ENHANCING PROTECTIVE CONTROL MEASURES FOR REDUCTION OF DIARRHOEAL DISEASE IN ATHI-RIVER, KENYA

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Enhancing Protective Control Measures For Reduction Of Diarrhoeal Disease In Athi-River, Kenya

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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DEDICATION

I dedicate this work to my husband Titus, my sons James and Peter, my daughter Sarah, relatives and friends, fellow Kenyans, the international community as well as future generations. Your tireless inspiration, encouragement and love as well as your consequent response will continue to contribute greatly to the goal of this work. Yes, it is possible for Kenya to access safe drinking water and thus reduce diarrhoeal diseases and for all people to have better health.

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LIST OF ABBREVIATIONS

AOAC	Association of Official Analytical Chemists
APHA	American Public Health Association
CDC	Centers for Disease Control and Prevention
DOMU	Disease Outbreak Management Unit
HCWs	Health Care Workers
HIV	Human Immuno Deficiency Virus
JKUAT	Jomo Kenyatta University of Agriculture &Technology
KMTC	Kenya Medical Training College
MDR	Multidrug resistance
MR	Mortality rate
NPHLS	National Public Health Laboratory Services
OR	Odds Ratio
PHO	Public Health Officer
PMO	Provincial Medical Officer of Health
PS	Permanent Secretary

USA	United States of America
WHO	World Health Organization

ABSTRACT

Diarrhoea is an infectious disease in humans, caused by bacteria, viruses or parasitic enteric agents. Yearly over 3 million children die as a result of diarrhoea diseases while most episodes occur in children under the age of five. Many more die from the combined effects of diarrhoea and malnutrition. Contaminated water and food play a major role as a source of diarrhoeal pathogens. It is estimated that up to 70% of cases of diarrhoea are caused by contaminated food whereas more than 20% are caused by contaminated water. In Kenya, diarrhoea disease is the 4^{th} most commonly occurring disease being particularly common in the major towns and slums. Athi-River is a small town situated about 30Kms from Nairobi, Kenya but has 11 upcoming slums due to the many industries within the town and its environs. The main objective of this study was to determine the incidence of diarrhoea in Athi-River town and to compare how this changes when control measures are instituted. Most of the stakeholders were sensitized about the objectives of the study before a cross-sectional survey commenced. The methods used included a retrospective medical records review for the period 2003-2006 to determine the diarrhoea disease trends. Measures were taken to enhance diarrhoeal protective control measures through health education. For effective communication during health education, skits and charts were used. Water and vegetable washings were sampled and tested using the multi-tube technique to identify contamination points. Contamination was quantified by use of McCrady probability chart while targeted interventions were reported to relevant stakeholders for corrective action. One hundred and fifty nine water samples were tested for total coli form count and *Escherichia coli* and results indicate a 66 % and 38 % contamination respectively. From June to December 2006 interventions for diarrhoeal disease prevention were enhanced and there was approximately 15.8% decrease in the incidence of diarrhoeal diseases in Athi-River health facility in Athi-River town. Well or borehole water had 68.8 % water contamination while water stored in open or dirty water containers had 62 % contamination. Contamination associated to absence of clean toilets or absence of proper waste disposal system for stool was 77.5 %. The small “Slota” sewer system which was prone to frequent blockage is now being replaced with a larger one. 159 households were sensitized on diarrhoeal infection control. 500 patients and mothers were sensitized on prevention of diarrhoeal diseases through formal presentations and skits. Four major water suppliers are already chlorinating their water as a result of the health education conducted. The Athi River population has gained skills on the importance of practicing good hygiene and how to control and prevent diarrhoea. This study concludes that enhancing protective control measures reduces diarrhoea diseases and leads to improved health of the community.

CHAPTER 1

1.0 Introduction

1.1 Diarrhoeal Diseases

Diarrhoea is a disease characterized by purging of stool more than the usual frequency and usually >3 in 24 hours. The stool could be watery, bloody, mucoid, semi-formed and foul smelling (Carddenas, 1993). Diarrhoea can be persistent and may be accompanied by other symptoms like vomiting, fever, malaise and tenesmus. If untreated, it may lead to dehydration, electrolyte imbalance, acidosis, circulatory collapse or even death (WHO, 2004).

A wide range of food borne diseases affects most developing countries. However, with poor or none existent reporting systems in most countries, reliable statistics on these diseases are not available. Their magnitude is therefore difficult to estimate. Yearly over 3 million children die as a result of diarrhoeal diseases while most episodes occur under the age of five (WHO, 2006). Many more die from the combined effects of diarrhoea and malnutrition. Contaminated water supplies or food play a major role as a source of pathogens. It is estimated that up to 70% of cases of diarrhoea diseases may be caused by contaminated food. An increasing prevalence of HIV may increase the number of under-five children deaths due to diarrhoea related to HIV (WHO, 2006). The kind of environment one lives in plays a role in occurrence of diarrhoea.

Pollution refers to a state of the environment which has effluents like dust, suspended particulate matter, fumes, and toxic organisms or chemicals, and may cause harm, damage or disruption of the surrounding flora, fauna, food, air, water or soil (Atambo, 1995). Water for cooking or drinking should be free from pathogenic micro organisms. Contact with contaminated water may result in infection which is dependent on the type of pathogen, the number of organisms, the strength of organism (virulence), the volume of water ingested as well as susceptibility of the individual. Purification of such water requires disinfection, and chlorination is the most commonly used method (White, 1978; Haas, 1987; Dalzell, 1994; Hay *et al*, 1995). Studies on particulate pollution in Mombasa and Nairobi showed a systematic reduction in the levels of pollution with increasing distance away from the industrial zones given the prevalent meteorological factors like wind speed and direction, sunlight amount, temperature variation with height, mixing depth and precipitation (Ng'ang'a, 1976; Gatebe, 1995). The ease with which bacteria become resistant to currently used antimicrobial agents has been and continues to be a concern to clinicians, public health officials and researchers. At times bacteria exhibit multidrug resistance as the use of antimicrobial agents in both human and veterinary medicine exerts a strong selective pressure (Akinyele and Christian, 1983; Mutanda *et al*, 1991; Webber *et al*, 1994). There is an urgent need to do a survey on water and food safety control measures and thus come up with reliable data for Kenyan foods and their impact on the health status of

