m^3/yr
Bahrain	86	120	17	223
Iraq	3800	40000	5600	49400
Israel	544	1105	105	1754
Jordan	190	650	43	883
Kuwait	295		8	383
Lebanon	310	750	60	1120
Oman	81	1150	5	1236
Qatar	76	109	9	194
Saudi Arabia	1508	14600	192	16300
Syria	650	6930	146	7726
Turkey	5200	22900	N/a	N/a
UAE	513	950	27	1490
Palestine	80	130	0	210
Yemen	168	2700	31	2899

Source: Al-Qurashi and Husain, 2001

Al-Qurashi and Husain (2001) assert that as a result of water shortage in the region, the riparian countries sharing ground water and surface water resources may, at some point enter into competition and conflict over water. They stress on the need of assessing the situation in order to avert conflicts related to water in the region.

2.4 Water Quality

The water quality is determined on the basis of water use and different water uses require different parameters to maintain the water quality. The water used for drinking, fishing, recreational, aquatic organisms requires higher levels of water quality. The water quality depends on the characteristics of physical, chemical, and biological parameters. Chemicals are frequently discharged into rivers, lakes, and coastal areas without any water treatment. Due to these discharges water related diseases, such as, cholera, dysentery and malaria causes illness in half of the developing countries and claims nearly five million lives annually in the world (WRI, 1997). Water quality is local in nature and differs considerably from one location to another, season, and span of time. It is therefore difficult to establish a criterion for the global water quality parameters (Shiklomanov 1997).

Shiklomanov (2000) observes that contamination in water supplies is a worldwide phenomenon. He points out that the main contamination problems are caused by fecal and organic pollution. Although fecal contamination of water has been eliminated in most of the developed countries, pollution due to organic matter continues to exist, he maintains. He emphasizes that other pollution problems in developed and developing countries are associated with agricultural runoff and industrial effluents. He goes on to maintain that in developing countries like China, India, Mexico, and Brazil, contamination due to untreated sewage and industrial wastes is a major cause of deterioration in the water quality.

There are a number of chemical, physical, and microbial factors which effect water quality these include organic pollutants, nutrients, freshwater heavy metals, microbial contamination, acidification and suspended particle (Shiklomanov 1997).

Although water-related diseases have been eliminated in most of the developed countries, they continue to remain a major concern in most of the developing countries. According to WHO, there are 4 billion cases of diarrhea each year, in addition to millions of other cases of illnesses associated with the lack of safe drinking water. In addition, there are numerous undiagnosed and unreported illnesses, which make it difficult to present a realistic figure on the illnesses caused by water pollution (Gleick, 2002 and WHO, 2000).

Water-related diseases can be categorized in four classes: (i) waterborne, (ii) water-washed, (iii) water-based, and (iv) water-related insect vectors. The first three are most clearly associated with the lack of improved domestic water supply. A brief description on the diseases associated with each class is provided in Table 2.17.

Waterborne diseases caused by the ingestion of contaminated water by human, which is due to animal faeces, urine containing pathogenic bacteria or viruses, is a major cause of diseases such as cholera, typhoid, dysentery as well as diarrhea. Water-washed diseases that are caused by poor personal hygiene, and skin or eye contact with contaminated water include scabies, trachoma, flea, lice and tick-borne diseases. Water-based diseases are caused by parasites found in intermediate organisms living in contaminated water. Other water-related diseases are caused by insect vectors, mosquitoes that breed in water and include dengue, filariasis, malaria and yellow fever (Gleick, 2002).

Table 2.17: Selected Water-Related Disease Morbidity and Mortality

Diseases	Estimated people infected/ year	Estimated Mortality (Deaths/year)	Relationship of Disease to Water and Sanitation Condition
Diarrheal diseases	1,000,000,000	2,200,000 to 5,000,000	Sanitary disposal, poor Hygienic conditions, unsafe drinking water
Intestinal helminthes	1,500,000,000	100,000	Unsanitary excreta disposal, poor hygienic condition
Schistosomiasis	200,000,000	200,000	Unsanitary excreta disposal, Safe water scarcity
Dracunculiasis	150,000	-	Strongly related to unsafe drinking water
Trachoma	150,000,000	-	Strongly related to lack of face washing, lack of safe water
Poliomyelitis	114,000	-	Unsanitary excreta disposal, poor hygienic condition, Unsafe drinking water
Trypanosomiasis	275,000	130,000	Safe water scarcity

Source: Gleick, 2002

The number of anticipated deaths from water-related diseases in the next two decades depend on the global population, relative rates of mortality from various diseases, the incidence of diseases, interventions on the part of the health community, and proactive approach in providing safe drinking water, and eradication of water born diseases (Gleick, 2002).

According to UN reports, global population, between 2000 and 2020 will grow from 6 billion to 7.5 billion, with the maximum population growth in the developing countries of Africa and Asia. The availability of safe drinking water will have greatest impact on the poorest populations of the world in the form of sickness, absenteeism from work and premature death. Unless United Nations Millennium Goals for safe drinking water in collaboration with national governments and international aid agencies work towards for providing safe drinking water, as many as 76 million people will die by 2020 due to water-related diseases, which otherwise can be prevented.

2.5 Safe Drinking Water

To provide adequate supply of safe drinking water to every segment of society is the greatest challenge of this century. The greatest impact of the poor quality of water is associated with high mortality rate among young children. As presented in Table 2.18 represents access to safe drinking water in developing countries.

Table 2.18: Safe Drinking Water in Developing Countries

Region	Population (1994)	Water Access Percentage (%)	Population Unserved (millions)
Africa	707	46	381
Latin America & Caribbean	473	80	97
Asia & The Pacific	3,122	80	627
Western Asia	81	88	10
Total	4,383	74	1,115

Source: Gleick, 2001

The United Nations, in collaboration with countries, regularly monitors availability of water around the world. According to a WHO report published in 2000, 89 percent of the 1.1billion people around the world lack access to 'improved water supply.'

Advancement in the water treatment technologies can provide safe drinking water for public water supply systems. Due to the lack of access to safe drinking water, in the last two decades bottled water has emerged as an alternate for safe drinking water in most of the countries. Bottled water fulfills demand for safe drinking water, but it is confined to a limited section of population. Global bottled water industry is one of the fastest growing industries.

Chapter III

LITERATURE REVIEW

3.1 Introduction

The safe drinking water quality is a matter of concern in most of the countries. A water quality analysis may provide dissolved mineral composition, organic matters and dissolved gas. The water treatment needs are different based on many water quality parameters. Due to the current drinking water demand and pollution problems, water quality is deteriorating and may need treatment for drinking uses. In the selection and design of water treatment system, selection of water quality is very significant. The drinking water quality guidelines of the World Health Organizations (WHO), Health Canada, International Bottled Water Association (IBWA) and Canadian Bottled Water Association (CBWA), can be considered for the water treatment and water bottling industries.

The water treatment technologies may include preliminary water treatment, filtration, such as micro-filtration, ultra-filtration, nano-filtration and reverse osmosis, the disinfection process may include ozonation and ultra violet (UV) radiation. Therefore, water quality and water treatment are very significant for water bottling process.

3.2 Water Treatment Technology

There are two types of water sources used for bottled water production, surface water and ground water. The water bottler considers regulations, consumer preference, and economical aspects of availability of the water source. The water quality sources as detailed by Hidell-Eyster (1997) are presented in Table 3.1.

Table 3.1: Water Sources for Bottled Water Treatment

Natural Mineral Water	A protected source where water is bottled directly at the source without any treatment to alter its natural mineral.
Spring Water	
Natural	A spring water or pumped groundwater connected to a spring water source may require minimum treatment for water bottling.
Spring Water	A naturally flowing spring water or pumped from ground water connected to a spring may require a treatment, which changes the chemical composition of the water.
Well Water	
Artesian	A drilled well through a 'confining layer' such as clay, due to hydraulic head pressures rises up the well casing to an elevation above the static level of the tapped aquifer.
Non-artesian	A drilled well into a ground water aquifer.
Surface Water Lakes/Rivers Surface	Surface water sources such as lakes, rivers and ponds.

Source: Hidell-Eyster, 1997

According to Health Canada Drinking Water Quality Guidelines (2006), three main indicators are, microbiological, chemical, and aesthetic. The microbiological indicator includes bacteria, protozoa, and viruses, which may cause gastrointestinal diseases. A chemical indicator, which covers a range of chemicals (such as magnesium, calcium, iron and manganese) may be found due to natural causes or from human activities. The presence of these materials in the drinking water may cause various diseases such as cancer. An aesthetic indicator deals with the issues of taste, odor, turbidity and color, which may be due to the presence of natural organic matters in the water. Some aesthetic indicators do not cause any disease. In order to ensure safe drinking water quality, these indicators must be managed properly.

3.2.1 Preliminary Water Treatment

3.2.1.1 Suspended Solid Removal

In the preliminary water treatment process for suspended solids removal, as shown in Figure 3.1, screening, sedimentation and filtration are considered. Screening process removes large debris, micro straining of algae, and other small particles. This process is necessary for a fast flowing stream or river. In order to oxidize organic matters chlorine and ammonia may be added. In the next step, turbid water with no debris, organic matter enters into sedimentation tank.

Screens which may retain particles (20 to 40 μm) or more may be used with parabolic design. In the main process, a large volume of lightly contaminated water is used so that filtration may be avoided (Wayman, 1998).

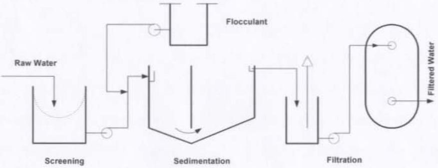

Figure 3.1: Suspended Solids Removal

Source: Wayman, 1998

In the sedimentation, as detailed in Figure 3.1, suspended materials are settled, and sand particles are detained, and smaller particles and organic matter may take about three (3) to four (4) hours time. In this process, a horizontal, vertical or radial flow may be considered. In a parallel way, sheet material is assembled and added to a conventional settler tank (Wayman, 1998).

The flotation process is performed in the initial stages of water treatment and a compressed air is used in this process. Dissolved air flotation (DAF) system is also used in combination with an activated carbon or a coagulant. Retention time is approximately 30 minutes, and DAF units may be installed in smaller spaces (Wayman, 1998).

3.2.1.2 Iron and Manganese Removal

In the preliminary water treatment for iron and manganese removal as shown in Figure 3.2, which may consist of aeration, iron removal and hypo chlorination chambers. The ground water enters into aeration chamber, which performs process of degassing, water then runs down in a packed column and use a reduced pressure in a special chamber. Then water enters into iron or manganese removal chamber, then enters into hypo-chlorination chamber at the same time, oxygen will be absorbed between 8 - 10 mg/liter (Wayman, 1998).

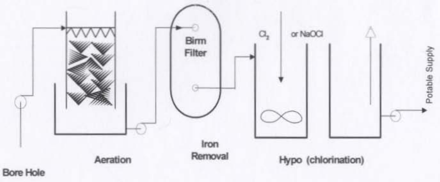

Figure 3.2: Iron and Manganese Removal

Source: Wayman, 1998

3.2.1.3 Water Softening

The preliminary water treatment process for water softening, as shown in Figure 3.3, which may consists of magnesium precipitation chamber, calcium precipitation chamber and settlement chamber. The source water enters into magnesium precipitation chamber and lime is added to perform action for magnesium precipitation, then water enters into calcium precipitation chamber and soda ash is added to perform action for calcium precipitation. This process removes calcium and magnesium minerals. The water may be softened by lime or soda ash. In the last process, all matters are settled and removed by filtration process (Wayman, 1998).

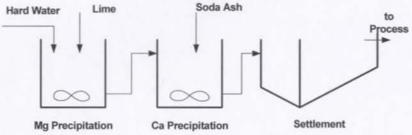

Figure 3.3: Water Softening Process
Source: Wayman, 1998

3.2.2 Filtration Process

Membrane filtration process use semi-permeable membranes to remove bacteria, organisms, particulate material, and natural organic material from the source water. Membrane filtration is sophisticated but its less expensive method for water filtration. This process may be installed easily and is very appropriate for water filtration process, and source water does not require any pretreatment.

Table 3.2: Summary of Membrane Filtration Technology

Technology	Efficiency	Operation	Waste	Limitation
MF	*Giardia*, and Viruses	Pre or Post Treatment	Low Volume	High quality water, pretreatment, and disinfection required for viral inactivation
UF	*Giardia* and Viruses	Pre or Post Treatment	Volume 5 - 20%	High quality water pretreatment and disinfection required for viral inactivation
NF	Cysts and Viruses	Pre or Post Treatment	Volume 5 - 20%	High quality water pretreatment, and disinfection required
RO	Cysts and Viruses	Pre or Post Treatment	Volume 25 - 50%	Pretreatment required to protect membrane surface

Source: Pailhes, 1997

Membrane filtration used in water treatment systems may include micro-filtration (MF), ultra-filtration (UF), nano-filtration (NF), and reverse Osmosis (RO) as detailed in Table 3.2 (Pailhes, 1997).

3.2.2.1 Micro Filtration (MF)

In micro-filtration, membranes with pore size of about 0.03 to 10 microns are used. The membranes also has specification that the molecular weight cutoff (MWCO) is greater than 100,000 Daltons and a relatively low feed water operating pressure of approximately 100 to 400 kPa or 15 to 60 psi. This process is effective to remove sand, silt clays, *giardia lambia* and *cryptosporidium*, cyst, algae, and some bacterial species. This process is not effective for virus removal, but virus removal may be designed in combination with disinfection process, such as ozonation and ultra-violet (UV) radiation (Pailhes, 1997).

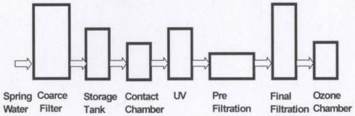

Figure 3.4: Micro-filtration in Bottled Water Industry

Source: Pailhes, 1997

As shown in the Figure 3.4, spring water enters to a coarse filter chamber then enters to different chambers to get desired water. Since ozone in the water may oxidize filter cartridge components, which may affect filter efficiency, therefore ozonation may be the last process in a water bottling process. In the selection of filter media (membrane vs depth) and the cartridge connection the recommendation of micron rating may vary from manufacturer to manufacturer. The water bottling process should evaluate the filter retention data for microorganism of concern like cryptosporidium, giardia and bacteria. The installation of micro filters may be as close as possible to the ozone contact chamber and water bottling system (Pailhes, 1997).

Micro-filtration may use a tubular and hollow capillary fiber design, which may process less than one million gallon per day (MGD). A complete design and construction of micro-filtration may have a prescreen, feed pump, membranes, cleaning tank, automatic gas backwash system, air compressor, membrane integrity monitor, backwashed water transfer tank, pressure break reservoir, air filter for the gas backwashed, control for the programmable logic controller, and coalescer (Pailhes, 1997).

3.2.2.2 Ultra Filtration (UF)

As shown in the Figure 3.4, the ultra-filtration process may use pressure-driven separation of material in the water source. Ultra-filtration media are membranes with pore size of about 0.002 to 0.1 microns with molecular weight cutoff (MWCO) and are approximately 10,000 to 100,000 Daltons and an operating pressure of approximately 200 to 700 kPa or 30 to 100 psi. This process may remove all microbiological species that cannot be removed by micro filtration. Ultra-filtration may also remove some types of virus in the water, but it may not remove all types of viruses. In ultra-filtration process, there is no need to add chemicals in the system for coagulation, flocculation and sedimentation process (Pailhes, 1997).

Ultra-filtration membrane designs have tubular and flat-sheet geometry. Ultra filtration membrane is used usually for water treatment plants of less than one and half million gallons per day (1.5 million gallons per day). Ultra filtration consist of auto cleaning pre-filter, feed pump, membranes, re-circulation pump, backwashed water pump, air compressor, chlorine dosing pump for the backwashed water, chlorine tank, chemical tank (detergent), control for the programmable logic controller with program and security sensor (Pailhes, 1997).

3.2.2.3 Nano Filtration (NF)

As shown in the Figure 3.4, the nano-filtration process may remove all cyst, bacteria, viruses, and humic materials. Nano filtration has filter media of membranes with pore size approximately 0.001 microns with molecular weight cutoff (MWCO) is approximately 1,000 to 100,000 Daltons and an operating pressure of approximately 600 to 1.000 kPa or 90 to 150 psi. This membrane is capable of reducing hardness of water, and due to this nano filtration is also called as softening membranes. This process consists of membranes, feed pump, and some equipment for pretreatment of water to avoid precipitation of hardness ion in the membranes (Pailhes, 1997).

3.2.2.4 Reverse Osmosis (RO)

Reverse osmosis process has membrane filtration system for small water treatment plants. This is a compact system and have minimum labor requirements. The function of reverse osmosis in the water treatment is to remove almost all organic contaminants, radium, natural organic substances, pesticides, cysts, bacteria, and viruses.

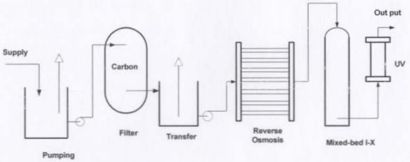

Figure 3.5: Reverse Osmosis Process

Source: Wayman, 1998

In this process, clean water can be obtained near zero effluent contaminant concentration but disinfection process is necessary to get safe drinking water. In the process a high water pressure approximately 2100 kPa or 300 psi through a semi-permeable membrane is passed. In the opening of the membrane water molecules passes and leaves a high percentage of inorganic contaminants. Pretreatment is preferred in this process, which may involves filtration and sometime softening, chemical additions or both to prevent membrane fouling. Reverse osmosis has high capital and operating cost due to the design parameters (Wayman, 1998).

3.2.3 Disinfection Process

Disinfection process may destroy any pathogen present in the water. Conventional water disinfection process involves chlorine to kill pathogenic microorganism in the water. In order to meet the standards for safe drinking water, one coliform organism per 100 ml drinking water may be present. An important criteria to use disinfection in the water treatment process is that the dose of disinfectant must be toxic to the microorganism but below the toxic threshold to humans.

3.2.3.1 Ozonation

3.2.3.1.1 Application of Ozone

Ozone is used for the disinfection of water. This process removes and control inorganic pollutant oxidation (e.g., iron, manganese and sulfide), organic micro pollutant oxidation may cause taste and odor problems, color removal and dissolved by products (DBPs). Ozone is a strong oxidant and may oxidize most of the organic and inorganic compounds in the water because it is more easily absorb in the water than oxygen (Kinman, 1975).

3.2.3.1.2 Ozonation Process

As shown in the Figure 3.6, the compressed air is passed to oxygen generator chamber, then oxygen is passed to ozone generator chamber. The generated ozone is injected into the water treatment process to disinfect micro organisms. In the next process the ozone extractor chamber removes the exess ozone and a process in ozone decomposer chamber (Rice, Overbeck and Larson, 1998).

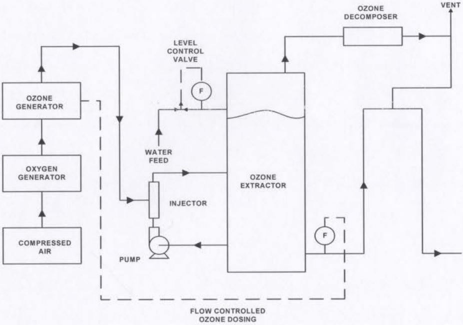

Figure 3.6: Ozonation for Water Bottling Process

Source: Rice, Overbeck and Larson, 1998

As shown in the Figure 3.6, the source water is then passed through a venturi throat, which creates a vacuum and pulls the ozone gas into the water or the air is then bubbled up through the treated water. Since the ozone will react with metals to create insoluble metal oxides, therefore post filtration is required.

The formation of oxygen into ozone occurs with the use of energy. This process is carried out by an electric discharge field as in the CD-type ozone generators (corona discharge simulation of the lightning), or by ultraviolet radiation as in UV-type ozone generators (simulation of the ultraviolet rays from the sun). In addition to these commercial methods, ozone may also be formed through electrolytic and chemical reactions. In general, an ozonation system includes passing dry, clean air through a high voltage electric discharge, i.e., corona discharge, which creates an ozone concentration of approximately 1% or 10,000 mg/l. In treating small quantities of water, the UV ozonators are most commonly used, while large-scale systems use either corona discharge or other bulk ozone-producing methods (Rice, Overbeck and Larson, 1998).

According to Hoigne and Bader (1976) ozone may be generated on site because it is unstable and decomposes in a short time. With the introduction of ozone to the water, it disinfects water with several mechanisms such as direct destruction of cell wall of the organism, reacting with radical by-product of ozone decomposition, damage the microorganism nucleid acids, and breakage of carbon-nitrogen bonds leading to depolymerization. A decomposition of ozone process starts with a series of steps, there is no established mechanism and reaction, which may be discussed.

3.2.3.1.3 Efficiency of Ozone

Efficiency of ozone disinfection depends on the sensitivity of the target organisms, contact time and concentration of the ozone. Ozone concentration generally ranges from <0.1 mg/liter to 1.0 mg/liter. Efficiency of the ozone production is 2% and 5%-7% with the use of air and oxygen respectively. The water bottling process use ozonation to treat large quantities of water because of its efficiency. Ozone may be added to the point of water treatment process, which may revert back to oxygen chamber, it may keep water sanitized throughout the facility (Zabel, 1985).

The International Bottled Water Association (IBWA) recommends that ozone may be applied in the range of 1.0 to 2.0 milligram per liter (mg/liter) for 4 to 10 minutes contact time to ensure an appropriate and safe disinfection. Application may maintain a 0.1 to 0.4 ppm residual ozone level in the water bottling process. This provides an additional safety factor because the bottles can be disinfected and sanitized while filling the treated water.

