

ASSESSMENT OF THE QUALITY OF WATER  
FOR INDUSTRIAL AND DOMESTIC USE

BY

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**ABSTRACT**

Unwholesome water for both domestic and industrial purposes constitute a serious health risk.

An assessment of the quality of water utilized in the domestic, industrial and commercial ventures, was carried out, using two approaches: (a) a survey on water utilization in food industries in Accra and Tema. Twenty food processing industries were evaluated on storage of water, the mode of cleaning of storage receptacles, quality control of water, treatment of water within the factory and problems encountered in production which might be related to water quality. Responses were analyzed using DBase 3 plus computer software.

The survey revealed that, there was poor water quality management practices in most of the food processing industries visited.

(b) Laboratory analysis of the microbiological status, physical parameters and chemical constituents of the water samples from two main sources of supply; Weiija and Kpong, was performed.

Water supplied by Weiija and Kpong Water Works, were both generally potable. The sodium, calcium and alkalinity of water were higher in Weiija water samples than in Kpong water samples.

In the rural areas, water from boreholes and deep wells may be able to meet bacteriological standards if protected, but water from such sources found in Ga Rural District, was not aesthetically pleasing to consumers because of high salt content.

Iced water and water served in informal food service centres were found to be microbiologically contaminated, some with microbes of faecal origin and therefore, may be injurious to human health.



**DECLARATION**

This Research was conducted by me as presented under the supervision of Dr. E. K. Collison of the Department of Nutrition and Food Science, University of Ghana, Legon.

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**DEDICATION**

To my dear husband, Worlanyo Kudjo Agra, who faithfully gave me every support I ever needed, and to my children, Edem, Sena, Delali and Elorm, who endured the periods of separation throughout the preparation of this manual.

Mansa

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## 1.0 INTRODUCTION

### 1.1 Water Quality

Industrial and domestic water supplies are derived from ground or surface water sources. The quality of both sources has been deteriorating rapidly, particularly during the past two decades as a direct consequence of several factors, some of which may be interrelated. Improper water management and agricultural practices have resulted in the contamination of surface and ground water sources by nitrates, pesticides and animal wastes (FAO, 1993). Furthermore, contamination by heavy metals, industrial chemicals, agrochemicals and the salinization of fresh water compound the water problem. Rapid urbanization observed in recent years has resulted in overcrowding, accompanied by poor conditions of hygiene, sanitation and water supply (Mott *et al*, 1991). Poor sanitation and disposal of faecal matter aggravates the situation, particularly in rural areas and periurban slums where seepage and run-off can contaminate ponds, streams, rivers and wells. The resulting deterioration in water quality has affected agriculture, industry and drinking water supplies (FAO, 1993).

The supply of unwholesome water and pollution of otherwise potable water sources for both domestic and industrial purposes, constitute a serious health risk. The gravest of all dangers to which water supplies are exposed is infection by pathogenic bacteria of which typhoid bacteria are now the most important (Society for Water Treatment and Examination,

1970). The problem is exacerbated by cross contamination of potable water. Cross contamination may occur as a result of poor handling practices and/or poorly managed receptacles. This is particularly common in the informal food service sector. Moreover, water used in industry requires specific standards of quality depending on the purpose for which it is required.

Non-alcoholic carbonated beverage manufacturers in parts of Accra, recently, indicated dissatisfaction with the quality of treated water from the distribution system. Complaints reaching the Ghana Standards Board indicated that, poor water quality affected production capacity and occasional poor product quality. Acceptable standards of water quality can be assured if the sources of water supply can effectively be controlled and monitored. This requires the identification of critical points of contamination or compromising of quality. This study is an attempt to evaluate the water quality at various points of distribution and storage in urban and rural Accra.

## **1.2 Objectives.**

### 1.2.1 Main Objectives

- (i) To determine the quality of water in areas with pipe borne water supply from Kpong and Weiija water works.
- (ii) To determine the quality of water in areas without pipe borne water supply.

- (iii) Relate the effect of source, handling and treatment to the quality of water for domestic and industrial use.

#### 1.2.2 Specific Objectives

- (i) Survey on source, storage, handling or treatment and utilization of water in formal industries in Accra.
- (ii) Determine physical, chemical and bacteriological quality of water samples from;
  - (a) rural areas
  - (b) urban areas on both the Kpong and Weiija Supply distribution lines.
- (iii) Determine bacteriological quality of samples from;
  - (a) informal food service centres
  - (b) "iced water" vendors.

## 2.0 LITERATURE REVIEW

### 2.1 Water and Human Existence: Dependency of life on Water.

Mayer (1987), noted that all forms of life on our planet are dependent on water. From the very beginning of civilization man has settled close to water sources; along rivers, beside lakes or near springs. Indeed, where people live, some water is normally available for drinking, domestic use and possibly for watering animals (Hofke, 1983). But since it is ubiquitous the presence of water, like air is taken for granted.

Water constitutes about sixty per cent of the human body. It provides a medium in which nutrients, enzymes and other chemical substances can be dispersed and in which the chemical reactions necessary for maintaining life can take place. It is also a means of transporting nutrients and waste products respectively to and from the cells through the blood plasma which is ninety per cent water. The normal functioning of the body involves a continual loss of water. Since excess water cannot be stored in the body, a regular intake is essential to keep the necessary balance (Gaman and Sherrington, 1981). This may be by means of drinking water, fruit, juices, formulated drinks and by oxidation of foods. Water is therefore the most precious resource on earth.



## 2.2 Availability of water

The surface of the planet is more than two thirds covered by water. Though the oceans seem unbounded, the amount of fresh water actually available to people is finite (Engleman and Le Roy, 1993). Less than one per cent of the earth's water is available for human consumption. Only 2.5 per cent of the planet's 1.4 billion cubic kilometres of water is fresh and fit for drinking, growing crops and most industrial uses. (Engelman and Le Roy, 1993). In theory, even this limited amount could support twenty billion people, nearly four times the world's current population (La Riviere, 1989). In reality, however, usable water supplies are distributed unevenly around the world. More than two thirds of the world's people live in areas already suffering from chronic water shortages including most of Africa, the near East, north Asia and Australia (Falkenmark, 1990). More than a billion people, mostly the poor, still have no access to potable water (WHO, 1993a).

Individual governments have made committed efforts to provide clean and potable water to both rural and urban dwellers. Indeed, by 1990, safe water supplies had been extended to eighty-one (81) per cent of urban dwellers and fifty eight (58) per cent of rural inhabitants (WHO, 1993a). However, most governments' efforts in providing good water, are not able to keep pace with the population growth. Consequently, as the population grows, the average amount of renewable fresh water available to each person declines.

Fresh water availability is dictated largely by climate, by the timing and location of precipitation and by "evaporative demand", a measure of how much moisture the atmosphere can absorb (Engelman and Le Roy, 1993). Water availability varies from season to season, causing distinct wet and dry seasons. It may also vary from year to year resulting in flooding or drought in many countries, leading to scarce water supplies.

Efforts need to be directed towards protecting the sources, as well as conservation methods to ensure the continuous availability of water, irrespective of the season. Some developing nations including Ghana, Indonesia and Mexico have boosted their efforts to conserve water supplies and prevent pollution through waste control facilities, water treatment plants, recycling and conservation (La Riviere, 1989).

### **2.3 Water Demand**

The amount of fresh water available is competed for by drinking water supply, sanitation, industry and agriculture (FAO, 1993). Due to population growth alone, water demand is expected to double in more than half of the world's countries by the year 2000 (FAO, 1986). Most of this increased demand is for irrigation and industrial uses. About sixty nine (69) per cent of the world's fresh water is used for irrigation, twenty three (23) per cent for industry and only eight (8) per cent for household use (World Resources Inst, 1992).

About 1.3 billion people in the developing world lack access

to clean and plentiful water (World Bank, 1994) (FAO, 1993). In slum areas where water is frequently purchased or the water supply is irregular or both, daily per capita consumption is about sixty (60) litres or less than half of middle-income neighbourhoods (World Bank, 1994).

Consumption of water soars if the source is within a hundred metres, and falls dramatically if the distance exceeds one kilometre or twenty minutes travel return time (Water Aid, 1993). Average consumption patterns, as related to sources of supply, distance to source, and purpose to which it is committed, are summarised in TABLES 1 and 2.

Table 1 Average Water Consumption from Communal Water Points (Wells, Boreholes, Stand posts).

Source distance (m)	Approx. Water Usage (L/head/day)
> 2,500	5
250 - 2,500	15
< 250	15 - 35

Source : Water Aid, 1993.



Table 2 Average Water Consumption from Piped supplies.

Type of supply	Approx. Water Usage L/Hd/Day
Yard/single household tap	75
Schools : Day	25
Boarding	45
Hospitals	300
Govt. Offices	30
Livestock : Horses	35
Cattle	40
Pigs	15
Sheep	12.5
100 chickens	15
Irrigation :	
750 L of water/kg of grain grown	
1500 L of water/kg of rice grown	
Small scale industries :	
100 L of water required/kg paper made	
4 L of water required/kg bread baked	
100 L of water required/kg steel made	

Source : Water Aid, 1993.

#### **2.4. Water Sector Development and Management**

Access to safe water remains an urgent human need in many countries. Water sector development is immediately relevant for billions of people in developing countries and for the quality of the environment in which they live. First, there is the "old agenda" of providing all people of the world with adequate water supply and sanitation services. Then, there is the challenge of a "new agenda" which requires that much greater attention be paid to ensuring that our use of water resources is sustainable in terms of both quality and quantity (Serageldin, 1994). Developing countries face the formidable challenge of completing the old agenda and making progress on the new agenda concurrently.

An alarming and disturbing statistic emerged during the UN

water Decade. In rural areas, where water supply is usually provided through point sources fitted with hand pumps or motorised pumps, a high percentage of facilities were reported to be out of order. Statistics for inoperative facilities ranging from forty per cent, fifty per cent and even higher have been reported. In some countries, it was discovered that all of the systems constructed under particular aid programmes were out of order and had been abandoned (McPherson, 1993). There are case histories of project failures in rural areas due to many factors including choice of inappropriate technology, lack of effective backup support, non-involvement of the user community in the planning and implementation process and implementation of projects for political gains (Muyibi, 1992). In large cities, it was found that an average of thirty per cent and even up to fifty per cent of the water produced was unaccounted for. Leakage, illegal connections, broken meters and other reasons were identified. Besides, only a part of the water bills are actually collected (Mashauri and Katko, 1993). High rates of unaccounted for water, whether they are caused by illegal connections, leakage, free water supply or the result of inadequate commercial operations, result in significant financial losses and consequent poor service performance of the agencies.

In the cities, wastage in the areas served is usually high. In addition, it is common that water rates are subsidised while the inhabitants in the marginal areas largely go unserved and obtain water on an irregular basis and at very

high costs from private vendors. The failure of water supply systems and the high percentage which are functioning at less than design capacity is directly attributable to poor operation and maintenance and the absence of adequate operation and maintenance (McPherson, 1993).

The experiences of the International Water Supply and Sanitation Decade, 1980 to 1990, (IDWSSD), have led to a much better understanding of the range of technologies available for environmental upgrading of low-income communities in the developing countries of the south. However, the technologies by themselves will not lead to the necessary environmental upgrading or promote health and quality of life. Unless the consumers are involved, systems will not be maintained correctly and will fail (Barker *et al*, 1991). A remarkable consensus has been emerging in recent years for managing water resources and for delivering water supply and sanitation on an efficient equitable and sustainable basis. There is the traditional view that assumes that government has the primary responsibility for financing, managing and operating services. Furthermore, it is thought that, government has to define the services to be provided, to subsidise these services (especially for the poor) and to develop public organisations for service delivery. All this is changing. The 1992 World Conference on water and the Environment gave rise to two principles which are now being widely adopted :

1. Water has an economic value in all its competing uses and should be recognised as an economic good.

2. Water development and management should be based on a participatory approach involving users, planners and policy makers at all levels, with decisions taken at the lowest appropriate level (Serageldin, 1994).

Past experience in water and sanitation issues illustrate the limitations of direct government provisions of house hold services. Despite technical progress in developing affordable engineering solutions to the problems of water and sanitation, the delivery and maintenance of these services especially by governments have been disappointing (World Bank, 1993). At the end of the IDWSSD, most people in the poorer regions of the world still lacked good sanitation and the number of urban residents without water had not been reduced.

The most obvious and poignant costs of these service shortfalls are those measured in human sufferings. Most people want safe water and good sanitation and are willing to pay for these services especially for plentiful water in or very near the house. Improvements in water supply raise productivity through savings in the fuel used to boil polluted water. A more important benefit is through the time and energy savings for women who have to collect water from distant sources (World Bank, 1993). Poor people often depend on private vendors who typically charge more for contaminated water collected by bucket, while the middle class pays less for treated water provided on tap in their houses by the publicly subsidised company. In Onitsha, Nigeria, for

instance, revenues collected by water vendors are about ten times the revenues collected by the formal water utility (Serageldin, 1994). Especially where formal institutions perform inadequately, a large informal private industry has arisen to meet those needs that are not adequately met. In cities throughout the developing world, households cope with the unreliability of formal water supply service by building in-house storage tanks installing booster pumps (which can draw contaminated ground water into the water systems) and sinking wells. The specific implications for the formal sector is profound and clear. There is an enormous reservoir of resources that can be drawn on at reduced costs for all. This can happen when the formal sector is able to meet consumer demand and provide its service in a responsive, accountable way. The differences in access between lower and within countries inequities continue to be striking. For example, a family on the top fifth income group in Peru, the Dominican Republic or Ghana is respectively, three, six and twelve times more likely to have a house connection than a family in the bottom fifth income group in those countries (World Bank, 1992). Inadequate investments in waste collection and disposal mean that large quantities of waste enter both ground water and surface water. Ground water contamination is less visible but often more serious because it can take decades for polluted aquifers to cleanse themselves and because large numbers of people drink untreated ground water. More environmental damage occurs when people try to compensate for inadequate provision. Sinking wells,

for example, often leads to overpumping and depletion. Inadequate water supply also prompts people to boil water, thus using energy. Investments in water supply can therefore reduce fuelwood consumption and air pollution.

Currently, the emphasis is on community management, ensuring that the end users are involved at all stages of the planning implementation, operation and maintenance of their own schemes. The highest potential for sustainability is achieved when the community is involved in all phases of the project starting from the planning stage. If the scheme is to continue to operate satisfactorily, people have to recognise the need for the improved service, be able and willing to pay for the maintenance cost and eventually the construction cost and also be willing to manage its maintenance. Community management occurs when the people of a community through a representative community organization, have the legal right to assume ownership and responsibility for their water supply. Secondly, it has to occur in an enabling environment. Government sector agencies and donors play a major role in providing this enabling environment. The provision of water is a service which requires a service oriented attitude by the agencies involved. To ensure long sustainability, water should be managed as a commodity in exactly the same way as any other resource. Sector professionals are advocating community management which has been successfully practised in different parts of Africa as the most effective way to plan, construct, operate and

maintain rural and periurban facilities (McCommon *et al*, 1990).

National sector policy in Ghana embodies the principle of community management of water supply rehabilitation, operation and maintenance. However, the main sector agency, Ghana Water and Sewerage Corporation, (GWSC), has not been able to progress very far in establishing community management of rural and urban water supplies. The Government of Ghana appears to regard the GWSC Assistance Project as a means to strengthen and streamline GWSC and to establish community management of urban and rural water supplies (Livingstone, 1993). Towns and cities in northern Ghana dealt within the GWSC Assistance Project all had existing mechanised water supplies, but no effective community water supply committees or groups existed. In some towns where boreholes equipped with hand pumps had been installed by a previous Canadian International Development Agency (CIDA) supported project, hand pump committees had been formed. These committees concentrated on raising funds for the hand pump tariff and keeping the pump site clean.

Most mechanised water supplies are inoperative or operating far below original capacity and all require major rehabilitation. While more than eighty per cent of boreholes with hand pumps are claimed to be operational, most shallow hand dug wells run out of water in the dry season each year (GWSC, 1992).

The impact of the activities of non-government organizations such as the CIDA and World Vision International (WVI) in mitigating drought in pastoral northern Ghana is seen in terms of water supply, rural health and sanitation, community participation and awareness, tariff rates and wider socio-economic outcomes (Cudjoe-Ofori, 1991).

## **2.5 Effect of Water Quality on Health**

Good and adequate water supply services are a pre-requisite for public health and well-being. Water quality affects health and with on ever-increasing population and greater environmental contamination, the risk of contamination of public water supplies increases. Water quality may be good at the source but its risk of contamination during transport and low likelihood of being boiled for sterilization raise the incidence of water-borne diseases (World Bank, 1994). The availability of water affects health since water is needed both for drinking and for good personal hygiene. Water availability is as important as water quality. Large quantities of water is needed to ensure good sanitation and personal hygiene. Washing hands after defecation and before preparing food is of particular importance in reducing disease transmission but without abundant water in or near the house, hygiene becomes difficult or impossible.

The general health status of a country has been connected to the water supply and water-borne diseases. This is reflected in the life expectancy and an infant mortality rates (WHO,

1986). The health burden of unsafe and insufficient quantities of water and inadequate sanitation facilities continues to be borne in terms of high rates of water related diseases, especially diarrhoeal diseases, dysentery, gastroenteritis, lepidospiral jaundice (Weil's disease), schistosomiasis, dracunculiasis enteric fever, cholera, trachoma and skin and eye infections (WHO, 1993a; Hofke, 1983). The most important of these, diarrhoea and intestinal worm infections account for an annual burden of 117 million DALY'S or ten per cent of the total burden of disease in developing countries (World Bank, 1993a). A review (Esrey et al, 1991) of findings from 144 studies revealed that, improved water supplies and sanitation often reduces child diarrhoeal mortality by fifty per cent and sometimes as much as eighty per cent.

There is now a global acceptance that the eradication of dracunculiasis is possible through improved water supplies. Major national efforts in Ghana, Indonesia and Nigeria give great promise that this disease can be eradicated during the 1990s (WHO, 1993a). Populations with improved water supply experience forty per cent lower incidence. Public water taps alone reduce the incidence by about twenty per cent. Improvements in the rural water supply in Africa have resulted in a remarkable reduction in the number of cases of Guinea worm infestation. In Nigeria, for example, 640,000 in 1991 as a result of a combination of improved water supply, treatment and education (WHO, 1993a).

The health risk due to chemical toxicants in drinking water differs from that caused by microbiological contaminants. The problems associated with chemical constituents arise primarily from their ability to cause adverse effects after prolonged periods of exposure. Mercury is known to produce neurological and renal disturbances whilst several other chemical constituents have been proven to be carcinogenic. Secondly, acute effects are noticeable more frequently in infants due to immature organs. For example, the most common cause of infantile methaemoglobinaemia is excessive levels of nitrate in water used for the reconstruction of baby food.