Kenyans (Bernard and George, 2004, Republic of Kenya, 1992). This approach to disease control is feasible, available, effective, affordable and sustainable especially when all stakeholders get on board and collaboratively endeavor to fulfill a common objective (WHO, TDR Newsletter-2006; CDC, Smdp Newsletter-2005). Where there is proper collaboration, networking and partnerships work well and there is a smooth flow of service as monitoring and evaluation enhance timely systematic financial flow resulting in great impact in coordination and development (WHO,TDR Newsletter-2006)

1.1.1 Epidemiology of Diarrhoea Diseases.

Diarrhoeal disease is characterized by purging of watery stool about every 3 to 6 hours up-to three or more times a day. Diarrhoea cases may also suffer vomiting, fever and at times the stool may be bloody. Other times the patient experiences abdominal cramps. When pathogens get to the ileum and colon, they invade the cells and multiply within cytoplasmic vacuoles. Diarrhoea is induced by prostaglandins produced by the polymorphonuclear leukocytes. The prostaglandins activate the cyclic adenyl monophosphate system, which results in a net loss of sodium and chloride ions and water from the cells to the gut lumen. The end result is secretory diarrhoea while there is a higher hydrogen ion concentration within the cells leading to acidosis (Manson-Bahr *et al*, 1987; Wold *et al*, 1992). Worldwide, diarrhoea causes over 2.2million deaths annually (WHO, 2002). Yearly over 3 million cases occur as a result of diarrhoea diseases with most diarrhoea episodes occurring in children under the age of five years. Many more millions die from the combined effects of diarrhoea and malnutrition. It is one of the common causes of death in Africa. Of the top ten causes of outpatient morbidity in Kenya, diarrhoea diseases are the fourth most common in Nairobi, Rift valley, Nyanza and Western Provinces according to MOH medical records. Diarrhoeal diseases accounted for 4.7% of all the outpatient new cases countrywide. Due to poor sanitation and poverty, these diseases are re-emerging and drain a lot of resources during outbreaks.

Athi- River town is situated about 30 kms from Nairobi city. One of the major rivers in Kenya traverses this town. There was an episodic sudden mortality of fauna (mainly fish in Athi River) towards the end of 1995. According to Athi-River medical records 1996, the pollutants in Athi River town are hazardous to humans, fish and other aquatic organisms. From time to time, pollution has caused crop failure in the irrigation strips along the river. The Export Processing Zone (EPZ) is situated within this town and a wide open trench also traverses the town and many people and industries use it as a dumping ground for human faeces and other wastes. `Flying toilets' is an upcoming culture which has arisen as people refuse to use the few dirty and overloaded toilets and deposit their human waste in paper bags which they pelt away to land elsewhere. With pollutant accumulation, the problem of diarrhoeal diseases has persisted and thus a need to protect the human population by enhancing protective control measures. In Kenya, pollution has risen to levels above 30% water contamination with coliforms or faecal contamination according to a report by MOH, 2005.

Bacterial pollution of ground waters in Wajir, Lamu and Ongata Rongai had 23% to 46% *Aeromonas* species identified (Abdulatif, 2005). As high as 127 ug/g lead levels in vegetables and cereals grown at Kenyan roadsides as compared to the normal range of 0.1 to 1.0 ug/g have been reported (WHO, 1990). Although there is now use of unleaded fuel in Kenya, other chemical contaminants should not be underestimated. An estimated 80% of all diseases and over one third of deaths in developing countries are caused by the consumption of contaminated water and on average as much as one tenth of each person productive time is sacrificed to water- related diseases (WHO 1997).

1.1.2 Modes of Transmission of Diarrhoea Causing Agents

Transmission of etiological agents is mostly through the faecal-oral route as bacteria are ingested from faecally contaminated dirty hands, food or water. Infection is either direct, indirect or by person to person contact from a wide range of bacteria, viruses or parasitic enteric agents (Peter *et al*, 1992; Herwaldt *et al*, 1992; Lim-Quinzon *et al*, 1994; Eisenberg *et al*, 2002). Municipal waste-water or sewage treatment plants harbors micro organisms in large numbers while waterborne disease outbreaks have been associated with sewage contaminated water supplies or recreational waters (Rosenberg *et al.*, 1976; Rosenberg *et al,* 1980; Stover *et al.,* 1986; Haas, 1986; Haas, 1987; Reeve *et al,* 1989; Levine, *et al* 1990; Blostein, 1991; Drenchen and Bert, 1994). Most of the adverse effects of pollution have included hospitalization respiratory symptoms in children, lower respiratory infections, increase in asthmatic cases as well as work, school and nursery school absenteeism and death (Bates, 1995).

1.1.3 Fundamentals of Diarrhoea Disease Infection Control.

To control diarrhoea, epidemiological intervention measures are put in place and the effects studied as per how it impacts on the disease incidence. Some of the control measures enhanced include protection, purification and chlorination of public water supplies, enforcement of proper garbage collection and disposal as well as latrine construction and maintenance (Abdulatif, 2005). Other control measures are: Increase of health education on personal hygiene, hand washing and proper faeces disposal, as well as discouraging the use of `flying toilets'. Ongoing surveillance should also cover other measures like encouraging reporting of sewer bursts and repair as well as treatment of the sick at health facilities. Treatment of the sick at times involves isolating all suspected cases and disinfecting linens and appliances used by patients. Treatment with antibiotics is not routinely used in childhood infections but preferred where there is accompanying septicaemia or metastatic infection. Sensitivity testing is done to determine the antibiotic to be used (Wold *et al* 1988). Otherwise, the use of infusions or oral fluids is commonly used. Hand washing facilities should be put in place where people handle food, children or patients. The sewer system needs a functional treatment plant where the contaminated waste is cleaned up and its quality determined (Stover *et al*, 1986; Cardenas *et al*, 1993). All cases should be reported and treated with antibiotics after stool tests are done and drug sensitivity tests carried out. Bacteriological studies of drinking water in Kibera slums showed that there was contamination of water at the collection point followed by further deterioration in the home (Chemuliti *et. al*., 2002). Informal settlements with no sewage system where residents discard waste including faeces directly into the river was discovered to harbor high *Escherichia coli* counts in Nairobi river water (Waiyaki *et al*, 1985; Okoth et al, 2001; Budambula, 2004). The highest number of coliforms was recorded during the warmer dry period. This was also found by other workers (An *et. al*, 2002). Reported disease patterns which are on the increase in the region include: - asthma, allergy cases, colds, sore throats, abdominal pains, diarrhoea, typhoid, amoebas, malaria, general malaise and, dizziness. Complaints of exhaustion and meningitis occur in outbreaks from time to time and cases of cancer are referred to main hospitals for biopsy and treatment. The increasing trend is reflected and supported by records available in the health centers and private clinics. Water should be chlorinated for protection from microbial organisms. When chlorine is added to water, other than distilled water, 0.25- 0.75 ppm reacts with water impurities and meets the chlorine demand. The chlorine left is called the total residual chlorine existing mainly as hypochlorous acid and reacts with microbial organisms. About 2-10ppm residual chlorine is required for in plant chlorination thus provision of safe water and less chance of infection with diarrhoeal disease (Rangana S, 1977, WHO, 1985; WHO, 1993; Kenya Bureau of Standards, 1996)