As discussed by Domingue (1998), ozone is very effective against bacteria, and concentrations 0.6 μg/l and 9 μg/l of ozone on *E.coli* and *legionella pneuophila*, respectively may be able to reduce their levels by 4 logs (99.99 % removal) in less than 1 minute. Peters (1989) mentioned, that protozoan cysts are more resistant to ozone, and the *giardia lamblia* is sensitive, but *cryptosporidium* is more resistant to ozone. Ozone efficiency results indicate that ozone is one of the most effective disinfectant for cryptosporidium. A brief description on inactivation of *cryptosporidium oocysts* is presented in Table 3.4.

Table 3.4: Ozonation Inactivation of Cryptosporidium Oocycts (99%)

Species	Ozone protocol	Ozone residual (mg/L)	Temperature (°C)	Contact Time (mg.min/L)	Reference
C. bailley	Batch liquid, modified batch ozone	0.6 & 0.8	25	2.4 – 3.2	Langlais et al., 1990
C. parvum	Batch liquid, batch ozone	0.50 0.50	7 22	9.0 3.9	Finch et al., 1993
C. parvum	Batch liquid, batch ozone	0.77 0.51	Room	4.6 4	Peeters et al., 1989
C. parvum	Batch liquid, continuous gas	1.0	25	5 - 10	Korich et al., 1990
C. parvum	Flow through contactor		22 - 25	5.5	Owens et al., 1994

Source: USEPA, 1998

Generally, viruses are more resistant to ozone. Ozonation may disinfect polio and coxsackie viruses up to 3 logs, by ozone residual 0.8 mg/liter and 1.7 mg/liter respectively with a 5 minutes contact time. The contact time requirements may vary from study to study which may leads to uncertainty to CT design requirements for specific applications and regulatory needs (USEPA, 1998).

3.2.3.2 Ultra Violet Radiation (UV)

3.2.3.2.1 UV Application

UV application for most of the bacteria and viruses require low UV dosages of 2-6 $mW\text{-}s/cm^2$ for 1-log inactivation. The UV doses for 2 and 3 log inactivation of viruses are 21 and 36 $mW\text{-}s/cm^2$, respectively. As discussed by DeMers and Renner, (1992) *giardia* and *cryptosporidium* are more resistant to UV inactivation than other microorganisms. The UV dose required to inactivate protozoa (*giardia* and *cryptosporidium*) is several times higher than the bacteria and virus inactivation. UV process in combination with ozone may improve the efficiency of disinfection in the water treatment process for *giardia* and *cryptosporidium*.

3.2.3.2.2 UV Process

As shown in Figure 3.7, ultraviolet (UV) radiation process inactivates organisms by absorption of light, which causes a photochemical reaction. As discussed by Dimitrion (1993), UV rays are electromagnetic waves and penetrate into the cell wall of microorganisms. The UV rays react with the nucleic acids and other vital cell, which results injury or death to exposed cells (Bukhari, 1999).

In this process UV lamp transmits radiation generated by an arc. The UV energy radiation wave ranges between 100 nm to 400 nm long (between X-rays and visible light spectrums (White, 1992). The UV disinfection utilizes either of the following process.

- Low-pressure lamp emits maximum energy at a wavelength of 253.7 nm,
- Medium-pressure lamp emits energy at wavelengths 180 -1370 nm and
- Lamps emit energy at wavelengths with a higher intensity.

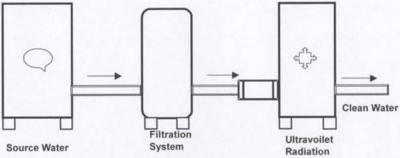

Figure 3.7: Ultra Violet Disinfection Process

Source: Hofmann and Andrews, 2002

3.2.3.2.3 Efficiency of UV

According to White (1992), the destruction or inactivation of microorganism is directly related to the UV dose, determined by:

$D = I \times t$; where,

D = UV dose (mW-s/cm^2)

I = Intensity (mW/cm^2)

t = Exposure time (s)

This dose response relationship for germicidal effect indicates:

- A high intensity of UV radiation over a short period of time.
- A low intensity of UV radiation over a longer period of time.

UV should absorb to achieve microorganism inactivation. Therefore, anything that prevents UV from reacting with the microorganism will decrease the disinfection efficiency. Factors that affects disinfection efficiency of UV are chemical and biological films, that develop on the surface of UV lamps, dissolved organic and inorganic matter, clumping or aggregation of microorganisms, turbidity, color and short circuiting in water flowing through the UV contactor (Scheible and Bassell, 1981; Yip and Konasewich,1972).

Innovative water treatments technologies are usually used in many bottled water industries to ensure the consumer that bottled water produced are the best quality. Water bottling industries generally use filtration and disinfection in the water treatment process. There are number of packages available for water treatment systems. Most of them are using combination of micro-filtration, ozonation and ultraviolet radiation. In order to apply appropriate water treatment technology and process, a detailed water quality analysis of the source water and other site investigations are required.

Chapter IV

BOTTLED WATER INDUSTRY

4.1 Introduction

Bottled water industry in the world is highly fragmented and dominated by local brands. Currently four bottled water companies dominate the international market. Out of these, Swiss food and beverage company Nestlé and French company Danone are the leaders in the bottled water industry. Nestle and Danone companies, in the past concentrated their operations around Western Europe and the United States, but now they have also entered into Asia, Latin America, and other countries.

The United States companies, Coca-Cola and PepsiCo are also in the bottled water business. Although, PepsiCo and Coca-Cola are the top two brands in the U.S. bottled water market, they do not pose any threat to Danone and Nestlé in Western Europe. In developing countries, bottled water demand is growing in Asia, Eastern Europe and South America.

4.2 International Bottled Water Association (IBWA)

As a business association of manufacturers and distributors of bottled water industry, International Bottled Water Association (IBWA) was established in 1958. IBWA is involved in regulating and promoting standards for bottled water quality. The IBWA promotes the adoption of Model Bottled Water Code of the Codex Alimentarius (Codex), IBWA Model Code and United States Food and Drug Administration (USFDA) code to regulate the quality of water source for the bottling of water. IBWA Technical Manual provides guidelines on the processing and quality control procedures in the production of bottled water. IBWA members undergo annual, unannounced plant inspection conducted by National Sanitation Foundation (NSF). The Canadian Bottled Water Association (CBWA) was established in 1992. During the last decade, the bottled water demand significantly increased during the flooding of Quebec and Manitoba as well as the ice storm crisis in Ontario and Quebec.

Water quality has always been an important issue for public concern. Increasing consumer awareness for the quality of drinking water has contributed in the refinement of regulations to ensue protection for public health. Regulations provide precise definitions for the bottled water quality, standards, processing, labeling, and advertising.

Internationally, regulatory agencies coordinate to solve trade disputes and differences in regulations and standards. The organizations listed below play an important role in the regulation of bottled water industry worldwide in cooperation with other regional organizations.

- World Trade Organization (WTO)
- Food and Agricultural Organization (FAO) and the World Health Organization (WHO) have developed Codex Alimentarius (Codex) for world food standard.
- United States Food and Drug Administration (FDA)
- International Bottled Water Association (IBWA) Model Code
- Canadian Bottled Water Association (CBWA) Model Code
- Asian Bottled Water Association (ABWA)

The Federal Regulations for the bottled water industries constitute a basis for Good Manufacturing Practice (GMP), Bottled Water Standard of Identity, advertising and labeling. The GMP covers regulations concerning all sealed water in bottles, packages, or other containers offered for sales, including bottled mineral water. The areas governed under the processing and the bottling of drinking water is as follows:

- Plant Construction and Design
- Sanitary Facilities
- Source Water
- Operations Water
- Analysis of Source
- Sampling and Analytical Methods
- Production and Process Control

Bottled water manufacturers must ensure that their products meet the applicable regulations and standards for bottled water. Bottled water must bear an appropriate name. The standards and regulations lays down parameters for microbiological, physical, chemical and radiological limits for source water and product bottled water.

4.3 Global Bottled Water Market

Global market for bottled water is growing enormously. An estimated market demand for ten (10) leading countries is presented in Table 4.1. In 2005, the United States ranked #1 with 28500.4 million liters and a compound annual growth (CAG) of 9.8%. In Europe, Germany, France and Spain are some of the largest consumer of bottle water: Germany consumes 10525.7 million liters and 4.7% compound annual growth, France with 8379.8 million liters and 2.4% compound annual growth and Spain with 5891.5 million liters and a 7% compound annual growth, respectively.

Table 4.1: Global Bottled Water Market (2000 – 2005)

2004	Countries	Quantity (million liters)		Compound Annual Growth (CAG) %
Rank		**2000**	**2005**	**2000/05**
1	United States	17860.8	28500.4	9.8
2	Mexico	12398.4	18761.2	8.6
3	China	5980.7	12833.4	16.5
4	Brazil	6802.4	12187.8	12.4
5	Italy	9202.4	11086.3	3.8
6	Germany	8382.9	10525.7	4.7
7	France	7446.6	8379.8	2.4
8	Indonesia	4291.4	7592.5	12.1
9	Spain	4198.8	5891.5	7.0
10	India	2145.1	6144.4	23.4
	Top 10 Subtotal	**78709.8**	**121903.5**	**9.1**
	All Others	29236.4	41760.6	7.4
	Total	**107946.2**	**163664.2**	**8.7**

Source: Beverage Marketing Corporation, 2006

South America, Mexico and Brazil have significant demand for bottled water. Mexico consumes 18761.3 million liters of bottle water and 8.6% compound annual growth, while Brazil consumes 12187.8 million liters of bottle water with a 12.4%, compound annual growth. In Asia, China tops the demand for bottle water with 12833 million liters and 16.5% compound annual growth followed by India with 6145 million liters and 23.4% compound annual growth and Indonesia consumes 28699.6 million liters with 12.1% compound annual growth. A global trend for the bottled water demand is shown in Table 4.2.

As shown in the Table 4.2, Asia's ranks #1 in terms of bottled water compound annual growth with 14% growth. North America ranks #2, South America ranks #3, Africa/Middle East/Oceania ranks #4 and Europe ranks #5. An average compound annual growth rate for global market during the years reviewed is 8.5%.

Table 4.2: Bottled Water Compound Annual Growth Percentage

Regions	2002/03 (%)	2003/04 (%)	2004/05 (%)	2005/06 (%)	5 yr CAG (%)
Europe	10.1	3.7	3.9	0.9	4.8
North America	9.1	7.2	9.0	8.8	8.9
Asia	13.3	13.9	10.3	15.9	14.0
South America	10.8	7.3	5.1	3.3	8.3
Africa/Mideast/Oceania	4.6	7.2	7.8	6.0	7.5
Subtotal	**10.4**	**7.4**	**7.1**	**7.3**	**8.5**
All Others	-11.6	13.5	13.8	-5.7	10.7
TOTAL	**10.1**	**7.5**	**7.2**	**7.1**	**8.5**

Source: Beverage Marketing Corporation, 2006

Bottled water consumption in most of the countries is showing increasing trend. The per capita consumption of bottle water in 2005 by leading fifteen (15) countries is presented in Table 4.3. In Europe, Italy ranks as #1 with 190 liters, followed by Belgium-Luxemburg, Spain, France, Germany, Switzerland, Portugal and Slovenia.

In the Middle East, United Arab Emirates ranks #1, with 191 liters per capita consumption, Lebanon ranks #2 with 106.6 liters per capita consumption, Cyprus ranks #3 with 98.3 liters per capita consumption and Saudi Arabia ranks #4 with 92.9 liters per capita consumption. Since United Arab Emirates and Saudi Arabia are robust and growing economies, bottled water consumption will continue to grow in this region.

Table 4.3: Bottled Water Per Capita Consumption (2000 – 2005)

2005 Rank	Countries	Liters Per Capita 2000	2005
1	Italy	159.5	191.0
2	United Arab Emirates	113.8	180.3
3	Mexico	123.6	178.7
4	Belgium-Luxembourg	117.9	160.2
5	Spain	105.0	146.2
6	France	125.5	138.3
7	Germany	101.3	127.7
8	Lebanon	76.7	106.6
9	Switzerland	89.9	103.6
10	United States	61.2	98.6
11	Cyprus	72.2	98.3
12	Saudi Arabia	80.1	92.9
13	Czech Republic	68.0	89.9
14	Portugal	71.4	83.1
15	Slovenia	56.3	81.27
	Global Average	17.7	25.3

Source: Beverage Marketing Corporation, 2006

Import of bottled water represents a very minor share of 1% of volume in France with 67 million liters, Italy with 35 million liters, and Spain with 27 million liters. Generally the bulk of domestic bottled water demand in all these countries is fulfilled by domestic production. The United States, Germany, Italy, France, Spain and Canada truly represent the bottled water market trends. The market trends for bottled water, in these countries reflect international trends for the bottled water industry.

4.4 Bottled Water Market in United States

Bottled water emerged as the second largest commercial beverage category by volume in the United States in 2006 and it continued to grow at a rapid pace between 2001 to 2006, as shown in Table 4.4. In 2006, bottled water demand in the United States was 31.2 billion liters with 9.7% annual change compare to 2005. In 2001, the revenue generated by bottled water business was about US$ 6.88 billion, which increased to US$ 10.98 billions in 2006.

Table 4.4: Bottled Water Market in the United States (2001 – 2006)

Year	Million Liters	Annual % Change	Million (US $)	Annual % Change
2001	19,600.0	9.7	6,880.6	12.6
2002	21,907.7	11.8	7,901.4	14.8
2003	23,699.8	8.2	8,526.4	7.9
2004	25,729.3	8.6	9,169.4	7.5
2005	28,490.2	10.7	10,012.5	9.2
2006	31,249.2	9.7	10,980.0	9.7

Source: Beverage Marketing Corporation, 2006

The bottled water per capita consumption increased from 71 liters with annual growth percentage as 8.7% in 2001 to 107 liters with annual growth percentage as 8.6% in 2006 and is expected to continue to grow in future as detailed in Table 4.5.

Table 4.5: Bottled Water Per Capita Consumption (2001 – 2006)

Year	Per Capita (Liter)	Annual Percentage Change (%)
2001	71.0	8.7
2002	79.0	10.7
2003	84.6	7.3
2004	90.7	7.6
2005	98.6	9.6
2006	106.9	8.6

Source: Beverage Marketing Corporation, 2006

The per capita consumption of bottled water is growing at the rate of approximately 4.0 liters annually and therefore is likely to be more than double in a decade.

4.5 Asian Bottled Water Market

The bottled water demand in Asia and the Middle East is the highest in the world due to the population growth and public awareness on the quality of water supply. In developing countries, public awareness for the water quality and safe drinking water is growing. In many developing countries inefficient water management practices are contributing in inadequate supply of safe drinking water.

As shown in Table 4.6, between 2001 and 2005, Asian beverages market grew 17.3% in 2000/2001 and 8% in 2004/2005. In 1999, ABWA completed its first bottled water industry market survey for 50 Asian and Middle Eastern countries, which was conducted by Zenith International of the United Kingdom.

Table 4.6: Annual Growth Percentage in Asian Beverage Market (2000 – 2005)

Beverage Categories	2000/01 (%)	2001/02 (%)	2002/03 (%)	2003/04 (%)	2004/05 (%)
Tea	9.4	0.9	5.8	2.2	1.9
Milk	1.6	1.6	-24.3	1.7	1.1
Beer	4.1	4.4	3.5	3.6	22.5
Bottled Water	17.3	20.0	10.1	9.7	8.0
Soft Drinks	4.1	8.7	1.7	3.0	-1.0
Coffee	3.0	6.1	-1.3	-1.1	1.1
Distilled Spirits	0.5	-3.0	-8.8	-1.1	15.6
Fruit Beverages	19.4	5.1	7.6	0.4	15.1
Subtotal	**6.9**	**3.8**	**-1.1**	**2.8**	**5.2**
All Others	0.5	0.6	1.5	1.1	0.6
TOTAL	**1.3**	**1.0**	**1.2**	**1.3**	**1.2**

Source: Beverage Marketing Corporation, 2006

Table 4.7 shows, a change in bottled water consumption pattern. India showed the highest percentage change of 24.1% in consumption pattern in 2000/2001 and 20.1% in 2004/2005. Korea consumed 6.9% in 2000/2001 while its consumption grew to 17.2% in 2004/2005. Malaysia, in 2000/2001, consumed 9.4% and 11.3% in

2004/2005. Pakistan consumed 48.7% in 2000/2001 but its consumption declined to 11.2% in 2004/2005. Brunei consumed 10.2% in 2000/2001 and 9% in 2004/2005. China and Taiwan consumed 26.9% in 2000/2001 and 10.1% in 2004/2005. The change in consumption pattern is indicative of strong bottled water demand in many Asian countries.

Table 4.7: Asian Bottled Water Market (2000 – 2005)

Countries	2000/01 (%)	2001/02 (%)	2002/03 (%)	2003/04 (%)	2004/05 (%)
China and Taiwan	26.9	30.0	7.5	11.9	8.1
Indonesia	19.1	20.0	13.0	6.0	3.4
India	24.1	26.0	25.0	22.0	20.1
Thailand	5.9	6.6	2.0	0.6	0.5
Republic of Korea	6.9	6.7	20.0	20.0	17.2
Japan	7.1	18.7	5.3	1.7	3.3
Philippines	8.4	6.5	5.5	3.8	4.4
Pakistan	48.7	52.0	5.9	9.8	11.2
China	10.0	11.0	10.0	10.0	10.1
Malaysia	9.4	8.7	8.5	12.0	11.3
Vietnam	11.3	9.8	9.1	3.6	4.2
Singapore	8.2	7.9	8.0	7.8	7.8
Brunei Darussalam	10.2	9.3	9.0	9.0	9.0
Total	**17.3**	**20.0**	**10.1**	**9.7**	**8.0**

Source: Beverage Marketing Corporation, 2006

4.6 Canadian Bottled Water Market

Bottled water industry in Canada is rapidly growing with 8% to 10% annually. Although, bottled water industry accounts for more than 1% of total food and beverage, bottled water products and services have shown remarkable growth. Bottled water industrial development began in the early 1980s and is still growing. As shown in Table 4.8, in 1995, annual bottled water consumption in Canada was 527 million liters with a per capita consumption of 17.8 liters, which increased to 743 million liters with 22 liters per capita consumption in 1998 (CBWA, 1999).

Table 4.8: Canadian Bottled Water Consumption in Liters (1995 – 1998)

Year	Annual Consumption (Million Liters)	Per-Capita Consumption (Liters)	Population (Million)
1995	527	17.8	29.6
1996	582	19.5	29.9
1997	643	21.2	30.3
1998	743	22.0	

Source: CBWA, 1999

As shown in Figure 4.1, Canada produced 2075.7 million liters of bottled water in 2005 with a Canadian market as 1906.5 million liters, which is an increase of 18.1% from 2004.

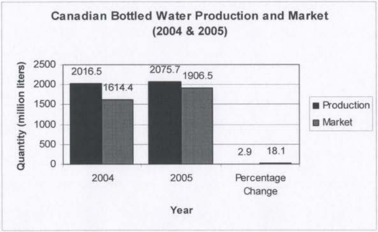

Figure 4.1 Canadian Bottled Water Production and Market (2004 &2005)

Source: CBWA, 2006

The majority of the water bottling plants is located in the Canadian provinces, which include, Quebec, Ontario and British Columbia. Quebec has the largest, 35% market demand with 246 million liters, Ontario has 28% market demand with 197 million liters, British Columbia has 22% market demand with 155 million liters, Atlantic Provinces have 6% market demand with 42 million liters and rest of Canada has 9% market demand with 63 million liters as detailed in Table 4.9 (CBWA, 1999).

Table 4.9: Canadian Bottled Water Market by Region

Region	Percentage (%)	Million Liters
Quebec	35	246
Ontario	28	197
British Columbia	22	155
Atlantic Canada	6	42
Rest of Canada	9	63

Source: CBWA, 1999

In 2004, Canadian companies exported 448.1 million liters of bottled water, which however declined to 222 million liters in 2005, a decrease of 50.5% from the year 2004, as detailed in Figure 4.2.

Canadian market has more than 100 bottled water brands, out of which about 20% are imported brands. There are three price categories in the market, premium brands, regularly priced brands and private label. Thus consumers have a wide range of choices for bottled water in Canada. In 1997, average retail price of one liter bottled water was $1.19 and for a delivered 18.9 liter bottle was $15. Also, bottled water products are well positioned to compete with other beverages (CBWA, 1999). The bottled water prices for regularly priced brands and private label brands are now less than $0.5 per liter and $7.0 for 18.9 liter of bottle.

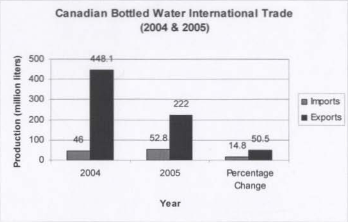

Figure 4.2 Canadian Bottled Water International Trade (2004&2005)

Source: CBWA, 2006

Considering the availability of freshwater resources in Canada and growing international demand for bottled water, there is a good potential to develop bottled water industry in Canada to meet the demand.

4.7 Bottled Water Industry in Newfoundland and Labrador

There are more than twenty (20) bottled water brands in the Province of Newfoundland and Labrador, as detailed in Table 4.10. Major bottled water brands available in the market are Aberfoyle, Apollinaris, Aquafina, Big 8, Crystal Spring, Danone, Dasani, Discovery, Echo Springs, Evian, Montclair, Our Compliments, S. Pellegrino Perrier, Sparkling Spring, Truly, Ultrapure and President's Choice in sizes of 250 ml, 330 ml, 500 ml, 750 ml, 1.0 liter, 3.78 liter and 18.9 liter.

In the province, bottled water price for a 4-liter Echo Spring is $1.19, which translates to $0.3 per liter, and premium 1.0 liter Apollinaris bottled water is priced at $2.19. Perrier, 750ml is priced at $1.59, which translates to $2.12 per liter and S. Pellegrino, 750ml is priced at $1.69 and translates to $2.25 per liter.

