

POPULATION GROWTH, URBANIZATION AND WATER SUPPLY: A GROWING CHALLENGE TO HUMAN AND ENVIRONMENTAL SECURITY IN THE PERI-URBAN INTERFACE IN GHANA

K. Nsiah-Gyabaah (MSc, PhD)

Sunyani Polytechnic, P. O. Box 206, Sunyani,
Brong Ahafo Region, Ghana

ABSTRACT

An adequate supply of potable water is essential for socio-economic development. However, many people in developing countries especially Africa have inadequate water supplies.

PLANNING

the danger of prolonged drought and over-exploitation of available ground water resources resulting of increasing population and urban sprawl, leading to the drastic fall in water levels with consequences of failing hand pumps, wells and water shortage in the urban and peri-urban areas. This paper examines the relationship between population dynamics and water supply in the peri-urban interface because the health, ecological and environmental problems facing poor households in the peri-urban areas are either directly or indirectly linked to population growth and urbanization dynamics.



Fig 1. Village Water Supply

Water is a basic human need and a fundamental human right, but many people in the developing countries lack access to adequate potable water supply mainly because of prolonged drought and aridity or pressure of population on available water resources. In many arid and semi-arid regions in Africa, water brings joy not only to farmers and women elderly but also to children who have responsibility for assisting women in water collection.

In many African countries, land degradation is increasing and water resources are under threat through rapid growth and urbanization. Human activities such as poor agricultural practices, inappropriate domestic and industrial waste disposal methods and destruction of watersheds are exacerbating water pollution. Another area of concern is

Keywords: *Pollution, Poverty, Peri-urban, Interface, Urbanization, Environment, Security.*

INTRODUCTION

Adequate potable water supply for urban, peri-urban and rural areas is essential for socio-economic development and the wellbeing of

people for drinking, cooking, cleaning, washing and bathing. (Fig 1) Water is the foundation for food availability and sustainable livelihoods in the developing countries because millions of people depend on water resources for crop processing and industrial development. They variously, either directly as employees or as employers, engage in agriculture including livestock and manufacturing that depend on adequate water supply.

However, access to potable water supply is a major problem in developing countries that are experiencing rapid population growth and urbanization. The rapid process of urbanization and population growth in many parts of Africa, especially Sub-Saharan African, are accompanied by significant influences on the quantity and quality of water supply and livelihoods of the people living in these areas.

It has been observed that the people living in the peri-urban interface are experiencing the most rapid changes and people in these areas to cope with water scarcity and pollution originating from the cities. For example, Kumasi, Ghana's second largest city lies on top of a major water shed and the inhabitants of the city pollute the rivers and streams used by inhabitants in the peri-urban interface by dumping night soil and waste tips close to sources of water supply. They also destroy the ecosystems of the wetlands through pollution of the streams.

In many urban and peri-urban areas, it has been observed that rivers, streams and aquifers are increasingly being contaminated in their recharge areas through human activities. Many urban and rural communities are constantly struggle with prolonged drought and aridity, water pollution, water shortage and rising costs of providing water. In addition they face the problems of fast rapid population growth and urbanization that the putting extreme pressure on available water resources leading to water pollution and water shortages in the peri-urban interface.

In Kumasi peri-urban area in Ghana, for example, rivers and streams that provide the main source of drinking water supply for the poor are polluted by or through domestic and industrial wastes, agriculture and urban runoff. The effect on the

population is serious, especially in the peri-urban areas, where urban wastes and runoff pollute rivers and stream that serve as the main sources of water supply.

THE PERI-URBAN INTERFACE

Despite its growing popularity amongst academic researchers and policy agencies, there is no universally agreed definition of the peri-urban interface (PUI). The peri-urban interface is dynamic and not a static zone, both spatially and structurally, and therefore different writers have defined the concept in different ways, depending on their objectives, professional background and interests.

