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An assessment of the impacts of Gypsum mining on water quality in Kajiado County, Kenya

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Abstract
In the recent past, Kenya has witnessed increased activity in the extractive industry targeting minerals such as titanium, gypsum and gold just to name a few. Mining activities are a potentially important contributor to water contamination. Discussions in the literature on impacts of gypsum mining on water quality are not conclusive as they tend to be site specific and lack in details. This study sought to establish the impacts of gypsum extraction activities on water quality in Kajiado. The study adopted the Mixed Method Research design. Questionnaires and interview schedules were used to collect qualitative data from a sample of 95 respondents and key informants selected through Simple Random Sampling, Stratified Random Sampling and Purposive Sampling. The APHA (1999 22[ND] edition) protocol was followed in the collection, storage and analysis of samples. Results indicated significant indirect influence of mining activities on water quality parameters. Even though chemical contamination was insignificant, the bacteriological concentration indirectly arising from gypsum mining was higher than WHO (2006) guide values and therefore exposed the public to waterborne diseases. The mean total coliform concentration in the surface water samples was 555/100 ml, with a minimum of 75 and maximum of 2400. There was no significant difference in the disease burden for children aged below 5 years and the rest of the population ($p \leq 0.206$). The study recommends awareness creation on safe use of mine pond water.

Key Words: Extractive Industries, Environmental Impacts, Water Quality.

Introduction

Kenya is endowed with mineral wealth including Titanium, Coal, Gold, Gypsum, Soda ash, Trona, Gemstones among others (RoK, 2016). In the recent past, the Country has witnessed increased investment in the mining sector, with new Multi-national mining companies coming on board. The intensification and expansion of mining activities across the counties has focused attention on existing deposits of minerals such as Gypsum. The gypsum mining industry is potentially an important contributor to water resources contamination which could negatively impact on human health.

As envisaged in the Constitution of Kenya 2010 and the National Development Blueprint; Vision 2030, the extractive industry activities continue to develop and attract requisite investment in the development of infrastructure to facilitate exploitation (RoK, 2010; RoK, 2007). The extractive industries therefore, have potential to generate a wide range of water contaminants with possible

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adverse health effects on the study area population (Kinney *et al* 2011). It is therefore necessary to understand the character and scale of water quality impacts, pollution and the attendant public health effects. Discussions in literature on the impacts of extraction of minerals such as gypsum on water quality were site specific and lacked in details. This study was carried out to address this need. The overall objective of the study was to identify and assess the impacts of gypsum mining on the quality of water in Kajiado County, so that the levels of contamination and its effects on public health could be considered.

Negative water impacts could be described as those that lead to a decline in the quality of natural water to the extent that it is not suitable for use by man or other forms of live. The impacts degrade water by alteration of biological, Physical and chemical properties of water (Magombedze, 2006). Previous research associates the presence of chemical pollutants in water to the extraction industry since the extraction of mineral ores affects the hydrology of the catchment area. Research has documented a relationship between mining activities and water pollution (Aigbedion and Iyayi, 2007, USDI, 2000). It is argued that water pollution occurs when metals contained in the excavated rock come into contact with water. Mining also affects water bodies when seepage from tailings and waste rock impoundments come into contact with the water bodies.

According to Miranda and Sauer (2010), water related impacts can arise at nearly every stage in the mining process and could have a significant impact on ground water resources with potential for generation of acid mine drainage. The mining process and activities such as drilling, extraction, benefication, dewatering of the subject area; leaching from the waste rock piles and tailing dams cause changes in the water quality and quantity. The water contamination also occurs when the pollutants are directly introduced to the water bodies by the miners as observed by Siegel (2013) who recorded instances where artisanal miners in Burkina Faso washed the ore in water pits and used mercury to amalgamate the gold which degraded water resources in the study area. In situations where mining involves sulphide bearing minerals, the potential pollution of water resources is a valid concern to government and host communities. This is more so because once the sulphide bearing rocks are exposed to water and oxygen, they undergo natural oxidation resulting in acidic discharge. The discharge then seeps through the waste rock piles, tailing dumps and country rocks, dissolving metals along its flow path, eventually finding its way to water bodies (Magombedze, 2006; Vermeulen and Bester, 2010).