Efforts should therefore be geared towards providing and maintaining water of a quality that can be safely consumed by everyone throughout their lifetime.

#### 2.5.1 Pollution of Natural Water Sources

Today, twenty-two (22) countries have renewable water resources less than 1,000 cubic meters per capita, a level commonly taken to indicate severe water scarcity. An additional eighteen (18) countries have less than 2,000 cubic meters per capita. Elsewhere, water scarcity is less of a problem at the national level but is nevertheless severe in certain regions at certain times of the year and during periods of drought. The situation is worsened by widespread mismanagement of water resources, with scarcity induced by the provision of large quantities of water at minimal or no cost for low-value agricultural uses. Pollution with human sewage

and agroindustrial effluent is a major cause whilst surface run-off in agricultural areas with intensive fertilizer use is another contributor. Pollutants from industrial, mining and agricultural activities are hard to remove from drinking water with standard purification facilities (World Bank, 1992).

Most rivers in and around cities and towns in developing countries are little more than open, stinking sewers that not only degrade the aesthetic life of the city but also constitute a reservoir for cholera and other water-related diseases (Serageldin, 1994).

#### 2.5.2 Disease: Consequence of unsafe water

The direct impact of waterborne disease is huge especially for children and the poor (who are most at risk). Unsafe water is implicated in many cases of diarrhoeal diseases which as a group kill more than three (3) million people, mostly children and cause about nine hundred (900) million episodes of illness each year. At any one time more than nine hundred (900) million people are afflicted with roundworm infection and two hundred (200) million with schistosomiasis. Besides, diarrhoea for instance can leave a child vulnerable to illness and death from other causes (World Bank, 1992).

The most widespread contamination of water is from disease-bearing human wastes, usually detected by measuring faecal coliform levels. Human waste pose great health risks for the

many people who are compelled to drink and wash in untreated water from rivers and ponds.

Enteric parasitic diseases in man in Malaysia are caused mainly by *Entamoeba histolytica*, *Giardia lamblia* (*G. duodenalis*), *Ascaris lumbricoides*, *Trichuris trichiuria* and hookworms. The endemicity of these faecal, soil and waterborne diseases is an indication of the environmental sanitation and socioeconomic status of the community, being more common in both urban and rural disadvantaged communities where living conditions, environmental cleanliness as well as personal and domestic hygiene are poor. As these highly endemic and easily transmitted enteric parasitic diseases are perpetuated by a vicious cycle of poverty, ignorance and insanitary living conditions, their control should be approached by an integrated multi-sectoral strategy (Kan, 1988).

Outbreaks of febrile illness or dengue were reported from six villages of Parbhani district of Maharashtra, India, in 1989. Water supply and storage systems were found to be included in factors that have a significant role in the extension of dengue to rural areas (Risbud *et al*, 1991).

The high prevalence of gastroenteric difficulties among waterborne diseases is outlined by Roodselaar and Van-Roodselaar, (1988).

Helmer *et al*, (1991) also investigated transmission pathways of human pathogens from their faecal origin back to man via drinking water, bathing waters, shellfish and sewage-irrigated crops. They came to the conclusion that total and faecal coliform guideline value for drinking water are generally complied with in urban water supplies but difficult to meet in rural areas for developing countries. Waste water reuse for crop irrigation is also rapidly expanding due to water shortages but poses health risk to farm workers and consumers.

Ashton and Laura (1989) reviewed the evidence for aluminium intake as a health risk. They described the widespread use of aluminium in a multiplicity of applications including water treatment. After looking at evidence of aluminium being a cause of Alzheimer's disease, that aluminium is neurotoxic and may be an etiological factor in amyotrophic lateral sclerosis, Parkinson's disease, Down's syndrome, muscular dystrophies and other diseases, they concluded that despite its many virtues, the potential health risks associated with aluminium can no longer be dismissed as negligible.

### 2.5.3 Chemical Water Quality

Factors contributing to the chemical composition of drinking water include, chemical weathering of mineral matter, atmospheric supply of salt particles from the sea, anthropogenic pollution (including acid precipitation) corrosion of water pipes and plumbing, water treatment, decomposition of organic matter and hydrological differences (Flaten, 1992).

Colour, taste, odour and turbidity of inorganic origin are caused by the presence of iron, manganese, magnesium, calcium, chloride, silicone and others. They normally exist at acceptable levels in most drinking water. In the presence of oxygen, iron and manganese are able to undergo changes, causing discoloration of water and sometimes sedimentation.

In Norway, water samples from 384 waterworks were analyzed for 30 constituents by Flaten in 1992. Norwegian quality criteria were generally fulfilled indicating that the chemical quality of drinking water is good in Norway. However, for iron, calcium, manganese, copper, pH, total organic carbon and colour, the norms for good drinking water were exceeded in more than nine per cent of the samples, reflecting two major problems associated with Norwegian drinking water supplies, namely:

- (i) many water sources contain high concentrations of humic substances,
- (ii) in large parts of the country, the waters are soft and acidic and therefore corrosive towards pipes, plumbing and other installations (Flaten, 1992).

Studies of drinking water quality in areas of the eastern United States have shown that the water can often be highly corrosive (Taylor and Symons, 1984). Even mildly acid waters cause elevated levels of copper, lead and zinc in municipally distributed domestic water (Meranger *et al*, 1986).

In a direct attempt to control nitrates in public water

supplies, the UK government, in 1990, introduced a pilot nitrate scheme to reduce leaching from inorganic and organic nitrogen fertilizers. Despite designation of Water Pollution Safeguard Areas since 1963, nitrate levels in public supplies have not shown substantial reductions. This is due to a range of factors determining farmers attitudes towards the environment and a range of economic pressures controlling to increase productivity. An imposition of fertilizer tax based on the nitrogen content of the fertilizer may serve as a deterrent of excessive applications (Foster *et al*, 1992). A decision aid has been developed for use by farmers and other pesticide users that permits the selection of pesticides on the basis of water quality impact in addition to other traditional selection criteria. The decision aid uses information of environmental fate and toxicity of pesticides, soil leaching potential or run-off to make site-specific selections that minimise the potential impacts of pesticide use on water quality. This will help agricultural and urban pesticide users select pesticides with less water quality impact and also aid regulatory agencies in developing meaningful ground water protection plans, and hopefully result in more equitable public policy decisions (Hornsby *et al*, 1993).

Knowledge of the benefits and costs to water users is required for a complete assessment of policies to create incentives for water quality improving changes in agricultural production (Ribaudo and Hellerstein, 1992).

#### 2.5.4 Disinfection by-products

The diseases, typhoid, dysentery, amoebiasis, salmonellosis, Shigellosis and hepatitis from which thirty thousand people die every day in the developing countries are virtually unknown in countries where water supplies are chlorinated. But recent research suggests that chlorine itself presents a health risk. Chlorine added to water forms by-products which may cause cancer, although after many years of continuous ingestion. The risks are small. People who drink water containing chloroform, one of the by-products of chlorine disinfection have a one-in-10 million chance of developing cancer in a life time (Baker, 1988). This is very different from the certainty that people who ingest just a few typhoid bacteria will develop the life-threatening waterborne illness within days. In the industrialized countries, however, chlorine is losing its favour. The fear is that, while chloroform exposes consumers to a negligible risk, other unidentifiable by-products of chlorine disinfection present a higher risk, the level of which is not quantifiable by the studies done so far.

Chlorination of aldicarb species during water treatment can reduce the initial concentrations but may produce compounds of concern to public health, the production rate of which is several magnitudes faster than the detoxification mechanism (Miles, 1991).

#### 2.5.5. Bottled Mineral water(Mistrust of tap water)

In recent years, consumption and use of bottled waters have increased considerably. In the UK, sales of bottled mineral water increased from three (3) million to 128 million litres between 1976 and 1986. There is a public perception that bottled water is in some manner safer than tap water (Dabeka *et al*, 1992). A survey of over 250 people in London and the midlands in 1988 showed that over a quarter never drank water directly from the tap. The water industry, feeling the consequences of privatization, stringent European community directives and growing pressure from environmental groups, is finding it hard to convince the public that tap water is still safe, let alone palatable. Scares like the accidental contamination of water at Camelford with aluminium only make it worse (Walker, 1992).

#### 2.5.6. Effect of improvement of services

Environmental sanitation, water supply and the safety of foods are important determinants of nutritional and health status. Contamination of water sources is determined by such sanitary habits as excreta and garbage disposal, although water availability itself is often the most important variable. Improved water and sanitation are associated with decreased diarrhoeal disease, improved nutritional status and lower childhood mortality. As shown in TABLE 3, health consequences are staggering, an estimated two million deaths from diarrhoea alone could be avoided each year if all people had access to satisfactory water supply and sanitation services.

Table 3. Effects of Improved Water and Sanitation on sickness

Disease	Millions of people affected by illness	Median reduction attributable to improvement (%)
Diarrhoea	900 <sup>a</sup>	22
Roundworm	900	28
Guineaworm	4	76
<u>Schistosomiasis</u>	200	73

<sup>a</sup> refers to the number of cases in a year

Source : Esrey *et al*, 1991,

The impact of the afore-mentioned parasitoses on employment and public health and the control measures adapted to urban environments can be considerable (Mott *et al*, 1991). Implications of lack of adequate, safe and clean water include:

- (i) Economic development would be more and more compromised as many people become unproductive as a result of ill health.
- (ii) The sources of income and the standard of living will dwindle
- (iii) The cumulative effect of all these will be a loss to the government and the overall National Development

#### 2.5.7 Health Education

If water sector programmes are to be successful, water supply, sanitation and personal hygiene education must all be sustainable. Studies show that the effect of making several

kinds of improvements on water and sanitation, at the same time are additive (TABLE 4).

Table 4 Effects of Water Supply and Sanitation Improvements on morbidity from Diarrhoea

<u>Type of improvement</u>	<u>Median Reduction in morbidity(%)</u>
Quality of water	16
Availability of water	25
Quality and Availability of water	37
Disposal of excreta	22

Source: Esrey *et al*, 1985.

Cited in World Bank, 1992.

Kendie (1992) surveyed water use patterns in Sissala district in the Upper Region of Ghana in 1991 to determine the sources of water for drinking both at home and when on the farm. His main finding was the link between education and the time people are most likely to use water from contaminated sources, which was thought to be the rainy season. To achieve lasting health benefits therefore, sustained education during the rainy season becomes indispensable.

## **2.6. Water Treatment**

Conventional water treatment comprises four major steps:

- (a) Storage and Settlement

- (b) Flocculation and settlement
- (c) Filtration
- (d) Disinfection or sterilization

### 2.6.1 Settlement

Storage in covered tanks can reduce bacteria population considerably. For instance, cercaria in bilharzia infection are unable to infect host and will die within a period of forty eight hours. Therefore, simple storage in covered pots for at least two days is able to remove the danger of bilharzia infection.

### 2.6.2 Flocculation

Coagulants are used to precipitate colloidal particles. Various coagulants that may be used are:

- (a) Aluminium sulphate (alum)
- (b) Sodium alumina in conjunction with aluminium sulphate
- (c) Ferrous sulphate and lime
- (d) Ferric chloride

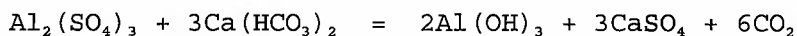
It has been found that the rate of precipitate formation attained a maximum at about pH 5.5 from sulphate solutions whilst from a chloride solution, this occurred at pH 8, demonstrating strong coagulating power of the sulphate ion. On the other hand, the alum floc dissolves again at about pH 10 - 11. To counteract this the use of a colloidal solution of aluminium hydroxide peptised with ferric chloride has been suggested as a coagulant over the whole range of alkalinity (James, 1971).

The successful clarification of water by alum appears to depend on three factors:

- (a) the minimum amount of alum necessary
- (b) the presence of an anion which will readily promote coagulation
- (c) the correct pH value of the water.

A saving of coagulant may be effected by adding the minimum amount of coagulant and adjusting the pH value of the water by acid or alkali. However, the treated water may be corrosive if the pH falls below 5.5. Consequently, the pH must be readjusted afterward. Control by pH alone may be of little use, but if carried out with a full knowledge of the contents of the water, it constitutes a most valuable method of control.

Attention has been drawn to the retention of carbon dioxide in solution when alumino-ferric coagulants are used and which has caused serious interference with flocculation. The removal of an alum floc may be represented by the equation:

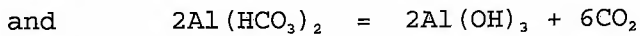
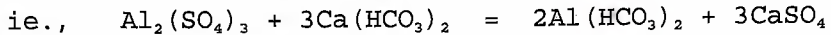


(James, 1971)

### 2.6.3 Sand filtration.

Various types of sand filters are used to meet particular demands. A forty four (44) gallon drum upward-flow sand

filter may be able to treat for example, 230L (50gal) of water per hour. Complete removal of *Giardia* through slow sand filtration was reported by Bryck et al, (1988).



If the  $\text{Al}(\text{OH})_3$  is not completely precipitated, the  $\text{Al}(\text{HCO}_3)_2$  is retained in solution.

#### 2.6.4 Disinfection and sterilization

##### 2.6.4.1 Chlorine

Chlorine is a remarkably efficient way to rid public water supplies of the most pathogenic bacteria, like the one that causes typhoid, viruses, helminths and protozoa. It is cheap and easy to use. It is able to maintain a residual protection in the distribution system. For these reason, it is likely to remain the most widely used chemical for water treatment especially in developing countries where up to 1,500 million people may be without safe water supplies. Often the total dosage which depends roughly on the total organic carbon (TOC) content of the raw water, is applied at two or three points in the plant. Typically a strong dose is given as the water enters the plant, followed by a booster after filtration and as adjustment of the residual as the finished water enters the distribution system. A simple modification consists of moving the point of initial chlorination to a point after the

coagulation and flocculation stages, which have been shown to remove about half the organic content and with it half the potential for haloform formation (Baker, 1988).

WHO, encourages practical alternatives to chlorine to minimise the formation of trihalomethanes but cautions that inadequate disinfection may result if care is not taken. Alternatives to chlorine disinfection include chlorine dioxide, chloramine, ozone ultraviolet and adsorption using synthetic resins.

#### 2.6.4.2 Chlorine Dioxide

Chlorine dioxide is widely used in water treatment plants for taste, odour and algal control, iron and manganese removal and in Europe, for disinfection. It is a highly effective biocide against bacteria and viruses, and leaves a residual.

#### 2.6.4.3 Chloramine

Free aqueous chlorine is applied as a primary disinfectant for an hour or so, and then ammonia is added to form chloramine as residual disinfectant. This inhibits further formation of haloforms and presumably other chlorinated organic compounds in the distribution system. In naturally ammonia-rich waters, simply adding chlorine will produce chloramines. Chloramine appears to be less effective than chlorine in preventing nuisance growths in pipes, causing unsightly filamentous sediments at consumers tap. For the same reason, the odorous secretions of algae, which are not killed by chloramine, may persist and chloramine is also not a strong enough oxidant to

remove the odorous products of decaying vegetation.

#### 2.6.4.4 Ozone

Widely used in Europe and Canada as a primary treatment technique, the technology of large scale ozone plants is well established. Ozone generation from air or oxygen requires a large power source and cooling, calling for relatively complex equipment.

The assimilable organic carbon bioassay is described together with its use in studying the effect of ozonation on the removal of organics by water treatment. Results confirmed that use of ozonation improves total organic carbon removal (Stanfield and Jago, 1989).

Nebel *et al* (1988) reported that ozone dissolved in the water inactivated *Giardia* cysts through oxidation. Concurrently, ozone oxidises colour, taste and odour found in water. The rate of oxidation of *G. lamblia* by ozone is faster than chlorine and chlorine oxide.

Surface water supplies were seeded with viable *G. muris* cysts and disinfected by ozone and Peroxone (an advance oxidation process for water treatment which is generated by combining ozone and hydrogen peroxide) in the pretreatment columns. Inactivation was examined in two source waters. Ozone residual appeared to be the most important determining factor in *Giardia* inactivation. A minimum inactivation level of 2-

logs of *Giardia* cysts was always achieved with an ozone residual of 0.65mg/l or greater, regardless of the source water, temperature turbidity or contact time (Scott et al, 1992).

#### 2.6.4.5 Ultraviolet

Ultraviolet radiation can be applied to water to kill micro-organisms in two distinct ways using either tubular reactors or open systems in which the lamps are placed above the water surface. Both require the raw water to have low turbidity because particulates absorb radiation. The technology was developed first for small private water systems, but has recently been applied successfully to a municipal system in the UK (World water, 1987).

Treatment does not leave a residual and regrowth is always a threat. In tests, regrowth, subsequent to UV radiation of *Escherichia coli* suspensions in water occurred under both light and dark storage conditions and reached nearly thirty percent of pretreatment levels (Mechsner et al, 1991).

#### 2.6.4.6 Adsorption

This method is widely used to treat water supplies containing volatile organic contaminants. Adsorption using granular or activated carbon or different types of synthetic resins has been used to remove the humic and fulvic acid precursors found in natural surface waters which react with chlorine to produce haloforms. Granular activated carbon (GAC) performs multiple

functions in the treatment of drinking water including removal of taste and odour of volatile organic compounds such as trihalomethanes (THM) and dechlorination. THM precursors are ill-defined, macromolecular structures. Their large size causes slow adsorption, and the high concentrations found in some surface waters cause the sorptive capacity of the granular media to be exhausted very quickly.

The THM desorption or displacement is controlled by GAC preferential adsorption of background organics other than THM. Background organic matter in natural waters compete with THM for GAC adsorption sites. This may be avoided by appropriate pretreatment (chlorination, coagulation or ozonation).

#### 2.6.5 Ion - Exchangers

The raw water to be treated passes through a special decarbonizing exchange material which absorbs only the hardness causing salts or sodium salts that are fixed to the bicarbonates of the raw water. Free hydrogen ions ( $H^+$ ) are let into the water to act as counter-ions for the hardness causing substances of the carbonate hardness. So that free, aggressive  $CO_2$  leaves the delivery side of the exchange filter. Exchangeability of resins is limited by capacity, that is, when resins are exhausted, they are no longer able to absorb any carbonate hardness. The carbonate hardness is no longer low, instead it corresponds with that of the raw water. The exchange material can be regenerated by adding mineral acids, for example, hydrochloric acid. Dilute acid

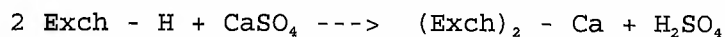
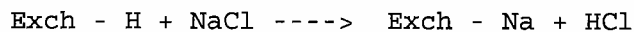
is capable of removing the deposited hardness causing substances and takes them to the waste water while free  $H^+$  of the acid are affixed to the exchange resin. After the excess acid has been washed out, the resin regains its full functional capacity. Carbon initially mixed with the treated water, is removed by a trickler in which countercurrent of air blows the  $CO_2$  into the exhaust air.