Rakodi [1] has defined the PUI spatially as the transition zone between the fully urbanized land in cities and areas in predominantly agricultural use [2]. It is also a zone of rapid use, economic and social change, characterized by pressures on natural resources especially land and water by rapid population growth.

DFID has been funding a major international research program in Kumasi in Ghana and Hubli-Dharwad in India known as the Natural Resources Systems Programme (NRSP). The main objective of the research is to contribute effectively to DFID's priority objective of reducing poverty. According to DFID, the land area that can be referred to as 'peri-urban interface' shifts over time as the city expands. The intense rural-urban interactions in the PUI give rise to numerous flows of capital investment, commodities natural resources, people, labour, knowledge, energy, waste and pollution [1].

The Kumasi peri-urban baseline studies define the PUI by the characteristics of strong urban influences, easy access to markets, services and other inputs, ready supplies of labour, relative shortage of land and risks from pollution and urban growth [2]. In the Kumasi baseline studies, the Village Characterization Survey team considered 50 kilometres to be the outer limit of Kumasi peri-urban region [3].

The ODA Renewable Natural Resources Strategy has also defined the peri-urban interface by its characteristics:

The peri-urban interface is characterized by strong urban influences, easy access to markets, service and other inputs, ready supply of labour, but relative shortage of land and risks from pollution and population growth" [2, 4].

An unpublished DFID funded research in India has also defined the PUI, tentatively as that socio-economic, ecological and spatial region where interactions between the city and its hinterland are dense, multiple and complex, and where the city's human and ecological impact is substantial. Among others, the PUI is characterized by pollution of surface water by domestic and industrial waste, use of unprocessed sewage for production of vegetables and other crops and sites for night soil and garbage disposal from the city [5].

It is not easy to define spatial (either the inner or outer) limits to the peri-urban area because they move as the city intra-urban city expands and there are considerable activities that cross any defined boundary such as water pollution that may have their own defined spatial extent. However, at a recent workshop in Kumasi, [6] defined the peri-urban interface as the last police barrier or checkpoint to the city.

THE GLOBAL SITUATION

It is estimated that by the beginning of the next century, more than half of the world's six billion people will be living in cities and towns, and most of the urban growth will be in the developing countries. More than 51 per cent of the world's population will live in urban areas, rising to 65 percent by the year 2025, and 80 percent of these urban residents will live in developing countries [7, 8].

At the beginning of the 20th century, only about thirteen cities had populations above one million. Today, there are 235 such cities, and the number would double within the next century. Available statistics show that about 75 percent of these cities will be in what we call today as 'developing countries' [9]. The challenge that this growth presents to decision-makers and planners in meeting the growing food and water needs of the population is complex.

In the next three decades, the UN has estimated that as many as 5.5 billion people worldwide may live in areas suffering from moderate to severe pressure on water resources, rendering availability of water even more difficult. Africa, the poorest continent in the world where rapid population growth and urbanization are putting tremendous pressure on natural resources, is the most affected region because of increasing aridity, drought and accelerated desertification of the continent.

In Africa, currently the most rapidly urbanizing continent in the world, about two out of three people will live in urban centers in the next 20 years. Although, the less developed countries are expanding the most rapidly, Sub-Saharan African has the highest projected regional annual population growth rate at 2.8 per cent. By contrast, the annual growth rate of the industrialized countries is 0.5 percent [10].

Such urban expansion and rapid population growth create particular problems and challenges in terms of poverty alleviation, provision of adequate food, water supplies sanitation and human security [11]. It is estimated that one in four of the world's population (two-thirds of them women) lives in abject poverty, without access to adequate food, clean water, sanitation, essential health care or basic education services. In the developing countries, about 1.3 billion people are poor. Due to poverty, many people, especially the poor in the PUI, have little opportunity to fulfill their aspirations and develop their potential [12].