Changes in metal concentrations above acceptable levels can result in serious environmental health challenges to the local population (Ternjej *et al*, 2014) as established in a study by Ezeh and Chukwu (2011) on small scale mining and its effect on soil pollution. The study revealed a strong association between the levels of soil pollution and proximity to mines. It was also confirmed that mining exposed geological materials to intensive weathering and subsequent chemical and mechanical breakdown with the help of rainfall and runoff. The concentration of heavy metals in the soils of the study area was directly attributable to the mining of lead, Zinc, Cadmium and copper ores. Mining therefore, affects water quality by increasing levels of suspended solids and decreasing the PH of the receiving surface water body. Odira *et al* (2012) warn that depending on scale, mining activities have potential to pollute water resources through introduction of waste rock, tailings, silt and effluent discharge. These pollutants contain a wide range of metal and chemical pollutants such as cyanide, cadmium and lead.

Mining moreover, degrades water resources through the introduction of harmful bacteria that make mine water unsafe for domestic use by rural communities (Obiekezie, 2006; Gyang and Ashano, 2010). An analysis of bulky water samples collected from a mining pit over a two year period confirmed presence of bacterial organisms including Bacillus Sp, Pseudomonas aeruginosa, Protes Sp, Escherichia coli, Chromobactarium Sp, Alkaligenes Sp, Shigela Sp and Flavobactarium. Merriam *et al* (2013) further confirmed this position when they noted a positive interactive effect of mining on biological condition of a stream caused by flow augmentation from deep mines. They observed that an increase in surface mining caused streams to exceed chemical or biological standards.

According to literature, the overall effect is the deterioration of water quality, which leads to a reduction of aquatic life, increased livestock mortality, contamination of the food chain by way of heavy metals presence in fish and plant tissue which ultimately leads to gastric disorders and diarrhoeal diseases. Mining impacted water resources further lead to ecosystem deterioration. To a large extent, the level and type of water contamination depends on the nature of mineralization, mining methods and processing chemicals employed in chemical extraction. There is evidence in literature that most critical changes occur as a result of leaching from stock piles and point discharges of mine drainage (Mestre, 2009; Nude *et al*, 2011). Mining in addition discharges huge amounts of mine water to the environment and degrades the water quality by further lowering the water P.H of the affected area (Tiwary, 2001, Liakopoalos *et al*, 2010; Ochieng *et al*, 2010). In non-acidic mines, water quality shows high hardness which indeed reduces its utility in domestic purposes.

Deleterious impacts of mining on water have been noted in other parts of the world. In a study of mining impacts on trace metal content of water, soil and stream sediments in the Hei river basin in China, it was established that the total concentration of calcium, lead and Zinc were high in some stream sediments and soil near the sites. High River PH and water flow rates appeared to contribute to limiting quantities of metals in the river water. In yet another study, measurements of major and trace metal elements within tributaries of a river of West Virginia confirmed that mines reclaimed nearly two decades earlier continued to contribute significantly to water quality degradation in the watershed. Heavy metal pollutants generated by mining activities in the Jordanian desert 2000 years ago, continue to persist in modern environments and impact on plants, animals and man (Pyatt and Grattan, 2001; Lindberg *et al*, 2011; Younger and Wolkersdorfer 2014).

However, the impact of mining on water resources is not universally accepted. The anti-mining school of thought maintains that mining negatively impacts on quality and availability of water by causing a series of physical impacts including lateral instability of river channels (Kitetu, 2014; Magombedze, 2006; Dashwood, 2007; Bebbington and Williams, 2008; Gilbert, 2010; Bayram and Onsoy, 2014; Padmalal and Maya, 2014). Related studies (Ohimain, 2003; Akabzaa *et al*, 2007; Aremu *et al*, 2010) on surface, ground and abandoned pond water samples within a mining area catchment found out that streams in the study areas had higher trace and major ions loading than ground water. The microprobe results indicated that waste rocks and related mine spoil contained a variety of Iron, Calcium, Lead and Zinc and co- bearing sulphides that accounted for the augmented levels of these metals in drainage proximal to mining.