A strongly acidic cation exchanger operates as the previously described exchanger but absorbs all cations contained in raw water.

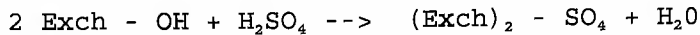
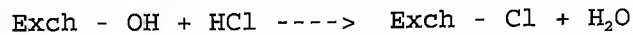
Full desalinization - demineralization is indicated if there is high content of salt in the raw water. Desalinization unit consists of a strongly acidic cation exchanger followed by an anion exchanger. Non - carbonate hardness turns into  $HCl$ ,  $H_2SO_4$ ,  $HNO_3$  and carbonate hardness is converted into free  $CO_2$ . Again, cation exchanger is regenerated with dilute  $HCl$  and sometimes  $H_2SO_4$ , whilst anion exchanger is regenerated with dilute soda lye.

Exchange reactions :

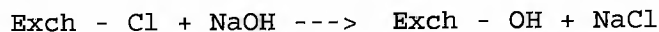
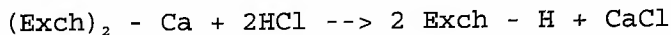
Cation exchangers



Anion exchangers



Regeneration :



## 2.7 Water Treatment in Ghana

Prior to the formation of the Ghana Water and Sewage Corporation in 1965, water supplies were provided by two organizations. These were Water Supplies Division of the Public Works Department, which had responsibility for supplies to municipal and urban centres and the Rural Water Supplies Unit which was responsible for the rural communities, providing mainly dug wells, with or without hand pumps. Construction of piped water supply systems in Ghana started as far back as the early 1900 and were mostly limited to urban centres where the colonial administration had its offices and officials.

The GWSC was established by a Parliamentary Act in 1965 and charged as the sole water supply authority in Ghana and therefore took over the running of all pipe-borne water

systems in the country. The GWSC now operates two hundred and nine piped water systems throughout the country serving ninety three per cent of the country's urban population. Furthermore, four major district water supply schemes are expected to come into operation shortly (Dovlo *et al*, 1993).

Until 1986, the GWSC was a government subvented organisation, but the economic decline since the mid 1970s seriously affected government commitments. The central maintenance system has worked satisfactorily except for doubts about its sustainability. The main problem against the system is the collection of tariff itself, a function of insufficient education, lack of funds, transparency and mistrust of GWSC by the consumer committees. Shortfalls in the operating budget as well as increases in personnel, energy and commodity costs have seriously affected the efficient performance of the Corporation and therefore the level of service to the consuming public. Loans and grants have been obtained from the World Bank, CIDA and other external support agencies for the rehabilitation of seventy six (76) water supply systems (Dovlo *et al*, 1993).

The water treatment plants are designed for conventional methods of treatment, that is, coagulation and flocculation with aluminium sulphate, followed by sedimentation and filtration before disinfection with chlorine, acidity adjustment and corrosion prevention with lime hydrated or soda ash. An excess of free residual chlorine level is maintained

in the distribution system to reduce the risk of bacteria regrowth.

The water distribution system is designed and operated to ensure that the quality of water that enters it from treatment works is maintained. The system is fitted with various types of valves and washouts at vantage points to facilitate flushing of the pipeline to rid the system of sediments and pollutants.

The GWSC also undertakes routine and periodic surveillance of drinking water quality in accordance with procedures recommended by the WHO. Under the programme, chemical, physical and bacteriological analysis of samples are carried out at regular intervals on a routine basis as a means of monitoring water quality in the distribution system.

## **2.8 Analytical methods**

### 2.8.1 Bacteriological analysis

New epidemiological data on waterborne diseases illustrate that even advanced water supply systems which meet generally accepted specifications for efficiency, may not always be failsafe. Constraints of recovery, sensitivity, survivability, time cost and laboratory capabilities have limited virological and parasitological analyses of water.

The most desirable index of pathogenic microorganism pollution

must be its own presence or absence. Current microbial indicators of water quality and treatment such as total coliforms and faecal coliforms, indicate only the presence of faecal pollution and an indirect health risk. Several studies have demonstrated that coliforms are inadequate to indicate the presence of pathogens, especially viruses and parasites (Payment and Eduardo, 1993). Some pathogens have only recently been recognised as causing problems in water either by their resistance to disinfection or their ability to grow in aquatic systems. Efforts are being made at improving existing methods and on developing new methods which will improve;

- (a) the detection of pathogens,
  - (b) understanding of their distribution in the environment
  - (c) the efficacy of water treatment in removing them
- (Watkins and Cameron, 1991).

At a water filtration plant that uses full conventional treatment including ozonation and post chlorination, a study was carried out to determine the elimination of human enteric viruses, coliphages and *Clostridium perfringens*. The results obtained suggest that coliphages and *C. perfringens* are slightly more resistant than cultivable human enteric viruses in treated water (Payment, 1991). In another study conducted by Bezzickheri *et al*, (1992), a high presence of *Aeromonas spp* was found even in waters without coliforms and or with small quantities of residual chlorine. They concluded that *Aeromonas* was a more resistant organism than coliforms and

could be isolated as an additional index of water quality.

### 2.8.2 Current Techniques in Bacteriological Analysis

Filtration by membrane is advocated for speed and repeatability to detect coliform bacteria, faecal coliforms and streptococci and also yeasts and moulds and to determine bacterial load in the waters of soft drink processing plants (Arena, 1980). A method is specified for evaluation and comparison of water testing membrane filters intended for the enumeration of specific organisms and mixed microbial populations. It provides general guidelines for comparative testing of the recoveries of bacteria, yeasts and other fungi or membrane filters as compared to recoveries by the spread plate and pour plate techniques (ISO, 1985).

New techniques based on the polymerase chain reaction opens doors for the detection of a wide variety of important waterborne viruses (Water Science and Tech., 1993). Turpin *et al*, 1993, also developed a most probable number (MPN) method that utilised a bioluminescent bacteriophage that allowed the specific determination of as few as one *Salmonella typhimurium* cell/100ml of material within 24 hours. The method has an efficiency of 100% when tested against a traditional MPN method. It is rapid, sensitive, inexpensive, has a lower operator time than traditional MPN method and is amenable to automation (Turpin, 1993).

### 2.8.3 Chemical Analysis

Total organic halide can be used as an indicator of water quality, providing a direct measure of disinfection by-product formation (Stevens *et al*, 1985).

A system and method for determining the concentration of nitrate ions in a nitrate ion-containing water sample which also contains chloride ions and bicarbonate ions is elucidated by Gunter (1991). The sample after having been treated with the two resins is passed into a conductivity cell with the conductivity being directly related to the nitrate ion concentration of the sample. The device and method find advantageous application in automated systems for monitoring and controlling water treatment facilities (Guter, 1991).

A cooperative study involving the US EPA, the University of Michigan and the South Connecticut Regional Water Authority (RWA) demonstrated and validated the use of modelling techniques in the RWA distribution system. Models are used to predict the propagation of chlorine residuals in one portion of the RWA system. It was found that residuals varied widely, both spatially and temperally. Long residence time in storage tanks caused residual disinfection concentrations to be low or nonexistent during discharge cycles (Clark *et al*, 1993).

### 2.8.4 Sampling

Sampling technique and storage time are critical when the

level of contamination to be detected is low (Ferguson, 1994). There is an inherent difference between sample of water collected manually and those collected automatically (using refrigerated automatic sampler) but the difference is minimal in practical terms when water samples are polluted.

## **2.9 Source Water in Industry**

Water has wide and varied application in the Ghanaian industry. It is used as a raw material in the food, beverage and pharmaceutical industries, as a solvent in the textile industry, as a cooling agent in the metal industry and as a heating agent in the chemical industry. Given the likely problems of water utilization and availability arising out of rapid urbanization and industrialization in Ghana, Boateng (1995) underscores the need for industries to evolve water management policies based on water recycling and conservation techniques.

Good quality and safe water of specific pH, taste, colour and stability is particularly important in the food industry for canning of foods, production of carbonated and non-carbonated beverages. This ensures products that are free from contamination, shelf stable and of acceptable organoleptic quality. Again, water of high chemical purity prevents corrosion in process or packaging vehicles.

It is recommended that only water classified as drinkable by WHO specifications should ever be used on premises where foods

are prepared, usual criterion: microbiological count of less than 100 organisms/ml at 20 - 22 °C. A limit of  $10^{-4}$ /ml should be fixed for oligotrophic bacteria which can develop in tap water and there should be regular checks for these and other organisms (Mossel *et al*, 1978).

### 2.9.1 Non alcoholic Beverages

Chemical dosing is the conventional treatment of process water in the food and soft drinks industries, but it requires adjustments to dosage rates with changes in the raw water constituents, particularly with the seasons and weather. A case study is presented of a soft drinks plant which experienced serious problems with its dosing treatment and switched to the application of reverse osmosis to produce their desired and constant quality of process water. In the long dry summer of 1973, Coca Cola, Southern Bottlers Ltd., Bristol, experienced a variation in the quality of raw water supplied to their bottling plant from the local water works. For two months, production was frequently interrupted. Batches of Coca Cola were produced in the normal way and initially appeared to be satisfactory, but after approximately twenty four hours, a thick brown floc would appear on the surface of the liquid and many thousands of gallons of Coca Cola had to be destroyed. It was established that the problem was due to the presence of polypeptides and polysaccharides in the raw water and the conventional water treatment was unable to cope with it. A reverse osmosis unit was installed with a small base exchange softener as pretreatment for the

influent raw water.

The treatment of water by reverse osmosis is complex, necessitating detailed analysis of each individual client's requirements and raw water supply and careful choice of the appropriate method of pretreatment. Correctly designed, sized and operated, reverse osmosis can be valuable, being capable of treating water with a total dissolved solids content of up to 3,000ppm removing at least 90% of inorganic salts from water and eliminating dissolved organic contaminants, bacteria and viruses (Digby, 1974).

Fertmann and Rakhmanin reported in 1974 that, the different methods of water softening, using chemicals, or by sodium or potassium ion exchangers, do not guarantee suitability of water for use in the manufacture of non-alcoholic beverages. According to them, the water alkalinity is not changed and the salt content increases. The treatment of water using ion exchangers in a hydrogen cycle, gives acidic water. Therefore, the amount of citric acid can be reduced from 440g/l to 100g/l to neutralize the water alkalinity.

### 2.9.2 Brewing

Water utilization in the breweries fall into four main categories :

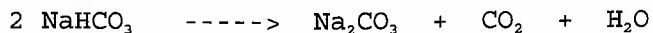
- (a) General process water
- (b) Treated process water
- (c) Brewing water
- (d) Boiler feed water

General process water is used for cleaning and similar jobs. It must be of potable water quality, that is, bacteriologically unobjectionable. If raw water is to be used, water treatment procedure may involve flocculation, filtration, chlorination and ozonation. In the case of using municipally treated water, it is imperative that the manufacturer ensures by checking that the water is potable at all times.

Process water is treated for use in washing bottles and in cooling. It is desirable that the total hardness, especially, carbonate hardness is very low to lower the consumption of washing agents and reduce the incidence of scaling. Process and brewing water is further treated by softening, decarbonization and demineralization.

Separation of lime in boiling water results in strong encrustation and thus partial function impairment of devices such as immersion heaters, boilers and coffee percolators. Scale formation on heated surfaces decreases transmission of heat and thus an additional consumption of fuel. The exceeding stress of heating surfaces due to accumulation of scale can easily result in mechanical damages of flame or water tubes. Corrosion can also impair the boiler operation. Acids and gases can cause damage. Soda fission, especially in the steaming room causes surface corrosions. This is of importance when the softening of the water is affected by means of a base exchanger. During the process, sodium

bicarbonate ( $\text{NaHCO}_3$ ) is formed. In the boiler, it completely divides into soda ( $\text{Na}_2\text{CO}_3$ ) and free carbon dioxide ( $\text{CO}_2$ ).



This soda splitting increases considerably with an increase in operating pressure, Hence, the criteria for selecting treatment process essentially combines (a) water conditions, that is, quality of water, (b) operating conditions and (c) economy. (European Brewing Convention Monograph on Water XIV, 1988).

### 2.9.3 Canning

Waegerle (1970), states that by adding phosphoric and hydroxy-acids to water for sterilization of cans, jars etc, . corrosion and scale deposits on autoclaves and containers are prevented.

Hardness of water is important in the canning of leguminous vegetables. Excessively hard water will cause hardening of the skins, while water containing no hardness may cause a too soft texture of the product and cloudiness of the brine (Hoather and English, 1968).

Soft waters with excess alkalinity are undesirable for cooling cans, as the tin will tend to be removed in the form of surface "spangling" or stripping and even partial removal of the coating will render the tins liable to rusting during storage.

#### 2.9.4 Dairy Products

Both chemical and bacteriological aspects of water quality are important in water used in dairy farms and in larger plants for milk bottling and butter and cheese making. In water used for butter making, standards for potable water must be met. In addition, the copper content should be very low as the presence of copper would tend to give an oxidised flavour to butter. It is also desirable that the water should be of good organic quality. Bacteriologically, the absence of certain psychrophilic organisms in the water is important. *Pseudomonas fragi*, for example, is a common cause of tainted flavour in butter due to its proteolytic action. Presence of *P. fragi* is indicated by a typical fruity smell.

#### 2.9.5 Industrial Equipment

Big economies were made by a company in the USA, following the treatment of its hard alkaline well water with weakly acidic cation exchanger. The company produced pasteurized orange juice, concentrate and several fruit beverages. Water was used primarily,

- (a) to convert the steam used in processing
- (b) for cooling in the refrigeration process
- (c) for use in the beverage.

The benefits of the use of the exchanger included, elimination of cooling tower scale, reduced corrosion of condensate lines and boiler feed pumps and reduced boiler and cooling tower blowdown frequency (Miller and Mitchell, 1977). Prior to the

installation of the exchanger, boiler feedwater was softened but not dealkalised, cooling water was neutralized by the addition of metered amount of sulphuric acid.

Another case history is presented relating to corrosion of boiler plant which provides clear examples of the problems that can arise with inadequate attention to water treatment. Failures were observed in various components of the steam circuit of a urea plant superheater tubes, stainless steel pipelines, expansion bellows, plugs and seats of steam admission valves, bolts and studs and the heads of Allen screws in reversing segments of the turbine and the turbine rotor disc. All the components that failed were using steam from the steam generation plant. Investigation revealed that carryover of boiler chemicals in the steam had resulted in build-ups of alkalinity and chlorides, leading to stress corrosion cracking (Verma *et al*, 1992).

#### 2.9.6 Washing and Cleaning

Water used for washing and cleaning such items as fish boxes, filleting troughs, tables, factory floors etc., should be of potable quality. Psychrophilic bacteria are always present on the slime on the skin, gills and often in the intestine of newly caught fish. Water should not be a source of these organisms. It is important that shellfish such as oysters, clams and mussels should not be grown in grossly polluted water. After removal from a growing area, shellfish may be cleansed by conditioning in bacteriologically pure water

whereby and possibly pathogenic bacteria are voided from the shellfish. It has been suggested that sea water should be avoided for washing fish before canning to prevent or slow down formation of struvite (magnesium ammonium phosphate) crystals in canned fish. For instance, in lobster meat, there are usually plenty of phosphorus and ammonia compounds, but not normally sufficient magnesium for struvite formation, but magnesium will be supplied from sea water unless removed by fresh water, However, struvite formation can be prevented by the use of sequestering agents (McFee and Swaine, 1953). The risk of disease through eating fresh fruit and vegetables contaminated with pathogenic organisms is very real. It is desirable that water of a potable standard should be used for washing purposes.

#### **2.10 Storage and Handling**

Stored water has a variety of uses, that is, direct consumption by livestock or humans or indirect consumption for irrigation and aquaculture. Reservoirs solve the problem of water shortage, especially in rural supply difficulties, since their storage potential far exceeds requirements. Numerous water supply facilities store potable water in steel tanks which are coated to prevent corrosion. Coating materials commonly in use present a potential risk to human health. Alban (1979) analyzed water samples from a tank coated with a commercial coal tar and found that levels of polycyclic aromatic hydrocarbons increased five to thirty times in storage tank effluent.

Rainjars are popular in northeast Thailand because of the time and effort saved in water collection resulting from their use. Bacteriological analysis showed rainjar water to be much more purer than drinking water from alternative sources. In rainwater samples from one village, *Escherichia coli* was absent in 60% of rainjars compared with 46% of other vessels used for storing drinking water in the home. The use of a tap and the physical height of the jar served to protect the water by limiting water handling. Moreover, mosquito netting fitted to the top of the rainjar significantly improved its water quality, probably by preventing access of small lizards (Pinfold et al, 1993).

The vending machine has contributed to a revolution in how we buy food and drink. Although occasionally blamed for non-specific illnesses, there have been few studies about the microbiology of food and drink from such machines. The few studies that have been reported have found high total viable counts and coliform organisms in dispensed drinks. This appears to be due to inadequate cleaning procedures or machine design (Hunter, 1992).

### 3.0 METHODOLOGY

#### 3.1 Survey

To prove the hypothesis that water supplied for industrial purposes was of poor quality, a survey was carried out to establish the basis for relating the problems encountered in the food processing industry to the quality of source water. It was also necessary to assess internal quality control measures applied in the various industries.

Questionnaires were administered to the industries, titled, "Survey on Factors Affecting the Quality of Water for Industrial Purposes" (APPENDIX I). They covered water storage, cleaning of storage vehicles, treatment, quality control and effect of poor water quality on product quality. A total of twenty (20) major food industries in Accra and Tema were included in the survey.

#### 3.2 Analysis of Samples

##### 3.2.1 Sample Collection

Water samples were obtained from;

- (a) A total of sixteen (16) water sources from four (4) rural communities in the Ga District, namely; Midie, Amasaman, Ofankor and Agbogba.
- (b) 50 taps in ten (10) suburbs in the Accra District representative of both Kpong and Weiya Water Supplies, that is, five locations within each suburb,
- (c) 20 informal food service centres ("chopbars"),
- (d) 20 "iced water" vendors.

Three (3) 500 ml samples were collected at each water source visited. Duplicate samples were stored in sterile borosilicate flasks for bacteriological analysis within 1-2 hours of collection, whilst the third sample collected was stored at 4°C prior to physicochemical analysis between 24 hours and one week of collection.