THE IMPORTANCE OF WATER RESOURCES IN SUSTAINING LIVELIHOODS

Water is a basic livelihood asset, one of the most important of all natural resources on which people depend for food and livestock production. It is vital for all living organisms as well as human health. Water is a finite resource and when it is scarce, drinking water supply is the uppermost priority. In arid and semi-arid areas where water resources are limited, people walk long distances and spend several hours to collect water to meet the household requirement.

An adequate and affordable water supply of

suitable quality makes a major contribution to agriculture and socio-economic development because several human activities are directly or indirectly related and dependent to water [13]. Therefore, pollution, growing water scarcity and misuse of fresh water pose a serious threat to socio-economic development and human security. The deterioration of water resources is a cause of global concern both for the sustainability of food supply and the health of the population and many people have called for greater research and investment in soil and water resources. Yet, water is one of the natural resources that is often taken for granted in many developing countries because of our failure to recognize and accept that it is an increasingly scarce resource.

Because of the important role of water in agriculture, livelihoods and human security, governments and water authorities in the developing countries such as Ghana celebrate the World 'Water Day' to create awareness about the need to conserve water resources, and the necessity to take precautionary measures against drought, water pollution and water shortage.

Global statistics on population growth and water supply are disturbing. In the year 2000, the world's population reached 6 billion, and by 2050, the United Nations estimates that it will probably be about 9 billion. Almost all that growth will occur in developing countries. At the same time available statistics show that about 2 billion people, mostly the poor in the developing countries, still have no access to adequate supply of clean water for household use or adequate sanitation [9,14,15]. Available statistics show that already people use more than 50% of all accessible surface water run-off. This proportion may increase to 70% by 2025, thereby reducing the quantity and quality of water available for aquatic ecosystems [9,16].

By 2025, it is estimated that as many as 5.5 billion people may live in areas suffering from moderate to severe pressure on water resources, rendering the hope of providing safe water difficult [17]. Despite shortages, misuse of water is widespread in many countries. In the light of these trends, new approaches are urgently needed to manage watersheds and water resources rationally and

equitably. This calls for efforts that will simultaneously address rapid population growth and urbanization in the developing countries especially Africa.

POPULATION GROWTH, URBANIZATION AND WATER LINKAGES

It is common knowledge that there is wealth and greater opportunities for education and employment in cities compared with the rural areas. The attractive urban life has resulted in the relentless urban drift and the growing poverty in the rural areas has 'pushed' the youth out of the rural areas to the cities over the last three decades.

Steve Lonergan [18] has noted that the major determinant of Third World urbanization is the "push" exerted by the inability of available resources in rural areas to sustain the population that drives the masses from impoverished villages to urban centres. While the causes of rural urban migration are clear, however, the long-term implications on human and environmental security in Africa has not been adequately analyzed and not clearly understood. The critical question confronting developing countries experiencing rapid population growth and urbanization is: can the cities continue to absorb people as they are currently doing and can available resources especially water maintain the increasing urban population?

In the debate on the environment, [19] Simon argues that population growth provides expanding resources and that fears of a population-glutted world are unfounded. Population optimists often cite the high standards of living in densely populated countries such as Japan and the Netherlands as proof of this point

However, in Africa especially in the arid and semi-arid regions, population dynamics negatively affect water resources in many ways. Rapid population growth increases pressure on available water resources. Human actions bring about water deterioration and scarcity through rising demand, unequal distribution and increased contamination. Water pollution results from a combination of factors including population growth, rapid urbanization and misuse of

underground and surface water resources. Figure 2 shows population dynamics and the casual relationships between population growth and water utilization.