1.2 JUSTIFICATION OF THE STUDY

Infectious diarrhoea is one of the major causes of morbidity and mortality worldwide. The major causes of this diarrhoea are contaminated food and water. Studies in Eastern Europe have shown that uncontrolled pollution could occur alongside gross economic inefficiency. While in the industrialized west, more progressive industries are found in countries whose environmental laws are strictest (Bates, 1993), in the less developed regions the siting of industries is not very well regulated resulting in gross pollution of the water systems and the environment. Yearly over 3 million children die as a result of diarrhoea diseases while most episodes occur in children under the age of five years. Many more millions die from the combined effects of diarrhoea and malnutrition. Contaminated water supplies or food play major roles as sources of pathogens while chlorination has been an effective disinfection during the 20^{th} century virtually eliminating waterborne diseases like cholera, typhoid, and dysentery in the United States (White, 1978; Alexandria, 1984; White, 1985; Stover, 1986; WHO, 1993). It is estimated that up to 70% of cases of diarrhoea diseases may be caused by contaminated food. An increasing prevalence of HIV may increase the number of children under five years old with diarrhoea mortality and morbidity that is related to HIV infection (American Public Health Association (APHA) 1995). It is the role of the ministry of health to monitor the health status of its population within and neighboring industrial zones so as to promote health (Bates, 1993). Pollution causes an increased mortality of fish and other fauna as well as great financial loses which occur when there is crop failure at the irrigation strip along Athi river. In Athi-River town some of the predisposing factors for diarrhoea are: several slums, few toilets and open drainage trench and river as well as unprotected water sources according to MOH records. There was, therefore an urgent need to do a survey on water and food safety control measures.

1.3 HYPOTHESIS

1.3.1 Null hypothesis

- Enhancing diarrhoeal disease preventive control measures in Athi-River town does not result in the reduction of the cases of diarrhoeal disease in Athi-River town.

1.3.2 Alternate hypothesis

- Enhancing diarrhoeal disease preventive control measures in Athi-River town results in the reduction of the cases of diarrhoeal disease in Athi-River town.

1.4 OBJECTIVES

1.4.1 General objective

- To determine the effect of instituting and enhancing protective control measures in Athi-River town on diarrhoeal disease.

1.4.2 Specific objectives

- To determine the diarrhoeal disease trends in Athi-River town.

- To identify sources of contamination of water in Athi-River town for targeted intervention.

- To identify and enhance protective control measures in the community using water sources in Athi-River town.

CHAPTER 2

2.0 Materials and Methods

2.1 Water Sampling Sites

The survey design included 12 sampling sites 10 of which are within Athi-River town and 2 at the suburbs of Athi-River town. The sampling sites were selectively chosen. Athi-River Health Centre and one Athi-River private hospital were used to study the incidence of diarrhoea. Human populations at the irrigation strips as well as 159 households were also educated on prevention of diarrhoeal diseases as water was sampled for testing. Athi-River has about 15,669 households, a population of about 45,000 people and is situated in Machakos district which covers 6,281 square kms (Central Bureau of Statistics 1999). This town is situated at the outskirts of Nairobi City and is only about 30 Kms away. It is an industrial town with most of its population having low income and many living in slums.

2.2 Study Design

A retrospective data review of medical records was done in Athi-River Public Health Facility and in Athi-River private hospital so as to come up with diarrhoea disease trends. This involved an examination of medical records from year 2006 back to 2003. The monthly diarrhoeal diseases data was compiled and canalized and interpretations made. This study was followed by a cross-sectional survey of water contaminants. Microbiological testing of vegetable washings and water samples was undertaken. This was a one time survey involving water sample collection and testing for contaminants. This descriptive kind of study started in June to December 2006.The sampling sites were selectively chosen so as to include the major water sources and so a random sampling method was not applied. The major water sources sampled were 4 private wells/ boreholes, piped water from 2 different sources as well as river and surface runoff water. The vegetables grown along the banks of Athi river were picked and washed with clean water as is done by the vegetable sellers before they release them to their clients and the washings tested for coliforms. The waters used to wash the vegetables and drinking water was tested using the same laboratory procedures for most probable number of coliforms and *Escherichia coli* count. At the same time, community members in Athi-River region were sensitized and taught about prevention of diarrhoeal disease.

2.3 Sampling method

The water samples were selectively chosen so as to include most major water suppliers in the region. A water sampling form Appendix 1 and a questionnaire Appendix 2 were filled. This was done with the particular purpose of identifying the water contamination sources and so all the major water suppliers had to be sampled and educated on the need to supply safe water.

2.4 Laboratory procedures for testing presence of coliforms in water and vegetable washings.

Sterilized bottles were obtained from the NPHLS and water put directly into each. Vegetables were taken and washed by owner with the water in use. This was done so as to capture the coli form levels as they are when one gets that water or vegetable for use. Multiple tube technique using McConkey broth of different volumes and strengths was used. The detailed method used was as follows:- Water sample or vegetable washing is screened by use of multiple tube technique mixing a sample of 10, 1, 0.1 ml volumes into 5 tubes for each category respectively with Mc conkey broth. The first two sets of 10 tubes have double strength McConkey broth while the last five have single strength. Three sets of five bottles are taken 0.1ml, 1ml and 10ml of water is added to each tube with McConkey broth respectively. Single strength of McConkey is added .The use of dirham tube within the broth is for identification of gas production while a yellow colour signifies fermentation of lactose by action of bacteria. Positive samples containing Peptone water is inoculated with the coli form positive samples then incubation for 48 hours in the water bath, the Ejickman test at 44^{o}C. Another set of tubes with McConkey broth and Durham tube is also inoculated with the contaminated reagent and set up in the water bath alongside for comparative purposes. Kovac's reagent is prepared as indicated in Appendix 3 and a drop or two of it is added to the samples containing peptone water, inoculated with the coliform positive samples after 48 hours in the water bath. A sample which has faecal