Table 4.10: Bottled Water Brands in Newfoundland Labrador

No.	Brand	Sizes	Price (US$)	Price/Liter (US$)
1	Aberfoyle	30 x 500 ml	5.97	0.4
2	Apollinaris	1 L	2.19	2.19
3	Aquafina	6 x 710 ml	3.49	0.82
		1.5 L	1.49	0.99
4	Big 8	500 ml	0.69	1.38
		1 L	0.99	0.99
		4 L	1.29	0.33
5	Crystal Spring	6 x 1 L	5. 29	0.88
		3.78 L	1.99	0.52
6	Danone	1 L	1.19	1.19
7	Dasani	6 x 500 ml	3.99	1.33
8	Discovery	1 L	1.09	1.09
		4 L	1.99	0.5
9	Echo Springs	8 x 250 ml	2.49	1.24
		4 L	1.19	0.3
10	Evian	1 L	1.79	1.79
11	Montclair	1.5 L	1.39	0.92
13	Our Compliments	750 ml	1.49	1.98
14	Perrier	750 ml	1.59	2.12
15	President's Choice	6 x 1.5 L	5.69	0.63
16	S. Pellegrino	750 ml	1.69	2.25
17	Sparkling Spring	500 ml	0.79	1.58
19	Truly	1.5 L	0.67	0.45
20	Ultrapure	3.78 L	1.49	0.39

Source: Sobeys and Dominion, 2006

There are five (5) bottled water companies in the province of Newfoundland and Labrador, with production facilities and locations, as detailed below:

- Shamrock Waters of Canada Inc., Daniel's Point
- Viking Beverages/Browning Harvey Limited, St. John's
- Canadian Iceberg Vodka Corporation

- George Yates, Springdale
- Garden Springs Inc., Mount Pearl

The lack of adequate drinking water supplies in developing countries and growing awareness on the importance of drinking water on human health has resulted in tremendous demand for bottle water globally. The bottle water demand in Asia and the Middle East is highest in the world due to population and higher consumption. Considering abundant freshwater resources in the province and international bottled water demand, there is good potential for Newfoundland and Labrador bottled water industry to export to the United States and the Gulf countries.

Chapter V

Bottled Water Analysis

5.1 Introduction

In this chapter the information for interpreting drinking water quality analysis is presented. It is important to set standards for assuring the purity and safety of water. The Health Canada Drinking Water Quality Guidelines, World Health Organization (WHO) Drinking Water Quality Guidelines, and National Primary Drinking Water Standard, USEPA (2006) for interpreting bottled water mineral analysis.

There are no scientific studies that may present an important effect of bottled water minerals on the human heath. The bottled water contains minerals, which may be useful to the human body. In this chapter, level of calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), chloride (Cl), sulfate (SO_4) and total dissolved solids (TDS) are examined.

371 bottled water samples were analyzed and statistical analysis was conducted from various countries bottled water details are available (Mineral Waters of the World, 2006).

5.2 Nutrient Minerals in Drinking Water

As discussed by the WHO (2004) report, that drinking water supplies may contain some of the fourteen essential minerals for good human health. These minerals in combination affect bone and membrane structure (Ca, Mg, P), water and electrolyte balance (Na, K, Cl), metabolic catalysis (Zn, Cu, Se, Mg, Mn, Mo), oxygen binding (Fe), and hormone functions (I, Cr). As further discussed that micronutrient deficiencies may include increased morbidity, mortality due to reduced immune defense systems and impaired physical and mental development. Deficiencies of some of the mineral elements, particularly Iron and Iodine are the main cause of health concerns in many parts of the world. In the world nearly 40% of women are estimated to be anemic due to deficiency of bioavailable dietary iron. The low intake of calcium and probably magnesium contribute to rickets in children and osteoporosis in women worldwide. Due to inadequate diets many children are deficient in Fe, Zn and Cu and other micronutrients in developing countries (WHO, 2004).

One third of the world's children fail to reach their physical and mental potential and are vulnerable to infectious diseases that account for half for all children's deaths. About two billion people have inadequate iodine nutrition. These nutritional deficiencies decrease productivity and increases rate of disease and death (WHO, 2004).

Drinking water supplies may contain some of these minerals naturally or by mineral injection in the water treatment process. Water supplies are highly variable in their mineral contents and some have significant amounts of minerals due to natural conditions (e.g. Ca, Mg, Se, F, Zn), intentional addition of (F) or leaching from piping (Cu), most system provides lesser amounts of nutritionally essential minerals. Many people consume mineral water because of the perception that they may be more healthful. Considering all these things, the nutrients found in drinking water at potentially significant levels of particular interest are detailed in Table 5.1.

Table 5.1: Nutrient Minerals and Recommendatory Daily Intake

Minerals	Nutritional Importance	Daily Intake (mg)
Calcium	Bone and cardiovascular health	800 - 1000
Copper	Anti oxidant, helps in hemoglobin	-
Iron	Helps in hemoglobin	10 - 30
Magnesium	Bone and cardiovascular health	300 - 400
Fluoride	Prevents dental caries	0.01 - 3.1
Sodium	Extra cellular electrolyte	2000 - 3000
Chlorine	Purify Water	1700 - 5100
Hardness	-	75 - 150
Selenium	Anti oxidant and Immune System	-
Potassium	Biochemical Effects	3000 - 4000
Sulfate	Maintains healthy, flexible cells	-
Iodine	For Thyroid Gland	0.15 - 0.18
Zinc	Helps in DNA building	15

Source: Mineral Waters of the World, 2006

As discussed in the WHO (2004) report on nutrient minerals in drinking water and potential health consequences of long term consumption of demineralized and altered mineral content drinking waters. The concentration of minerals is significant for human health. Calcium, magnesium and Bicarbonates are not included in the guidelines.

As detailed in the Health Canada (2006) Guidelines, that public acceptance for hardness of water varies, between 80 to 100 mg/liter, which are acceptable, levels more than 200 mg/liter are considered poor but can be tolerated, but in excess of 500 mg/liter are normally unacceptable. Table 5.2 presents Drinking Water Quality Guidelines for WHO and Health Canada.

Table 5.2: Drinking Water Quality Guidelines

Minerals	WHO (mg/liter)	Health Canada (mg/liter)	US EPA (mg/liter)
Calcium	-	-	
Chloride	250	≤ 250	250
Copper	-	≤ 1.0	1.0
Fluoride	1.5	1.5	2.0
Iron	0.3	≤ 0.3	0.3
Manganese	0.1	≤ 0.5	0.05
Magnesium	-	-	-
Silver	-	-	0.1
Sodium	-	≤ 200	-
Sulfate	250	≤ 500	250
TDS	-	≤ 500	-
Zinc	-	≤ 5.0	5.0

Source: WHO, 2006, Health Canada, 2006, and USEPA, 2006

5.3 Mineral Concentrations in Drinking Water

Calcium and magnesium mineral concentrations are the most important, because epidemiological studies during 1957 to 1978, provides evidence that magnesium inhibits coagulation while calcium helps in promoting the process. The report, further illustrates that calcium to magnesium ratio of 2:1 may be the most suitable for coagulation and other processes. As observed by Reinhart (1991) that due to magnesium deficiency, an increase in the cases of cardiac arrhythmias is reported. It is also reported that by supplementing magnesium intake, may decrease arrhythmias cases. Epidemiological studies suggest that magnesium is beneficial for cardiovascular diseases to decrease the number of cases.

Klevay (1975) observed that a correlation (0.96) between calcium and hardness in water exists. Calcium in hard water may supplement 175 -180 mg of calcium daily intake. It is observed that calcium and magnesium in water are also correlated (0.8). The report further, discuses, that the inverse correlation between coronary heart disease mortality and magnesium in water is similar to that of calcium. As detailed in the Table 5.3, mineral concentration range in bottled water analysis is presented.

Table 5.3: Mineral Concentration in Bottled Water

Minerals	No. of Samples	Concentration Range (mg/L)
Calcium	355	0.1 – 451
Magnesium	344	0.05 – 650
Sodium	344	0.01 – 4800
Potassium	296	0.1 – 254
Chloride	322	0.1 – 2700
Bicarbonate	355	0.1 – 4250
Sulfate	308	0.1 – 8060
TDS	227	1.0 – 8020

Source: Mineral Waters of the World, 2006

WHO (2004) recommendations are considered as standard to analyze levels of concentration in different international bottled water brands.

5.3.1 Calcium

Level of calcium concentration in about 68.6% of bottled water brands lie above the maximum standard requirement of calcium in drinking water that is two times of magnesium concentration (US EPA, 2006). In the bottled water analysis a range of calcium concentration between 0.1 mg/liter to 451 mg/liter was observed. Table 5.4 and Figure 5.1 presents the illustration for calcium concentration distribution of 355 bottled water samples.

Table 5.4: Distribution of Calcium Concentration

Concentration (mg/l)	Percentage
< 25	40.8
25 - 50	18.3
50 - 75	17.2
75 - 100	5.9
100 - 125	4.8
> 125	13.0
Total	100.0

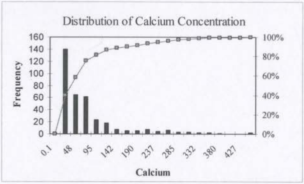

Figure 5.1: Distribution of Calcium Concentration

Source: Mineral Waters of the World, 2006

5.3.2 Magnesium

Level of magnesium concentration in about 95.6% of bottled water brands is below the minimum standard of 90 mg/liter (US EPA, 2006). The magnesium concentration range in the bottled water brand ranges between 0.05 mg/liter to 650 mg/liter. Table 5.5 and Figure 5.2 presents the illustration of magnesium concentration distribution of 344 samples in this study.

Table 5.5: Distribution of Magnesium Concentration

Concentration (mg/l)	Percentage
< 25	74.4
25 - 50	16.0
50 - 75	4.4
75 - 100	1.5
100 - 125	1.7
> 125	2.0
Total	100.0

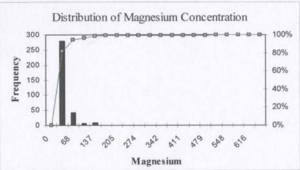

Figure 5.2: Distribution of Magnesium Concentration

Source: Mineral Waters of the World, 2006

5.3.3 Sodium

Level of sodium concentration in about 53.8% of bottled water brands is above the maximum standard requirement of sodium 10 mg/liter in drinking water (US EPA, 2006). About 81.9% of samples have sodium concentration above 100 mg/liter and 2.0% of samples have above 1000 mg/liter and one bottle water brand has a highest level 4800 mg/liter. Table 5.6 and Figure 5.3 presents the illustration sodium concentration distribution of 344 samples in the study.

Table 5.6: Distribution of Sodium Concentration

Concentration mg/l	Percentage
< 25	65.4
25 - 50	12.8
50 - 75	5.5
75 - 100	2.9
100 - 125	2.6
> 125	10.8
Total	100.0

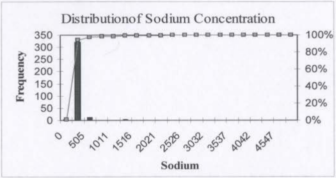

Figure 5.3: Distribution of Sodium Concentration

Source: Mineral Waters of the World, 2006

5.3.4 Potassium

Level of potassium concentration in about 95% of bottled water brands is under 30 mg/liter. The rest of the brands have potassium concentration between 30 to 254 mg/liter. There is no specific standard by WHO, EPA and Health Canada for the potassium concentration. However, concentration above 1000 mg/liter is considered as extreme value in drinking water. Table 5.7 and Figure 5.4 presents the illustration of potassium concentration distribution in 296 bottled water samples in this study.

Table 5.7: Distribution of Potassium Concentration

Concentration mg/l	Percentage
< 25	95.6
25 - 50	3.4
50 - 75	0.0
75 - 100	0.0
100 - 125	0.0
> 125	1.0
Total	100.0

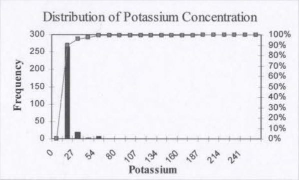

Figure 5.4: Distribution of Potassium Concentration

Source: Mineral Waters of the World, 2006

5.3.5 Chloride

Level of chloride concentration in about 5% of bottled water brands is above the maximum standard 250 mg/liter chloride in drinking water (US EPA, 2006). About 16 samples have concentration above 1000 mg/liter. The chloride concentration range between 0.1 mg/liter to 2700 mg/liter in the bottled water. Table 5.8 and Figure 5.5 presents the illustration chloride concentration distribution of 322 samples in this study.

Table 5.8: Distribution of Chloride Concentration

Concentration mg/l	Percentage
< 50	81.1
50 - 100	8.7
100 - 150	3.1
150 - 200	0.6
250 - 300	1.2
> 300	5.3
Total	100.0

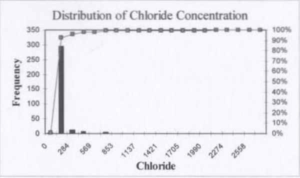

Figure 5.5: Distribution of Chloride Concentration

Source: Mineral Waters of the World, 2006

5.3.6 Sulfate

Level of sulfate concentration in about 4.2% bottled water brands are above the maximum standard requirement of 250 mg/liter sulfate in drinking water (US EPA, 2006). However, there is concentration level more than 1000 mg/liter in two bottled water samples. *A* sulfate concentration range between 0.1 mg/liter to 8060 mg/liter was observed in the analysis. Table 5.9 and Figure 5.6 presents the illustration of sulfate concentration distribution of 308 samples in this study.

Table 5.9: Distribution of Sulfate Concentration

Concentration mg/l	Percentage
< 50	81.1
50 – 100	8.7
100 – 150	3.1
150 – 200	0.6
250 – 300	1.2
> 300	5.3
Total	100.0

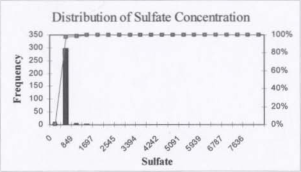

Figure 5.6: Distribution of Sulfate Concentration

Source: Mineral Waters of the World, 2006

5.3.7 Bicarbonate

Level of bicarbonate concentration in about 86% bottled water brands is under 500 mg/liter. About 11% of bottled water samples have concentration of bicarbonate more than 1000 mg/liter. There are no specific WHO, EPA and Health Canada standards for bicarbonate concentration in drinking water. However, concentration above 1000 mg/liter is considered as extreme value. The bottled water brands have concentration between 0.1 mg/liter to 4250 mg/liter. Table 5.10 and Figure 5.7 presents the illustration on bicarbonate concentration distribution for 355 samples in this study.

Table 5.10: Distribution of Bicarbonate Concentration

Concentration mg/l	Percentage
< 50	18.1
50 – 100	14.5
100 – 150	9.6
150 – 200	7.8
250 – 300	11.0
> 300	39.0
Total	100.0

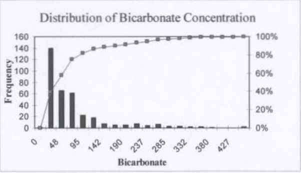

Figure 5.7: Distribution of Bicarbonate Concentration

Source: Mineral Waters of the World, 2006

5.3.8 Total Dissolved Solids (TDS)

Level of TDS concentration in about 18.0% of bottled water brands is above the maximum standard requirement of 500 mg/liter in drinking water (US EPA, 2006). However, 10.5% of the samples indicate concentration values between 1000 mg/liter to 8020 mg/liter. Table 5.11 and Figure 5.8 presents the illustration of TDS concentration distribution for 227 samples in this study.

Table 5.11: Distribution of TDS Concentration

Concentration mg/l	Percentage
< 50	15.4
50 – 100	13.6
100 – 150	9.6
150 – 200	12.7
250 – 300	10.5
> 300	38.2
Total	100.0

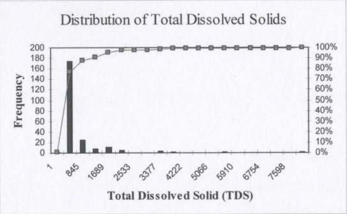

Figure 5.8: Distribution of TDS Concentration

Source: Mineral Waters of the World, 2006

5.5 Health Impact of Minerals

There are no harmful health effects associated with the consumption of calcium and magnesium. A significance of the essential calcium and magnesium minerals is well known. A suggestive evidence exists from the calcium and magnesium intake and benefits in some of the diseases such as stroke, renal stone formation, cognitive impairment in elderly, very low birth weight, bone fracture in children, pregnancy complications and hypertension. It is therefore suggested that by the injection of calcium and magnesium into bottled water mineral injection process would likely provide health benefits to the consumer population (WHO, 2004).

As discussed by Klevay (1975) that calcium and magnesium are the main elements, which gives hardness to water. A correlation between calcium and hardness in water is about 0.96. Calcium in hard water can be a significant dietary supplement because hard water can contribute 175-180 mg of calcium daily intake. Calcium and magnesium in water also are correlated about 0.80, and magnesium and hardness in water at about 0.9. Lower intakes of dietary magnesium (less that 186mg daily) are associated with higher risk of coronary heart disease. Higher magnesium intake may improve cholesterol metabolism and prevent cardiac arrhythmias (Klevay, 1975).

Finally it may be summarized that hard water is good for health because it contains nutrient minerals, and these nutrients can decrease impact of toxic elements in the environment. To minimize heart disease risk, the ideal drinking water should contain sufficient amount of calcium and magnesium and should be moderately hard. No effort should be made to eliminate trace metals such as copper and iron, where these elements are in short dietary supplies (WHO, 2004).

WHO (2004) reported importance of calcium and magnesium in the human diet, primarily in maintaining the health of bones (in the case of calcium) and in reducing the risk of cardiovascular disease (magnesium). In most of the countries, many people do not get enough of these minerals in their diets. Therefore disinfection and other treatment process should not compromise injection of calcium and magnesium in bottled water production.

Therefore it is important to maintain a balanced ratio (2:1) between calcium and magnesium in the bottled water production. In the light of these studies, the WHO Guidelines for Drinking Water Quality (GDWQ) may provide point of reference for the bottled drinking water quality regulations and standards worldwide. The WHO (2004) report also pointed out that several gap needs to be filled by research and epidemiological studies on the health effect of water borne calcium and magnesium, and identification of the population groups who are most vulnerable to calcium and magnesium deficiencies.

Chapter VI

CASE STUDY - Environmental Impact on the Gisborne Lake and Bottled Water Industry

6.1 Introduction

This chapter discusses a case study for the bottled water production at the Gisborne Lake in Newfoundland. The case study illustrates a scenario of 1.5 liter bottle size with a production capacity of 4.0 million bottled water per year. LGL (1998) study in 1997, presents that the Gisborne Lake has adequate water quality for water bottling. In the subsequent study, the lake water quality results are also compared to the WHO Drinking Water Quality Guidelines (2006) and Health Canada Drinking Water Quality Guidelines (2006). The desired water quality can be obtained by filtration process and Ultra violet (UV) radiation.

There are a number of water bottling systems available in the North America, such as Norland International, Severn Trent, ZYI Corporation, Aqua Technology, Steelhead and Siedel. In this study a combination of Siedel, Norland and Aqua Technology systems are considered.

6.2 Gisborne Lake Watershed Area

The Gisborne Lake is located at a distance of approximately 10 km north of the community of Grand Le Pierre, on the south coast of Newfoundland. The Lake watershed area is a part of a hydrological region in the Newfoundland (Figure 6.1). The regional classification is based on a study of peak flow data from 39 recording stations, the Water Resources Management Division in the Department of Environment and Conservation, Government of Newfoundland and Labrador. There are four hydrologically homogenous regions, identified in the province., which also has flow-recording stations. The Gisborne Lake watershed area is within the western boundary of Region A, "Avalon and Burin Peninsulas Region" (LGL, 1998).

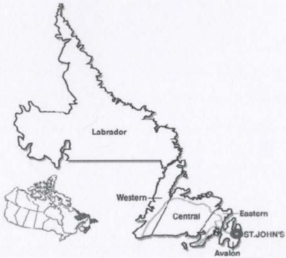

Figure 6.1: Newfoundland and Labrador

6.2.1 Topography

The Gisborne Lake catchments area has 103.5 km^2, and total Lake surface area is 26.2 km^2 and remaining total downstream watershed area is 34.7 km^2. The Lake watershed (Figure 6.2) is located at 150 – 200 m above sea level (LGL, 1998).

6.2.2 Drainage Systems

The feeder brooks, Doctor Brook, Outlet Mary Ann Pond, Murray Pond Brook and Moulting Pond Brook are discharging 6.62 m^3/second into the Gisborne Lake (Figure 6.2). Southwest brook extends at a distance of about 8 km from the Gisborne Lake to Saltwater at Long Harbor Sound (LGL, 1998).

6.2.3 Climate Data

The Gisborne Lake centre is at a distance of 15 km from the south coastline. There is no Climate Recording Station; Pools Cove Climate Station at a distance of 50 km from the Lake is considered for climate data. Environment Canada, provides record for mean precipitation data for Pools Cove.

Environment Canada also provides temperature records for Pools Cove station, which may be considered for the Gisborne Lake. According to the "Water Resources Atlas" mean annual temperature at Pools Cove and the Gisborne Lake are between 5°C to 7.5°C, and minimum temperature goes to -16.8°C (LGL, 1998).

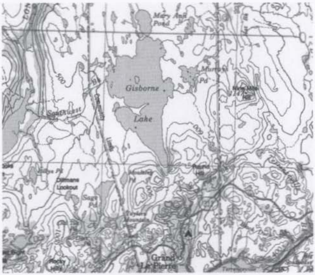

Figure 6.2: The Gisborne Lake Watershed Area

Environment Canada at Gander and St. Lawrence are the closest station for wind data records. Wind speed in Gander ranges between 17 – 25 km/hour and St. Lawrence ranges between 18 – 32 km/hour (LGL, 1998).

In an Environment Canada, proceedings on the "Climate Change and Climate Variability in Atlantic Canada," a paper presented by PJ Lewis on the future trends on climate parameters, has indicated extreme temperature and precipitation events in the Maritime Provinces during 1944 to 1990. Considering these trends, weather is expected to become colder and stormy weather in the future.