### 3.2.2 Bacteriological Examination

The plate count technique and multiple tube method were employed in the analysis of water samples, according to the American Public Health Association (APHA) Standard Methods for the Examination of Water and Waste-water, 1971. In the case of rural water samples, only the plate count technique was used. Analysis was done in duplicates.

### 3.2.3 pH

pH was determined with pH meter : Model HM - 305 TOA Electronics Ltd, Tokyo, Japan.

### 3.2.4 Turbidity

Turbidity measurements were done in duplicates with a Nephelometer : EEL Nephelometer Head/ DS29 Unigalvo. Diffusion System Ltd London.

### 3.2.5 Alkalinity

Alkalinity of water samples were determined in duplicates, within 24 hours of sample collection by AOAC (1984) titrimetric method no. 33.014.

### 3.2.6 Colour

This was done by means of a Lovibond colour comparator.

### 3.2.7 Metallic contaminants

Sodium and Calcium were determined using the Flame Photometer whilst Copper, Iron, Chromium, Nickel were determined with Atomic Adsorption Spectrophotometer : Perkin Elmer.

### **3.4 Data Analysis**

ANOVA procedures were performed using the Statgraphics Software (Graphic Software System, STCC, Inc., U.S.A.).



#### 4.0. RESULTS AND DISCUSSION

##### 4.1. Survey

Data collected from the food processing industries was grouped under four major topics:

- (a) storage and cleaning of storage receptacle,
- (b) water treatment,
- (c) water quality control and
- (d) problems encountered that were attributed to poor water quality.

##### 4.1.1 Water storage and cleaning of storage receptacle.

TABLE 5 depicts the type of receptacle used by some food manufacturers in Accra and their cleaning times.

Table 5 Storage and Cleaning Schedules of Water Storage Receptacles Food Industries

<u>WATER SOURCE</u>	<u>PRODUCT</u>	<u>RECEPTACLE</u>	<u>CLEANING FREQUENCY</u>
Weiija	carbonated soft drink	concrete	month or less
Weiija	carbonated soft drink	concrete	quarterly
Weiija	carbonated soft drink	iron	month or less
Weiija	carbonated soft drink	concrete	month or less
Weiija	lager beer	concrete	month or less
Weiija	lager beer	concrete	month or less
Weiija	liquor	n/a	n/a
Weiija	liquor	steel	quarterly
Weiija	ice cream	aluminium	not stated
Weiija	toffee	plastic	month or less
Weiija	biscuits	aluminium	month or less
Kpong	carbonated soft drink	plastic	biannually
Kpong	orange squash	aluminium	annually
Kpong	canned fish	aluminium	annually
Kpong	evaporated milk	concrete	biannually
Kpong	weaning food	concrete	biannually
Kpong	ice lollies	aluminium	month or less
Kpong	margarine	iron	month or less
Kpong	chocolate	aluminium	not stated
Nsawam	canned fruits & vegetables	concrete	annually

The storage of water in food processing industries is an important operation. This is illustrated in the observation that all the processing industries that were visited had a clear policy to store water, and therefore installed storage receptacles. Only one factory did not store water. No reasons were offered by the manufacturer for non - storage of water. The factory simply shut down when the water supply was interrupted and no production was done until water supply was restored. Hence, the factory suffered economic losses.

Water storage receptacles in the processing factories were observed to be made of three main types of material: metal, plastic and concrete (TABLE 5). The choice of receptacle type did not seem to be related to the source of water or the type of product that are processed.

The frequency of cleaning of the receptacles was however related to the source of water used in the factory (TABLE 5). Most factories that obtained water from the Weiija source had a routine weekly or monthly schedule for cleaning the storage receptacles. On the other hand, factories that obtained water from the Kpong source cleaned their receptacles only once in a year (TABLE 5). This observation underscores a fundamental difference between the two sources of water in the Accra metropolis. The Weiija source seemed to have a much heavier load of sediment and debris, which settled on the inner surfaces of water receptacles, and therefore created the need for a more frequent cleaning.

4.1.2 Water quality control in industry

Determination of water pH, as a quality control measure, seems to be most popular among the food processing industries (TABLE 6), probably because it is a cheap, easy and rapid procedure. Water pH is thought to give an indication of the effectiveness of treatment. It also helps to determine the kind of pH adjustments necessary to ensure good quality water for processing operations in the factory. Other indices that are determined for quality control purposes include hardness, alkalinity, bacterial load and residual chlorine.

Table 6 Analysis of Water in the Food Industry

<u>WATER SOURCE</u>	<u>PRODUCT</u>	<u>QUALITY PARAMETERS DETERMINED</u>
Weija	carbonated soft drink	pH,hardness
Weija	carbonated soft drink	pH
Weija	carbonated soft drink	alkalinity
Weija	carbonated soft drink	residual Cl,alkalinity
Weija	lager beer	bacteriology,pH,conductivity, alkalinity,hardness,Fe, Si,Cl,p- and m-value
Weija	lager beer	pH,hardness
Weija	liquor	hardness(Mg,Ca levels)
Weija	liquor	pH,taste,colour
Weija	ice cream	bacteriology,pH,Cl,hardness, specific gravity
Weija	toffee	bacteriology,pH,dissolved solids,suspended solids
Weija	biscuits	no quality control
Kpong	carbonated soft drink	bacteriology,residual Cl (in filters)
Kpong	orange squash	no quality control
Kpong	canned fish	bacteriology,pH,hardness
Kpong	evaporated milk	bacteriology,pH,residual Cl,hardness
Kpong	weaning food	bacteriology,pH,residual Cl,hardness
Kpong	ice lollies	refraction
Kpong	margarine	bacteriology,pH
Kpong	chocolate	pH,hardness,alkalinity, dissolved solids
Nsawam	canned fruits & vegetables	residual Cl,Cu content

Fifty per cent (50%) of the factories determine bacteriological quality of water. The assumption made by those who do not do this analysis was that, the processing steps that involve application of heat including sterilization by autoclaving destroys the microbes. In other cases, sanitization with chemicals is expected to inhibit microbial growth.

#### 4.1.3 Water Treatment.

TABLE 7, compiled from the survey, shows the water treatment schedules for processing industries in Accra. The table shows the source of water, type of treatment and reasons for treatment. The general impression gathered from the survey (TABLE 7), was that , water treatment method was not related to the quality of water. This was inferred from the fact that, most of the industries did not have elaborate quality control procedures (Section 4.1.2). It appeared that the treatment method was incorporated as part of the production procedure package, either imported or copied from elsewhere.

Table 7 Water Treatment in The Food Industry

WATER SOURCE	PRODUCT	TYPE OF TREATMENT	REASONS FOR TREATMENT OR NON-TREATMENT
Weija	carbonated soft drink	chemical & filter	softening for steam generation
Weija	carbonated soft drink	chemical & filter	reduce bacterial load
Weija	carbonated soft drink	chemical & coagulation	reduce bacterial load alkalinity & particles to meet standards
Weija	carbonated soft drink	chemical	ensure complete treatment
Weija	lager beer	ion exchange	reduce hardness, meet brewing standards
Weija	lager beer	chemical & filter	reduce scaling in boiler
Weija	liquor	ion exchange	improve product appearance
Weija	liquor	chemical & filter	get rid of impurities
Weija	ice cream	chemical & filter	reduce bacterial load and sediments, protect equipment
Weija	toffee	not applicable	GWSC controls water quality
Weija	biscuits	not applicable	tap water is clean
Kpong	carbonated soft drink	chemical & filter	reduce bacterial load
Kpong	orange squash	not applicable	tap water is clean
Kpong	canned fish	chemical	reduce bacterial load
Kpong	evaporated milk	ion exchange	soften water meet internal specification for bacteria and Cl
Kpong	weaning food	ion exchange	protect equipment
Kpong	ice lollies	not applicable	no response
Kpong	margarine	distillation	reduce bacterial load
Kpong	chocolate	ion exchange	reduce energy requirements
Nsawam	canned fruits & vegetables	not applicable	tap water is clean

Of the twenty manufacturers, twenty five per cent (25%) do not treat their incoming water at all. Their assumption is that, piped water is treated and hence fit for every type of operation that requires clean water. Some other factories however, found the piped water to be hard, and therefore needed to be softened before use. Almost fifty per cent (50%) of the factories were observed to use chemicals for softening

water. Majority of these factories (78%) use water from the Weija source. Most factories that soften their water however, do not determine the constituents of the water before softening. This suggests that the hardness level is not usually known, and therefore, softening procedures may be over done, or under estimated, leading to severe economic implications. Such indiscriminate softening procedures may have a direct effect on the product quality.

#### 4.1.4 Problems encountered in industry attributable to poor water quality

Only three respondents indicated that they had ever had a defective product due to the use of water of low quality. Some others conceded that the quality of water from Weija may be a factor, but would not include it in the response to a formal questionnaire as it reflected internal inadequacies. In almost all three cases, they were taken unawares due to the assumption that the water was treated from source.

As shown in TABLE 8, two of the respondents who admitted to having defective products from poor water quality, use water from Weija. One factory produced carbonated soft drink whilst the other factory blended liquors. In both cases, the production defect seemed to be related to the high salt content of the water.

Table 8 Problems encountered in the Food Industry alleged to be due to poor water quality and control measures adopted by the factories

WATER SOURCE	PRODUCT	PROBLEM DESCRIPTION	CONTROL MEASURES
Weija	carbonated soft drink	floc in finished product	change water source
Weija	carbonated soft drink	not applicable	not applicable
Weija	carbonated soft drink	..	..
Weija	carbonated soft drink	..	..
Weija	larger beer	..	..
Weija	larger beer	..	..
Weija	liquor	Ca,Mg scum in neck of bottle	installation of ion exchanger
Weija	liquor	not applicable	not applicable
Weija	ice cream	..	..
Weija	toffee	..	..
Weija	biscuits	..	..
Kpong	carbonated soft drink	..	..
Kpong	orange squash	..	..
Kpong	canned fish	..	..
Kpong	evaporated milk	..	..
Kpong	weaning food	..	..
Kpong	ice lollies	..	..
Kpong	margarine	high bacterial count in water and product	test water daily, clean system more regularly
Kpong	chocolate	not applicable	not applicable
Nsawam	canned fruits & vegetables	..	..

Neither of the two factories affected, seemed to have a policy of determining chemical components of the water. However, the factory which produced liquors, believed that the problem was related to high concentration of calcium and magnesium salts. It then installed an ion-exchange filter and the problem was resolved. The carbonated soft drink manufacturer could not identify the source of the problem. The control measure was to change their water source by buying water from a water point supplied by Kpong. The third factory, manufacturing

margarine, derived its water from Kpong. The microbial load of the source water was found to be high, accounting for similar levels of microbial load in the final product.

## **4.2. Laboratory Analysis**

### **4.2.1. Bacteriology of Urban Water (piped)**

The results of bacteriological analysis of piped water samples obtained are presented in Tables 9 and 10. The results reveal that, except for a few isolated cases of contamination, the water samples are bacteriologically sound or safe regardless of whether the source was Weiija or Kpong. Three samples, two from Adabraka and one from Industrial Area gave positive reaction to faecal coliform test. Since contamination was not common to all five samples within a particular locality coupled with the fact that the presence of faecal coliform is indicative of recent pollution, it may be inferred that, pollution occurred after distribution. Ideally, drinking water should not contain any microorganisms known to be pathogenic. It should also be free from bacteria indicative of pollution with excreta. With efficient treatment ending in disinfection, no coliform bacteria should be detected in any 100 ml portion of water (WHO, 1993). One of the five samples taken from Tesano recorded the highest most probable number, MPN, of 24 but there was no microbial growth in any of the tubes incubated at 44°C, indicating absence of faecal pollution. It is significant to note that water in Adabraka, Industrial Area and Tesano comes from Weiija.

**Table 9. Total Plate, Total Coliform and Faecal Coliform Counts\* at 37°C/24h of piped water in Accra**

Source	Town**	Total count	Total coliforms	Faecal coliforms
Weiija	Dansoman 1	32	nd	nd
	Dansoman 2	nd	nd	nd
	Dansoman 3	2	nd	nd
	Dansoman 4	nd	nd	nd
	Dansoman 5	1	nd	nd
	Tesano 1	1	nd	nd
	Tesano 2	1	2	nd
	Tesano 3	nd	1	nd
	Tesano 4	nd	nd	nd
	Tesano 5	nd	nd	nd
	Adabraka 1	nd	nd	nd
	Adabraka 2	nd	nd	nd
	Adabraka 3	4	nd	nd
	Adabraka 4	nd	nd	nd
	Adabraka 5	nd	nd	nd
	Industrial Area 1	7	nd	nd
	Industrial Area 2	nd	nd	nd
	Industrial Area 3	nd	nd	nd
	Industrial Area 4	nd	nd	nd
	Industrial Area 5	nd	nd	nd
	Achimota 1	nd	nd	nd
	Achimota 2	nd	nd	nd
	Achimota 3	nd	nd	nd
	Achimota 4	nd	nd	nd
	Achimota 5	nd	nd	nd
Kpong	Teshie 1	nd	nd	nd
	Teshie 2	nd	nd	nd
	Teshie 3	nd	nd	nd
	Teshie 4	nd	nd	nd
	Teshie 5	nd	nd	nd
	Cantoments 1	nd	nd	nd
	Cantoments 2	nd	nd	nd
	Cantoments 3	nd	nd	nd
	Cantoments 4	nd	nd	nd
	Cantoments 5	nd	nd	nd
	Madina 1	nd	nd	nd
	Madina 2	nd	nd	nd
	Madina 3	nd	nd	nd
	Madina 4	nd	nd	nd
	Madina 5	nd	nd	nd
	Dzorwulu 1	nd	nd	nd
	Dzorwulu 2	nd	nd	nd
	Dzorwulu 3	nd	nd	nd
	Dzorwulu 4	nd	nd	nd
	Dzorwulu 5	nd	nd	nd
	Legon 1	nd	nd	nd
	Legon 2	nd	nd	nd
	Legon 3	nd	nd	nd
	Legon 4	nd	nd	nd
	Legon 5	nd	nd	nd

\* counts are reported in cfu/ml, nd = none detected

\*\* 1,2,3,4,5 indicate different taps in one town.

Table 10 Most Probable Number (MPN) of Bacteria per 100 ml of piped water in Accra

Town** (Weija)	MPN	Town (Kpong)	MPN
Dansoman 1	5	Teshie 1	3
Dansoman 2	0	Teshie 2	0
Dansoman 3	0	Teshie 3	1
Dansoman 4	0	Teshie 4	1
Dansoman 5	0	Teshie 5	0
Tesano 1	0	Cantoments 1	0
Tesano 2	0	Cantoments 2	0
Tesano 3	24	Cantoments 3	0
Tesano 4	0	Cantoments 4	0
Tesano 5	0	Cantoments 5	0
Adabraka 1	1	Madina 1	0
Adabraka 2	0	Madina 2	0
Adabraka 3	3 +	Madina 3	0
Adabraka 4	2 +	Madina 4	0
Adabraka 5	0	Madina 5	0
Industrial Area 1	1 +	Dzorwulu 1	0
Industrial Area 2	1	Dzorwulu 2	0
Industrial Area 3	3	Dzorwulu 3	0
Industrial Area 4	3	Dzorwulu 4	0
Industrial Area 5	0	Dzorwulu 5	0
Achimota 1	0	Legon 1	0
Achimota 2	0	Legon 2	0
Achimota 3	0	Legon 3	0
Achimota 4	0	Legon 4	0
Achimota 5	0	Legon 5	0

\*\* 1,2,3,4,5 indicate different taps in one town.

+ = positive for faecal coliforms

It is possible that water from source has low chlorine residual and therefore disinfectant was not sustained at the instance of sampling.

#### 4.2.2 Bacteriology of Rural Water samples

Unlike water in urban Accra, all the water samples obtained from the rural areas were heavily loaded with microorganisms except those taken from the borehole and the Domi well (TABLE 11).

Water from all the ponds and the stream were observed to have very high microbial load. This is probably because they are surface waters, exposed to soil and atmospheric contamination as well as contamination from human activity.

Table 11 Total Count, total Coliform and Faecal Coliform Counts at 37°C/24h of Water in Ga Rural

Source	Total count	Total Coliforms cfu/ml	Faecal coliforms
Reservoir 1	113	24	2
Reservoir 2	196	30	12
Reservoir 3	tntc	504	7
Reservoir 4	416	67	8
Reservoir 5	128	24	4
Reservoir 6	144	6	nd
Well 1	tntc	828	448
Well 2	8	6	nd
Pond 1	tntc	656	342
Pond 2	392	197	49
Pond 3	704	412	1
Pond 4	608	364	228
Pond 5	tntc	204	nd
Stream	504	176	32
Borehole	5	nd	nd

tntc = too numerous to count      nd = none detected

Well 1 was found to be highly contaminated with microorganisms. Well 1 is a community well. It is about 30m deep, and is a ground water source. It was usually uncovered. The mode of fetching water from it was by lowering a rope tied to a bucket into it and drawing water. This probably accounted for the level of contamination compared to Well 2 which is a household well that was covered and hardly used.

The borehole water from Midie was the least contaminated. The borehole was fitted with a handpump that drew water from

several depths below the surface.

The water from reservoirs were supplied by tankers with tap water from Accra or tap water available Midie, in the case of Reservoir 6. These are also quite contaminated with microorganisms probably due to the insanitary conditions under which the water is stored and handled in the reservoir.

#### 4.2.3. Aesthetic and Chemical quality of Water in Accra

Physical and chemical analysis of the water samples obtained in Accra, shows basic differences between Kpong and Weiija sources, in almost all the parameters determined (TABLE 12). The observed differences probably account for the difference in quality as indicated in the survey on industries.

Table 12 ANOVA Summary Table showing Comparison of Water Quality between Kpong and Weiija Sources

<u>Variable</u>	<u>Kpong</u>	<u>Weiija</u>	<u>F-ratio</u>
pH	7.39	7.62	5.59*
Alkalinity (mg/L)	49.15	86.15	64.89*
Turbidity (NTU)	0.19	1.79	5.99*
Sodium (mg/L)	3.14	11.08	53.89*
Calcium (mg/L)	8.18	15.33	45.75*
Iron (mg/L)	0.05	0.10	5.40*
Copper (mg/L)	0.01	0.01	1.21
Chromium (mg/L)	0.00	0.00	2.40
<u>Nickel (mg/L)</u>	<u>0.01</u>	<u>0.01</u>	<u>1.28</u>

\* Significant at 95% confidence limit.

Among the localities from which water samples were obtained, there were considerable variations in almost all the quality parameters determined (TABLE 13).