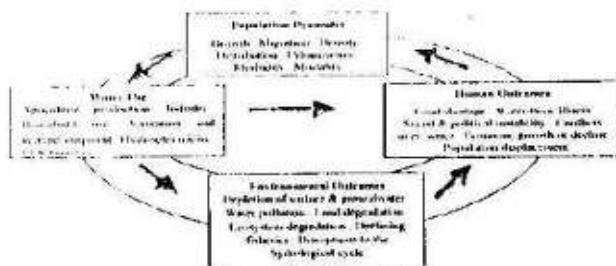


Fig 2: Population Dynamics and Relationships Between Population Growth and Water Utilization Source: IUCN and PRB (1996), *Water and Population Dynamics*

In Ghana, for example, the population has increased from 12.3 million in 1984 to 18.2 million in 2000 [20]. The annual growth rate in the country generally is 3 percent. The Ashanti region's population has increased from 2 million in 1984 to 3, 187, 601 in 2000. In Kumasi alone, the second most important city, the population has grown from 260,28 in 1970 to 376,246 in 1984 and 1,017,000 at the 2000 census, showing an increase of more than 600,000 people between 1984 and 2000. A similar growth trend occurs in Greater Accra, Ghana's largest city, where the population has grown from 1,431,099 in 1984 to 2,909,932 in 2000 [20]. In 1984, Accra-Tema metropolitan area. The largest concentration of urban population had about 1.2 million persons and contained about 30 percent of the national urban population. This increased urban population and urban expansion have come about as a result of major stream of irrigation, coupled with high fertility and reduced mortality rates during the past three decades.

The impact of urbanization and rapid population growth on the natural resources and the environment are not only leading to small farm sizes and undermining food security but they are forcing many women who produce subsistence crop in these areas out of agriculture. Rapid

population and urban expansion are placing great demands on land and water resources, leading to over crowding land degradation, water pollution and water scarcity especially in the urban and peri-urban areas. Women and children, who do almost all the domestic chores, must walk long distances to collect water that is often contaminated and unsafe to drink. The depletion and contamination of fresh water resources affect human security and poor water quality has serious health consequences especially on the population that lives in the urban fringes.

Rapid population growth and urbanization also lead to changes in land cover and land use that ultimately affect water resources and ultimately local climate topography and vegetation, which also affect water quality and availability. In Ghana for example, a series of studies by Kwame Nkrumah University of Science and Technology revealed that the quality of several watercourses in Kumasi metropolitan and peri-urban areas was poor or pollution with levels that may be higher than the World Health Organization (WHO) standard [21]. Around Kumasi, levels of manganese, which is required for chlorophyll production at low concentrations and can be toxic at high levels, were found by the HR Wallingford study to be higher than recommended by Food and Agriculture Organization (FAO) as the limit for irrigation [22].

It has been reported that the mean level of bacteriological pollution in terms of the recommended measure of the microbiological suitability of Kumasi area water for irrigation, number of faecal coliforms per 100ml, was highest at Asaago and lowest at Sepetimpom [22]. Although levels of arsenic and nitrate have been not been assessed, Acquah [23] has observed that there are indications of arsenic and nitrate in groundwater from surface mining and agricultural practices. During a survey, women in Duase and Abrepo said that water from rivers Sesa and Akos had a lustrous surface, indicating some level of pollution. Consequently the water was not drunk but used for irrigating vegetable crops and washing cars.

The Owabi and Berekese dams the main water

reservoirs in Kumasi, were contaminated by wastewater from drains and from municipal dumping of sewage. In the urban fringed settlements, surface water quality was fast deteriorating from agriculture, urban and industrial wastes. In the valleys groundwater was polluted from increasing use of agro-chemicals in peri-urban agriculture and horticultural crop production. Although the extent of water contamination from agro-chemicals had not been accurately studied and assessed, it was believed that indiscriminate use of agro-chemicals were responsible for water related diseases in the urban and peri-urban areas.

Due to rapid population growth and urbanization the Kumasi metropolitan Assembly (KMA) could not effectively managed the liquid and solid wastes which the people produced in the city. Moreover KMA found it difficult to acquired waste disposal sites from landowners in the peri-urban area. The waste department of the KMA collected night soil (human excreta) and simply tipped it into the Subin River the main source of water supply for people in some of the fringe settlements.