6.2.5 Water Quality

As reported the Gisborne Lake has a water capacity of about 139 million cubic meters by LGL (1998). The water quality of the lake has a low level of 10 mg/liter total dissolved solids (TDS). A water quality analysis of Gisborne Lake is presented in the Table 6.1.

Table 6.1: Water Quality Analysis of Gisborne Lake

Chemicals and Minerals	Value (mg/liter)
Sodium	2.5
Potassium	0.1
Calcium	0.7
Magnesium	0.3
Alkalinity (as $CaCO_3$)	2.0
Sulfate	2.0
Chloride	2.9
Reactive Silica (as SiO2)	0.5
Ortho Phosphorus (as P)	< 0.01
Nitrate + Nitrite (as N)	< 0.05
Ammonia (as N)	< 0.05
Iron	0.03
Manganese	< 0.01
Copper	< 0.01
Zinc	< 0.01
Color	< 5
Turbidity	0.2
Specific Conductance	24.3
PH	6.1
Dissolved Organic Carbon	2.2
Total Dissolved Solids (TDS)	10.0

Source: MDS Environmental Services Limited, 1997

The Lake can be treated with filtration process including micro-filtration and ultra-filtration and ultraviolet (UV) radiation processes. The water quality analysis results are compared with the WHO and Health Canada Drinking Water Quality Guidelines, as presented in the Table 6.2.

Table 6.2: Comparison of Drinking Water Quality Guidelines

Minerals/Chemicals	WHO (mg/liter)	Health Canada (mg/liter)	Gisborne Lake (mg/liter)
Calcium	-	-	0.7
Chloride	250	≤ 250	2.9
Copper	-	≤ 1.0	< 0.01
Fluoride	1.5	1.5	3.0
Iron	0.3	≤ 0.3	0.03
Manganese	0.1	≤ 0.5	< 0.01
Magnesium	-	-	0.3
Ortho Phosphorus	-	-	< 0.01
Sodium	-	≤ 200	-
Sulfate	250	≤ 500	2.0
TDS	-	≤ 500	10
Zinc	-	≤ 5.0	< 0.01

Source: WHO (2006), Health Canada (2006) and MDS Environmental Services, 1997

6.2.6 Water Withdrawal

Water withdrawal facilities consist of equipment for transmitting water from the source into the storage tank. The pumping machine may include a water screen in the inlet and a valve for supporting facilities for pipe installation. There are various types and sizes of water pumps for bottled water industry purposes. The pumps with discharge capacity of 60 gallons/minute or 227.4 liters/minute can be appropriate for water withdrawal purposes for a small bottled water facility, while pumps with discharge capacity of 300 gallons/minute or 1,137 liters/minute are adequate for big bottled water facility. Figure 6.3, illustrates a standard facilities for small to medium bottled water industry. Water storage and water treatment is operated at the same time as blow molding system. Once water is pumped from the source, it is stored into stainless steel storage tanks. The standard capacity of water treatment is usually 10 to 60 gallon/minute or 2.27 to 13.64 m^3/hour. The water treatment process may involve, micro-filtration, and UV for disinfection process, depending on the water source quality.

6.2.7 Water Treatment Process

There are some organic and inorganic chemicals, which must be removed from the lake water. A two steps filtration process, including micro-filtration and ultra-filtration may be used to remove debris, leaves, algae, fish and any other material in the lake water as shown in the Figure 6.1.

Gisborne lake water quality analysis result presents calcium (Ca) level as 0.7 mg/liter and magnesium (Mg) level as 0.3 mg/liter. WHO and Health Canada water quality guidelines does not provide any levels of concentration for calcium and magnesium, but the health benefit are well documented according to WHO (2004) report 'Nutrients in Drinking Water.' In the mineral injection process these levels of minerals according to drinking water guidelines may be maintained.

6.2.7.1 Micro-filtration

As depicted in the Figure 6.3, the micro-filtration is a screen installed in the intake of water withdrawal facility, carbon filter, ultra-filtration system, and nano-filtration system. The screen may eliminate debris such as leaves, algae, fish or any material coming to the water source.

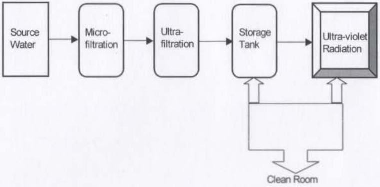

Figure 6.3 Water Treatment Process for Gisborne Lake

Source: Adapted from Pailhes, 1997

6.2.7.2 Ultra-filtration

As detailed in the Figure 6.3, ultra-filtration is a pretreatment process before water enters to the nano-filtration system. This process further removes molecular particles, viruses and smaller particles before the storage of water.

6.2.8 Ultra Violet (UV) Radiation

As discussed in the chapter III, literature review of this study the ultra-violet (UV) radiation can be used to disinfect the lake water before using it in water bottling for rinsing and filling purposes (Figure 6.4). The UV radiation is emitted from electron flow through ionized mercury vapor to produce UV energy. The UV energy radiation waves range from 100 to 400 nm long (between the X-ray and visible light spectrums). The UV disinfection may utilizes either of the following configuration:

- Low-pressure lamps, emits maximum energy at a wavelength of 253.7 nm,
- Medium-pressure lamps, emit energy with wavelengths from 180-1370 nm or
- Lamps, emits at other wavelengths with a higher intensity.

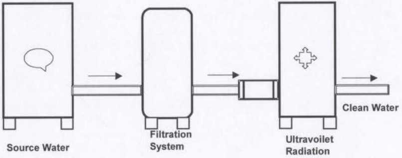

Figure 6.4: Ultra Violet Disinfection Process
Source: Adapted from Hofmann and Andrews, 2002

6.3 Integrated Blow Molding Process

An integrated blow molding system (BM-600) for polyethylene terephthalate (PET) bottles as presented in the Figure 6.3. The PET bottles are most commonly used in the bottled water industry. In the blow molding process, PET water bottles can use custom molds. A production capacity of 600 to 3000 bottles can be reached for producing bottled water size of 1.5 litters. The treated water can be used to rinse the bottles produced by blow molding system. A separate section, outside the 'Clean Room,' is used for the blow molding process. A conveyor system located on the exit of blow molding system leads to the 'Clean Room.'

6.4 Water Bottling Process

6.4.1 Clean Room

The water bottling process can be performed in a 'Clean Room' at a controlled temperature and contaminant free environment. 'Clean Room' and the water bottling system should be properly designed to maintain contaminant free clean water, as shown in the Figure 6.5. Physical surroundings of the 'Clean Room' should be aesthetically pleasant as it is important for a quality bottled water production facility. The 'Clean Room' should a good air circulation system in order to remove moisture and ozone gases (Vickers, 1998).

The bottled water production facility should follow the Department of Environment and Conservation, Health Canada, Canadian Bottled Water Association (CBWA) and other Federal Guidelines. The water bottling process includes (i) automatic bottle inspection (ii) rinsing (iii) filling (iv) mineral injection (v) capping (vi) bottle turner (mixer) (vii) labeling and Shrink wrapping (viii) distribution, as detailed in the Figure 6.3.

A small bottled water production facility can be approximately 25 meter by 40 meter or about 1,000 square meters. The plant operations can have two floors. The ground, floor with an area of approximately 800 square meters, can be used for water bottling process and other facilities.

6.4.2 Automatic Bottle Inspection

As detailed in Figure 6.5, the bottles should be inspected checks for defects such as chipped neck, finish and other bottle deformations in a large-scale production. An automatic bottle inspection machine is an important component in a 'super block' configuration. These machines can be installed within the 'super block' configuration, and the bottle inspection system may be incorporated within the filler operation system. The bottle inspection can be electronically interfaced with the 'filler system' (Vickers, 1998).

6.4.3 Rinsing

As detailed in the Figure 6.5 and Figure 6.6, rinsing process with a bottle rinser system (BF-300), which may includes 'rotating rinser carousel', a 'bottle platform' and a 'conveyor belt system.' Conveyor openings into filler room should be properly designed to permit passage of a bottle. In the idle condition, the conveyor opening must be covered. A positive pressure ventilation system is used to supply a filtered air curtain. The rinsing process starts before filling of the bottle (Vickers, 1998).

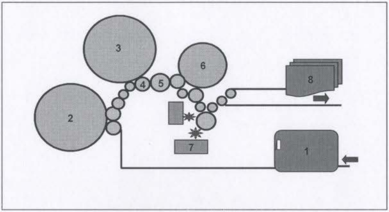

Figure 6.5: Water Bottling Process (Super Block)

Source: Adopted from Technology of Bottled Water, 1998

1. Bottle Inspection **2**. Rinsing **3**. Filling **4**. Mineral Injection
5. Capping **6**. Bottle Turner (Mixer) **7**. Labeling **8**. Distribution

6.4.4 Filling

As detailed in the Figure 6.5 and Figure 6.6, filling process with a bottle filler system (BF-300), which may include 'rotating filling carousel', a 'bottle platform' and a 'conveyor belt system.' Conveyor openings should be properly designed to permit passage of a bottle. In the idle condition, the conveyor opening must be covered In the filling system, the bottles are transferred from a conveyor belt through 'star wheel system.' In a standard water bottling system, rinser, filler and capper are interfaced. The bottles entering in the filling process from the 'star wheel' are properly pitched with the valve location in the 'rotating filler carousel' (Vickers, 1998).

A bottle 'neck support system,' can be used as bottle clamping device within the system design. In this process with the help of 'neck support system' and without lifting the platform, bottle is placed under the filling valve position. To reduce deformation and shrinkage in the PET bottle, the 'neck support system,' may position bottle under the 'filling valve.' In the 'super block' configuration, automatic inspection, rinsing, filling, capping and labeling with inter connecting conveyor system can be interfaced (Vickers, 1998).

6.4.5 Mineral Injection

As shown in the Figure 6.5 and Figure 6.6, the 'super block' may include mineral injection while bottle closing and mixing is processed. The mineral injection of calcium, magnesium or any other mineral in a balanced amount can provide safe bottled water. According to bottled water mineral web site, recommended daily calcium intake between 800 mg to 1000 mg and magnesium daily intake 300 mg to 400 mg. To introduce a balanced amount of mineral injection can further add a component within the 'filler block.' The filler unit is interfaced with a special 'star wheel' arrangement that incorporates a mineral injection system. This is interfaced with a 'rotary capping machine block' with a 'bottle turning carousel' (Vickers, 1998).

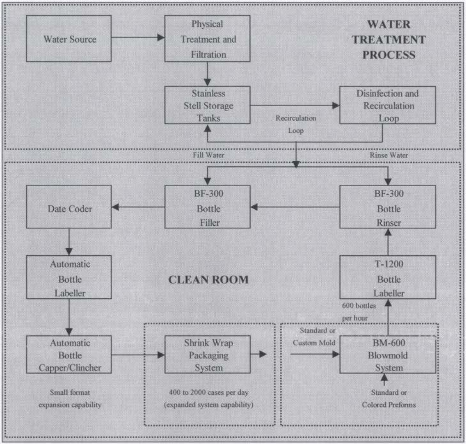

Figure 6.6: Water Bottling Process

Source: Aqua Technologies, 2006

6.4.6 Capping

As illustrated in the Figure 6.5 and Figure 6.6, the bottle capping is applied at this stage (Senior, 1998).

6.4.7 Bottle Turner (Mixer)

As detailed in the Figure 6.5 and Figure 6.6, in this section bottle turning or mixing process is performed, before entering to the labeling section.

6.4.8 Labeling and Shrink Wrapping

As shown in the Figure 6.5 and Figure 6.6, after the process of bottle turning, the bottle enters the labeling section, where labels are applied. After labeling, shrink wrapping (polymer plastic material) is applied, which forms a seal and covers the bottled water (Senior, 1998).

6.4.9 Distribution

Once the production processes cycle is complete, the produced bottles are place on pallet structures Figure 6.5 and Figure 6.6, mobile lifts and other devices are used in the transportation of water bottles. Finally the bottled water is ready for the distribution and export.

There is a considerable potential to develop bottled water production facility in view of the Gisborne Lake water quality. It is important to remove some organic and inorganic chemicals from the lake water. A four steps filtration process, i.e., micro-filtration, carbon filtration, ultra-filtration and nano-filtration can be used to remove debris, leaves, algae, fish and other undesirable elements from the lake water. The ultra-violet (UV) radiation can be an effective method to disinfect the lake water before using it for water bottle rinsing and filling purposes.

6.5 Environmental Impact on the Gisborne Lake Watershed Area

6.5.1 Environmental Impact and Sustainability

The environmental impact due to water withdrawal from the Gisborne Lake depends on the location of the water bottling industry. In any natural conditions, if water is withdrawn from any water body, there is a proportionate drop in the water levels of the water body. Due to water withdrawal, from a river, down stream flows will be affected and will be affected as water level decrease. In a water withdrawal from ground water source, the water table will drop accordingly. The water withdrawal may take place naturally through outflows, infiltration and evaporation. However, water withdrawal, may also add the water balance of inflows and outflows. As pointed out by Feehan (2001), significant parameters include:

- Water withdrawal quantity
- Environmental impact due to water withdrawal

A large quantity of water withdrawal, may result drop in water levels of the Gisborne Lake, which may in turn affect the environment of surroundings. The environmental impact may include decline in water quantity, which may affect other water uses, such as a sustainable level for fish habitat. Water withdrawal may also create ecological change in due course of time, such as water quality, temperature, sedimentation and deposition. All these environmental impacts will depend upon the location and size of the project.

Since all water flows are directed towards sea, there are many estuarine environments, where low water levels may adversely affect the environment. Generally most of the intertidal zones are small which are not affected by freshwater flows. In the marine environment, currents and tides have a role in controlling water quality. According to Feehan (2001), precipitation in Newfoundland ranges between 700 mm to 1,700 mm per year.

Sustainability parameters demand that "water withdrawal should create a condition that surplus water should be available at all times in the future." If water withdrawals and local conditions are appropriately managed, an indefinite sustainability may be achieved.

In Newfoundland and Labrador, the monitoring of water flows for about 85 hydrometric stations and a Geographical Information System (GIS) database is developed for any water related developmental activity for the government and industry. Feehan (2001) observes that water withdrawal can be a sensitive issue in terms of water resources engineering and management. An Environmental Assessment process requires, a detailed examination of the proposed project and the evaluation of future environmental impacts on the ecosystems. Although Environmental Assessment process is performed as per the government guidelines, public involvement is fundamental to this process. In case an adverse effect is identified by a proposed project, mitigation measures should be proposed, and in case of non-compliance the proposed project can be rejected.

6.5.2 Water Use Authorization

In case of a bottled water project, the project may be referred to water use authorization division for appropriate permits. Permits may contain relevant terms and conditions for a specific project to ensure that project adhere to regulations and adopt appropriate environmental protection practices. Water use authorization allows, operation to proceed, using water from a specific source, for water bottling production for a specified period of time. The permits issued by the Water Use Authorization are issued by the Department of Environment and Conservation, which addresses environmental, sustainability and monitoring issues and concerns. The department may include some of the conditions:

- Crown retains ownership of water rights; water use permit will be non-exclusive.
- Communities and other water users will be protected for present and future water requirements.
- Water quality should not be affected due to water use and water required to sustain fish and fish habitat.
- Water use operation should not cause erosion, flooding, water quality deterioration and ground water depletion.
- Terms and condition should contain provisions for pollution prevention, marine interference, public safety for water users.

6.5.3 Environmental Impact on the Gisborne Lake Watershed Area

As discussed in the LGL (1998) study, the environmental factors may be examined for the effect of changes in the water levels and ecology of the Gisborne Lake. To maintain Lake water quality within natural limits is advantageous, as it is likely to be affected by flooding or pollutants. There can be three main environmental issues concerning the water withdrawal from the Gisborne Lake:

- Water level changes in the Gisborne Lake may affect environmental conditions in the watershed area, which may create ecological imbalance.
- Fish migration between the Gisborne Lake and the upper reaches of Southwest Brook.
- Fish habitat in the lower reaches of Southwest Brook.

As per the LGL (1998) study estimates water withdrawal of 300,000m^3/week and 500,000m^3/week, may not affect the natural environmental conditions. Feehan (2001) observes that the environmental assessment process indicate that the water withdrawal for water bottling project at the Gisborne Lake, would not have a negative environmental impact. The water withdrawal for water bottling industry at the Gisborne Lake is estimated as approximately 6 million liters or 6000m^3/year, which are much lower than the 300,000m^3/week water withdrawal, as thus may not adversely effect the environment and sustainability of the Gisborne Lake watershed area.

Chapter VII

SHIPPING AND TRANSPORT

7.1 Introduction

Shipping has an important role in the transportation system. With the advent of containerization, shipping companies are now capable of providing an economical transportation. Approximately 250 shipping companies are providing transportation services globally. Frost (2005) projects 10% growth in the container port. Asia is the largest market for container shipment. International supply chain management and trade liberalization has considerably increased the demand for containerized transport. North American has witnessed significant container volume growth during the last decade. Canadian ports handled approximately 4 millions Twenty Equivalent Feet Units (TEU) of containers in 2004.

Newfoundland and Labrador Refining Corporation (NLRC) has submitted a proposal for the construction of a new oil refinery at Southern Head in Arnold's Cove region, Placentia Bay, Newfoundland and Labrador, with an initial production capacity of 300,000 barrels per day that will be expanded to 600,000 barrels per day in future. In the light of the development in Arnold's Cove area, Placentia Bay, Newfoundland and Labrador, three transportation models are presented for bottled water export.

- Transport by shuttle service by Maersk or Oceanex (1004 TEU)
- Transport by Suez vessels (42,000 T)
- Transport by VLCC Vessel (260,000 T)

Considering the favorable cost of transportation from Newfoundland and Labrador and proximity to potential markets, the Canadian companies should explore the possibility for bottled water export by shuttle service or Suez vessel to the United States and by VLCC vessel to the Middle East. This chapter provides a brief description on the cargo handling at various Canadian ports.

7.2 Transportation System

Shipping is one of the most important components in the transportation system. The shipping companies are now capable of providing an economical mode of transportation to various destinations and thus are contributing in the efficient delivery of goods to every part of the world. Considering the growing demand for shipping, an integrated transportation system should be designed to meet the specific market requirements (Stopford, 1997). Most of the cargo shipping companies are using containerized transportation system, and can be categorized as follows:

- Container ships
- Multi-purpose ships
- Tween decker
- General cargo liners

There has been a tremendous growth in the container ships, rising from 750 to 2094 between 1997 and 2004. In the containerization operation, bigger ships are preferred, which are believed to provide economies of scale (Stopford, 1997).

7.2.1 Shipping Companies

Currently about 250 companies are offering shipping services. Ten biggest shipping companies, detailed in Table 7.1, control 11% of the dry bulk fleet, 17% of the tanker fleet, and 35% of container ship fleet. In order to achieve greater economies of scale in transportation, bigger ships and more frequent services are required. Major companies such as APL, OOCL, MOL, and Nedlloyd have forged an alliance with 187 container ships to provide an integrated Europe-Far East services. Another alliance among Hapag-Lloyd, NOL, NYK, and P&OCL includes 182 ships. In 1995, two large shipping companies, Maersk and Sealand, formed an alliance with 206 ships (Stopford, 1997).

Table 7.1: International Shipping Companies

Shipping Companies	Container Capacity Twenty Feet Equivalent Unit (TEU)	Number of Ships	Market Share
AP Moller-Maersk Group	1,665,272	549	18.2
Mediterranean Shipping SA	748,248	299	8.6
CMA CGM	507,954	256	5.6
Evergreen Marine	477,911	153	5.2
Hapag-Lloyd	412,344	140	4.5
China Shipping Lines	346,493	111	3.8
American President Line	331,437	99	3.6
Hanjin-Senator	328,794	145	3.6
COSCO	332,326	118	3.5
NYK Line	302,213	105	3.3

Source: International Maritime Organization (IMO), Lamb (2004), Maersk Shipping Lines and Stopford (1997)

7.2.2 Container Port Growth

As shown in the Table 7.2, Asia is projected to experience the biggest container port growth during the years 2004 to 2015. In the near future, exceptionally high container port demand is expected in the world.

Table 7.2: Container Port Growth

Region	2004 (Million TEU)	2010 (Million TEU)	2015 (Million TEU)
Asia	159.1	240.5	303.4
Americas	62.2	90.7	118.8
North America	41.1	56.9	71.6
Europe/Medetarararian	74.1	105.8	139.5
Others	36.8	58.2	85.6
Total	332.2	495.1	647.3

Source: Brook and Frost, 2005

7.2.3 North American Container Traffic

International economic trends, particularly supply chain and trade liberalization has greatly contributed in the demand for containerized transport. In the North America, container volumes have shown a remarkable growth in the last decade. As shown in Table 7.3, North American TEUs grew about 7% and is expected to grow every year. The containerized transport growth varies from port to port depending on the port infrastructure facilities.

Table 7.3: Container Traffic in Canada and the United States (2000 - 2004)

Country	2000 (TEU)	2001 (TEU)	2002 (TEU)	2003 (TEU)	2004 (TEU)
Canada	3.0	2.9	3.3	3.6	3.9
United States	30.4	30.7	32.7	35.6	38.0

Source: Association of American Port Authorities, 2006

7.2.4 Canadian Ports

In 2004, Canadian ports handled about 4 millions TEUs. Container cargo handled at various ports, i.e. the port of Vancouver, Montreal, Halifax, Saint John and St. John's are presented in the Table 7.4. In 2004, the port of Vancouver handled 1,700,000 TEUs, Montreal handled 1,226,296 TEUs, Halifax handled 525,553 TEUs, the port of Saint John handled 50,000 TEUs and the port of St. John's handled approximately, 70,000 TEUs.