Other scholars however, found no harmful impacts on the environment associated with extraction (AlHarthi, 2001). In evaluating the impacts of quarrying of gypsum deposits on the environment, AlHarthi (2001) conducted field and laboratory tests of gypsum deposits at Maqna area in Saudi Arabia and found no harmful impacts of mining on water. This particular study however, was conducted with the sole objective of identifying the most effective method of quarrying and might not therefore; provide adequate and conclusive evidence of the impacts of mining on water. A different school of thought adopted a middle ground and suggests that the impacts of mining to watersheds are highly variable and depend on type of mining, processing and environmental factors (Zabowski *et al*, 2001).

Methodology

3.1 Study Area Location and Description

The study area is located in Kajiado County, Kajiado East Sub County and covers Enkirigirri, Olturoto, Ilpolosat and Nkama locations as shown in Fig. 1.

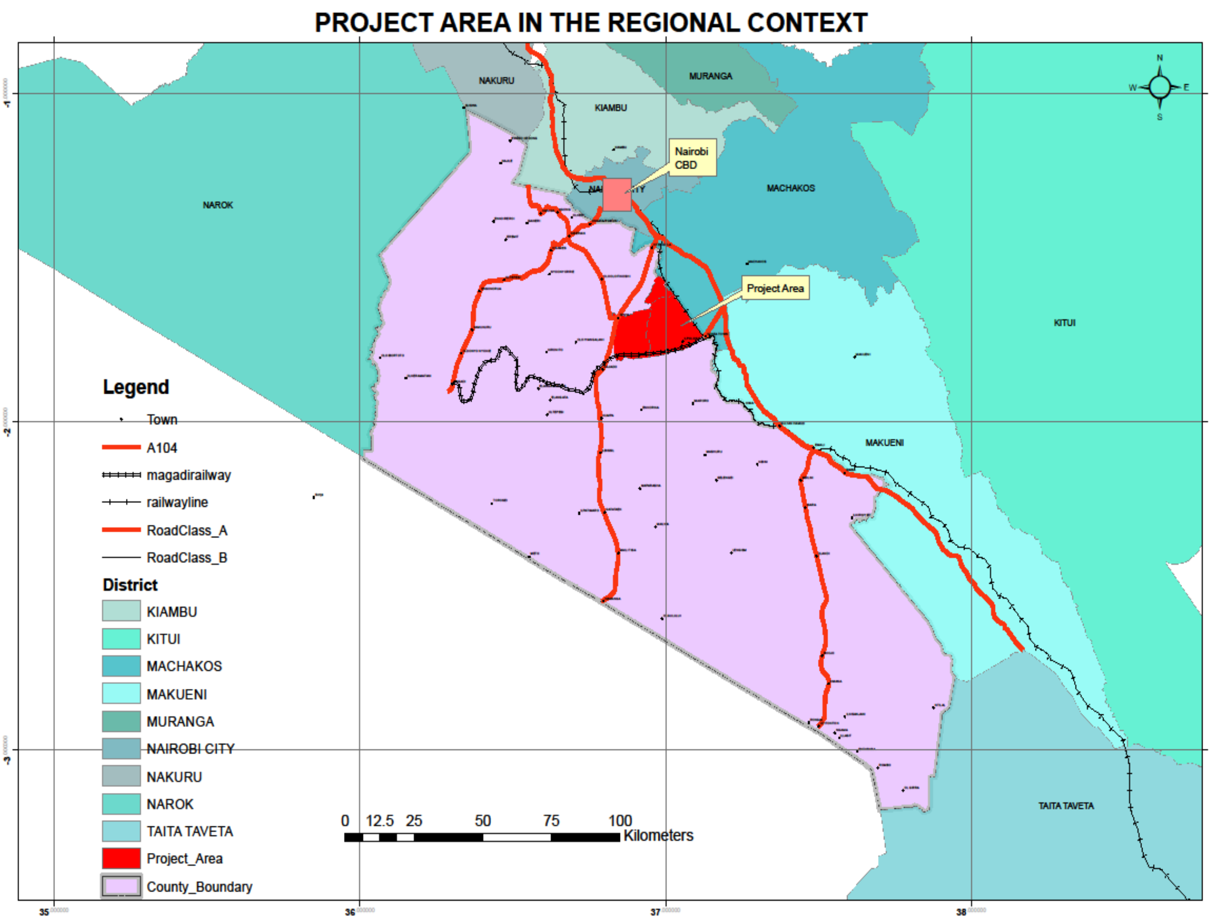

Figure 1: Study Area in Regional Context

Data Collection Methods and Techniques

Data was obtained from both primary and secondary sources. Secondary data was collected by reference to administrative data including existing government documents such as public health records on outpatient consultation rates in the study area as. Quantitative data was obtained using interviews, questionnaire study and sample analysis. Samples were taken at selected sites including mine ponds and borehole and subjected to physical, chemical and bacteriological examinations focusing on indicators such as turbidity, electrical conductivity, PH, Nitrates concentration and water hardness. The results were compared to standards, to ascertain if the water was safe for human consumption.

Results and Discussion

To consider the impacts of gypsum mining on water quality by direct observation and selected parameter measurements, we conducted field water quality measurements. Water samples were collected from surface and ground water bodies (Fig. 2) including mine ponds and boreholes for physical and bacteriological analysis. 25 samples were taken from different water body settings in the study area, 5samples being from borehole water and 20 being from mine pond water, taken at different points and depths in the mine ponds. The borehole selected was located 5 Km outside the mining area and acted as the control sample site

FIGURE 2: GYPSUM MINE POND AT THE STUDY AREA

The samples were collected, preserved and analysed using the APHA 1999 (22ND edition) protocol as recommended by Ahmad *et al* (2015). Samples were collected in plastic bottles that were rinsed three times using the water that was to be sampled before the actual samples were taken. Sample analysis was performed at the Kenya Water Institute laboratories, in accordance to standard water analysis methods. For trace metals analysis, the samples were analysed at the