Escherichia coli forms a red ring when Kovax reagent is added and also shows gas production noted at the Durham tube in the Mc Conkey broth set up. Observations are made so as to rule out faecal contamination but if it is present then quantification is done using McCrady's chart (Cowan and Steal, 1965; Ernest *et al*, 1974; AOAC, 1990; William *et al*, 1995). The number of tubes read as positive has gas production and a yellow colour due to fermentation. The positive number of tubes in each category is recorded and quantification is done by use of McCrady's Most Probable Number (MPN) chart in Appendix 4. The results were interpreted as follows:- Presumption coliform count should be between 0-25/100mls of water. If it is above this figure or *E. coli* appears, all the water should be considered unsatisfactory for drinking purposes (WHO, 1985; Kenya Bureau of Standards, 1996, Denmark guidelines, 1990). Untreated Water can be in the following categories:-

Class I: less than 0 Coliforms-Highly Satisfactory

Class II: 0-2 Coliforms-Satisfactory

Class III: 3-10 coliforms-Suspicious

Class IV: Above 25 Coliforms -Unsatisfactory

2.4.1 Prevention of diarrhoeal disease through community Health Education

Community sensitization was done by involving the main Athi-River area water suppliers to ensure that they provide safe water to the region. This involved person to person discussions on water chlorination and need to overhaul and change water pumps to keep off microbial contaminants which could leak into water being pumped using old rusty pumps. A caution was given if water sample from a main supplier was tested and found to be contaminated. The community was reached through posters pinned at strategic places within Athi-River region with information on diarrhoeal disease prevention. Other control measures taken were:- Increase of health education to households on personal hygiene, hand washing and faeces disposal as well as discouraging the use of flying toilets, We publicly condemned this culture and encouraged reporting of sewer bursts and repair, treatment of the sick, isolation of all suspected cases especially if there is cholera and disinfection of linens and appliances used by patients. Hand washing facilities could be put in places where people handle food, children or patients. The sewer system could have a functional treatment plant where the contaminated waste is cleaned up and a surveillance system to monitor water quality enhanced (Cardenas, *et al* 1993,Indian Public Health,1989).

Enhancing water and food safety through health education was done by use of existing MOH posters prepared by Disease Outbreak Management Unit. Five hundred posters were distributed and a hundred pinned at strategic places. Two hundred stakeholders and household members were sensitized about the need to enhance protective control measures for diarrhoeal disease reduction. Patients and health care workers were taught at the Health facility during a two week "Fight against diarrhoea campaign". Those trained included mothers as well. Skits and charts were used to emphasise the importance of safe waste disposal and safe water at the house hold level. Water chlorination, diagnosis and timely treatment were emphasised. One fifty nine water samples were taken and tested at the NPHLS for total coli form count and *Escherichia coli* as an indicator for public health interventions enhanced.

CHAPTER 3

3.0 Results

3.1 Diarrhoeal Disease trends.

Retrospective review of medical records show that, an annual total of 1553 cases of diarrhoea were reported in Athi- River Health facility in 2006 as compared to 1846 noted in the previous year. There was a (15.8 %) decrease in the incidence of diarrhoeal disease in Athi-River health facility in Athi-River town as protective control measures were instituted from June to December 2006 (Table 1). These results reflect a clear increase of diarrhoeal disease cases from 2003 to 2005 and then a decrease after June 2006 when some interventions were put in place. The diarrhoeal cases seem to be closely related in two year periods 2003-2004 and 2005-2006. This may be attributed to other prevailing circumstances like:-pollution, industrialization and population increase since Athi-River is an industrial town and factories come up from time to time. Protective control measures against diarrhoeal diseases were instituted or enhanced and observations were made (Figure 1).

Table 1. Reported diarrhoea cases as reflected in Athi River Health facility

Time	2003	2004	2005	2006
January	104	97	171	153
February	115	93	198	69
March	106	89	160	238
April	74	72	169	256
May	154	209	141	222
June	143	131	133	148
July	75	100	90	34
August	56	53	71	34
September	62	140	121	90
October	71	157	150	120
November	110	121	216	69
December	70	77	226	120
Totals	**1140**	**1339**	**1846**	**1553**

It is assumed that the total population for the two years was nearly the same and that people kept on going to the public health facility as usual and so any changes in the number of diarrhoeal disease cases was due to the fact that interventions were put in place or enhanced. It is only in June 2006 when health education was done at household level as water sampling was taking place. In August 2006 a two week sensitization formal talks on prevention of diarrhoeal disease took place as well as water testing for contaminants. The medical data review for the four years shows that, the least number of cases of diarrhoeal disease (34) was reported in July and August 2006 when diarrhoeal preventive intervention measures were intensified. Seasonal changes seem to be attributed to a slight increase in the number of diarrhoeal cases occurring and reported towards the end of every year of study but from June to December 2006, monthly diarrhoea cases remained low as compared to the same period in 2005. Retrospective data review of diarrhoeal cases in Athi-river Health facility show that, in 2003 there was a peak in February at 115 cases and another at 154 in May and the last one of 110 in November. This coincided with the rainy seasons. The lowest cases of diarrhoea were 74 in April, 56 in August and 70 in December. The total cases of diarrhoea that year were 1140 as reported at the health facility.

In 2004, there was a decrease in the cases of diarrhoeal disease from 97 in January, 53 in August and 77 in December while cases rose to 209 in May and October, 157 cases were recorded. The rainy as well as dry seasons had low and high cases of diarrhoea. The total cases that year were 1339.

In 2005, the cases of diarrhoeal disease were 171 in January and rose to 198 in February and later decreased to 71 in august. A gradual increase followed from 121 in September to 226 in December. The rainy season as well as the dry season had high levels of cases with diarrhoeal disease. This marked a total of 1846.