Table 7.4: Container Cargo Handled at Canadian Ports (2004)

Canadian Port	Cargo Handled (TEU)
Vancouver	1,700,000
Montreal	1,226,296
Halifax	525,553
Saint John	50,000
St. John's	70,000

Source: Canadian Ports web sites, 2006

7.3 Container Details

7.3.1 Container Specification

There are several types of containers; Maersk has one of the biggest operations in the world. Oceanex has the largest container-shipping terminal in the province, which connects North American destinations. Oceanex has services to Halifax, Montreal, and Corner Brook and is capable of handling container ships with better capacity. Various types of container and their specifications are presented in the Table 7.5.

Table 7.5: Container Specifications

Container Type	Dimension (m) L x W x H	Capacity of Container (m^3)	Payload Capacity (kgs)
45' High Cube	13.5 x 2.3 x 2.7	85.7	28,390
45' Reefer	13.5 x 2.3 x 2.7	85.7	28,390
40' High Cube	12.0 x 2.3 x 2.7	76.0	29,600
40' Dry Freight	12.0 x 2.3 x 2.4	67.0	27,400
20' Dry Freight	5.9 x 2.3 x 2.4	33.0	22,100
40' Open Top	12.0 x 2.3 x 2.2	64.0	26,181
40' Reefer	11.2 x 2.2 x 2.1	55	27,400

Source: Maersk, 2006

There are several types of container shipments; Maersk has one of the largest ship liner operations in Canada. The container specifications are presented in the Table 7.6.

Table 7.6 Container Specifications

Container Type	Capacity of Case	Number of Bottles	Extreme Weight (kg)	Payload (kg)	Status
40' High Cube	3304	39,648	75,992	28,400	Overpay load
40' Dry Freight	2926	35,112	67,298	27,400	Overpay load
20' Dry Freight	1435	17,220	33,005	22,100	Overpay load
20' Open Top	1374	16,488	31,602	21,826	Overpay load
40' Open Top	2783	33,396	64,009	26,181	Overpay load
40' Reefer	2391	28,692	54,993	27,400	Overpay load

Container shipments are convenient, safe, easy to handle, and the only effective means for bottled water transportation. Although it is technically possible to transport bottled water by air, the air transportation will not be a viable mode of transportation for bottled water.

7.3.2 Capacity of Container and Payload

The capacity of each container and maximum payload capacity are presented in the Table 7.7 for the handling of bottled water cases.

Table 7.7 Capacity of Containers for Handling of Bottled Water Cases

Container Type	Capacity of Cases (m^3)	No. of Bottles	Weight (kg)	Payload (kg)	Status
40' High Cube	3,304	39,652	61,461	29,600	Over payload
40' Dry Freight	2,926	35,113	69,305	27,400	Over payload
20' Dry Freight	1,435	17,217	26,687	22,100	Over payload
20' Open Top	1,374	16,487	25,555	21,826	Over payload
40' Open Top	2,783	33,391	51,757	28,390	Over payload
40' High Cube Reefer	2,861	34,330	69,305	27,400	Over payload
40' Reefer	2,3891	14,400	44,397	27,400	Over payload

- Volume of a case of bottled water is 0.023 m^3 with weight of about 18.25 kg.

7.3.3 Efficient Payload in a Container

Based on the container specifications shown in the Table 7.6, it is evident that all types of containers may not handle the weight of bottled water in its full load condition. For example 40' Reefer container can handle 2391 bottled water cases or 28,692 bottles of 1.5 liter units in full load condition. The weight of bottled water in 40' Reefer container will be 54,993 kg, which exceeds allowable load of the container that is 27,400 kg. Assuming this condition, the maximum load of each type of container relates to the weight of the total bottled water cases. Table 7.8 presents the efficient load of each type of container.

Table 7.8: Efficient Load of Each Type of Container

Container Type	Payload (kg)	Efficient No. of Cases	No. of Bottles	Volume of Cases (m^3)	Volume Percentage
40' High Cube	28,390	1,622	19,463	28	51
40' Dry Freight	27,400	2,391	28,692	34.5	51
20' Dry Freight	22,100	1,211	14,532	27.9	84.40
20' Open Top	21,826	1,196	14,351	27.5	87.05
40' Open Top	26,181	1,435	17,215	33.0	51.56
40' High Cube Reefer	27,400	1,544	18,529	35.5	53.97
40' Reefer	27,400	1,200	14,400	28	51

(Volume percentage = volume of cases/container capacity) x 100 %)

7.3.4 Transportation Cost of Container

The cost of transportation for bottled water from the production facility to the market depends on the distance and type of container used. The cost is subject to a bunker adjustment factor (BAF) and equipment imbalance surcharge (EIS). The BAF is US$ 105 and US$ 210 for 20' and 40' containers respectively. The EIS is US$ 225 and US$ 450 for 20' and 40' containers respectively (Maersk, 2006). Assuming these projections, the cost of transportation, for various types of container, can be derived as detailed in the Table 7.9.

Table 7.9: Container Transportation Cost

Type	Rates (US$)	No. of Cases	Rate/Case (US$)
45' High Cube Container	4,500	1,556	2.89
40' High Cube Container	4,395	1,622	2.71
40' Dry Freight Container	4,395	1,501	2.93
20' Dry Freight Container	3,720	1,211	3.07
20' Open Top Container	3,720	1,196	3.11
40' Open Top Container	4,395	1,435	3.06
40' High Reefer Container	4,395	1,544	2.85
40' Reefer Container	4,500	1,200	3.75

Source: Maersk, 2006

(Based on BAF, EIS and container cost of 40' containers is assumed US$ 4,500)

Therefore, the cost of one case of 12 bottled water in a 40' Reefer Container is US$ 3.75, which translates the cost of transport of one bottle of 1.5 liter as US$ 0.31 or US$ 0.20 (20 cents) per liter.

7.4 Bottled Water Transport

This section provides discussion on three scenarios for the bottled water transport. Bottles with 1.5 liter water capacity and total 4.0 million liter water production capacity are considered for the transportation. The first scenario is based on an assumption of approximately 3,425,000 liters of bottled water by shuttle service; the second scenario presents transport by Suez vessel, and the third scenario is based on the use VLCC vessel. The proposed scenarios are outlined as under:

- Transport by shuttle service (1004 TEU) from St. John's, Newfoundland and Labrador to Boston, Philadelphia, New York and Miami, the United States.

- Transport by Suez vessels (42,000 T) from St. John's, Newfoundland and Labrador to Boston, Philadelphia, New York and Miami, the United States.

- Transport by VLCC vessel (260,000 T), which after delivering Arab light crude oil at Newfoundland and Labrador Refining Corporation (NLRC) refinery, at Southern Head, Placentia Bay, Newfoundland and Labrador, can transport bottled water on their way back to Jeddah and Dammam, Saudi Arabia.

As discussed in the case study (chapter VI), a production capacity of 4.0 million bottles per year with the 1.5 liter capacity of bottled water translates into a total bottled water production capacity of 6.0 million liters. Also, a scenario considering 28 million liters bottled water production capacity, provide production cost that conforms to the economies of scale. In the light of these assumptions, capacity of one 40 feet equivalent unit (FEU) container for three (3) bottled water in different sizes, i.e., 1.0 liter, 2.0 liter and 4.0 liter are discussed in the subsequent section as shown in the Table 7.10.

Table 7.10: Capacity of Container (FEU) for Different Sizes of Bottles

Bottled Water (liter)	Number of Bottles	Total Capacity (liters)
4L	6,850	27,400
2L	13,700	27,400
1L	27,400	27,400

According to container specification in Table 7.6, one 40' (FEU) container may contain 67.0 m^3 of water (maximum payload of 27,400 kg) or 27,400 liters of water, therefore, one container may accommodate bottles of different sizes, as detailed in Table 7.11. A total cargo capacity of 1004 TEU or 502 FEU will be 13,700,000 liters (13.7 million liters), as estimated in the Table 7.11.

Table 7.11: Different Sizes of Bottled Water Delivered at one Location

Size of Bottle (L)	FEU (40')/Ship	Bottles/Container	Total Bottles	Total Quantity (L)
4	25	6850	171250	685000
2	50	13700	685000	1370000
1	50	27400	1370000	1370000

7.4.1 Transportation and Cost by Shuttle Service

Assuming total 3,425,000 liters bottled water production in three different sizes of bottles, i.e., 4.0 liter, 2.0 liter and 1.0 liter, can be transported to four destination of the United States. Brooks and Frost (2006) present the cost of transport by various vessels as shown in Table 7.12. According to this study, oceanex vessel cost US$ 36,185 and is selected for the various destinations of the United States.

Table 7.12: Ship Chartering and Operating Cost Per Day

Vessel Name	Cost per day (US$)	Operating Cost Per day (US$)	Total Cost Per day (US$)	Cost per TEU (US$)
Oceanex	19,672	16,513	36,185	72
Shamrock	7,900	8,624	16,524	83
Damen	8,579	14,704	23,283	57

Source: Brook and Frost, 2006

Cost of transport for one (1) day = US$ 36,185

Cost of transport for seven (7) days = US$ 253, 295

Cost of transport per liter = US$ 0.018 or 1.8 cent (2 cents)

Table 7.13 Cost of Bottled Water Transport

Size of Bottle (liter)	Total Quantity (liter)	Cost per Bottle (US$)
4	685000	0.072
2	1370000	0.036
1	1370000	0.018

As presented in the Table 7.13, the cost of transport for 4.0 liter, 2.0 liter and 1.0 liter bottle will be US$ 0.072, US$ 0.036 and US$ 0.018 respectively, which is approximately two (2) cents per liter. If the vessel transit time will increase by eight (8) to ten (10) days, the cost of transport for one liter may be 3 - 4 cents per liter.

7.4.2 Transportation and Cost by Suez Vessel

Suez vessel is capable of carrying a load of 42,000 metric tons. Assuming transportation of 28 million liters of bottled water sizes of 4.0 liter, 2.0 liter and 1.0 liter. A 40' (FEU) container can carry a payload of (maximum 27,400 kg) 25,000 kg or 25,000 liters of water. Based on this logistics the number of containers required for different sizes of bottled water can be listed as in Table 7.14.

Table 7.14: Bottled Water Transport

Bottle Size (liter)	Quantity (liters)	No. of Bottles	Bottles/Container	Containers
4	16,000,000	4,000,000	6850	584
2	8,000,000	4,000,000	13700	292
1	4,000,000	4,000,000	27400	146

According to Feehan (2001) report, as evident from the data in Table 7.16, the cost of transportation by Suez vessel is US\$ 26,000 per day, which can be translated to US\$ 0.65/m^3. Thus a trip of 30 days will cost US\$ 19.5/m^3 and a trip of 40 days will cost US\$ 26/m^3. The transport cost of bottled water can be calculated as follows:

Transport cost for 10 days for (1000 liters) of bottles = US\$ 6.5

Transport cost for 30 days for (1000 liters) of bottles = US\$ 19.5

Transport cost per liter = US\$ 0.065

In this analysis, the cost of transportation by shuttle service is 3 - 4 cents per liter, and by Suez vessel the transport cost is approximately 6.5 cents per liter. The Suez vessel appears to be a more efficient in terms of transit time and shipping volume. However, the cost of transport by shuttle service and by Suez vessel does not have much difference. A ship chartering service can provide more competitive transportation cost.

7.4.3 Transportation and Cost by VLCC Vessel

Newfoundland and Labrador Refining Corporation (NLRC) has submitted a proposal for the construction of a new oil refinery at Southern Head, Placentia Bay, Newfoundland and Labrador, with an initial production capacity of 300,000 barrels per day and to be expanded up to 600,000 barrels per day in future. NLRC can explore the possibility of importing Arab light crude oil from Saudi Arabia to the proposed oil refinery by a Very Large Crude Oil Vessel Carrier (VLCC). Since VLCC, after delivering crude oil to the refinery is likely to sail empty, feasibility study for using suitably modified VLCC vessel to transport bottled water from Southern Head, Placentia Bay, Newfoundland and Labrador, Canada to Jeddah and Dammam, Saudi Arabia should be conducted.

The International Maritime Organization (IMO), and International Convention for the Prevention of Pollution from Ship (MARPOL) have laid down parameters for the design of oil tanker vessel. Since tanker vessels are used in international trading, regulations governing tanker's design and construction are governed by international rules and regulations. A modified VLCC vessel and ballast water section design can provide a cargo facility for the bottled water transport to Saudi Arabia. The modified

VLCC vessel design should take into consideration the environmental and safety regulations in addition to adopting cargo and ballast water management practices.

In a tanker vessel design, besides the environmental and safety standards, depth of double bottoms and the width of the wing tanks are of significant considerations. A design protocol called as the 'concept of protectively located (PL) spaces, requires that the ballast tanks should be located in a defensive position. All tankers entering into the Canadian and the United States water must have double hulls or an alternative arrangement.

7.4.3.1 VLCC Vessel

There are a number of systems, which contribute in the overall functionality of a tanker system needed for the transportation of oil safely and economically. Various functions and systems are interrelated and therefore a systems approach is required to develop an efficient tanker design. The tanker system consists of the storage and transport of cargo including cargo tanks, tank gauging, cargo piping, tank heating, tank cleaning, inert gas and cargo tank venting. Modern tankers can provide remote control operations of the cargo and ballast section from the control room.

7.4.3.2 VLCC Vessel Cargo and Ballast Section

The oil tanker vessel's cargo-carrying section can be divided into different tanks by longitudinal and transverse bulkheads. Double bottom or double sides or double hull is fitted in the cargo-carrying section of an oil tanker. A pair of wing tanks are created by longitudinal bulkheads. These wing tanks helps to reduce the free surface effect. A tankar can have several ballast tanks including double bottom tanks, wing tanks as well as forepeak and aftpeak tanks. Adding ballast to a vessel lowers its center of gravity, and increases the draft of the vessel, which helps for proper propeller immersion. Table 7.15, presents the capacity of different sizes of tankers and ballast section (Lamb, 2004).

Table 7.15: Capacity of Oil Tankers

Tanker	Cargo Capacity (m^3)	Ballast Capacity (m^3)
Stena Vision (VLCC)	351,700	107,743
Murex (VLCC)	345,000	99,800
Poalr Endeavour	161,229	60,841
Stena Alexia	141,783	55,544
British Harrier	170,000	54,000

Source: Lamb, 2004

A modified tanker design and ballast water management can provide cargo facility for the bottled water containers. A detailed design analysis is required to adjust the volume of ballast water taking into consideration the bottled water cargo weight.

7.5 Cost of Transportation by VLCC Vessel

This section discuses the cost of bottled water transport by VLCC vessel. As described in the case study (Chapter VI), the export of bottled water to various destinations, is based on North Atlantic Free Trade Agreement (NAFTA) and other trade obligations. The feasibility for a large-scale bottled water export can be examined to determine if the cost of transportation by vessel is cost effective.

Feehan (2001) report reveals that the daily cost of operation by VLCC vessel, based on the sensitivity cost analysis, is US$ 40,000, which translates to US$ 5.1 per m^3 to US$ 6.8 per m^3 for 30 days and 40 days return trip respectively, as shown in Table 7.16.

Table 7.16: Tanker Cost to Volume and Rates per day

Tanker Capacity	Cost per day (US$) / m^3	30 Day Return Trip (US$) / m^3	40 Day Return Trip (US$) / m^3
VLCC (260,000 T) Capacity 230,000 m^3 @US $40,000/day	0.17	5.1	6.8
Suezmax (130,000 T) Capacity 120,000 m^3 @US $40,000/day	0.33	9.9	13.2
Aframax (80,000 T) Capacity 80,000 m^3 @US $30,000/day @US $50,000/day	0.37 0.62	11.1 18.6	14.8 24.8
Suez (42,000 T) Capacity 40,000 m^3 @US $26,000/day	0.65	19.5	26.0

Source: Feehan, 2001

According to information provided by Maersk shipping, transportation days from Southern Head, Placentia, Newfoundland and Labrador to Jeddah and Dammam, Saudi Arabia are 30 days and 40 days and a minimum cost of transportation is unlikely to be below US$ 5.1 per m^3 to US$ 6.8 per m^3.

Cost of 1.0 m^3 (1000 liters) = US$ 5.1 - US$ 6.8

Cost of 1.0 liter = US$ 0.0051 - US$ 0.0068

Therefore the cost of transport from Southern Head to Jeddah and Dammam is likely to be 0.5 to 0.7 cent per liter, which needs further investigation.

A container transit time to Saudi Arabia is presented in the Table 7.17. The prices are subject to a bunker adjustment factor (BAF) and equipment imbalance surcharge (EIS). The BAF is US$105 and US$ 210 for 20' and 40' containers respectively. The EIS is US$ 225 and US$ 450 for 20' and 40' containers respectively (Maersk, 2006).

Table 7.17: Transit Time from St. John's to Saudi Arabia

Origin	Destination	Transit Time
St. John's	Jeddah	30 days
St. John's	Jeddah	30 days
St. John's	Dammam	40 days
St. John's	Dammam	40 days

Source: Maersk, 2006

Assuming a total production capacity of 28 million liters bottled water with 4.0 liter, 2.0 liter, and 1.0 liter bottle capacity as detailed in the Table 7.19, a 40' (FEU) container may carry a maximum payload of 27,400 kg or 27,400 liters of water. Therefore, a payload of 25,000 kg (maximum payload 27,4000 kg) or 25,000 liters of water for different sizes of bottles may require the number of containers as projected in Table 7.18.

Table 7.18: Bottled Water Transport

Bottle (liter)	Quantity (liter)	Bottles	Bottles/Container	Containers
4	16,000,000	4,000,000	6850	584
2	8,000,000	4,000,000	13700	292
1	4,000,000	4,000,000	27400	146

As shown in the Table 7.15, a VLCC vessel has a carrying capacity of 351,700 m^3.

Cost of transport per day by VLCC vessel = US$ 40,000

Cost of transport for 30 days = 30 x 40,000 = US$ 1,200,000 (US$ 1.2 million)

Cost of transport for 40 days = 40 x 40,000 = US$ 1,600,000 (US$ 1.6 million)

Since the VLCC vessel is likely to return empty after delivering crude oil, the cargo space can be utilized for the transportation of bottled water. If a preferential cost at 20% less than of crude oil transport cost is taken into consideration, projected results are as follows:

Cost of Transportation to Jeddah = US$ 240,000

Cost of Transportation to Dammam = US$ 320,000

Cost of transport per liter = US$ 0.0085 or cent 0.85,

Cost of transport per liter = US$ 0.011 or 1.1 cent

(maximum 2.0 cents)

In this analysis, the transportation cost is US$ 0.011 (maximum 2.0 cents) per liter for Saudi Arabia. The transportation cost by shuttle service which is likely to be 1-2 cent per liter for Saudi Arabia needs to be investigated. A crude oil cargo with a capacity of 260,000 m^3 (maximum capacity 351,700 m^3) can be used to transport bottled water with 28,000 m^3 (28,000,000 liters) capacity. This will require modifications in the VLCC tanker design to use for the bottled water transportation. The next chapter VIII provides feasibility analysis considering the maximum cost of transportation and for assessing the export potential for bottled water.

Based on the discussion and the analysis, number of conclusions can be drawn. The short sea shipping such as Suez vessel as suggested by Brook and Frost (2006) appears to be the best option. However, further analysis for using time chartered container ships and large Ro-Ro ships such as Altina appears to be a better alternative. However, further analysis is required to determine the benefits of using time chartered container ships and large Ro-Ro ships such as Altina.

In terms of the transport cost, short sea shipping appears to be very competitive. However, it requires further investigation to establish the cost-effectiveness of the transportation cost. The cost of transportation by shuttle service is 3 - 4 cents per liter and by Suez vessel 6.5 cents per liter for the United States. The transportation cost by VLCC, as analyzed, is 1 - 2 cent per liter for Saudi Arabia, which, however, needs to be further investigated.

The promotion of short sea shipping can considerably reduce the traffic congestion, improve the utilization of waterway capacity, and reduce the impact of greenhouse gas emission. The short sea shipping can also increase the efficiency of the transportation system in the North America. There also appears to exist considerable prospects for the collaboration with African, Asian and the Middle East agencies for providing the transfer of technology from Canada to these countries.

Chapter VIII

FINANCIAL ANALYSIS

8.1 Introduction

The financial analysis demonstrates the feasibility for establishing a bottled water industry; it also examines the feasibility of the bottled water export from Newfoundland and Labrador to various international destinations. A financial analysis for the production of a 4.0 million per year (1.5 liter bottled water) is presented in this chapter. The analysis will include the following components:

- Capital Cost
- Production Cost
- Raw material Cost
- Packaging Cost
- Labor Cost
- Transportation Cost
- Cost Benefit Analysis

8.2 Capital Cost Investment

The capital cost investment consists of the cost of building construction and the cost of the production plant. The capital investment is a basis for calculating annual cost using depreciation cost and interest rate.

8.2.1 Building Cost

There is no standard design for bottled water production facility. However, a building area of 1,000 square meters is a reasonable size for bottled water production. The cost of land and building per square meter is approximately US$ 800 (Norland Inc., 2006).

8.2.2 Plant Cost

In the water bottling process, the cost of equipment used for water withdrawal, water storage, water treatment, PET bottle raw material cost, blow molding process, rinsing, filling, and labeling process, wrapping and packaging process is being considered. The cost of facilities, equipments and installation are given in Table 8.1 (Norland Inc., 2006).