Rapid population growth was also leading to increased demand for water food, fuel wood and urban expansion was accelerating deforestation. Deforestation, in turn, was altering the hydrological cycled and decreasing water flows. The forests, that acted as water regulators by reducing run-off and soil erosion and helped to replenish groundwater, were being cut for residential development. Deforestation was also reducing assimilation, fish supply and wildlife habitats, and leading to siltation of watercourses and reduction in ground water reserves. The urban population was also generating environmental and health problems associated with waste disposal and water pollution for people in the peri-urban areas.

A recent DFID funded research project-Kumasi Peri-urban Natural Resources management at the Watershed Level has also noted that in general that when populations are large and excessive amounts of domestic and industrial wastes that are produced in the city end up in aquifers, rivers and streams, the natural process of self-purification cannot keep pace with the input of

pollution and so water quality rapidly deteriorates. In Kumasi, peri-urban area, all the major streams were haboured the snail vector of schistosomiasis and such wastes were responsible for the transmission of infectious diseases such as cholera, typhoid, dysentery and diarrhoea. Inadequate medical care and poor nutrition exacerbated the health problem associated with water pollution.

The DFID funded study revealed that waste petroleum products from vehicle repair workshops and washing of vehicles (car wash) around rivers and streams were contaminating ground water draining into the Owabi reservoirs and polluting the Sesa and Subin rivers.

FACTOR AFFECTING WATER SUPPLY

Many factors affect world water supply. The amount of rainfall, changes in hydrology that may result in increased erosion siltation, flooding or reduced water availability prolonged drought, loss of vegetation from bush fires and land clearing affect water supply and availability. However, in many developing countries, rapid population growth and urbanization have become important.

The past two centuries have seen dramatic increases in world population from 1 billion in 1800 to 6 billion at the close of the 20th century. More people and rapid urbanization have led to increasing demand for water for consumption, industrial and agricultural production, and other domestic uses. In the urban and peri-urban areas in Ghana, for example, most industries have very little or limited capacity for treating their effluents. Consequently, large volumes of untreated effluents are discharged into water bodies and open drains[24]. Some of the untreated effluents contain high levels of dissolved solids, suspended solids, acids and heavy metals and organic loading.

In many urban areas, especially the arid and semi-arid regions in Africa, increasing demand and utilization of water resources have exceeded nature's capacity to deliver through the hydrological cycle, resulting in water scarcity and displacement of people. In the competition for water between local and urban dwellers, poor

people lose out. Heavy demand by industry and urban households for water can also threaten supplies to rural and peri-urban areas, where water is required for agriculture and domestic consumption.

Already in some Africa countries, there is evidence that food production has declined and water pollution and scarcity have posed a serious threat to the health of the poor living in the rural areas and on the margins of cities. A recent report on peri-urban research funded under the Department for International Development (DFID). Natural Resources Systems Programmes (NRSRP) in Ghana noted that in Accra, whilst the majority of city dwellers have access to piped water, only 18 percent of those in the fringes of the city do. About 50 percent of those without piped water depend on water vendors and 32 percent on streams and wells [3,6].

Other factors that affect the quality and quantity of water supply especially in the urban and peri urban areas include: agriculture industrial activities such as mining, agro-processing, waste disposal. A recent study in Ghana has revealed that in the urban and peri-urban areas such as Kumasi, surface water quality is fast deteriorating due to agriculture, and inappropriate disposal of industrial and domestic wastes. As a result of the increasing use of agro-chemicals in horticultural crop production, it is believed that water is polluted through horticultural crop production. The use of water for irrigation is also believed to contribute to decreasing water flows, reducing assimilation, fish supply and destroying wildlife habitats.

GENDER ROLE IN WATER SUPPLY

In many developing countries such as Ghana, the role of fetching water and the activities required to make it safe for household uses is predominantly performed by women. Fig. 3 shows the role of children, particularly girls in water collection for domestic use.