In January 2006, 153 cases reported to the health facility and 69 in February. April had 256 while a decrease was noted from June resulting to 34 cases in July and August. November had 69 while in December, 120 cases were reported totaling to 1553 cases that year. High levels of diarrhoeal disease cases were reported in January, February, May, June, and finally in October and November. These high levels coincided with the end of the rainy season and the onset of the dry season. As interventions were enhanced, there was a decrease in the cases of diarrhoeal disease. This was especially from July to December 2006.

Table 2 shows that approximately 40% of total terminally ill people had a symptom of diarrhoea while 21% of the total cases with diarrhoea died as reported in a private Athi-River health facility. No study was done to show if

Table 2. Number of reported diarrhoea cases as reflected in a private hospital records.

Year	Diarrhoea cases	Terminally ill patients	Terminally ill patients with diarrhoea as one of the symptoms.
2003	171	104	41
2004	208	101	40
2005	263	139	55
2006	156	78	31
Total	**798**	**422**	**168**

People preferred to attend this health facility for treatment thus increasing the death rate of those who had diarrhoea and did not recover.

3.1.1 Total coliform and *Escherichia coli* count

Total coli form count and *Escherichia coli* in water were highest at the beginning of the survey but as targeted interventions were put in place the levels decreased (Table 3). Of all the 159 samples tested, 100 did not have any *Escherichia coli* at all. Before interventions in June 2006, 9/50 samples were free from contamination reflecting 18% safety while after control measures for diarrhoeal prevention were enhanced 54/109 were free from contamination a 49.5% safety. The Water was tested for coliform and *Escherichia coli* counts/100 ml between June, and October. Some of the water sources tested included Devki Water Supply with 1800 coliform and 0 *Escherichia coli,* Ndeti water supplies 140 then 2 coliforms but no *E. coli* , Mavoko county council water 1800 then 2 coliforms but no *E. coli,* EPZ water supplies 6 coliforms and the water became free from contamination when tested after interventions. All the surface run off and sewer waste had Escherichia coli counts of 1600 and above per 100 ml sample. The vegetable washings had above 25 *Escherichia coli* counts per 100 ml sample and thus were contaminated. As shown in

Table 3. Water contamination with *Escherichia coli*

Escherichia coli PER 100 ml water sample	Number of water samples tested	Water samples contaminated (%)
0	100	62.9
1	5	3.1
2	7	4.4
3	3	1.9
4	1	0.6
5	1	0.6
8	3	1.9
9	3	1.9
11	3	1.9
13	1	0.6
14	3	1.9
17	1	0.6
24	1	0.6
25	1	0.6
30	1	0.6
35	1	0.6
50	1	0.6
61	1	0.6
90	1	0.6
115	1	0.6
170	1	0.6
180	2	1.3
225	1	0.6
1600	3	1.9
1800	13	8.1
Total	**159**	**100**

3.2 Laboratory findings of the coliform status of Athi-River town waters:-

Table 4. Presumptive Coliform count in water

Coliform count per 100 ml water	Number of samples tested	Water samples contaminated (%)
0	54	34
1	1	0.6
2	4	1.3
3	8	0.6
4	4	1.3
6	2	0.6
8	7	1.9
10	1	0.6
11	1	0.6
12	1	0.6
14	1	0.6
17	4	2.5
18	1	0.6
35	1	0.6
50	2	0.6
61	1	4.4
90	3	10
140	2	1.3
160	2	1.3
180	16	10.1
200	2	0.6
225	1	5
350	1	2.5
550	1	1.3
1600	5	3.1
1800	1	0.6
1800	31	19.5
1800	1	2.5
Total	**159**	**100**

In Table 3, an overall 62.9% of water tested was free from faecal contamination while 38.1% was contaminated with *Escherichia coli*. Presence of 1 or more *Escherichia coli* in 100 ml water is reported as contaminated with faecal matter (Cowan and Steal, 1965).

Thirty four percent of water tested was free from coliforms while 66% had one or more coliforms present (Table 4). Water sample found to have 1 – 25 coli forms was treated as satisfactory and represented a 45.7 %. All the surface run off and samples from the sewer system were contaminated with coli forms and had as high as 1800 or more coli forms per 100 ml of water. All the vegetable washings also had coli forms present of 180 or more per 100ml. The coli form contamination continued to decrease as the study went on and latter many samples tested were found free from contamination. There was a change in the water quality as many people got word that the state of water as being tested and as we went to many hotels, they had displayed the water guard in their premises and the water tested turned out to be free from coliforms. This was the evidence that the community was benefiting from the health education which was going on at the same time.

According to Table 5, faecal contamination of 68.8% was reported in well/borehole water while 31.2% was satisfactory and so well/borehole water was associated to faecal contamination. There were many pit latrines within the slum areas which many times would be located closely to the wells or boreholes.

On page 26 table 6, 77.5% was attributed to contamination of samples of water which were stored where there was no proper waste disposal

Table 7 shows that, water which was mostly safe had been sampled from containers at household level representing a contamination level of 55.3 followed by well or borehole water at 68.8%. Athi-river water and surface runoff water samples had 100% contamination and such are points of contamination to be targeted for water treatment.

Sixty two percent contamination was found in water stored in containers which were not covered as shown in Table 8.

Total faecal coli forms were highest in untreated Athi-River water. This is consistent with informal settlements with no sewage system where residents discard waste including faeces directly into the river.

Table 5. Contamination of well/borehole waters

Water state	Number of samples tested	Percent %
Contaminated	11	68.8
Not contaminated	5	31.2
Total	**16**	**100.0**

Table 6. Water contamination associated to absence of toilet.

Waste Disposal	Number of water samples Contaminated	Water samples not contaminated	Total
Presence of toilet	32	43	75
Absence of toilet	57	16	73
Total	**89**	**59**	**148**

Table 7. Water source and faecal contamination

Source of Water	Number of samples tested	Contaminated water samples	Non contaminated water samples	% Contamination
Container	132	73	59	55.3
River	1	1	0	100
Surface runoff	8	8	0	100
Well	16	11	5	68.8

Table 8. Contamination of water samples in covered or uncovered containers

Container Type	Positive to Faecal contamination	Negative to Faecal contamination	Total
Water from Open Containers	45	46	91
Water from Closed Containers	28	13	41
Total	**73**	**59**	**132**