Table 8.1: Cost of Water Bottling Plant

a. Water Withdrawal Facilities	
- Water Pump and Pipe Installation	3,500
b. Water Treatment Facilities	
- Stainless Steel Storage Tank	4,000
- Disinfection System (DP-10)	12,792
- Spares filter for DP-10	16,752
- Water Storage Control	192
c. Blow Molding Process and Cost of Raw material	
- Blow Molder System (BM-600)	79,827
- Mould	11,200
- Spares for Blow Molder (BM-600)	3,098
- Spares for Preheater (BM-600)	1,053
d. Water Bottling Process Facilities	
- Bottle Rinser (BR-3000)	17,264
- Bottle Filler (BF-3000)	35,788
- Spares for BF-3000	3,060
- Conveyor	10,000
- Spares for Conveyor	99
- Rotary Feed Table (48")	10,699
- Compressor for Bottling (7.5 HP)	3,600
e. Labeling Process Facilities	
- Bottle Date Coder	14,371
- Spares Date Coder	538
- Bottle Labeler and Capper (LC-3000)	79,843
- Cap Clincher (CC-3000)	11,757
f. Wrapping and Packaging Facilities	
- Bottle Wrapping and Packaging Facilities	47,600
Total Plant Cost	367,033
Building Cost	800,000
Total Capital Cost Investment	1,167,033

Source: Norland Inc., 2006

8.2.3 Depreciation Cost

Depreciation cost is calculated by dividing total building cost and plant cost by the number of capital years. The number of capital years usually considered are 7 years. A simple formula for the calculation of depreciation is given as:

$$D = \frac{BC + PC}{year}$$

D = 367,033 + 800,000 / 7 = US$ 166,719

Where D is the depreciation (US$), BC is the total building cost (US$), PC is the total plant cost (US$), and year is the capital years. Based on the building cost and total plant cost, the depreciation every year will be US$ 166,719.

8.2.4 Interest Cost

Annual financial interest rate for bottled water industry is taken as 8%. Based on the current interest rate value, interest to be paid can be calculated as follows:

I = IR x IC
I = 0.08 x 1,167,033 = US$ 93,362

Where I is the total interest to be paid (US$), IR is the annual interest rate, and IC is the total investment cost. If the annual industrial interest rate is 8%, the interest to be paid will be US$ 93,362 per year.

8.3 Production Cost

Production cost consists of the cost of source water, water withdrawal process, water treatment process, blow molding process, filling process, labeling process, packaging process, labor, and transportation.

8.3.1. Cost of Source Water

Source water price or water royalty depends on the location of industry. Water royalty of Newfoundland and Labrador is US$ 0.67/m^3. Based on this price, the total cost of source water for 4 million bottled water productions are calculated as:

$$RWC = 4000000 \times \frac{(WB + WR)}{1000} \times 0.67$$

Where, RWC is the total source water cost (US$), WB is the volume of water in every bottle (1.5 liter), and WR is the volume of water required for rinsing and cleaning (0.15 × WB). Based on the equation as above, the amount of water annually needed is 6,900 m^3 with a price of US$ 4,623.

8.3.2. Cost of Water Withdrawal

Operational cost for water withdrawal is based on the amount of electricity used for conveying water from the source to the storage facilities. The pump with discharge capacity of 225 liters per minute consumes 1.1 kW of electricity. Bottled water production of 15,000 per day of 1.5 liter bottled water size will need 25,875 liters of water every day for bottle rinsing and filling. The pump will operate about two hours every day to fulfill the requirement of water for daily bottled water production. If the annual effective operational days are 260 days and the price of electricity is $0.08 /kWh, the annual cost of water withdrawal process will be about US$ 42.

8.3.3. Cost of Blow Molding and Raw material

Total cost of raw material for bottling is the function of annual production, volume required per bottle, and price of raw material. The cost of raw material for bottles can be calculated as:

$$RBC = 4000000 \times \frac{VB}{1000} \times RC$$

Where RBC is the total cost of raw material for bottles (US$), VB is the volume of raw material for PET bottle required for every bottle (L), and RC is the price of raw material (US$/$m^3$). However, there is a standard price, which can be used for the production of bottled water in Canada. As obtained from Sidel, standard prices are approximately 7.2 cent per liter of bottle. This price includes the cost of raw material and electricity. Based on this price and the production of 4,000,000 bottled water per year, the annual cost for blow molding process is US$ 100,000 (Siedel, 2005).

Cost of Bottles = 4,000,000 x 0.025 = US$ 100,000

8.3.4. Cost of Electricity in Rinsing, Filling and Labeling

The total cost of filling and labeling process is a combination of the price of electricity required by each facility in the process. In the following Table 8.2, list of facilities and amount of electricity needed for the operation is presented (Noland Inc., 2006).

Table 8.2: Cost of Electricity in Rinsing, Filling and Labeling

No.	Facilities	Electric Consumption (kW)
1	Bottle Rinser (BR-3000)	0.6
2	Bottle Filler (BF-3000)	0.2
3	Conveyor	1.1
4	Rotary Feed Table (48")	1.1
5	Compressor for Bottling (7.5 HP)	1.1
6	Bottle Date Coder	1.1
7	Bottle Labeller and Capper (LC-3000)	1.1
8	Cap Clincher (CC-3000)	1.1

Source: Norland Inc., 2006

Total cost of electricity is, then, calculated as:

$$EC = \sum (EH \times EUC) \times PC$$

Where EC is the total electricity cost (US$), EH are the annual effective operation hours, ΣEUC is the total of electricity used by the facilities (kWh), and PC is the unit cost of electricity (US$/kWh). Table 8.3 presents the annual price required for rinsing, filling and labeling process based on the type of facilities and their working hours.

Table 8.3: Annual Cost of Rinsing, Filling and Labeling (US$)

Facilities	Electricity (kW)	Working Hours/day	Price unit ($/kWh)	Annual Cost ($)
Bottle Rinser (BR-3000)	0.6	8	0.08	99.84
Bottle Filler (BF-3000)	0.2	8	0.08	33.28
Conveyor	1.1	8	0.08	183.04
Rotary Feed Table (48")	1.1	8	0.08	183.04
Compressor for Bottling (7.5 HP)	1.1	8	0.08	183.04
Bottle Date Coder	1.1	8	0.08	183.04
Bottle Labeller and Capper (LC-3000)	1.1	8	0.08	183.04
Cap Clincher (CC-3000)	1.1	8	0.08	183.04
Miscellaneous	2.0	8	0.08	332.8
Total				1,564

Source: Norland Inc., 2006

Electricity needed for miscellaneous processes include electricity for wrapping, packaging, light and other facility at the production plant such as heater and air conditioner.

8.4. Packaging Cost

The cost of every case of bottled water will depend on the price of the material of the case. Total cost will be US$ 0.30 for every case containing 12 units of bottled water. Based on this price, total annual cost for packaging will be US$ 100,000. The breakdown of packaging process price is presented in the Table 8.4.

$$PC = 4{,}000{,}000 / 12 \times 0.30 = \text{US\$ } 100{,}000$$

Table 8.4: Packaging Material for Bottled Water

No.	Packaging Material	Packaging Cost (US$)
1	Case	0.58
2	Tape	0.05
3	Wrap	0.01
4	Bands	0.01
5	Total	0.65

Source: Norland Inc., 2006

8.5 Labor Cost

At least five workers and one manager can manage a bottled water production operation. The workers may have different sets of skills in technical operations. If all the workers are working 8 hours per day, labor cost based on their hourly wages and working hours are shown in Table 8.5.

Table 8.5: Labor Cost for Bottled Water Production

No.	Type of worker	Salary/hour (US$)
1	Manager	50
2	Blow mould technician	35
3	Palletizer operator	15
4	Quality control inspector	15
5	Raw material handler / office boy	12

Table 8.6: Labor Cost per Year

No.	Type of worker	Salary/hour	Working hours/year	Salary/year (US$)
1	Manager	50	2,080	104,000
2	Blow mould Technician	35	2,080	72,800
3	Palletizer Operator	15	2,080	31,200
4	Quality Control Inspector	15	2,080	31,200
5	Raw material handler / Office boy	12	2,080	24,960
Total Labor cost per year				264,160

8.6 Transportation Cost

The shipping companies are now capable of providing economical transportation especially with the introduction of containerization. Most of the cargos are now using transportation system. Growth in international trade, particularly supply chain and trade liberalization has greatly increased the demand for containerized transport. As per various transportation cost scenarios discussed in detail in Chapter VII of this study, the cost for bottled water transport are presented in the Table 8.7.

Table 8.7: Transportation Cost for Containers

Type of Container	Maximum No. of Cases	Containers/year	Rate/Container (US$)	Cost/year (US$)
45' High Cube Container	1556	214	4,500	963,000
40' High Cube Container	1622	206	4,395	905,370
40' Dry Freight Container	1501	222	4,395	975,690
20' Dry Freight Container	1211	275	3,720	1,023,000
20' Open Top Container	1196	279	3,720	1,037,880
40' Open Top Container	1,435	232	4,395	1,019,640
40' Reefer Container	1,553	215	3,720	798,455
40' High Cube Reefer Container	1,544	216	4,395	949,320

Source: Maersk Inc., 2006

From the Table 8.7, the most efficient and economical containers for transportation are 40' Reefer Container. This container may be selected for bottled water transport with an annual cost of about US$ 798,455.

8.7 Cost Benefit Analysis

The cost benefit analysis for the bottled water industry include the total annual cost of production against the total expected benefits, taking into account annual income, and overhead cost. A summary of annual cost of bottled water production process is presented in the Table 8.8.

Table 8.8: Summary of Annual Cost of Production (US$)

Items	Cost (US$)
1. Depreciation	166,719
2. Interest	93,363
3. Production Cost	
(a) Source Water Cost	4,623
(b) Water Withdrawal	42
(c) Blow Molding	100,000
(d) Rinsing, Filling and Labeling	1,564
(e) Packaging	100,000
4. Labor	264,160
5. Transportation	798,455
Total Annual Cost	1,528,926

Annual income from bottled water production depends on the price of each bottle of water sold in the countries of import. Based on the bottled water price survey, the price of a 1.5 liter of bottled water in the North America varies from US$ 0.79 to US$ 1.39.

Table 8.9 presents the analysis of final annual cost of bottled water production with a production capacity of 4 million @1.5 liter bottled water from year (1 - 10).

Table 8.9: Cost of Annual Production Years (1 - 10) in million US$

Year	Depreciation	Interest	Production Cost	Transport Cost	Labor Cost	Overhead Cost	Annual Cost
1	0.167	0.093	0.106	0.798	0.264	0.086	1.514
2	0.167	0.093	0.106	0.798	0.264	0.086	1.514
3	0.167	0.093	0.106	0.798	0.264	0.086	1.514
4	0.167	0.093	0.106	0.798	0.264	0.086	1.514
5	0.167	0.093	0.106	0.798	0.264	0.086	1.514
6	0.167	0.093	0.106	0.798	0.264	0.086	1.514
7	0.167	0.093	0.106	0.798	0.264	0.086	1.514
8	0.000	0.000	0.106	0.798	0.264	0.073	1.421
9	0.000	0.000	0.106	0.798	0.264	0.073	1.421
10	0.000	0.000	0.106	0.798	0.264	0.073	1.421

The total cost of annual production components of bottled water industry constitutes: production cost, depreciation cost, interest, labor cost and transportation cost. The overhead cost, which is approximately 5% of the sum of total of these costs, is also added to calculate the annual cost. As it is obvious from the Table 8.9, the annual cost of production of bottled water industry starts declining in the 8th year, this is because depreciation and interest on capital investment have been completely paid off till the 7th year. The capital cost of each bottled water is about US$ 0.19 from the 1st year to the 7th year and will decrease starting 8th production year.

The analysis in the Table 8.10 presents annual income and profit for the bottled water production of 4 million @1.5 liter, in years (1 - 10), with an export target to the United States and Saudi Arabia. The range of prices in this analysis is taken between US$ 0.1 and US$ 0.5. Every price is symbolized with specific term called $Price_n$. The explanation of the symbol is given as follow:

$Price_1$ = US$ 0.1

$Price_2$ = US$ 0.2

$Price_3$ = US$ 0.3

$Price_4$ = US$ 0.4

$Price_5$ = US$ 0.5

Table 8.10: Annual Income Years (1 - 10) million (US$)

Year	$Price_1$ @($0.1/b)	$Price_2$ @($0.2/b)	$Price_3$ @($0.3/b)	$Price_4$ @($0.4/b)	$Price_5$ @($0.5/b)
1	0.4	0.8	1.2	1.6	2
2	0.4	0.8	1.2	1.6	2
3	0.4	0.8	1.2	1.6	2
4	0.4	0.8	1.2	1.6	2
5	0.4	0.8	1.2	1.6	2
6	0.4	0.8	1.2	1.6	2
7	0.4	0.8	1.2	1.6	2
8	0.4	0.8	1.2	1.6	2
9	0.4	0.8	1.2	1.6	2
10	0.4	0.8	1.2	1.6	2

Table 8.11: Annual Profit from Years (1 - 10) million (US$)

Year	Price $_1$ @($0.1/b)	Price $_2$ @($0.2/b)	Price $_3$ @($0.3/b)	Price $_4$ @($0.4/b)	Price $_5$ @($0.5/b)
1	-1.14	-0.714	-0.314	0.086	0.486
2	-1.14	-0.714	-0.314	0.086	0.486
3	-1.14	-0.714	-0.314	0.086	0.486
4	-1.14	-0.714	-0.314	0.086	0.486
5	-1.14	-0.714	-0.314	0.086	0.486
6	-1.14	-0.714	-0.314	0.086	0.486
7	-1.14	-0.714	-0.314	0.086	0.486
8	-1.01	-0.621	-0.221	0.179	0.579
9	-1.01	-0.621	-0.221	0.179	0.579
10	-1.01	-0.621	-0.221	0.179	0.579

Table 8.11 illustrates profit and loss scenario, due to the variation in bottled water prices. However, the dominant factor in the profit is the increase in optimum production capacity. Table 8.11 illustrates profitability by exporting bottled water to various destinations of the United States and Saudi Arabia, which can be realized with a minimum price of US$0.40. The negative values in Table 8.11 presents a negative profit or loss.

Alternatively, economizing in the transportation cost can also increase the profitability. As discussed in Chapter VII of this report, for economical transportation system, a special container ship with the capacity of 100 containers should be chartered by the bottled water industry.

Thus the level of production must be adequate to utilize the capacity of 100 containers per month. If it is assumed that the most efficient containers with the cheapest cost of transportation is 40' Reefer Container with efficient capacity of 1,553 cases or 18,641 bottles, then the production of bottled water must be at least 1,864,100 bottled water per month or 22.4 million bottled water per year in order to fulfill 100 containers per month. Table 8.12 and Figure 8.1, illustrates the relationship between level of production and profitability during 1st to 7th year in the bottled water industry.

Table 8.12: Analysis of Annual Profit from Years (1 - 7) million (US$)

Annual Production (million bottles)	Annual Cost (US$)	Annual Income (US$)		Transportation Cost (US$)	Annual Profit (US$)	
		Price $_4$	Price $_5$	Cost Reduction	Price $_4$	Price $_5$
22.40	8.48	8.96	11.2	0.45	0.48	2.72
44.80	16.96	17.92	22.4	0.90	0.96	5.44
67.20	25.44	26.88	33.6	1.34	1.44	8.16
89.60	33.92	35.84	44.8	1.79	1.92	10.88

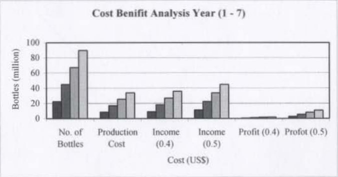

Figure 8.1: Cost Benefit Analysis Years (1-7)

Table 8.13 and Figure 8.2, illustrates the relationship between level of production and profitability during 8^{th} to 10^{th} year in the bottled water industry.

Table 8.13: Analysis of Annual Profit from Years (8 - 10) million (US$)

Annual Production (million bottles)	Annual Cost (US$)	Annual Income (US$)		Transportation Cost (US$)	Annual Profit (US$)	
		Price $_4$	Price $_5$	Cost Reduction	Price $_4$	Price $_5$
22.40	8.48	8.96	11.2	0.45	1.0	3.24
44.80	16.96	17.92	22.4	0.90	2.0	6.48
67.20	25.44	26.88	33.6	1.34	3.0	9.72
89.60	33.92	35.84	44.8	1.79	4.0	12.96

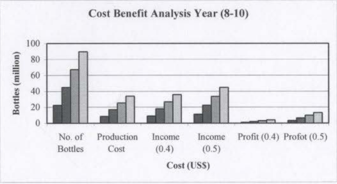

Figure 8.2: Cost Benefit Analysis Years (8-10)

Price $_4$ and Price $_5$ are used in calculation with the assumption that these are the most applicable prices for bottled water export to the United States and Saudi Arabia.

The capital cost calculation in the Table 8.12 and Table 8.13 are based on the production cost of each bottled water that is about US$ 0.20 from the 1st to 7th year and US$ 0.18 from the 8th to 10th year.

Assuming, a planned production capacity of 22.4 million bottled water, profitability due to transportation cost savings will be about half million dollar. The profitability will increase with the increase in the bottled water production as economies of scale hold true in the scenario discussed.

The financial analysis is presented based on the cost of production for 4 million bottled water per year of 1.5 liter size. In other scenarios of bottled water sizes of 4 liters, 10 liters and 19 liters and optimum production capacity may increase profitability based on detailed technological, economic and environmental parameters.

Cost of shipping and transport to export to various destinations may also economize by the introduction of chartered ships, instead of cost of transport considered on container basis. Shuttle service to various United States destinations may provide most economical cost of transportation. Export of bottled water to Saudi Arabia by chartered ships (Suez vessel) or by a modified VLCC vessel in the way back after delivering crude oil to a proposed refinery by the Newfoundland and Labrador Refining Corporation (NLRC) at Southern Head, Arnold's Cove region, Placentia Bay, Newfoundland and Labrador. In Saudi Arabia, Jeddah may be a central port of import and other African destinations such as Cairo, Egypt; Nairobi, Kenya and Cape Town, South Africa may be covered, and similarly Dammam may be a central port which may cover Doha, Qatar; Kuwait; Basra, Iraq; Dubai, U.A.E and Muscat, Oman by short sea shipping routes.

Considering the cost factor and potential international markets for the bottled water export, Canadian companies should actively explore the possibility of bottled water export by shuttle service to the United States and by VLCC vessel to Saudi Arabia.

8.8 Environmental Cost

Environmental perspective in the water bottling industry include, waste minimization in the production process. Waste minimization will contribute in conserving resources as well as energy. To incorporate waste minimization strategy, a sound knowledge of the water bottling system is essential. Often waste generation is part of the supply chain and is directly related to a particular type of packaging material and equipment. Generally management approach for waster minimization focuses on processing waste after it is generated, and then to recycle it for reuse. However, pollution prevention strategy calls for reducing waste and energy, which in turn reduce cost of production.

In the water bottling industry, an efficient manufacturing process and better quality raw material can significantly reduce the waste during production process. The waste minimization in water bottling industry can not only reduce environmental impacts but also bring significant benefits such as:

- Reduced raw material cost.
- Reduced cost of raw material processing, transportation and bottled water product.
- Reduced waste disposal cost for collection, transport, processing and disposal

While waste minimization require an extra investment, it may be compensated with the savings.

Transportation sector is a major energy user. It generates carbon monoxide, NO_x emission and greenhouse gas emissions. Hydrocarbon fuels may also produce carbon dioxide and greenhouse gases, which are the main cause of global climate change. Environmental impacts of transport system may also include traffic congestion.

Environmental cost takes into consideration economic and environmental impact information. It may be considered as a part of accounting system, which identifies measures and environmental costs associated with industrial impact of bottled water on the environment. The environmental cost may also include, cost to cleanup, remediation of contaminated sites, environmental fines, penalties and taxes, purchase of pollution prevention technologies and waste management cost. Environmental accounting system may contribute:

- Elimination of environmental cost.
- Improved environmental performance to provide positive impact on human health and bottled water industry.
- More accurate costing of bottled water product and environmental friendly water bottling process.
- Assisting in the development of environmental management system.

8.9 Discussion

In the last few decades, the demand for safe drinking water has grown considerably in world markets. In many countries, the contamination of ground water and surface water sources have been one of the major cause of increased reliance on the bottled water. In the last few decade, bottled water demand for 1 liter, 1.5 liters, 4 liters and 19 liters have increased substantially and consequently bottled water markets in the United States, Canada, Europe, United Kingdom, Mexico, South America, Middle East, Africa and Asia have flourished manifold.

Generally, in most of the countries technology for water bottling is available, but many technical collaborations for water treatment technologies and water bottling are continuously under discussion in the international trade shows on bottled water industry. Canadian bottled water industry has shown strong growth, and is capable of providing technical services to many developing countries in establishing a water bottling industry. Canada maintains "Good Manufacturing Practice (GMP)," which are provided by USFDA regulations, to ensure free from chemical, physical and bacteriological contamination during the water bottling process and packaging. Design and construction of a water bottling facility require a very high degree of technical expertise, the sanitary maintenance of buildings and fixtures, the design and maintenance of equipments, production and the process control of raw materials and manufacturing operations, including sanitation and quality control of receiving, inspecting, transporting, packaging and storage to coordinate all the operations.

Generally all the bottled water companies have transportation network to deliver the bottled water and export to international markets. France is the largest bottled water exporter worldwide. Transportation of bottled water in temperature-controlled containers has created new avenues for bottled water export throughout the world. In general, the bulk of bottled water demand is fulfilled by domestic production in most of the countries.

Chapter IX

Conclusions and Recommendations

9.1 Conclusions

Globally, water scarcity and the lack of safe drinking water has become a serious concern for human health. Considering the availability of freshwater resources in Canada and growing international demand for bottled water, there is a good potential to develop bottled water industry in Newfoundland and Labrador and to explore the possibilities of export to the United States and Middle East. In the light of proposed development for Newfoundland and Labrador Refining Corporation (NLRC) refinery at Southern Head in the Arnold's Cove region, Newfoundland and Labrador, there is a need to conduct a detailed study for establishing bottled water industry and explore possibilities of bottled water export to various destinations of US and Middle East. The following conclusions are drawn from this study:

- The growth of Canadian bottled water industry can be attributed to local as well as exports market demand for safe drinking water. The statistics on global bottled water consumption indicates that the bottled water market in 2005 was 163,664.2 million liters, with 8.7% annual growth, and current annual growth is projected more than 10%. In 2005, the Canadian bottled water production was 1906.5 million liters, out of which 52.8 million liters was exported.