Fig 3. Children carrying in Water from the stream

With economic development, the need to minimize the time spent on these activities is critical in reducing the burden placed on women. The provision of reliable supplies of water and protection of watershed will therefore not only reduce the time spent on water retrieval but also free labour that can be used in other economic activities.

POLICY MEASURES TO ENSURE SUSTAINABLE MANAGEMENT OF WATER RESOURCES

Water is a public good and therefore its use must be controlled to reduce pollution and water shortage. Procedures and effective policies are required to assist in regulating human behaviour that affects the quality and quantity of ground water resources. To ensure sustainable water supply, especially in the arid and semi-arid regions, many international organizations and conferences such UNCED have called for long-term policies to protect watersheds and improved water quality

Some of the measures include:

The adoption of policies based on a comprehension approach to planning and management that provides for local/ share-holder participation in decision-making and operation of water supply schemes. The promotion of policies to decentralize responsibility at the grassroots for management of demand and delivery of water, and The protection of watershed, prevention of water

pollution, protection of aquatic ecosystem.

Many of these measures were the focus of the UNDP Global Consultation on Safe Water and Sanitation for the 1990s held in New Delhi in 1990 (UNDP, 1990). The UNDP's international

Population growth, urbanization and water supply.....

sedimentation and drying up. District Assemblies, traditional authorities and the EPA should enforce rules regarding the use and protection of watersheds.

EFFICIENT WASTE DISPOSAL SYSTEM

Lastly, effective waste management especially promotion of environmental sanitation at the household level, proper location of waste dumps away from water courses, composting of night soil for soil fertility improvement, controlled landfill and waste recycling are important strategy options. Water and Sanitation Committees, local development agencies and Unit commodities should ensure that dumps and village latrines are not located on top of hills or near water sources. The District Planning officer and Health and sanitation officers should embark upon environmental education and closely monitor activities that degrade watersheds and take appropriate preventive measures.

CONCLUSION

Although human access to water is a fundamental human right, in as much as it is essential for all aspect of human life and survival, the majority of poor people in the developing countries lack access to adequate water supply. In the last two decades, population growth and urbanization, together with changes in production and consumption, have placed unprecedented demands on water resources leading to water scarcity and pollution of fresh water especially in the urban and peri-urban areas. The essential role of water and the over-dependence of the poor on water resources make it necessary to have a strategy to protect water resources and manage watersheds.

In the light of current trends, dissemination of information on simple water conservation techniques and effective methods to protect watersheds and manage water resources rationally and equitably would be necessary. This entails efforts that will promote local involvement in water resource management, address consumption patters, harvest rainwater to augment supplies, protect and conserve water

intensity of weed growth in the crop and the resources that farmers must invest to achieve good yields.

Conservation tillage is an approach to land preparation that avoids turning the soil and drying

Nsiah-Gyabaah

resources. The design of appropriate water resources management strategies or water action plans also requires research to better understand the relationship between population dynamics and water resources.

ACKNOWLEDGEMENTS

The author is grateful to DFID project staff in Kumasi and the individual collaborators. The suggestions offered by Professor Simon David of the Department of Geography, Royal Holloway University of London is very much appreciated. The views expressed in this paper are those of the writer and they should not be taken to represent DFID policy.

REFERENCES

1. Rakodi, Carole 'Poverty in the Peri-Urban Interface', in DFID/NRSP Research Advances, No. 5. February, p. 1 (1999).
2. Holland, M. Kasanga, R.K. and Lewcock, C.P. and Warburton H.J. Peri-Urban Baseline Studies, Kumasi Ashanti Region. Ghana: Main Report Natural Resources Institute, Chatham, UK. (1996).
3. DFID National Resources Systems Programme: Research Highlights 1998-1999. HTs Development Ltd., UK P-9 (2000).
4. Cunnindgham, P.W. and Saigo Woodworth Environmental Science: A Global Concern. Third Edition, Wm. Brown Publishers, USA and London, p. 409 (1995).
5. Birley M. and Lock, K. The Health Impacts of Peri-Urban Natural Resources Development, Cromwell Press, Trowbridge, p 137-138 (1999).
6. Nsiah-Gyabaah K. Kumasi Natural Resources Management Research Project (KNRMP) Proceedings of Final Workshop, 9th - 11th February, NRI/DFID,