Kenya Department of Mines and Geology laboratory. The procedures used in examining the specific parameters and the respective findings are briefly discussed below:

Nitrate Concentration Levels

In investigating the nitrate concentration, the palintest method was used. The study utilized an ELE International photometer, Serial number 41833. Test tubes were rinsed with distilled water and the nitratest tube was filled with sample water to the 20ml mark. One level spoonful of nitratest powder and one nitratest tablet were added into the sample. The screw cap was replaced and the test tube shaken for one minute. The tube was allowed to stand for one minute and inverted to aid flocculation. The screw cap was removed and the sample decanted to a 10 ml test tube. One nitricol tablet was added and crushed before the sample was allowed to stand for 10 minutes to facilitate full colour development. Using a photometer at wavelength 570 nm and a nitrates calibration chart, a reading was taken. To ensure validity, triplicate readings were taken precisely at the lapse10 minutes and an average calculated for each sample. The analysis revealed a mean of 10.12 ±0.41 mg/NO3. The findings on nitrates concentration concur with Margutti (2009) who associated the presence of nitrates in the water samples with the blasting material usage and came to the conclusion that gypsum quarrying had insignificant impacts on ground water quality.

The findings for surface water samples however, are a departure from the Al-Harthi (2001) verdict. This could be explained by the fact that Al-Harthi (2001) investigated the gypsum mining activities in an area that was devoid of surface water bodies and generally desolate. The absence of water, trees, pasture and therefore the attendant anthropogenic activities including farming, industrial and settlement makes the two study areas incomparable. The current study area accommodates human settlements in close proximity to the gypsum mining sites. The surface water is useful for domestic and livestock farming and is prone to contamination resulting from runoff. This is in agreement with Galay (2008), who in an examination of socio-economic impacts of gypsum mining at the Kothagpa mine observed that while there were was no evidence of negative water impacts resulting from the mining activities, there was a relationship between the poorly stored gypsum tailings and mud waste that were dumped near the mine pits that eventually got deposited in the surface water bodies by runoff and wind erosion.