- The bottled water mineral statistical analyses for 371 brand shows, that all bottled water are not safe for human consumption. Some of the bottled water brands are deficient in containing essential minerals required for human health. To overcome this problem, minerals can be injected in a balanced quantity during bottled water production to improve water quality.

- There are well-established water treatment technologies available for water bottling. Micro-filtration, ultra-filtration and nano-filtration are some of the effective filtration processes. For disinfections process, ozonation and ultraviolet (UV) technologies can be used for source water.

- An integrated water bottling and export project (600 – 3000 bottles per hour capacity), with 4 million bottles of 1.5 liter size per year, can be a feasible project for establishing a water bottling plant at Gisborne Lake, Grand Le Pierre, Newfoundland and Labrador. Innovative water treatment technologies such as micro-filtration, ultra-filtration and ultraviolet (UV) radiation are some of the effective technologies for water bottling process. Also there have been significant innovations in clean room technologies such as automatic inspection, rinsing, filling, mineral injection, packaging and the distribution of bottled water.

- The cost of transportation to export bottled water by shuttle service is 3 - 4 cents per liter and by Suez vessel it is 6.5 cents per liter for the United States. After delivering crude oil to the proposed refinery at Southern Head, Arnold's Cove region, Newfoundland and Labrador, a modified VLCC vessel can be used for bottled water export to Saudi Arabia by incurring approximately 1-2 cents per liter transportation cost.

- The financial analysis indicates that the cost of bottled water production is about US$ 0.45 per liter from the 1st year to the 7th year and US$ 0.35 for production starting 8th year. With the planned production of 22.4 million bottles per year, the profit will increase as the economies of scale hold true in the scenario discussed.

9.2 Recommendations

Based on this study the following recommendations are made:

- A detailed study should be conducted for the Gisborne Lake watershed area, including water balance and environmental impact assessment.

- Conduct hydrological impact assessment of the regions, to determine appropriate water bodies for water bottling industry.

- Study the possibility of using a modified VLCC vessel to export bottled water containers in order to reduce the cost of transportation and achieve a competitive edge in the world market.

- Conduct a detailed environmental cost analysis.

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Aqua Technology : http://www.aquatechnology.net/

Barry Rogliano Salles (BRS): http://www.brs-paris.com/

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APPENDIX - A

APPENDIX -A

Mineral Waters of the World, 2006

BRAND	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Bicarbonate	TDS
Aquafina	35	22	11	4	71	8	46	
Aberfoyle Springs	100	37	33	2	68	61	240	
ABN Agua Mineral			9		14	5	377	490
Acqua della Madonna	304	62	73	15	170	28	1135	1311
Acqua Panna	14.9	5.1	0	17.2	11.2	6.1	88	188
Acqua Panna	30.2	6.9	6.5	0.9	7.1	21.4	100	137
Ades	36	16	8.5		12	5	80	
Adria	50.3	6.6	5	1.1	10.6	22.5	146.4	
Agros Sport	28.9	13.1	14.9	0.4	14.2	20.2	134.2	
Agua Mineral Kaiary	0.11	0.11	0.01	0.47		0.1	0.4	
Aguas del Plata	20	3.5	3.2	0.5	4.8	21	70	137
Al Ain								
Albion								
Alborz	80	24	18	2	20	85	280	330
Alfa Blue	33.45	9.74	11.69		6.95	12.73		154
Alhambra	0.7	0.8	3.8		3.5	3.4		
Almasif	22	14	22	2	39	18	98	240
Alpha	17.4	16.4	210					1057
Alpine	20	16	5	4.2	12	5	335.6	75
Alpine	18.9	7.3	27.8	3.8	43	11		
Alpineb	66	4	6.9	5	6	4.6	89	115
Alp's	37.9	15.2	4.6		1	10.1	165	
Al-Qassim	7.6	1.2	31.2	0.54	34.8	19.3	18.2	160
Alto						2.46		97
Alwadi	60	8	35	0.8	45	14	140	
Aman n'Rasrou	58.4	42.5	12.8	3.1	17.7	28.5	372.7	
Amrat Jal	40	20.5	24.72	254	32.5		2.8	

BRAND	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Bicarbonate	TDS
Apani Southwest Inc.								
Apenta	197	55	280		250	440	600	1853
Apollinaris	100	130	410	20	100	80	1810	
Appalachian Springs								
Aqua	35	14.6	18.9		23	40	140	
Aqua	30.4	12.96	38	3.5	24		195.2	253
Aqua Africa	7	2	17	1	5	5		95
Aqua Antonia	37.6	11.1			3	42.4	186	
Aqua d'Or		6	14.9	1.2	16.5	11	71	
Aqua d'Or (Za)	0.6	0.8	8	0.3	12.7	1.4		31
Aqua Fennica	3.5	1.4	3.7	0.4	1	1.1	23.5	
Aqua Mathias	228	58	79	4.4	5	29	1160	1406
Aqua Prima Mountain	18.56	14.34	15.97	2.14	7.8	4.45	97.78	180.6
Aqua Terrena	3.3	0.95	9.8	0.8				
Aqua Viva	8	0.4	8.5	0.7	11	1.5	28	
Aquamine	43.9	37.9	3.91	3.13	8.64	8	218	300
Aquasana	62.2	6.6	1.5	0.3	2.5	6	219	155
aQuelle	3	2	8	4	11	5		52
Arctic Chiller	23.4	6.4	3	10.9	0.4	30	89.8	98
Arctic Glacier	0.8	0.2		0.2	1	1	1	10
Aretuza	44	26	95		75	20	379	
Arrowhead	19.7	3.8	11.1	1.8	10.8	3.4	80.2	125
Atlas Premium	16	6.8		1.6	16			140
Aura	69	8.1	4.8	1.3	0.6	4.6	237.37	242
Avahy	26.1	57.3	34.3	10.8	14.9	30.8		230
Avalon	73	36	9	1	16	57	260	
Avita Artesian	45.9	10.3	1	0.32		6	151	160
Awa	56.7	2.7	21.5	4.3	8.7	8.6	216	
Aysu	51.5	9.2	3.2	3.2	7	26	187	
Bad Vilbeler Elisabethen	110	20.2	6.3	5.4	6.3	43	397	

BRAND	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Bicarbonate	TDS
Bad Vilbeler Urquelle	174	25.8	90	13.6	93.6	36	702	
Badarijan	234	159			99	152	888.5	
Badoit	190	85	150	10	40	40	1300	120
Ballygowan	114	16	15	3	28	15	400	420
Bankia	3.2		61.9	0.65	4.3	52.7	61	237.1
Baraka	60	26	62	5	50	45	325	440
Batna	58.4	42.5	12.8	3.1	17.7	28.5	372.7	
Beckerich	96.5	5	2.8	0.6	6.3	29.6	274	360
Beckon	42.42	17.79	130.5	4.84				
Beijian	56.3	17.4	28.1	2.43	10.1	38.6		430
Ben Haroun	38.8	6.8	52.8	1.35	41.6	50	157	
Biborteni Aqua Magnesia	264.5	87.6	257.1	38	90	15.2		1618
Bisleri	13.6	7.77			22	19.34	58	160
Bizzl Mineralwasser	62	10.8	13.2	1.5	25.8	102	103	
Black Mountain	25	0.73	8.3	0.67	10			44
Bleu	23	3	30	0.8	4	4	116	187
Bonaqa	110	75	30		300	80	357	
Borjomi	100	50	2250		2000		4250	
Borsec	310	97	53	12	29	24	1800	1402
Caledon	1.9	1	17	5	23	1.7	32	93
Calistoga	1.7	1.7	183.7	14.5	224.9	83.5	36.3	571
Canadian Bourassa				0.4	0.1	1.2	0.1	7
Carlsberg Kurvand	50	5	30	2	40	35	147	220
Carolina Mountain	5.84		4.83			9.3		60
Cathareine	43	3	10	0.6	9.5	1	165	
Cellier	25	15	134	10	30	28		520
Cetina	54.8	14.2	4.8		12	14.3	107	218
Champlain	36	6	4		1	13	140	
Chantilly	15.2	7	9		5	5		
Chispal	10.3	1.4	31.2			5	30	120

BRAND	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Bicarbonate	TDS
Club	20.4	13.3	8.7	3.4	4.8	5.1	152.6	215
Cobb Mountain Spring	5.9	1.7	4	5.2	8		29	63
Colorado Crystal			1		1.2	2		95
Contrex	451	66	8	3	6	1058	386	203
Cool Valley	4	17	17	2.9	17	4	28	73
Cottonwood Valley	12	15	24	5	27		158	
Crystal (Mp)	18	14	17	1	21.6	10		
Crystal Canadian	16	9	12	1	29	9	65	
Crystal Geyser	12	3.1	130	8.7	260	2.6		590
Crystal Geyser	18			1.9				120
Crystal Spring	2	4	24	2	45	4	8	
Crystal Springs								
Crystal Tropical	0.62	0.94	7.2	6.2	11.71	1.95	8.1	
Daisy Spring	4.73	0.38	2.58	4.85	7.1	1	97.5	108
Dali	74	39.7		9.9				1177
Dannon Natural Spring								
Dasani	0.5	3.4			6.9	14	5	
Deep Rock Water	5.2							180
Deer Park	26.5	2.6	1.1	0.4	0.7	1.8	88.8	90
Delta	25.5	14.5	36	3.5	12	12	205	240
Devin	1.6		65.5	1.59	3.5	20.6	85.4	255
Dew Drops	58	44	24	22	10	9.6	466	170
Diamond	35	3.2	3.3	0.43	3.7	3.3		
Diamond Natural Spring	74	3		1.6	7.2	19		170
Dilijan	4.2	1.6	36.55					42.97
Discovery Springs			9.2	0.4				
Drakenstein	0.5	0.3	5.9	0.7	8	0.6		28
DrLudo	35.32	5.6	2.47	0.81	4.06	24.8	89.97	
Eastern Source	56		1.1	0.22				260
Eau Claire	41	4.4	4.3	9.9	1	745	153	147

BRAND	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Bicarbonate	TDS
Eau de Chamonix	2.2	1.2	11.8	0.95	15.4	0.3		
Echo Spring	77	30	3	0.92	9.7	22	282	
Eco Water Predela	8.8	3.2	6.2	0.25	2.6	4.5	48.8	88
Eiszeitquell	135	35	6.9	3.8	3.2	200	354	774
Emerald Forest	0.16	1.33	9.9	0.22	4.26		2	
Empress Springs	70.8		71.9		26.9	7.74		235
English Mountain	22	4.3	0.45					68
Euregio	68	8.4	4	1.7	0.4	23	220	
Evian	0.5	3.4	5		4	10	357	
Evian	78	23	5.5	0.75	2.2	10	357	357
Evian	78	23	5.5	0.75	2.2	10	357	
Falcon	50	46	28	2.4	6	20	152	242
Farmakas	28	9	39	0.1	21	46	140	
Farris	26	30	400	15	590	15	300	
Fatima	65.8	11.3	4.3	1.6	2.5	24.6	228.8	
Ferrarelle	362	18	49	43	21	6	1372	127
Fiji	17	13					140	160
Fiji Natural	17	13					140	160
Finn Spring	3.9	1.1	20		2	3	26	
First	53.8	19	22.3	2	15.1	47.5	217.5	405
First	48	14	40		15	17	259	330
Fiuggi	15.9	6.3	6.4	4.4	13.9	6	81.7	122
Font d' Or	24	3.9	8.3	1.6	4.6	14.8	62.2	120
Font del Regas	32.9	4.1	13.5	1.6	7.2	10.2	129.2	156
Fonte Randa	83.7	12.7	16.8	2.57	5.5	14	338	
Fountainhead	9	0.3	0					55
Fyresdal	3	0.4	1.6	0.5	1.6	3.5	13	
Galway	104	11	15	1.1	32	22	334	
Gasteiner	24.05	2.19	15	2.3	7.23	34	66.51	170.86
Gerolsteiner Sprudel	347	108	119	10.8	39.7	36.3	1817	252
Gesundbrunnen	154	71			7.8	7.8		601

BRAND	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Bicarbonate	TDS
Gibraltar Springs	80	25	3	2	5	6	290	
Glaciar	20.7		10		36.3		18.1	85.1
Glacier Water	4	3.5	8	1	8.5		28	53
Gleichenberger	187	107.7	1020	44	279		3420	5070
Glendale Spring	65.7	29.5	16	4.2	11.6	17.6	354	368
go Get Oxygenated	43	34	6	4	11	16		267
Goldaqua	228	58	79	4.4	5	29	24	1406
Golden Tulip	0.5	0.5	5	1	9	5		26
Golden Valley	8	4	8	4	10	4	50	
Great Bear	1.3	1	1.7	0.7	1.4	5.3	5.5	24
Gussinger	114.6	24.55	292.2	15.79	126.6	5.85	1049.5	1683.2
Hadda	24	1.2	90	1.7	33	27.2	207	
Hankavan-2	252	16.7	19.2	2.7	3	11.2	1117	1010
Hartz Mineral Water	86	9	35	0.2	70	28	260	400
Hassia	186	36.1	228	26.7	121	42	1144	
Hawaiian Springs	7.2	3.3	6	2.2		4	44	64
Health	15	2.5	15	3	9	5	80	
Hechtl Plus Sauerstoff	86	34.8	4.82	1.52	0.8	21.7	430.2	
Heldenspruit	7.35	5.02	38	1.53	59	5	40	
Hello	18	12	38	1.8	25	16	50	175
Hessen Quelle	242	42.4	320	33.5	294	49	1296	
Hex Valley	0.5	0.5	1.8	1	5	5		10
Highland Spring	35	8.5	6	0.6	7.5	6	136	136
Hildon	97	1.7	7.7		16	4	136	312
Hillcrest Spring Water	47.2	16.4		2.4				210
Himalayan	49	35	8.6	1.1	8		246	350
Himalayan Natural Spring	1.4	0.47	0.9	0.7	3.34	0.2	4.3	14
Hissaria	3.4		62.3	1.04	8	28.8	109.8	276
Hogsback Montaine	6.3	1.7	7	1	5	5		34
Honey	8	3.8	38	0.8	15	17	86	165

BRAND	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Bicarbonate	TDS
Hualong	118.2	24.3	18.2	1.2			262.4	687
Ice Blue	5.5	2.5	11.6	0.7	13.9	3.9		57
Ice Mist	3.3	0.95	9.8	0.8				
Ice Mountain	1.3	1.3	1.1	0.8	1.1	4.7	46.1	19
Iceland Spring	4.5	0.92	11.5	0.5	10.9	5		36
Ifri	65.5	15.8	15.8	2.1	19	35	263	328.7
Irpinska	47.1	12.8	21.8			2.9	244	
Isbre	2.6	0.24	1					19
Izvorul Minunilor	17.7	3.8	1.2	0.7	0.6	2.3	70	115
Jan	115.8	19.5	13.3	1.9	21.3	50.7	418.6	
Jana	63	32.5	2.2	0.8	1.1	5.7	354.7	
Jektiss	31.9	14.1	69.19		72.17	115.65	50.5	
Johanniter Quelle	264	94	98		80	188	1207	
Karoo	79.5	28	39	2	29	43	316	442
Karoo Full Moon	79.5	28	39	2	29	43	316	442
Keeper Springs								
Kekkuti	242	68	40	9.6	16	50	1804.3	1599
Kilimanjaro			15.5	5.2	35.5			
Knutwiler	88	24	5		5.9	22	371	537
Koktem	8	2	91		26	54.5	10	
Kootenay Springs	94	35	41	0.4				426
Ksour	68	6	10	1	28	10	207	
L' Origin	38.5	9.5	0.65	0.5	3	12.6	153	214
La Vie	23	8	60	4			251	232
La Vita	4	2.2	3.3	1	1.58	0.35		36.3
Lahnsteiner	45	19	211	9	124	111	456	
Laoshan	114	22	105				286	
Les Creus	28	7.3	11.7	1	5.3	12.3	119	160
Lichtenauer	69.5	10.8	11.9	1.7	19.6	80.3	165	
Lithinia	53.7	15.7	166	1.3	9	1	673	920
Liulong	35.1	20.4	91.8	1.8				584

BRAND	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Bicarbonate	TDS
Loli	54.1	31.5	8.2	0.8	13.5	15	267.5	289
Loon Country	26	15		0.88	0.8	9.1		120
Luisen	347	44.2	240	20.3	319	45	1336	
Lynx	51.4	4.8	2.4		4.05	12.4	165	165.5
Maarum	30	20	400	10	200		1100	
Magnesia	36.69	236.3	5.001	2.039	3.949	25	1292	1665
Malavella	53.7	9.2	1113	48	594.2	47.3	2136	3049
Maqua-2000	2				25	35		90
Marwa	80	10	37	2	64	24	244	
Masafi	4.5	21.5	14	1			70	175
Merit Selection Merite	36	8	2	2	3	26	130	160
Mineneral	30.4	11.6	56	2.5	92	40	68.32	300
Mineral Natural Drink	30.4	11.6	56	2.5	92	40	68.32	300
Minere	22	7.7	115.5	1.61	55.5	68	219	405
Mira	230	496	4800		2700	8060	1226	
Monashee	23.4	6.4	3	10.9	0.4		89.8	81
Mont Cole Natural Spring	38	8	2	2	3	26	130	
Montclair	8	12	475	13	230	39	890	
Montelis	2	0.5	3	4	1.6	5.5	8	33
Montellier	3	3.3	3.4	5	26	1.5	902	
Montrolland	64	9.7	69	4.2	121	24.5	219	
Mostini	185.2	107.1	412.4		144.2	0.185	2058	2995
Mount Franklin	3	5	14	1	20		2	
Mount Olympus Waters	7.9	2.4	3.4	0.48	5.9	8.8		56
Mountain Lite	58.7	11.5	1	1				
Mountain Valley	69.68	10.56	2.88	1.13		9.72	238.05	
Nabeghlavi	139	125	1250	5.5	83	143	4210	
Nanton	36.7	48.6		7.5	4			
Nash's	101	25	22	2.3	32	9.2	436	450
Natural Icelandic Water	5.7	1.5	4	0.5	7.1	5	18	54

BRAND	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Bicarbonate	TDS
Natural Spring	29	1	4	2	10	1		126
Natures Spring	9.5	15			10			
Naya Spring Water	45	25	7	2	1	17	245	200
Nestle Pure Life	51	6	21		99	10	53	243
Norda Daggio	7.9	2	1.5	0.7	0.9	4.6	40.9	44.5
Norda Ducale	12.6	2.1	1.6					54.5
Northern Crystal	20	7	13	1	44	13	46	160
Oasis Spring Water								
Olden	4.4	0.31	1.89	0.32	2	10		
Our Compliments	68	14.8	4.2	1.3				220
Overberg Aqua	0.5	0.3	5.9	0.7	8	0.6		28
Oxygizer	242.9	41.1	3.8	1.9	3.4	548.7		
Ozarka Natural Spring	2	1.2	2.3		3.5	2.1	4.9	32
Palm Spring								
Palomar Mountain	12	5.2	9.3	2.4		9	80	95
Panther Creek Inc.	10.5	0.05	0.5	1				5
Penafiel	131	41	159	11	131	130		880
Penafiel	131	41	159	11	131	130		880
Penta								
Perrier	147.3	3.4	9	0.6	21.5	33	390	475
Perrier - Nestle	147.3	3.4	9	0.4	21.5	33	390	478
Picardie	2.7	4.5	33	3.2	52	5		166
Poland Spring Corporation	8.3	0.8	2.9	0.5	6.1	5	20	37
Polla	65.7	17.1	35	3	3.7	7.2	372	
President's Choice	132	41	20	1	32	278	256	
Prince	53.7	21	6.2	2.43	6	1.92	274	
Pristine	7	3.2	5.1	0.2	10	2	24.4	50
Pure Lifekare	0.6	1.2	4		14		29	46
Pureza Vital	51.5	5.2	4.6	1.6	80.3	18.1	32.8	
Qua-ter	32.9	4.2	70	1.5	9.6		75.8	

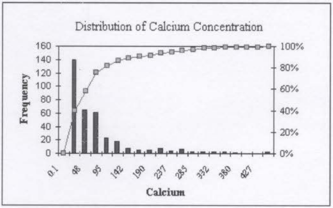
BRAND	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Bicarbonate	TDS
Qvarzia	68.8	7.9	1.4	0.4	2.8	8.2		226
Rain Farm	0.1	0.1	0.2	0.5	2	2		1
Rainbow	61	5	9	2.5	15	8	246	
Raindrops	0.8	0.2	10		8.8	0.1		16
Ramlosa	2.2	0.5	222	1.5	23	7.3	12	817
Randegger Ottilien-Quelle	88	31	9.7	1.7	5.9	33	392	526
River	16	4	7	2.6	17	23	31	
Robust				2.5		1.8	80	62
Roc Vert	17.6	46.5	2.3	6.2	3		260	
Rocky Mountain Spring	40.9	6.2	3.7	1.1	1.4	5.8	161	165
Roscommon	209	37.9	19.4	4.3	15	45	261	
Rosport	295	119	66.1	19.8	76.1	405	1043	
Royal Mountain								58
Sabrine	35	10	24	4	3	14	170	280
Safi	7	8.3	34	17	28	16.5	107.4	200
Safia	68	6	10	1	28	10	207	
Saint Justine	7	6	415	3	350		560	
Saint Nicholas	49	28	18		19	11	292	290
Salacia	245.1	33	24.5	1.9	4.6	16.7	1005	1300
San Pellegrino	208.6	58	43.8	2.9	66.2		222.7	1074
San Pellegrino	208	55.9	43.6	2.7	74.3	549.2	135.5	110
Santa Claus	10.1	4.7	7.4		9.1	15.5	31.7	
Sao Cristovao	3.11	0.83	6.3	0.9	4.7	0.6	14.8	49
Saratoga Spring Water	11	2.2	7.2	0.65	9.4	7.1	26	
Sarbi-Afash	64	0.1	240	2.9			390	
Saryagach	39	14	107				219	574
Schlossquelle Friedrichsroda	296	106	110	3	105	945	171	
Schweppes Mineral Water	26.8	12	40	3.7	22.6	12	195.2	240
Scotch Mist	55	20	12.1	0.9	21	0.6	151	