Table 13 ANOVA Summary Table showing Comparison of Water Quality between towns in Accra

<u>Variable</u>	<u>F-ratio</u>
pH	7.73*
Alkalinity	188.65*
Turbidity	3.03*
Sodium	42.37*
Calcium	39.60*
Iron	3.84*
Copper	0.51
Chromium	1.05
<u>Nickel</u>	<u>1.07</u>

\* Significant at 95% confidence level

However, it was observed that, there was a degree of consistency in the analytical results among samples from Kpong. The results were strikingly different from those obtained from Weija. Whilst the average alkalinity, for example, of the Kpong samples was about 45 mg/l, with a range of 44.0 to 47.3 mg/L, the alkalinity of the Weija samples was mostly above 90mg/l, with a range of 63.4 to 98.8 mg/L (Table 14).

Table 14 Physical Quality of piped Water in Accra

Source Town		pH	Alkalinity mg/l	Turbidity NTU	Colour Hazen
Weiija	Dansoman	7.82	91.74	0.08	<5
	Tesano	7.66	98.78	3.30	<5
	Adabraka	7.65	97.90	4.62	<5
	Industrial Area	7.84	97.24	0.48	<5
	Achimota	6.93	63.36	0.20	<5
Kpong	Teshie	7.11	45.10	0.46	<5
	Cantoments	7.36	45.32	0.04	<5
	Madina	7.50	45.76	0.02	<5
	Dzorwulu	7.53	47.30	0.38	<5
	Legon	7.63	44.00	0.34	<5
<u>WHO values (1984)</u>		6.5-8.5	-	5.0	-

Similarly, the concentrations of sodium, calcium and iron, were found to be slightly higher in Weiija water than in Kpong water (Table 15).

Table 15 Chemical Quality of Piped Water in Accra

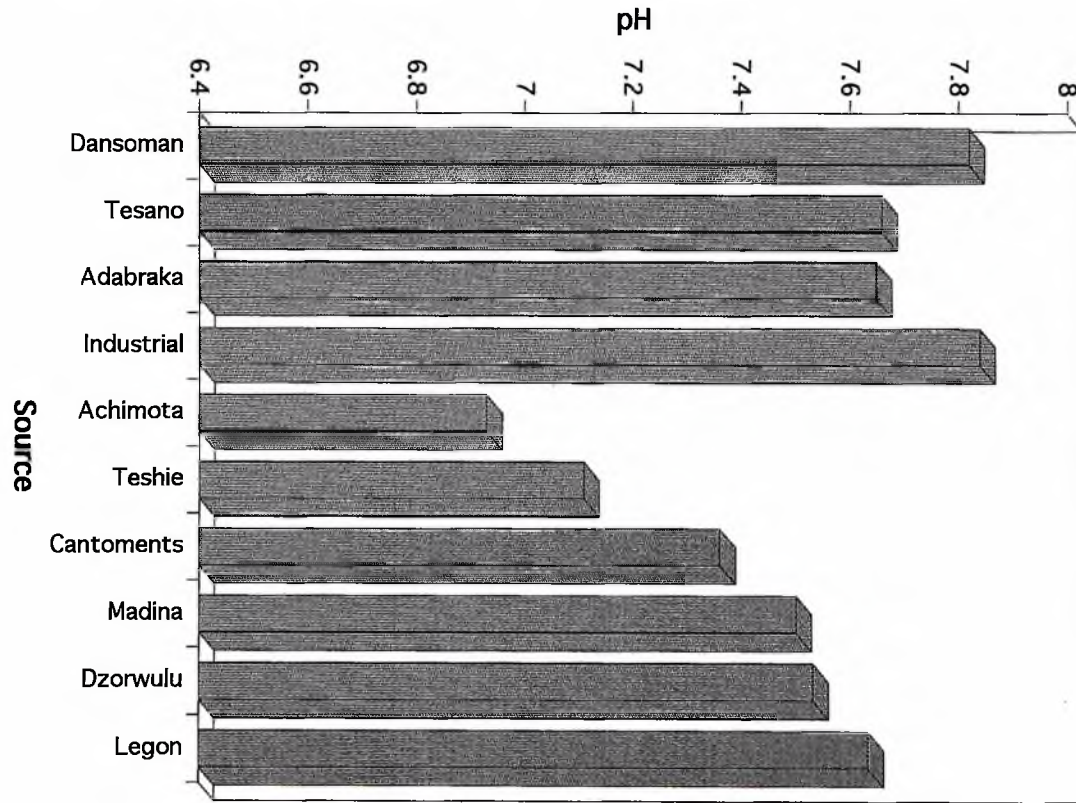
Source	Town	Fe	Cu	Na	Ca	Cr	Ni
(ppm)							
<u>Weiija</u>							
	Dansoman	0.026	0.006	13.50	18.22	0.000	0.024
	Tesano	0.096	0.006	12.28	15.18	0.002	0.008
	Adabraka	0.242	0.008	11.98	17.96	0.006	0.012
	Industrial Area	0.048	0.006	14.44	17.82	0.010	0.016
	Achimota	0.068	0.006	7.95	12.68	0.000	0.000
<u>Kpong</u>							
	Teshie	0.110	0.008	3.20	7.63	0.012	0.010
	Cantoments	0.058	0.010	2.98	8.35	0.002	0.022
	Madina	0.052	0.006	1.52	6.49	0.004	0.010
	Dzorwulu	0.026	0.012	1.92	6.43	0.004	0.010
	Legon	0.030	0.018	1.33	6.93	0.000	0.000
<u>WHO values (1984)</u>		0.300	1.000	200.00	-	0.050	0.020

Table 15 shows that the levels of the minerals measured were all below WHO guideline threshold, and therefore do not pose any health threat.

#### 4.2.3.1 pH

The pH of the water samples obtained in all of Accra (6.93-7.84), were within the WHO guideline range of 6.5 and 8.5 (WHO, 1984). However, the pH of water samples from the Kpong system shows less deviation about the mean, than pH of water from Weiija. FIGURE 1 shows the variability of the pH of all the water samples obtained.

Fig. 1. pH OF PIPED WATER IN ACCRA



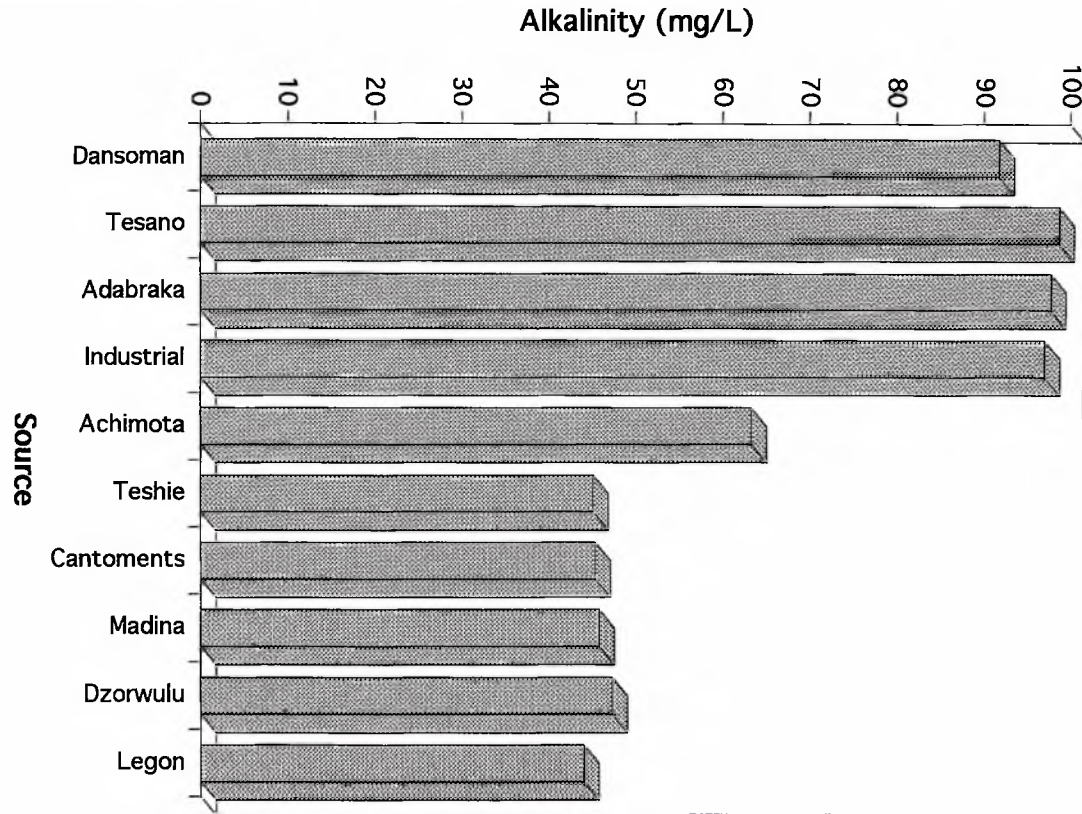
The lowest pH (6.78), was recorded in Achimota whilst the highest (8.07), was recorded in Industrial Area. Both of these suburbs derive water from the Weiya Water Works. The pH of water from Kpong ranged from 6.94 to 8.06. It is difficult to explain the observed wide range in the variability of pH from Weiya. Apart from the wider range in the pH of water from Weiya, average pH (7.58), is also higher than the Kpong average pH (7.43). A statistical analysis of the results, using ANOVA, reveals that the difference between the pH of Kpong water and that of Weiya is significant ( $p \leq 0.05$ ).

#### 4.2.3.2 Alkalinity

There was a marked difference in alkalinity between water samples from Weiya and those from Kpong (FIGURE 2).

The samples from Kpong were all low in alkalinity, varying from 42.9 to 49.5 mg/L with an average of 45.5 mg/L. Alkalinity of samples from the Weiya distribution, ranged from 57.2 mg/L (for Achimota) to as high as 108.9 mg/L with an average of 67.7 mg/L. The analysis of the variations in alkalinity showed that there were significant ( $p = 0.05$ ) differences between the sources of water. Further statistical tests using multiple range analysis, indicated that, the alkalinity of water supplied by Kpong is comparable among the five towns but not with water supplied by Weiya.

Fig. 2. ALKALINITY OF PIPED WATER IN ACCRA



#### 4.2.3.3 Turbidity

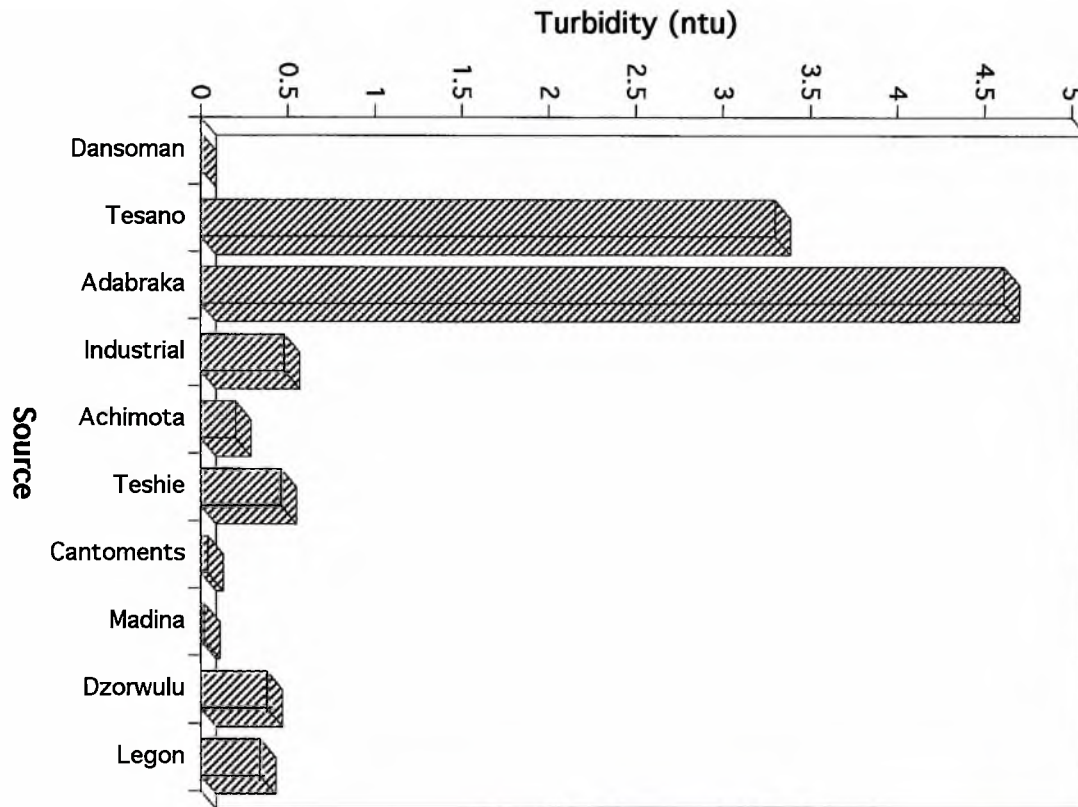
Results obtained showed that, piped water was generally not turbid. This was evident from water from both Kpong and Weiija, as depicted in FIGURE 3. In all the 50 samples collected, only two samples had high turbidity of 11.4 ntu and 11.6 ntu. These were from Tesano and Adabraka respectively, and originate from the Weiija source.

#### 4.2.3.4 Colour

None of the samples examined, were found to be above 5 Hazen units, which is the limit of detection of the Lovibond Tintometer used. Colour of 5 Hazen units cannot be detected in a glass of water by most people, and is therefore acceptable to consumers. Hence, it may be said that the water samples from both sources were acceptable.



Fig. 3 TURBIDITY OF PIPED WATER IN ACCRA



#### 4.2.3.5 Ionic constituents of Piped Water

As indicated in FIGURE 5, calcium and sodium are the most abundant cations to be found in piped water in Accra, but the concentrations are low (TABLE 15). Samples of water from Weiija have higher salt content than those from Kpong. This may be attributable to the geology and/or geography of the water bodies. Near coastal areas, windborne sea spray can make the important contribution, either by fallout on to land surfaces where it drains to the water source or from washout by rain from air to surface water sources (WHO,1979).

#### 4.2.3.6 Sodium

The source of water is of primary importance in determining sodium content, as shown in FIGURE 5. While, there was little variation amongst the Kpong samples in sodium content, three distinct groups of samples could be observed from Weiija. The concentration of sodium in water samples ranged from 1.3 to 14.4 mg/L. In general, sodium salts are not acutely toxic substances because of the efficiency with which mature kidneys excrete sodium (WHO,1979). Modern infant feeding practice using cow's milk, which contains about three times sodium than in human breast milk (WHO,1979), has been suggested as a cause of hypernatraemia. The situation could be exacerbated if tap water containing high levels of sodium was also incorporated into the feed.

Fig. 4 CONCENTRATION OF CATIONS IN PIPED WATER IN ACCRA

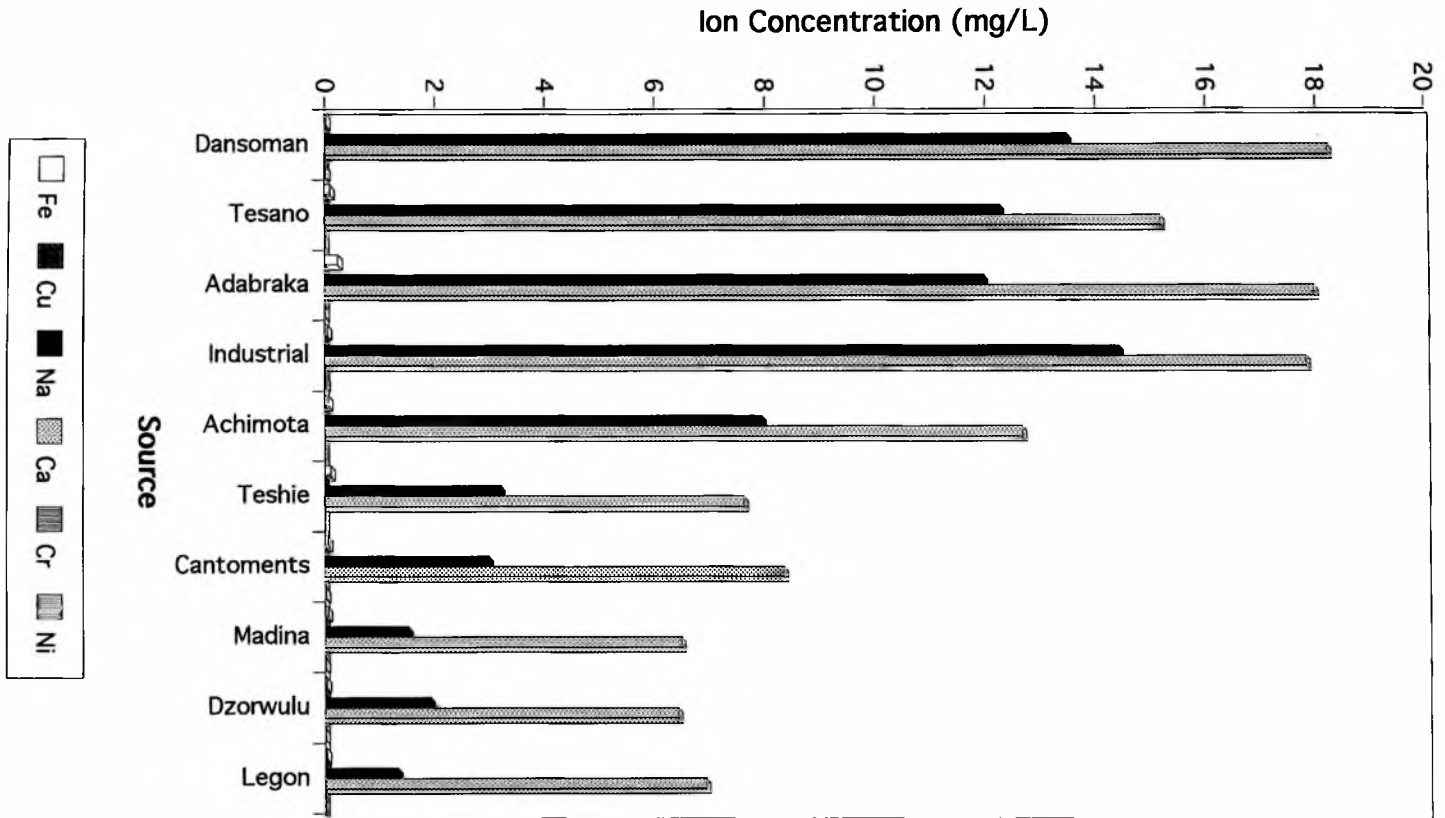
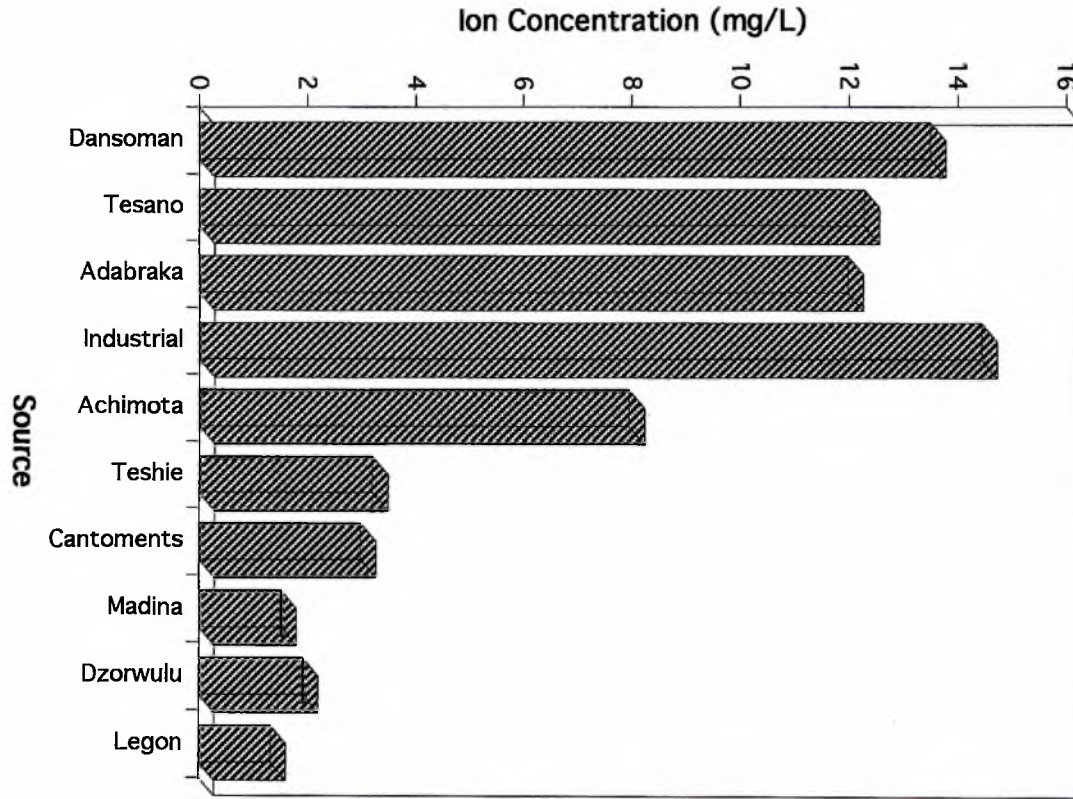