3.3 Monthly diarrhoeal trends and targeted interventions.

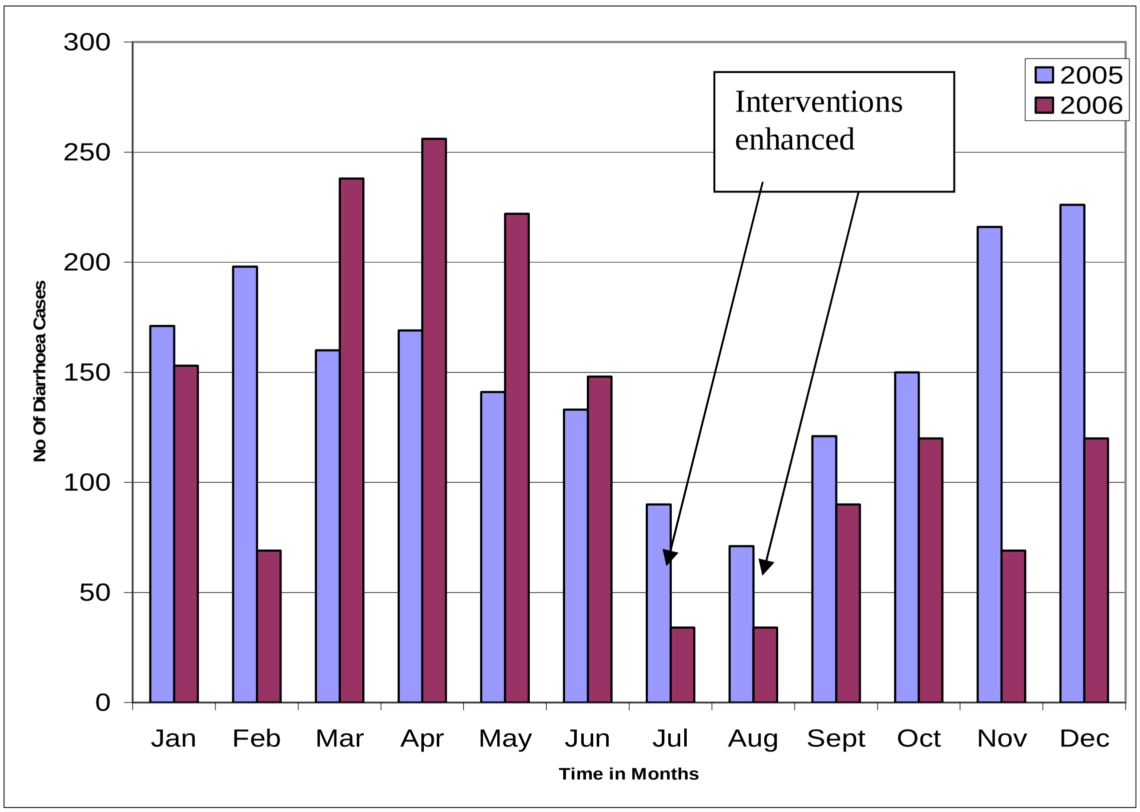

Figure 1. Monthly diarrhea cases between 2005 – 2006 as reported at Athi River public health facility and intervention points

The highest numbers of coliforms were recorded during the warmer dry period. River, well and borehole water were the most contaminated with coliforms.

Figure 1 shows the trends of diarrhoea disease as reflected by medical records in the year 2005 -2006 in Athi-River. Generally, the diarrhoeal diseases cases were higher during 2005 - 2006 as compared to 2003 -2004 results reported in Table1. The bar charts show a systematic trend with lowest number of cases occurring yearly in February, July and August and coinciding with the onset of rains as well as interventions in June 2006.

High peaks were in January, February, May, June and coincided with the end of the rainy season and the onset of the dry season.

3.4 Targeted interventions for prevention of diarrhoeal disease.

Approximately, seven hundred people were educated on prevention of diarrhoea disease among them mothers, healthcare workers, and municipal council and water supply officers. After repeated, water sample testing, health education awareness and meetings for a period of three months, four of the major water supplies had reduced total coliform count. The ‘Slota’ sewer system which would burst or get blocked frequently is now being replaced with a larger one as shown in Figure 4. The Athi-River population has gained skills on the importance of practicing good hygiene and how to control and prevent diarrhoea. This is reflected in the Figure 1 showing the decrease in cases of diarrhoea from June to December 2006.

Figure 2 below shows a sewer line which is small, old and broken down. The waste is overflowing into the environment and exposes the waste to the residents of this slum area. This Slota sewer that had been polluting this environment was reported to the relevant authorities and action taken.

Figure 2. A picture showing a burst sewer in Slota area, Athi-River.

Figure 3. A picture of a contaminated environment in the study area of Athi River

Figure 3 above is a picture depicting the consequences of lack of proper waste disposal and children are mostly at risk of contamination. Such sites are common in slum areas and many times children who do not understand the dangers play with this kind of waste and end up with diarrhoeal diseases.

Figure 4 seen below is a sewer system being made to replace a smaller one which would burst and pollute the Athi-River region as shown earlier in Figure 2.

Figure 4. A picture of a sewer system under construction.

Figure 5 is a picture showing a public toilet with hand washing facility recommended for reduction of diarrhoeal diseases. Water is stored in a drum for use when the taps run dry. A small fee is paid before one uses such a facility. This toilet is used by residents of Jua-Kali, Athi-River and is clean and well maintained, evidence that it is possible for communal toilets to be kept clean when cleaners are well facilitated.

Figure 5. A picture of a public toilet with a hand washing facility in "Jua -Kali" Athi-River

Figure 6 is a picture of a trench which was littered with human waste before the study started but now it is clean as a result of health education. There are also pit latrines built closely together in most of the plots in the slum areas.

Figure 6. A picture of a trench which traverses Athi-River town and was cleaned

CHAPTER 4

4.1 DISCUSSION

MOH health records information show a 15.8% (1846-1553) decrease in diarrhoea incidence in Athi-River health facility during 2005 to 2006. This can be explained as an impact of the intensified health education undertaken. Table 2 shows that approximately 40% of total terminally ill had a symptom of diarrhoea while 21% of the total cases with diarrhoea died as reported in a private Athi-River health facility. Mainly during outbreaks, the case fatality rate rises above normal levels.

So far, 700 people were educated on prevention of diarrhoea disease among them mothers, healthcare workers, county council and water supply officers. After repeated water sample testing and feedback to the stakeholders, results show that 4 of the major water supplies indicated a reduced total coli form count and the water was satisfactory. The "Slota" sewer system which was small and blocked frequently is now being replaced with a larger one.