BRAND	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Bicarbonate	TDS
Selters	110	38	299	13	269	20	850	
Sidi Ali	22.4	7.3	26.8	3.4	18.5	31.6	97.6	191
Sidi el Kebir	55	11	34		22	21	230	297
Sidi Harazem	70	40	120	8	220	20	335	
Silver Source		29	112	3.9	165	74		650
Silver Stone	104	11	15	1.1	32	22	334	
Siwa	7.5	8.7	44	16.5	36	18	116.1	215
Snow Valley					2.6	3.7		30
Soha	53	28	57		67	116	204	
Sole	108	31.1	2.6	43	2.9	19.3	439.3	399.5
Sollar	65.8	34.5	57.2	41	17.5	42		
Soul Water								
Source d'Or	26.85	14.25	2.4	5.7	22	10		63
Spa Reine	3.5	1.3	3	0.5	5	6.5	11	33
Spa Reine	4.5	1.3	3	0.5	5	4	15	33
Sparkletts Water	0.7	0.8	3.8		3.5	3.4		
Sparkling Spring								
Sparta	21.6	6.6	0.9	0.33	0.2	12.7	83.8	98
Spirit Water								10
Spring Fresh	9.19	0.26	4.94	0.33	4.97		5.3	49
Sprint Up	40	1.5			36			106
Spritzer	7.5	1.8	6	4.6	1	3	55	146
St. Andrew	269.3	73.7	81.3	18	59	165	1117.2	1805.61
St. Laurent	90.2	1.2	2.5	0.4	5.5	29.5	229	
Studena	62.25	20.67	9.51	0.65	2.85	11.94	299.28	280
Sugarloaf Spring Rain	23	1.6	8.1	0.4	8.4	7.7		
Sun Best	48.9		18.5	2.2			191	339
Sun Ridge								
Sun Spring Eau de Glacier			0.4	0.8				40
Supermont	16	10.2	12.7	5.2	2.1	1	128	

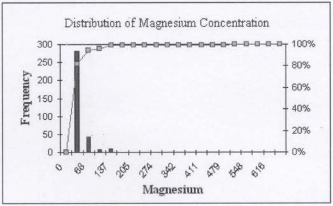
BRAND	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Bicarbonate	TDS
Taiga World			1.22		2.59	6.2		251
Tezh Sar	12.2	1.19	6.8	1	0.67	4.6	71	79
Thachbich	5.4	1.9	115	1.3	9.7	8.2	132	
Thanh Tan	148	29.9	48.3		39	331.6	237.9	
Tiba	27.2	14.4	33	3.5	16	14	195.2	235
Tipperary	37	23	25	17	15	10	282	272
Tipperary	37	23	25	17	15	10	282	272
Tjan-Schan	72	43	3		21	118.5	232	
Tonissteiner	164	130	108	13.7	31	30	1351	1829
Top-Kwaliteit	64	9.7	8.5		11	28	250	260
Toudja	60.92	13.44	52.1	0.8	71.34	20.89	212.28	
Tovtri	60	45	150	180	100	100	600	
Trenque	19.2	9.8	12.2		6.7	5		
Truly	87	31	2	1	5	8	330	
Tulbagh	10.4	15.4	35	1.6	68	5		194
Tuzlanski Kiseljak	56.05	650.3	186.2	11.44	411.8	0.1	3706	3398
Ty Nant	22.5	11.5	22	1	14	3.7	116	165
Valser	436	54	10.7	2	2.5	990	386	1918
Valvita	41.9	23.5	5		5	6	202	225
Varshetz	7.2		44.9	0.51	4.7	25.1	97.6	
Vesi Vatten	3		1.8	0.32	1	3		
Vichy Catalan	54.1	9.2	1110	48	601.5	47.3	2135	3052
Villavicencio	25.9	23.6				220	403	
Vincentka	245.29	18	2017	166		5.76	3989.4	8020
Vital	19.6	17.7	18.6	1	32.4	15.5	95.3	
Vitinka		41	446.5	23.5	570	41	3415	
Vittel	202	36	3.8			306	402	841
Vitty	2	1	16	2	17			
Viva Rosport	191	64.5	34.6	15.8	26.6	398	461	
Volvic	9.9	6.1	9.4	5.7	8.4	6.9	258	109
Volvic Natural	10	6	9	6	8	7	10	

BRAND	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Bicarbonate	TDS
Wah Water	18	31	22	2	35	50	350	
Wahaha	50	3.5	10	1.3	3.5	2	200	300
Wan Quan Shen Shui	59.6	16.61	25	1.1	15.91	22.67	261.2	451
West Best Natural Spring	13.5	4.2	3.7	0.4	0.1	25.5		112
Wilhelmstaler Brunnen	310	111	91.4		92.7	236	1347	
Winny	80	8	8	2	12	13	263	300
Xishibao	75.6	7.78	1.44					
Youkous	67.32	10.08	11.96	4.82	20.82	27.36	216.07	230.87
Yukon Spring	84.7	13.9	6.13	1.71	29.1	46.9	305	
Zam	31.7	7.3	12		12.5	10	130	
Zamkowa Zora	105	25	50		25	40	350	500
Zephyrhills	58	3.9	5.1	0.2	11	8		1.5
Zevenwacht	1.3	0.71	5	1	10	5		22

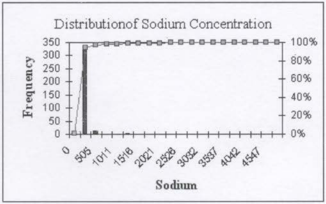
Bin	Frequency	Cumulative %
0.1	1	.28%
24	140	39.72%
48	65	58.03%
71	61	75.21%
95	23	81.69%
119	18	86.76%
142	7	88.73%
166	5	90.14%
190	5	91.55%
214	7	93.52%
237	4	94.65%
261	6	96.34%
285	3	97.18%
309	3	98.03%
332	2	98.59%
356	2	99.15%
380	1	99.44%
404	0	99.44%
427	0	99.44%
More	2	100.00%
	355	



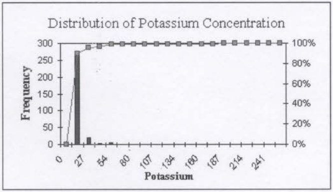
Bin	Frequency	Cumulative %
0	1	.29%
34	280	81.69%
68	43	94.19%
103	7	96.22%
137	9	98.84%
171	1	99.13%
205	0	99.13%
240	1	99.42%
274	0	99.42%
308	0	99.42%
342	0	99.42%
377	0	99.42%
411	0	99.42%
445	0	99.42%
479	0	99.42%
513	1	99.71%
548	0	99.71%
582	0	99.71%
616	0	99.71%
More	1	100.00%
	344	



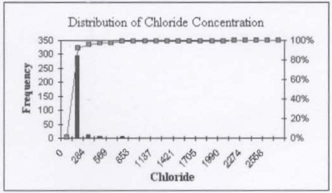
Bin	Frequency	Cumulative %
0	2	.58%
253	322	94.19%
505	12	97.67%
758	1	97.97%
1011	0	97.97%
1263	4	99.13%
1516	0	99.13%
1768	0	99.13%
2021	1	99.42%
2274	1	99.71%
2526	0	99.71%
2779	0	99.71%
3032	0	99.71%
3284	0	99.71%
3537	0	99.71%
3789	0	99.71%
4042	0	99.71%
4295	0	99.71%
4547	0	99.71%
More	1	100.00%
	344	



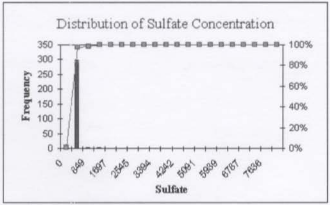
Bin	Frequency	Cumulative %
0	1	.34%
13	264	89.53%
27	19	95.95%
40	3	96.96%
54	6	98.99%
67	0	98.99%
80	0	98.99%
94	0	98.99%
107	0	98.99%
120	0	98.99%
134	0	98.99%
147	0	98.99%
160	0	98.99%
174	1	99.32%
187	1	99.66%
201	0	99.66%
214	0	99.66%
227	0	99.66%
241	0	99.66%
More	1	100.00%
	296	



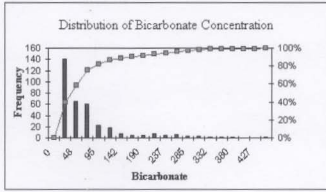
Bin	Frequency	Cumulative %
0	2	.62%
142	296	92.55%
284	11	95.96%
426	6	97.83%
569	0	97.83%
711	5	99.38%
853	0	99.38%
995	0	99.38%
1137	0	99.38%
1279	0	99.38%
1421	0	99.38%
1563	0	99.38%
1705	0	99.38%
1847	0	99.38%
1990	0	99.38%
2132	1	99.69%
2274	0	99.69%
2416	0	99.69%
2558	0	99.69%
More	1	100.00%
	322	



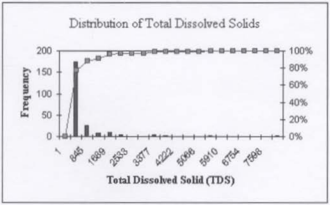
Bin	Frequency	Cumulative %
0	3	.97%
424	297	97.40%
849	4	98.70%
1273	3	99.68%
1697	0	99.68%
2121	0	99.68%
2545	0	99.68%
2970	0	99.68%
3394	0	99.68%
3818	0	99.68%
4242	0	99.68%
4666	0	99.68%
5091	0	99.68%
5515	0	99.68%
5939	0	99.68%
6363	0	99.68%
6787	0	99.68%
7212	0	99.68%
7636	0	99.68%
More	1	100.00%
	308	



Bin	Frequency	Cumulative %
0	1	.28%
24	140	39.72%
48	65	58.03%
71	61	75.21%
95	23	81.69%
119	18	86.76%
142	7	88.73%
166	5	90.14%
190	5	91.55%
214	7	93.52%
237	4	94.65%
261	6	96.34%
285	3	97.18%
309	3	98.03%
332	2	98.59%
356	2	99.15%
380	1	99.44%
404	0	99.44%
427	0	99.44%
More	2	100.00%
	355	



Bin	Frequency	Cumulative %
1	1	.44%
423	174	77.09%
845	25	88.11%
1267	7	91.19%
1689	10	95.59%
2111	4	97.36%
2533	0	97.36%
2955	0	97.36%
3377	3	98.68%
3799	1	99.12%
4222	0	99.12%
4644	0	99.12%
5066	0	99.12%
5488	1	99.56%
5910	0	99.56%
6332	0	99.56%
6754	0	99.56%
7176	0	99.56%
7598	0	99.56%
More	1	100.00%
	227	



APPENDIX - B

The Magnesium Online Library

A list of the most common bottled waters from around the world, the content of calcium, magnesium and sodium varies from water to water.

Bottled Water Name	Ca mg/l	Mg mg/l	Na mg/l	Ca:Mg Ratio	Book
A Sante	4	1	160	3.3	1
Abbey Well	54	36	45	1.5	2
Abita	-	-	48	-	1
Acqua di Nepi	72	26	32	2.8	2
Acqua Fabia	124	5	15	25.9	2
Adobe Springs	3	110	5	.0	*
Agua de Viladrau	16	2	9	7.1	2
Alhambra	10	5	5	1.9	1
Apollinaris	89	104	425	0.9	2
Aproz	454	67	8	6.8	2
Aqua Cool	45	1	3	45.0	1
Aqua-Pura	53	7	27	7.5	2
Aquamine	57	31	5	1.8	2
Arrowhead	20	5	3	4.0	1
Artesia	61	13	-	4.6	1
Badoit	200	100	160	2.0	2
Ballygowan	114	16	15	7.1	2
Belmont Springs	-	-	9	-	1
Black Mountain	25	1	8	34.2	1
Boario	124	41	6	3.0	2
Brecon Careg	48	17	6	2.9	2
Bru	23	23	10	1.0	2
Buxton	55	19	24	2.9	2
Caddo Valley	36	3	2	10.6	1
Calistoga	7	1	150	7.0	2
Canadian Glacier	1	0	1	6.3	1

Canadian Spring	11	3	2	3.8	1
Canada Geese	282	10	36	29.4	2
Carolina Mountain	6	-	5	-	1
Caxamba	-	-	3	-	1
Chiltern Hills	104	1	8	74.3	2
Clairval	20	7	13	2.9	1
Claudia	104	22	56	4.7	2
Cobb Mountain	6	2	5	2.8	1
Colorado Crystal	-	-	1	-	1
Contrex	467	84	7	5.6	2
Contrexeville	546	45	-	12.3	1
Cristalp	115	40	20	2.9	2
Crodo Lisiel	60	2	6	35.3	2
Crodo Valle d'oro	510	51	2	10.0	2
Crystal Drinking	1	1	4	0.9	1
Crystal Rock	2	2	3	0.9	1
Crystal Springs	-	-	-	-	1
Crystal Water	-	-	4	-	1
Crystal White Spr.	2	0	12	10.0	1
Deep Rock	2	0	-	10.0	1
Deer Park	1	1	1	1.3	1
Diamond Pure Water	7	1	-	9.1	2
Diamond Water	74	3	2	24.7	1
Eden	26	18	32	1.4	2
Ephrata Diamond	27	7	10	3.7	1
Evian	78	24	5	3.3	2
Fachingen	113	62	500	1.8	2
Ferrarelle	408	23	50	17.7	2
Fiuggi	15	5	6	3.1	2
Font Vella	26	5	12	5.2	2
Fonter	35	7	11	4.8	2
Franken-Brunnen	198	42	52	4.8	2
Georgia Mountain	2	0	-	3.6	2
Gerolsteiner Sprudel	364	113	128	3.2	2

Glenpatrick Spr.	112	15	12	7.5	2
Golden Eagle	22	37	1	0.6	2
Great Bear	1	1	3	0.8	1
Hassia Sprudel	176	36	232	4.9	2
Hayat	23	5	4	4.3	2
Hella	51	4	8	14.2	2
Henniez	111	19	9	5.8	2
Highland Spring	39	15	9	2.6	2
Ice Mountain	0	1	5	0.3	1
Jabal Akhdar	55	21	19	2.6	2
Kaiser Friedrich Quelle	5	4	1419	1.2	2
Kentucky Bubbling	80	-	19	-	1
Kentucky Spring	80	-	19	-	1
Kentwood	2	1	6	1.9	1
Krystynka	176	60	900	2.9	2
La Croix	37	22	4	1.7	1
La Vie	23	8	60	2.9	2
Lanjaron	50	12	-	4.2	2
Laoshan	111	70	1500	1.6	2
Levissima	18	1	1	16.7	22
Lithia Springs	120	7	680	16.4	1
Loka	4	4	139	0.9	1
Mendocino	310	130	240	2.4	2
Minere	54	27	110	2.0	2
Mount Olympus	8	2	3	3.3	1
Mountain Valley	68	8	3	8.5	2
Naleczowianka	119	24	21	4.9	2
Naya	38	20	6	1.9	2
Noah's	3	110	5	.0	*
Oasis Spring	39	11	10	3.5	1
Ozarka	18	1	5	18.4	1
Panna	15	5	13	2.8	2
Passugger	286	24	46	11.9	2
Pedras Salgadas	132	9	550	15.5	2

Penafiel	131	41	159	3.2	1
Perrier	145	4	14	41.4	2
Peterstaler	216	49	215	4.4	2
Poland Spring	-	2	3	0.0	2
Polar	13	2	9	6.6	1
Pracastello	164	46	28	3.5	2
Pure Hawaiian	-	-	-	-	1
Quibell	-	-	5	-	1
Radenska	217	97	470	2.2	2
Ramlosa	-	-	222	-	2
Ramona	10	5	22	2.1	1
Rippoldsauer	248	37	150	6.7	2
Rock Spring	-	-	5	-	2
Romerquelle	146	65	13	2.2	2
Rosbacher	256	128	40	2.0	2
Saint Yorre	30	7	1108	4.3	2
Salus Vidago	78	10	660	7.6	2
San Benedetto	43	25	8	1.7	2
San Bernardo	12	1	1	20.0	2
San Narciso	53	9	1120	6.1	2
San Pellegrino	204	57	47	3.6	2
Sangemini	322	19	21	16.9	2
Santa Ynez	19	87	-	.2	*
Sao Lourenco Fonte Oriente	68	65	82	1.0	2
Saratoga	64	7	9	9.7	1
Sidi Harazem	70	40	120	1.8	2
Sierra	-	-	-	-	1
Snow Valley	-	-	-	-	1
Sohat	31	5	4	6.0	2
Spa Reine	4	1	3	2.7	2
Sparkletts	5	5	15	1.0	1
St. Gero	407	121	175	3.4	2
St. Michaelis	43	4	21	11.6	2
Strathmore	60	15	46	4.0	2

Talawanda	-	-	3	-	1
Talking Rain	2	2	0	1.0	1
Tanuf	52	20	21	2.6	2
Thorspring	6	1	8	12.4	2
Tipperary	37	23	25	1.6	2
Uberkinger	26	17	1180	1.5	2
Utopia	76	17	8	4.5	1
Valser St.Petersquelle	436	54	11	8.1	2
Valvert	68	2	2	33.8	2
Vera	34	13	2	2.6	2
Vichy Catalan	33	8	1133	4.2	2
Vichy Celestins	100	9	1200	11.1	2
Vichy Novelle	70	110	1	0.6	2
Vichy Original	100	110	220	0.9	2
Vichy Springs	157	48	1095	3.3	1
Villa del Sur	25	15	154	1.7	2
Vittel Bonne	91	20	7	4.6	2
Vittel Grande	202	36	3	5.6	2
Vittel Hepar	575	118	13	4.9	2
Volvic	10	6	9	1.6	2
Voslauer	57	37	5	1.5	2
Zephyrhills	52	7	4	7.0	1

Source Book 1: The Pocket Guide to Bottled Water, Arthur von Wiesenberger, 1991.
Source Book 2: The Good Water Guide, Maureen and Timothy Green, 1994.
* Lab report.

http://www.mgwater.com/waters.shtml

APPENDIX - C

Survey of Bottled Water Prices

Aquafina	1 liter	$0.99
AquaSlim	500ml	$0.79
Arrowhead	1.5 liter	$0.89
Arrowhead	24 oz.	$0.55
Avalon	1 liter	$1.09
Big K (Artesian)	2.5 gal	$1.49
Big K (Artesian)	1 gal	$0.49
Big K (Artesian)	1.5 liter	3 for $2.00
Big K (Artesian)	1 liter	2 for $1.00
Big K Sparkling	12 oz can	6 for $1.49
Blu Botol	1 liter	$1.39
Blu Botol	500 ml	$0.75
Calistoga	1.5 liter	$0.89
Calistoga	1 liter	$0.79
Calistoga	500 ml	6 for $4.79
Calistoga Sparkling	1 liter	$0.89
Castle Rock	1.5 liter	$0.99
Castle Rock	20 oz	2 for $1.00
Canadian Gold	1 liter	$0.79
Canadian Gold	20 oz	$0.59
Crystal Geyser	1.5 liter	$0.89
Crystal Geyser	750 ml	$0.55
Crystal Geyser	500 ml	$6 for $2.39
Dannon	1.5 liter	$0.89
Dannon	1 liter	$0.79
Dannon	500 ml	6 for $4.09
Deep Rock (Artesian)	2.5 gal	$1.99
Deep Rock (Artesian)	1 gal	$0.69
Deep Rock (Artesian)	1.5 liter	$0.89
Deep Rock (Artesian)	1 liter	$0.79
Deep Rock (Artesian)	20 oz.	$0.59
Eldorado Artesian	1 gal	$0.79
Eldorado Artesian	1.5 liter	$0.95

Eldorado Artesian	1 liter	$0.82
Eldorado Artesian	500 ml	$0.55
Evian	1.5 liter	$1.79
Evian	1 liter	$1.19
Glacier Bay	1 gal	$1.19
Hinckley & Schmitt	1.5 liter	$0.95
Hinckley & Schmitt	1 liter	$0.75
Hinckley & Schmitt	2.5 gal	$1.99
Hinckley & Schmitt	1 gal	$0.79
Kidz Water	12 oz	6 for $2.79
King Soopers Sparkling	2 liter	$0.75
Life 02	20 oz	$1.19
Naya	1 liter	$0.99
Naya	500 ml	$0.69
Nursery Drinking	1 gal	$1.09
Perrier	750 ml	$1.55
S.Pellegrino	750 ml	$0.99

Source: http://www.bottledwaterweb.com/pricescan.jsp
Retrieved on Feb 2, 2007

APPENDIX - D

Bottled Water

Capacity Oceanex:	1004 TEU or 500 FEU		
Capacity of One Container:	25000 kg (payload) or 25000 L		
Total Capacity of Ship:	500 x 25,000 =	12,500,000	=12.5 million L
			= 12.5 million bottles

Bottled Water Production:

Per hour	= 22,500
12 hours/day	= 12 x 22,500 = 270,000 ~ 250,000 Bottles of 1.0 L
25 day production	= 25 x 250,000 = 6,250,000 million bottles
2 months production	= 12,500,000 million bottles

Therefore shipping once in two month at this production capacity = 12,500,000 million

Approximate cost of production/purchase	= \$ 0.40 per L	
Approximate cost of transport	= \$ 0.05 per L	
Profit of exporter	= \$ 0.05 per L	
Total cost to Importer	= \$ 0.50 per liter	(SR 1.5)

Cost of 4.0 L is the most economical to purchase after 18.9 L.

This may further add profit to the exporter.

Total profit per ship load @ \$0.05	= 12.5 x 0.05 = \$ 625,000 / 2 months
Profit per month	= \$ 300,000