Fig. 5 CONCENTRATION OF SODIUM IN PIPED WATER IN ACCRA



#### 4.2.3.7 Calcium

The result show that calcium content ranged from 3.49 to 21.4mg/l in all the water samples analyzed. The water samples from the Kpong source fell within the lower half of the range (3.49 - 8.43)mg/l. Calcium content of Weiija samples ranges between 9.85 to 21.4mg/l. The minimum calcium content of 3.49mg/l was recorded in Madina which is on the Kpong distribution network.

The average Calcium content of Kpong water samples clearly differs from calcium content of Weiija water samples (FIGURE 6). Besides, there are more variations in calcium content of water from the towns on the Weiija distribution system than those on the Kpong system.

Other cations that were determined in the water samples were iron, copper, chromium and nickel. Their concentrations were generally low, that is, below 0.25 ppm and not much variation could be established. However, variations shown in iron content were found to be statistically significant ( $p = 0.05$ ), between the two sources of water supply to Accra. This was due to a very high iron content of 0.46 ppm which was found in only one of the water samples from Adabraka. High concentrations of iron makes water unpalatable and stains laundry. It is prudent to maintain levels below 0.3 mg/L in water (WHO,1984). The average iron concentration in water samples from Kpong was fairly constant, and generally lower than the iron content of water samples from Weiija.

Fig. 6 CONCENTRATION OF CALCIUM IN PIPED WATER IN ACCRA

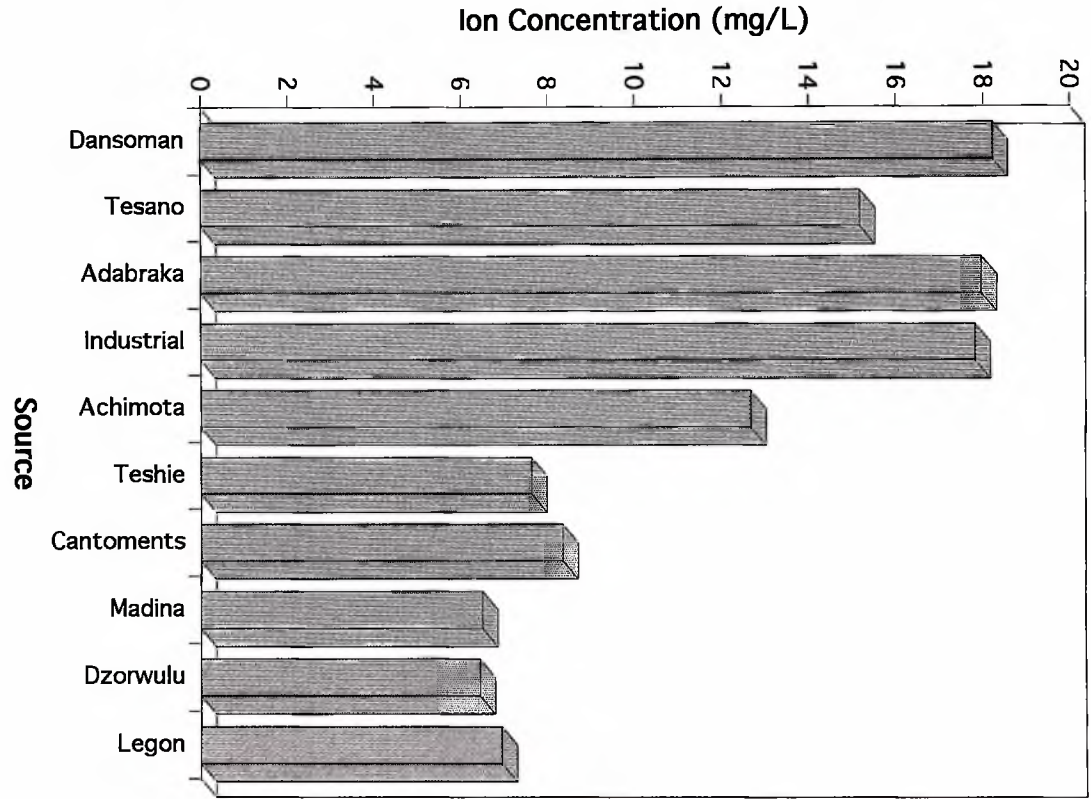
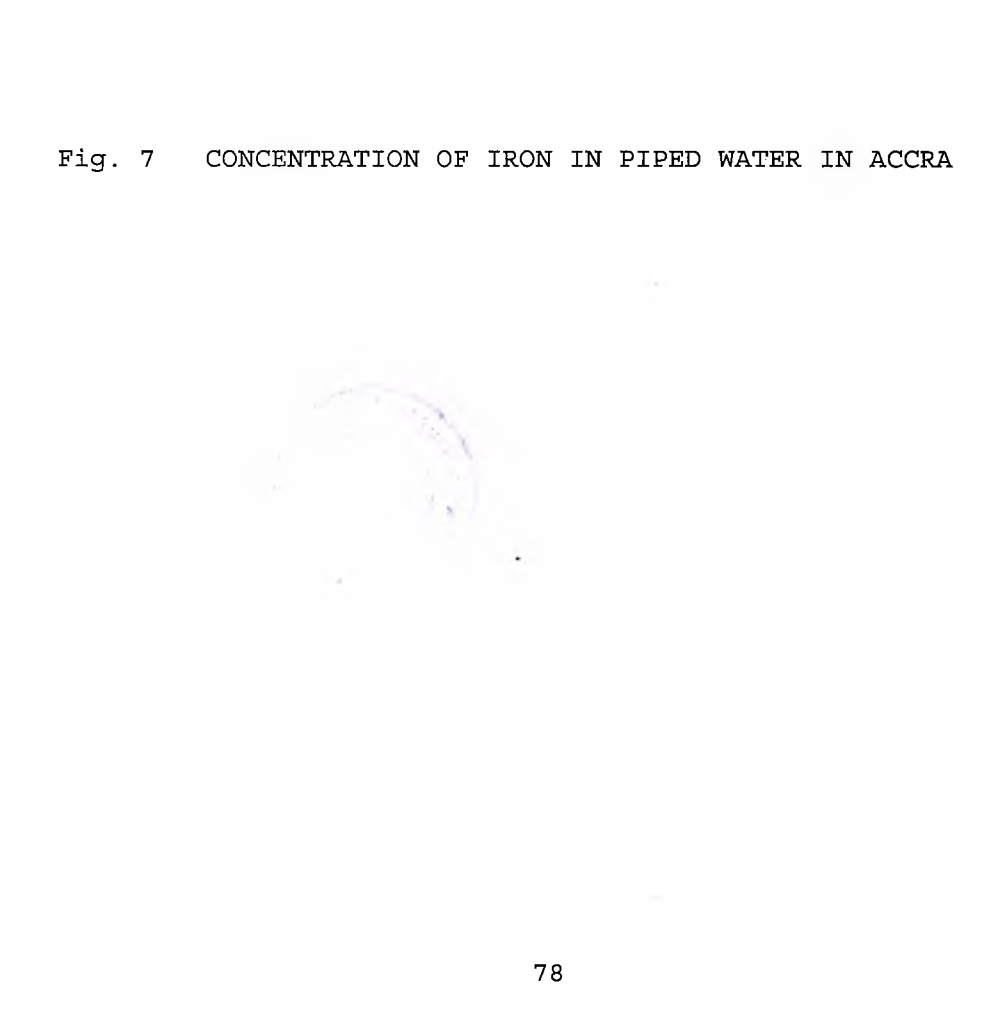


Fig. 7 CONCENTRATION OF IRON IN PIPED WATER IN ACCRA



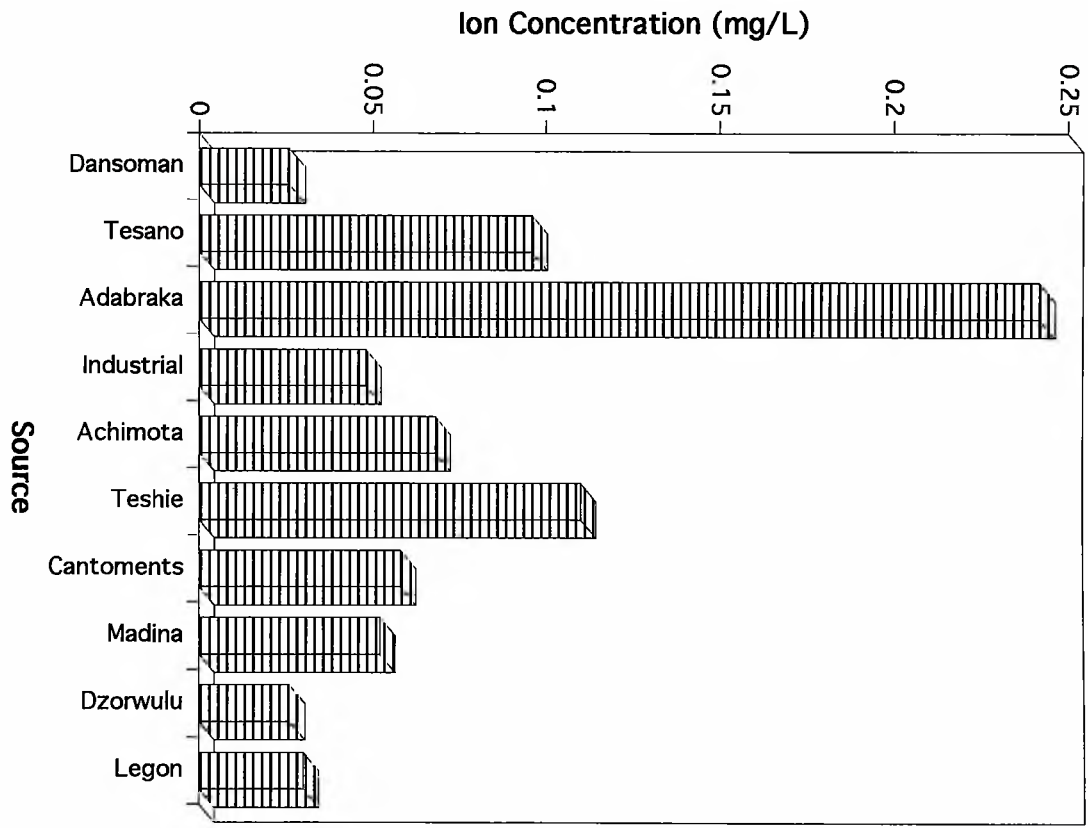


Fig. 8 CONCENTRATION OF COPPER IN PIPED WATER IN ACCRA



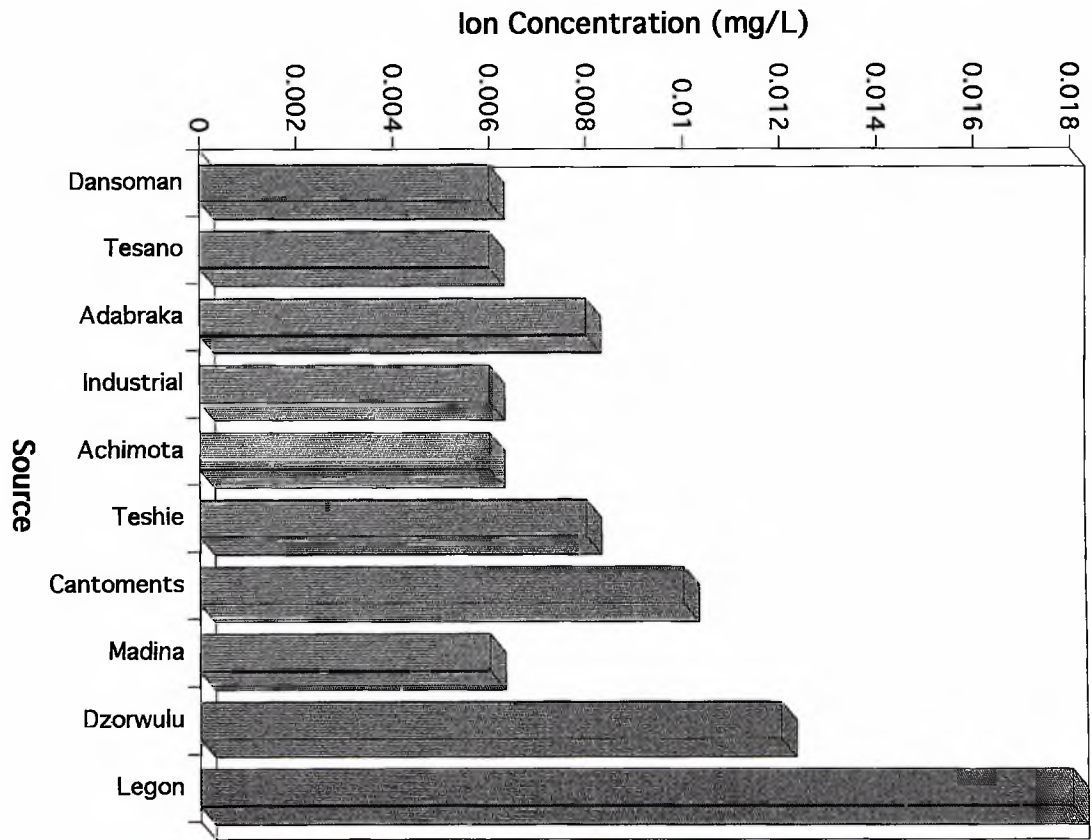
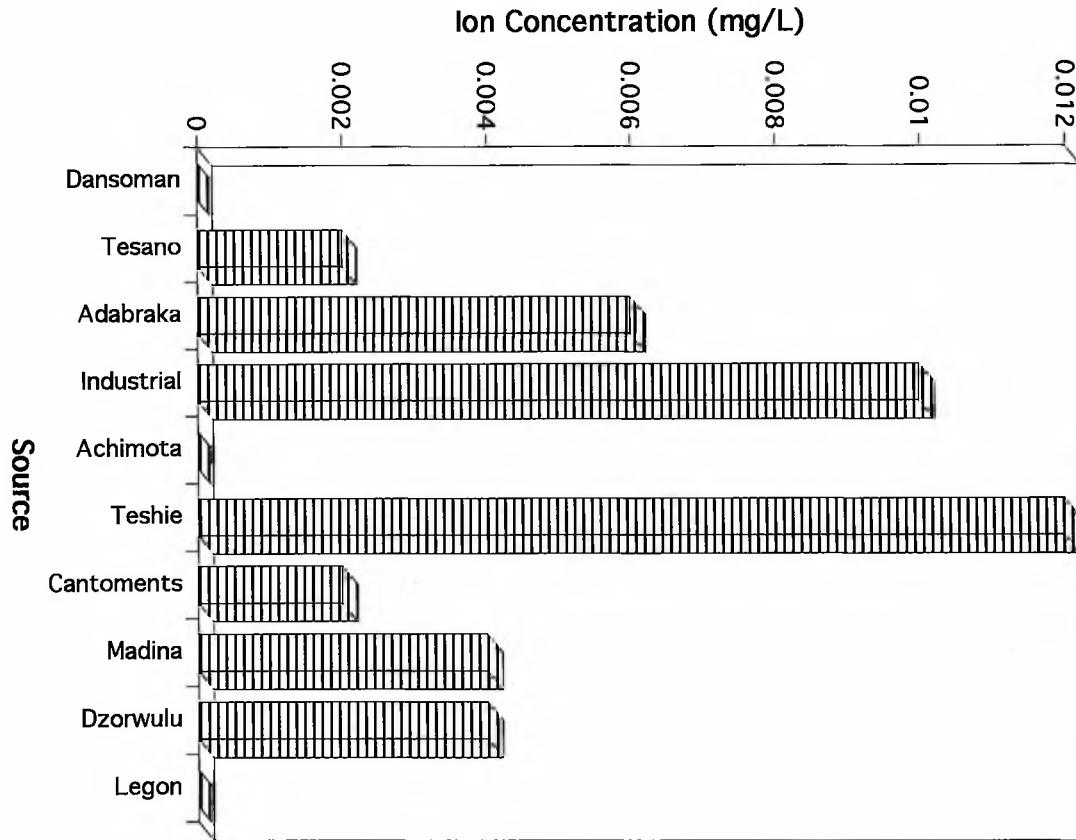