The 159 samples of vegetable washings or water tested for a period of three months indicate that well or borehole water was associated with water contamination. At least 62.9% of water samples tested was free from faecal contamination while 38.1% was contaminated with *Escherichia coli.* Presence of 1 or more *Escherichia coli* in 100ml water is reported as contaminated with faecal matter (Kenya Bureau of standards, 1996; WHO, 1997; Filho. A and Filho. B, 2003)

This can be explained by the presence of pit latrines in most of the residential regions. At least 34% of 159 water samples tested was free from coliforms while 66% had coliforms present and 45.7% was satisfactory.

Total faecal coliforms were found in untreated Athi- River water and in the entire surface run off water samples which included that of burst sewer. This is consistent with findings that Municipal waste water or sewage treatment plants harbors micro-organisms. This explains the rise of diarrhoeal disease cases during the rains as these sewers get flooded (Blostein, 1991; Wold *et al*, 1992). The open trench which traverses the town is a major source of contamination to the river water as many residents live next to it and make use of flying toilets. This is consistent with informal settlements with no sewage system where residents discard waste including faeces directly into the river as was discovered in Nairobi (Budambula, 2004; Abdulatif, 2005). The highest number of coliforms was recorded during the warmer dry period. This was also found by other workers (An *et. al*., 2002; Nogueira *et. al*., 2003). River, well and Borehole water were the most contaminated with coli forms. The use of dirty water containers, presence of dirty toilets and absence of proper waste disposal system were associated to unsafe water.

The Athi River population has gained skills on the importance of practicing good hygiene and how to control and prevent diarrhoea. Safe food handling leads to less chances of contamination thus better health (Bernard and George, 2004; The Republic of Kenya, 1992). Most water suppliers are disinfecting their water as reflected in the data obtained and some of the wells or boreholes had water which was completely free from faecal contamination. Approximately, 159 samples were tested for total coliform count and *Escherichia coli*. Originally, the water was contaminated from the collection points followed by further deterioration in the homes as shown by other studies done by (Chemuliti *et al.*, 2002, Abdulatif, 2005). As interventions were put in place, or enhanced, the coliform count and *Escherichia coli* decreased greatly with 49.5% samples turning out to have no coliform contaminants. Of the 16 well/ borehole water samples tested, a faecal contamination level of 68.8% was reported while 31.2% was satisfactory and so well water was associated with faecal contamination. 0.775 is the probability at 63 degrees of freedom associated with contamination due to absence of toilet or waste disposal thus no significant association between them. This depends on whether the stool comes into contact with drinking water or not (David *et al,* 2004).

The water which was mostly safe had been sampled from containers at household level representing a contamination level of 55.3% followed by well or borehole water. Water contamination occurs at household level and this could be due to contact with a person suffering from a diarrhoeal disease and others can also get infected (Peter *et al*, 1992) Athi-river water and surface runoff water samples had 100% contamination and such are points of contamination to be targeted for water treatment in future.

The odds ratio of 0.45 resulted as test were done on the association. There was no significant association between the state of closed or open container and fecal contamination however, 62% of water contamination was found in containers which were not covered.

Figure 2 and 3 show a contaminated environment which was targeted for clean up and a replacement of sewer is now ongoing as in figure 4. The surface run off and sewer waste are thus a major source of contamination within the slum areas. Children are at most endangered as they are seen playing around with the dirty water. This is also common even in other slum areas and there is also a role played by poverty which cannot be overlooked. Figure 5 is a good example of a clean community toilet with hand washing facility recommended for use in slum areas. When the toilet cleaner is well facilitated, he keeps it clean. Figure 6 shows a clean trench which had earlier been dirty. This is a result of health education and better facilitation. As different stakeholders were sensitized, the officers whose duty it is to keep the trench, toilets clean and city cleaners are now doing it regularly. The trench traversing the town is now clean and these efforts should be acknowledged.

Therefore the Athi- River community has benefited greatly and the town is cleaner than it had been before.

CHAPTER 5

5.1 CONCLUSIONS

1. Enhancing protective control measures leads to reduction of diarrhoeal diseases.

2. Sources and factors associated with unsafe water include:- river, well and borehole water and factors like the use of dirty water containers, presence of dirty toilets and absence of proper waste disposal system.

3. People who should be consistently educated on prevention of diarrhoeal diseases for better impacts include mothers, healthcare workers, and municipal council and major water supply officers.

4. Persistent reporting of burst or blocked sewer systems leads to quick replacement.

5. Athi-River population has gained skills on the importance of practicing good hygiene and control and prevention of diarrhoeal diseases.

5.2 RECOMMENDATIONS

1. An ongoing programme needs to be set up in every town in Kenya to enhance preventive control measures for reduction of diarrhoeal diseases.

2. There is need to upgrade the national microbiology laboratory to carry out surveillance on microbial organisms.

3. Safe water is paramount for better health and so monitoring and evaluation of water contaminants should be intensified.

4. Landlords in this country should build toilets with hand washing facilities for their tenants and provide water for the same.

5. Town councils should maintain clean public toilets and sewer systems.

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APPENDICES

APPENDIX 1: Water sampling form

Lab Ref No ………………..

Bacteriological Analysis of water

Sample No…………………………..

Time and Date…………………………………………………

Time and Date sample example……………………………….

Taken by……………………………………………………….

Authority……………………………………………………….

Reason for sampling…………………………………………….

Source of sample……………………………………………..

Is it protected?..

If so how?..

Is it completely covered or sides only?.....................................

If a well , is there a pump …………………………………….

If so how long has it been in use?..

Has it been overhauled recently?..

Exact site sample taken………………………………………..

Tap, through cistern or direct from mains…………………

Are there any latrines or other source of pollution? Stool littered.............

If so where?...

Is it a chlorinated supply? ……………………………………

Report Coli form count…………………………………….

Escherichia Coli………………………………….

Date reported…………………………………………………….