- Levine Hall, UST, Kumasi, p. 36-49 (2000).
7. United Nations Population Fund The State of the World Population, United Nations, New York (1991).
 8. IFPRI 'Urbanization and Agriculture to the Year 2020'. In News and Views: A 2020 Vision for Food, Agriculture and Environment., IFPRI October p. 1 - 6 (1994).
 9. Ghana Water Company "Water Quality Assessment and Monitoring Reports' Kumasi Peri-Urban Natural Resources Management at the watershed Level, Project R7330, DFID/Royal Holloway University, UK (2000).
 10. Rourke, T.J 'Is the United Nations Advocating Objectionable Policies to World Population Growth?, in Taking Sides, Sixth Edition, The Dushkin Publishing Group; Inc. p. 309 (1995).
 11. IBSRAM 'Africaland-Restoring the Rural Urban Nutrient Cycle'. International Broad for Soil Research and Management Newsletter, No. 51. P.4 (1999).
 12. Short ' Globalization' in Development. The International Development Magazine, Issue 9, First Quarter, 2000, p. 11 (2000).
 13. IUCN, Water and Population Dynamics Local Approached to 9 Global Challenge INC's World Conservation Congress, Montreal, Canada. P. 3 (1999).
 14. World Bank World Development Report 199. Oxford University Press (1992).
 15. World Resources Institute World Resources 1992-1993, New York Oxford University Press, P. 258 (1993).
 16. Ehrlich, P.R. Postel, S1 and Daily, G.C. Human Appropriation of Renewable Fresh Water', Science., Vol. 27. (9 February) 785-788 (1996).
 17. United Nations Comprehensive Assessment of the Freshwater Resources of, the World New York: United Nations Department of Policy Coordination and Sustainable Development New York (1997).
 18. Lonergan (Undated)' The Role of Environmental Degradation in Population Displacement' in Global Environmental Change and Human Security Project, Research report 1. P.14.
 19. Simon The Ultimate Resource, Oxford: Martin Robertson (1981).
 20. Ghana Statistical Service 2000 Population and Housing Census (Provisional Estimates), GESS, Accra (2002).
 21. Mensah, E A report on Water Quality Analysis of Major Waterbodies in Kmasi Metropolis for the Period of February and March 1999. In Collaboration with HR Wallingford for DFID Peri-Urban Project, 'Urban Wastewater Irrigation of Vegetables' (1999).
 22. Cornish, G.A., Mensah, E & Ghesquire, P. As Assessment of Surface Water Quality for Irrigation and Implications for Human Health in Peri-urban Zone of Kumasi, Ghana. HR Wallingford, Report OD/TN 95 (1999)
 23. Sarfo Acquah (Personal Communication) on Water Quality Assessment in Kumasi Peri-Urban Area (2001).
 24. Environmental Protection Agency "Water Quality Assessment and Monitoring Reports' EPA, Kumasi, Ghana (2002).
 25. Agenda 21 The Earth Summit: The United Nations Conference on Environment, And Development (UNCED): London: Graham & Trotman/Martinus Nijhoff (1993)
 26. Noordwijk J. Political Statement and Action Programme for the Ministerial

- Conference on Drinking Water and Environmental Sanitation March 22-23 Noordwijk, The Netherlands, New York: UNDP (1994).
27. Natural Resources Institute Peri-Urban Baseline Studies; Executive Summary and Main report, Kumasi, Ashanti Region, NRI, Volume 1, p ii (1996).