Fig. 9 CONCENTRATION OF CHROMIUM IN PIPED WATER IN ACCRA



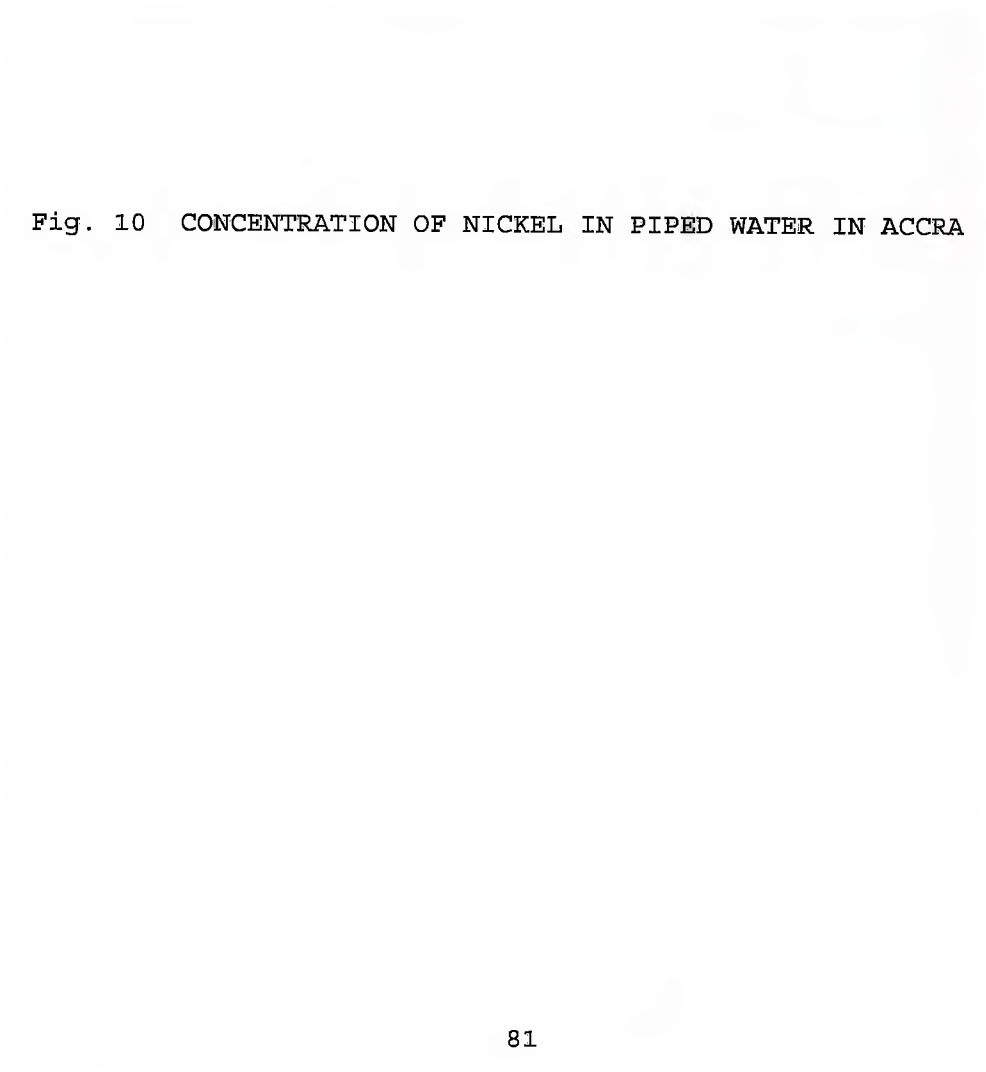
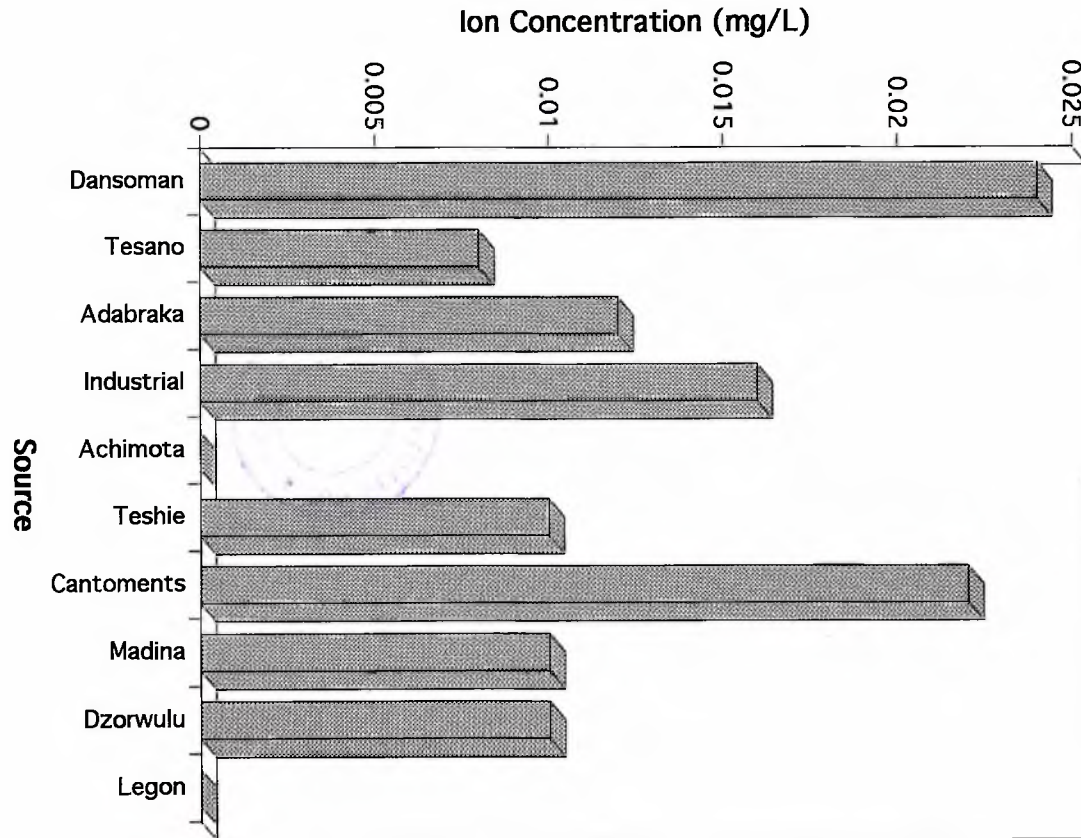


Fig. 10 CONCENTRATION OF NICKEL IN PIPED WATER IN ACCRA



#### 4.2.4. Aesthetic and chemical quality of Water in Ga Rural

##### 4.2.4.1 pH

pH of rural samples varied from 6.41 to 8.84. The pH of Well 2 was the lowest (6.41) and the highest pH was that of Reservoir 5 (8.84). These two pH values, fall outside the range recommended by WHO (6.5 -8.5). Two other samples had pH above the range, Reservoir 2 (8.68) and Reservoir 6 (8.6). Three of the six water samples from reservoirs, had pH beyond 8.5. This suggests an underlying phenomenon that may be linked either to the source of water, or the material used to build the tanks.

##### 4.2.4.2 Alkalinity

The alkalinity of the reservoir samples generally fell in the lower half of the group range of 24.2 mg/l to 185.9 mg/l. Generally, the alkalinity of the reservoir samples have alkalinity less than 60 mg/l. That of the well samples was greater than 100 mg/l. They were comparable to the pond and borehole samples. The stream sample had relatively high alkalinity of 185.9 mg/l.

##### 4.2.4.3 Turbidity

Only the pond water samples were found to be highly turbid, due to fine particles suspended in water.

Fig. 11 pH OF WATER SAMPLES FROM GA RURAL

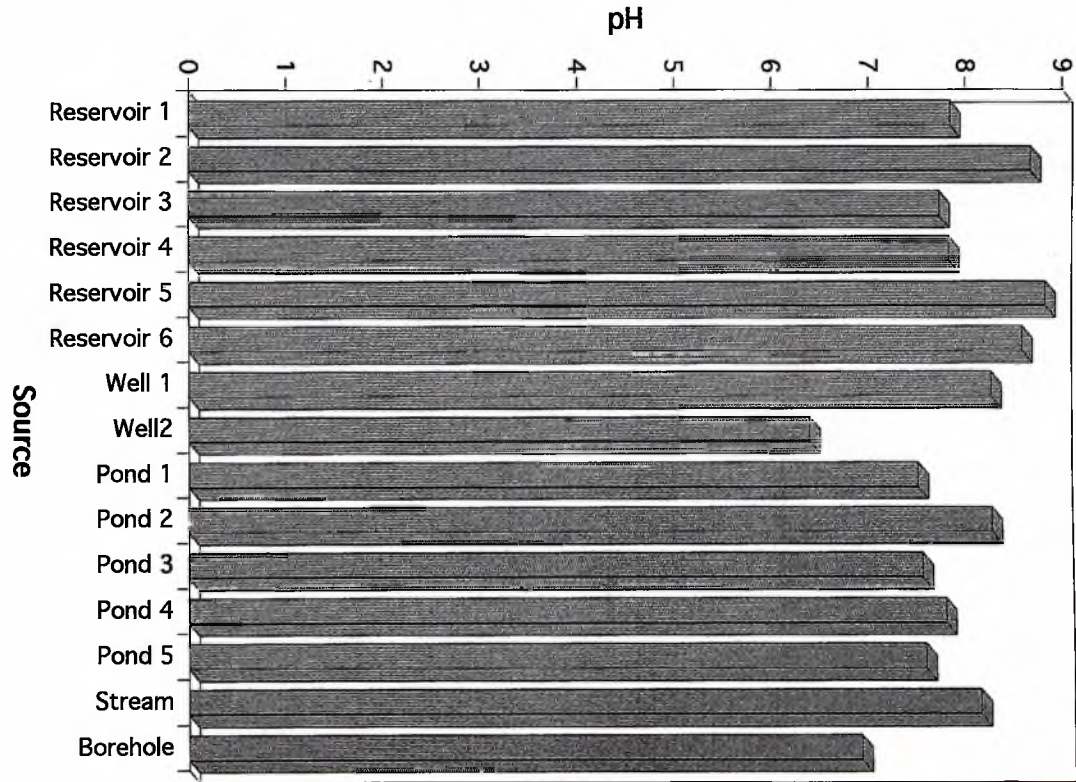


Fig. 12 ALKALINITY OF WATER SAMPLES FROM GA RURAL

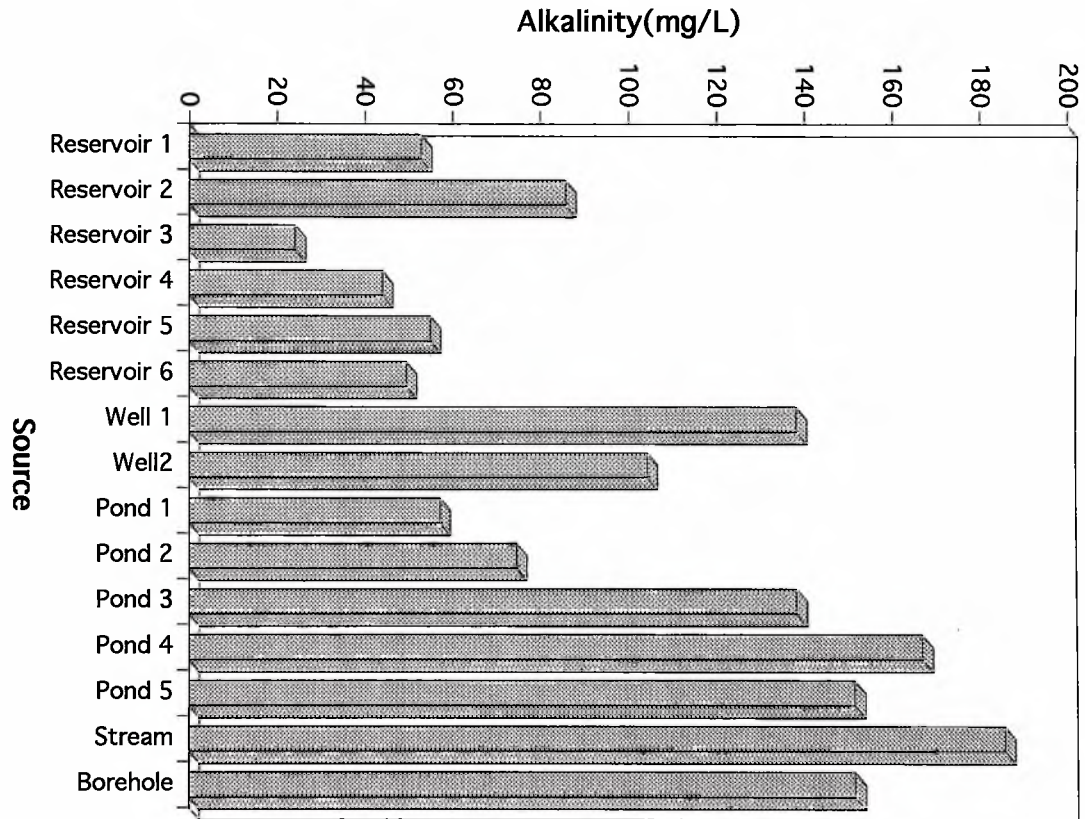
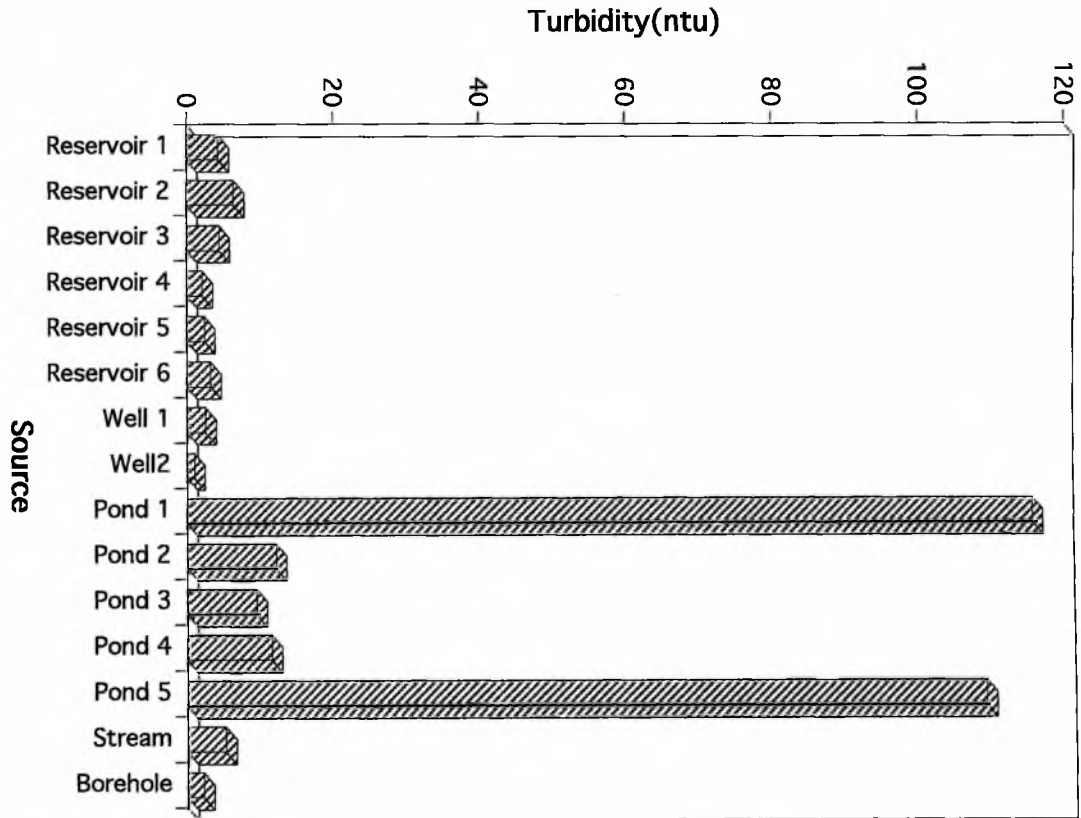


Fig. 13 TURBIDITY OF WATER SAMPLES FROM GA RURAL





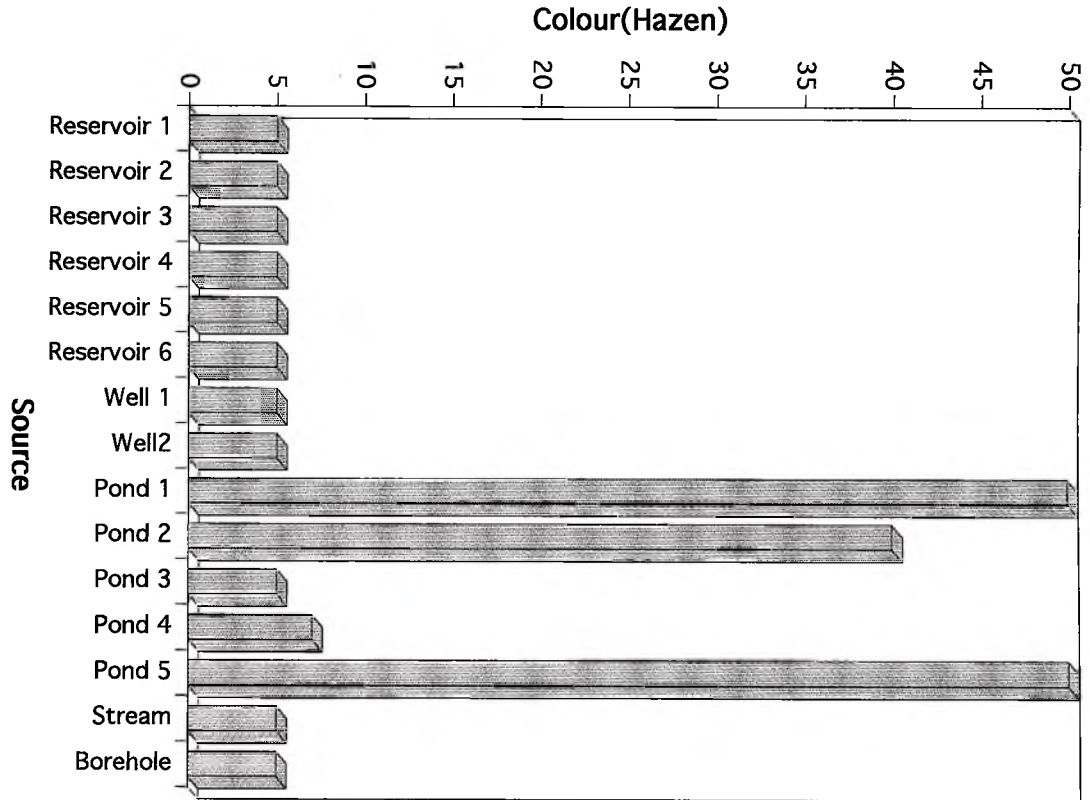
#### 4.2.4.4 Colour

All the reservoir water samples were as colourless as water from tap sources, assuming that all were obtained from treated piped water. Water from the wells, stream, borehole and one pond were also colourless. Four of the pond water samples were coloured (FIGURE 14). In the towns where these samples were obtained, the rural folk often added alum to almost all their supplies for clarification.