Reported by………………………………………………………

APPENDIX 2:

Data collection questionnaire for water bacteriological contaminants

1. Lab Ref No ………………..

2. Bacteriological Analysis of water

3. Sample No…………………………..

4. Time and Date…………………………………………………

5. Time and Date sample example……………………………….

6.Reason for sampling…………………………

Comparison

Routine

Suspected of causing ill health

7. Source of sample……………………………

Treated bottled water

Drainage;

Jerican

Pool

Public supply tap

River

Sewer

Vegetable washings

8. Is it protected?...

9. If so how?..

10. Is it completely covered or sides only?......................................

11. If a well , is there a pump ……………………………………….

12. If so how long has it been in use?..

13. Has it been overhauled recently?..

14. Exact site sample taken……………………………………..

15. Tap, through cistern or direct from mains…………………

16. Are there any latrines or other source of pollution?.............Yes /No

17. If so where?..

19. Method of water treatment…… choose as appropriate

Boiling

Chlorination

N/A

Other methods

20. Report   Coli form count…………………………………….

Escherichia Coli.…………………………………

21. Water state choose as appropriate

Contaminated

Highly Satisfactory

Satisfactory Suspicious

22. Other commends

Dirty /foul smelling water

Dirty looking water

Normal clear looking water

Soapy looking water

Turbid looking water

23. Taken by…………………………………………………………

24. Authority…………………………………………………………

25. Reported by……………………………………………………

26. Date reported………………………………………………….

27. Source of water

Well

River

Surface runoff

Container ………If container, does it have a lid…Yes/No, Is lid clean…. Yes/No

28. Method of waste disposal

None

Latrines………………If latrine is it clean…………With hand washing facility

APPENDIX 3.

Protocol for media preparation

Kovac's reagent with P – dimethlyaminobenzaldehyde 5g, isoamyl alcohol 75ml and concentrated HCL 25ml was prepared by dissolving the aldehyde in the alcohol by worming in a water bath at 50°- 55°C. The mixture cooled and HCL added. The reagent was stored in a brown bottle at 4°C as described by (Cowan and Steel, 1965.)

APPENDIX 4. MacCrady’s chart for coliform count quantification

QUANTITY OF WATER	50ml.	10ml.	1ml.	Probable number of coliform bacilli in 100 ml. of water
No. of samples of each quantity tested	1	5	5	
7Number giving positive reaction (acid and gas).	0	0	0	0
	0	0	1	1
	0	0	2	2
	0	1	0	1
	0	1	1	2
	0	1	2	3
	0	2	0	2
	0	2	1	3
	0	2	2	4
	0	3	0	3
	0	3	1	5
	0	4	0	5
	1	0	0	1
	1	0	1	3
	1	0	2	4
	1	0	3	6
	1	1	0	3
	1	1	1	5
	1	1	2	7
	1	1	3	9
	1	2	0	5
	1	2	1	7
	1	2	2	10
	1	2	3	12
	1	3	0	8
	1	3	1	11
	1	3	2	14
	1	3	3	18
	1	3	4	20
	1	4	0	13
	1	4	1	17
	1	4	2	20
	1	4	3	30
	1	4	4	35
	1	4	5	40
	1	5	0	25
	1	5	1	35
	1	5	2	50
	1	5	3	90
	1	5	4	160
	1	5	5	180+

QUANTITY OF WATER	10ml.	1ml.	0-1ml.	Probable number of coliform in 100ml. of water.
No. of samples of each quantity tested	5	5	5	
Number giving positive reaction (Acid & Gas)	**10ml.**	**1ml.**	**0-1ml.**	**Probable number of coliform in 100ml. of water.**
	0	0	1	2
	0	0	2	4
	0	1	0	2
	0	1	1	4
	0	1	2	6
	0	2	0	4
	0	2	1	6
	0	3	0	6
	1	0	0	2
	1	0	1	4
	1	0	2	6
	1	0	3	8
	1	1	0	4
	1	1	1	6
	1	1	2	8
	1	2	0	6
	1	2	1	8
	1	2	2	10
	1	3	0	8
	1	3	1	10
	1	4	0	11
	2	0	0	5
	2	0	1	7
	2	0	2	9
	2	0	3	12
	2	1	0	7
	2	1	1	9
	2	1	2	12
	2	2	0	9
	2	2	1	12
	2	2	2	14
	2	3	0	12
	2	3	1	14
	2	4	0	15
	3	0	1	11
	3	0	2	13
	3	1	0	11
	3	1	1	14
	3	1	2	17
	3	1	3	20
	3	2	0	14
	3	2	1	17
	3	2	2	20
	3	3	0	17
	3	3	1	20
	3	4	0	20
	3	4	1	25
	3	5	0	25
	4	0	0	13
	4	0	1	17

QUANTITY OF WATER	10ml.	1ml.	0-1ml.	Probable number of coliform in 100ml. of water.
No. of samples of each quantity tested	5	5	5	
Number giving positive reaction (Acid & Gas)	**4**	**0**	**2**	**20**
	4	**0**	**3**	**25**
	4	**1**	**0**	**17**
	4	**1**	**1**	**20**
	4	**1**	**2**	**25**
	4	**2**	**0**	**20**
	4	**2**	**1**	**25**
	4	**2**	**2**	**30**
	4	**3**	**0**	**25**
	4	**3**	**1**	**35**
	4	**3**	**2**	**40**
	4	**4**	**0**	**35**
	4	**4**	**1**	**40**
	4	**4**	**2**	**45**
	4	**5**	**0**	**40**
	4	**5**	**1**	**50**
	4	**5**	**2**	**55**
	5	**0**	**0**	**25**
	5	**0**	**1**	**30**
	5	**0**	**2**	**45**
	5	**0**	**3**	**60**
	5	**0**	**4**	**75**
	5	**1**	**0**	**35**
	5	**1**	**1**	**45**
	5	**1**	**2**	**65**
	5	**1**	**3**	**85**
	5	**1**	**4**	**115**
	5	**2**	**0**	**50**
	5	**2**	**1**	**70**
	5	**2**	**2**	**95**
	5	**2**	**3**	**120**
	5	**2**	**4**	**150**
	5	**2**	**5**	**175**
	5	**3**	**0**	**80**
	5	**3**	**1**	**110**
	5	**3**	**2**	**140**
	5	**3**	**3**	**175**
	5	**3**	**4**	**200**
	5	**3**	**5**	**250**
	5	**4**	**0**	**130**
	5	**4**	**1**	**170**
	5	**4**	**2**	**225**
	5	**4**	**3**	**275**
	5	**4**	**4**	**350**
	5	**4**	**5**	**425**
	5	**5**	**0**	**250**
	5	**5**	**1**	**350**
	5	**5**	**2**	**550**
	5	**5**	**3**	**900**
	5	**5**	**4**	**1600**
	5	**5**	**5**	**1800+**