#### 4.2.4.5 Cationic constituents of water from Ga Rural

As in the urban water samples, sodium and calcium are the dominant cations in the rural water samples (FIGURE 15). The highest calcium content was found in the deep well from Ofankor (FIGURE 15). This well also had the highest sodium content of 361 mg/l. The more shallow well had lower salt content, but was relatively high for calcium (17.3 mg/L) and sodium (28.8 mg/l). The borehole sample had 61 mg/l sodium and 4.3 mg/l calcium. Particularly elevated levels of sodium are associated with ground water in areas where there is abundance of sodium mineral deposits or where there has been contamination from saline intrusion or other forms of pollution (WHO, 1979). Hypertensive patients and patients with congestive heart failure need to restrict their overall dietary intake of sodium.

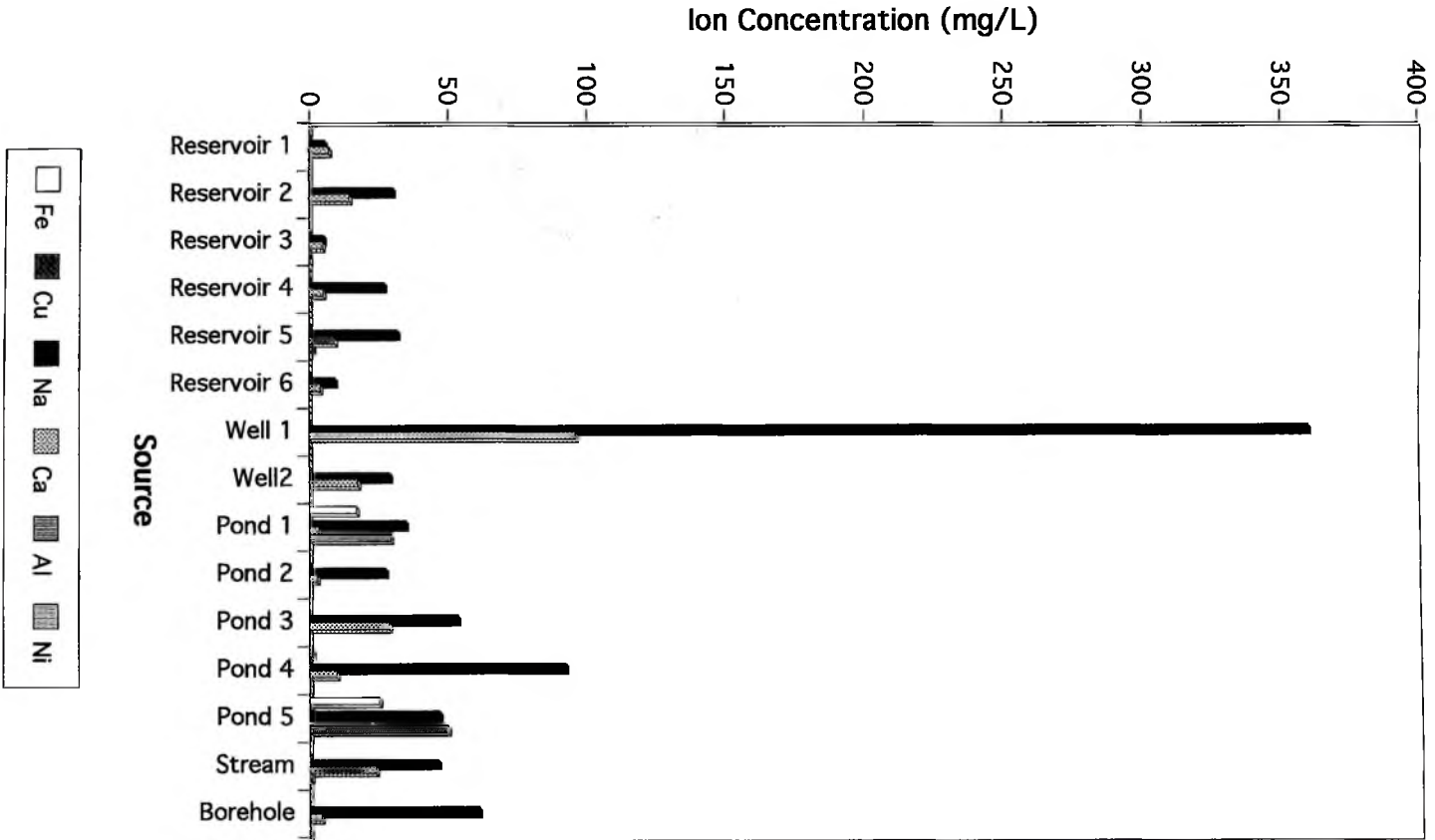
Fig. 14 COLOUR OF WATER SAMPLE FROM GA RURAL



The rest of the elements were present in very low concentrations in most of the samples except for Ponds 1 and 5 which had high iron and aluminium. Iron is an essential element in human nutrition, but ingestion of large quantities, results in a condition known as haemochromatosis (Hopps,1972) (Jacobs,1977). Aluminium does not appear to be an essential nutrient in man. It is not normally absorbed from food or water but complexes with phosphate and is excreted in the faeces (Thienes and Haley,1972). Consequently, high levels of aluminium lead to loss of phosphate. Incidentally, water samples from the two ponds had high turbidity and colour. This lends credence to the fact that the aesthetic quality of water samples is related to the metallic content.



Fig. 15 CONCENTRATION OF CATIONS IN WATER SAMPLES FROM GA  
RURAL



4.3. WATER UTILIZATION AND HANDLING BEYOND THE TAP4.3.1 Informal Food Service Centers

Drinking water in food service center were sampled, and analyzed for microbial contamination. Results indicate that most samples had high bacterial load (TABLE 16), but none was found to be positive for faecal coliforms, which is an indication of recent pollution. The kind of exposure that the water pitchers or containers are given and the mode of handling and utilization, exposes them to various agents of enteric diseases.

Table 16 Bacteriological Analysis of Water from Informal Food Service Centers

<u>Location</u>	<u>MPN</u>	<u>Location</u>	<u>MPN</u>
Legon 1	>161	Ministries 1	>161
Legon 2	3	Ministries 2	>161
Legon 3	24	Ministries 3	>161
Legon 4	>161	Ministries 4	>161
Legon 5	>161	Ministries 5	>161
Legon 6	24	Ministries 6	161
Legon 7	>161	Ministries 7	>161
Legon 8	17	Ministries 8	>161
Legon 9	>161	Ministries 9	>161
Legon 10	18	Ministries 10	17
<u>Industrial Area 1</u>	24	<u>Industrial Area 2</u>	>161

4.3.2 Iced water Samples

Iced water is retailed in two main packages, using transparent polyethylene bags, or dispensed directly with cups. All the samples of iced water bought from the vendors were heavily contaminated with bacteria. Two of the five samples obtained by means of the cup were contaminated with coliform bacteria of faecal origin as against one contaminated polythene bag sample. A similar pattern could be seen in samples from both stations examined (TABLE 17).

Table 17 Bacteriological Analysis of "Iced water" samples

Circle Lorry Station		Accra Lorry Station	
Receptacle	MPN	Receptacle	MPN
cup 1	>161	cup 1	>161
cup 2	>161 +	cup 2	>161 +
cup 3	>161 +	cup 3	>161
cup 4	>161	cup 4	>161 +
cup 5	161	cup 5	24
bag 1	>161 +	bag 1	>161
bag 2	92	bag 2	161
bag 3	>161	bag 3	54
bag 4	24	bag 4	161 +
bag 5	161	bag 5	>161

+ = positive for faecal coliforms

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Survey

#### 5.1.1 Storage and Cleaning of Water vessels

Most food factories store water in anticipation of interruptions in water supply. The frequency of cleaning of the storage receptacles depends on the source of the water. Water from Weiija Water Supply apparently leaves deposits in the tanks more frequently than does water from Kpong.

Filtration is one of the treatment steps that is in use in our water treatment plants. It is recommended that, more filtration steps be included in treatment at Weiija, since leaving this responsibility with individual factories will make a higher demand on the national economy.

#### 5.1.2 Water Quality Control in Industry

Only a few manufacturing concerns were involved in thorough quality check of water before embarking on production. All food industries must be closely monitored to ensure complete quality assurance to their consumers.

#### 5.1.3 Water Treatment in Industry

Water treatment in industries was generally instituted as part of production package imported or copied from elsewhere, and not necessarily designed according to source water quality. As a consequence, the quality of products cannot be expected

to be consistent.

#### 5.1.4 Production problems encountered in Industry relating to Water Quality

The survey revealed that, there was poor water quality management in the food industries. Manufacturers must be advised to explore the use of the concept of Hazard Analysis Critical Control Points. Also, employing more competent personnel might be the solution in some cases.

### **5.2. Urban Water**

Generally, water treated by GWSC at both Weija and Kpong Water Works, is potable. Weija water is more alkaline. A periodic monitoring must be instituted by an appropriate authority as a matter of urgency, to monitor municipal water treatment.

### **5.3. Rural Water**

All the water sources found in Ga rural can be classified into two groups. The ponds and streams form one group. Water from these sources is difficult to use unless thoroughly treated by at least the basic treatment procedure for potable water. Water from the borehole and well is the second group. It is the only type that is low in microbial count. Such water is not quite welcomed by inhabitants of Ga rural because of high salt content.

### **5.4. Water in Informal Food Service Centers (Chopbar Water)**

Water used in informal food centers constitute a

microbiological hazard.

### **5.5. Icewater**

Water sold in polythene bags is less likely to be contaminated by pathogenic microorganisms than the water dispensed by vendors in cups. However, other means of selling drinking water on the street must be explored since the polythene bag water is not completely devoid of contamination. Also, a more comprehensive study should be carried out to form the basis for formulating national or local council policy regarding the sale of icewater. It is suggested that the study;

- (a) holds an interview and a discussion with people who use icewater
- (b) conduct an interview of vendors and
- (c) covers a larger sample size.

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## 7.0 APPENDICES

## APPENDIX I QUESTIONNAIRE

## UNIVERSITY OF GHANA

## DEPARTMENT OF NUTRITION AND FOOD SCIENCE

Survey on Factors Affecting the Quality of Water for  
Industrial PurposesSECTION A

Date.....

1. District.....

2. Town/Village.....

3. Type of Industry.....

4. Product.....

5. Professional Status of respondent.....

6. Educational Background

None[ ] Primary[ ] Middle [ ] Secondary [ ]

Tech[ ] Voc[ ] Col[ ] University [ ]

7. Did you complete this level? Y[ ] N[ ]

8. How long have you been producing the above-named  
product?.....SECTION BSource of Water

9. What is the source of water to your taps? Kpong[ ]

Weiija[ ]

Other Specify.....

10. How regular is the flow of water? .....

11. From where do you obtain water when the taps are not  
flowing? .....

12. Is there any difference between water from the main source and that of the alternate supply ? Y[ ] N[ ]

13. If Yes, please specify

14. Do you always have water for all your operations ? Y[ ] N[ ]

15. If No, what activities do you suspend ?

.....  
.....

SECTION C

Storage of Water

16. Do you have a holding tank specifically for water ?

Y[ ] N[ ]

17. If Yes what material is it made of ?

Plastic[ ] Aluminium[ ] Iron[ ] Earthenware[ ]

Glass[ ] Other (Specify).....

18. How often do you clean the tank?

Daily[ ] Weekly[ ] Monthly[ ] Quarterly[ ]

Annually[ ] Other Specify.....

19. Why do you store water, if you do ? Give Reasons

.....

SECTION D

Utilization/Handling of Water

20. State all operations that involve the use of water. eg. Steam generation, Cooking, As raw material ingredient

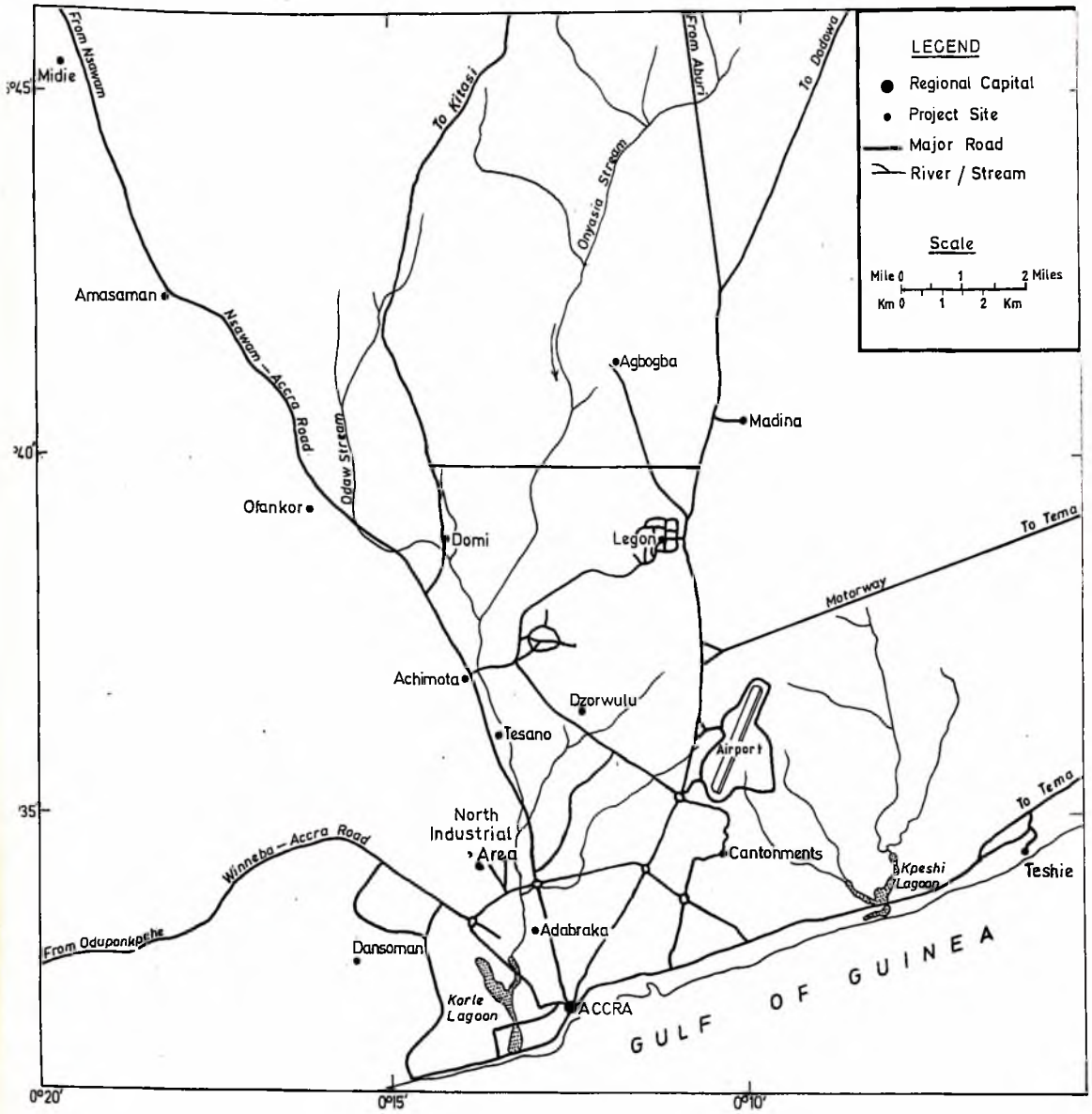
etc.

.....  
.....  
.....

- 21. Which do you consider most critical in terms of water quality ?  
.....
- 22. Do you treat the water before use ? Y[ ] N[ ]
- 23. Why.....  
.....
- 24. If answer to 22 is Yes, what type of treatment do you give it?  
Boiling[ ] Filtering[ ] Chemical[ ]  
Other.....
- 25. Do you observe any changes ? Y[ ] N[ ]
- 26. What difference does treatment make?  
.....  
.....
- 27. Do you have a quality control (QC) system which analyses the water before/after treatment ? Y[ ] N[ ]
- 28. If no, how do you know if your water quality is adequate for your purposes or not ?  
.....
- 29. If Yes, what parameters do they analyse for ?  
.....  
.....  
.....
- 30. Have you ever had a problem with the water that resulted in a poor quality product ? Y[ ] N[ ]
- 31. If Yes, how did you relate the problem to the water quality ? Please explain  
.....

.....  
32. How did you resolve the problem?  
.....

APPENDIX II MAP OF ACCRA AND GA RURAL SHOWING DISTRIBUTION  
OF SUBURBS FROM WHERE WATER SAMPLES WERE TAKEN



## APPENDIX III

MOST PROBABLE NUMBER (MPN) AND 95% CONFIDENCE LIMITS FOR THE 50ML PORTION, FIVE 10ML AND FIVE 1ML PORTIONS PER 100ML SAMPLE

Number of tubes giving positive reaction out of			MPN per ml	95% confidence limits	
1x50ml	5x10ml	5x1ml		Lower limit	Upper limit
0	0	1	1	0.5	4
0	0	2	2	0.5	6
0	1	0	1	0.5	4
0	1	1	2	0.5	6
0	1	2	3	0.5	8
0	2	0	2	0.5	6
0	2	1	3	0.5	8
0	2	2	4	0.5	11
0	3	0	3	0.5	8
0	3	1	5	0.5	13
0	4	0	5	0.5	13
1	0	0	1	0.5	4
1	0	1	3	0.5	8
1	0	2	4	0.5	11
1	0	3	6	0.5	15
1	1	0	3	0.5	8
1	1	1	5	0.5	13
1	1	2	7	1	17
1	1	3	9	2	21
1	2	0	5	0.5	13
1	2	1	7	1	17
1	2	2	10	3	23
1	2	3	12	3	28
1	3	0	8	2	19
1	3	1	11	3	26
1	3	2	14	4	34
1	3	3	18	5	53
1	3	4	21	6	66
1	4	0	13	4	31
1	4	1	17	5	47
1	4	2	22	7	69
1	4	3	28	9	85
1	4	4	35	12	101
1	4	5	43	15	117
1	5	0	24	8	75
1	5	1	35	12	101
1	5	2	54	18	138
1	5	3	92	27	217
1	5	4	161	39	450