PH Analysis

Water PH is a measure of how acidic or base the water is and is therefore an important indicator of water that is changing chemically. The PH determines solubility and biological availability of chemical constituents such as nutrients and heavy metals (WSDE, 2003). The degree to which heavy metals are soluble therefore, depends on the PH. To determine the water PH in the samples, the PH meter was calibrated using freshly prepared buffer solutions (4 and 7) and rinsing the electrode with distilled water as suggested by Ladwani *et al* (2013). The electrode was then immersed in the sample water and readings taken. Three readings were taken for each sample and an average figure adopted as the validated result. The meter reading indicated a mean PH reading of 8.3 and 8 for ground water and surface water respectively. These are within the WHO recommended guide values of 6.5 to 8.5 and do not therefore facilitate the dissolution and seepage of heavy metals (WHO, 2006; WSDE, 2003).

4.3 Turbidity

The study examined water usability and palatability parameters including turbidity and total hardness. Turbidity in drinking water is caused by the presence of suspended and dissolved matter, such as clay, silt, organic matter, plankton and other microscopic organisms. The particulate matter may be present from source as a consequence of deposition of sediments in the water system and as a result of run-off from mining pits and tailings (WHO, 2005). In this study, turbidity of the samples was measured using an ELE Paqualab Turbid Meter, Serial Number T891105. The turbid meter was calibrated to zero by placing the Off/On knob at the off position, and turning it on. Using the Zero function, the meter was adjusted to read Zero. The Standardization functionality was also used to attain a reading of 205. The sample water was then placed in the measuring cells and three readings were taken for each sample. A validated average figure was recorded.

It was revealed that while ground water turbidity concentration had a mean of 0.3 Nephelometric Turbidity Units (N.T.U) with a minimum of 0.26 and a maximum value of 0.38, surface water samples had a mean value of 80.1, with a minimum of 1.38 and maximum of 156. The mean turbidity value for surface water was 16 times the recommended WHO value of 5 N.T.U (WHO, 2006). Among the effects of high turbidity is the inefficiency in the water treatment process. WHO (2006) warns that for water treatment to be effective, the turbidity of the water being treated must be less than 1 because higher levels of turbidity protects microorganisms from the effect of disinfection.

Total Hardness

This study also examined the total hardness of the sample water. Total hardness was investigated using ethylenediaminetetra-acetic acid and its sodium salts method (ETDA) method. For each sample, 50 ml of sample water was put in the conical flask and by use of a pipette; 1ml of the total hardness buffer solution was added. One spatula of the total hardness indicator was added to the sample before titration using the 0.01N ETDA. The titration was stopped at the point when a colour change from pink to blue was noted. A titre range reading was taken for each titration and the result multiplied by 20 to arrive at the total hardness. Three titre range readings were taken for each sample and their arithmetic average adopted as the validated hardness result.

It was established that the total hardness limit for ground water had a mean value of 933 while for surface water samples the mean total hardness was 1102. Both water sample sources therefore indicated higher than the WHO (2006) guide value of 300 caCO3/L. WHO (2006) attributes hardness calcium and magnesium deposition and is indicated by the precipitation of soap scum and the need to use soap to achieve cleaning. Concentrations of between 100 to 300 mg/Litre, and in some instances 500mg/Litre are acceptable (WHO, 2006) since there is no evidence in literature on effects of water hardness on mortality (Lake *et al*, 2009). Hardness is believed to be a constraint to water utilization by poor families since hard water takes considerably more soap to lather. Research links water hardness to dissolved polyvalent metallic ions, predominantly calcium and magnesium from sedimentary rocks, seepage and runoff (WHO, 2003). Although there is no evidence that hard water causes any adverse effects on human health, it is confirmed that water with hardness of above 200mg/Litre could increase soap consumption and therefore reduces the ability of the study area residents to utlise the surface water for domestic purposes.

The physical analysis findings are consistent with Akabzaa (2007), who in an investigation of the impacts of mining activities on water resources in the vicinity of Obuasi mine, observed elevated levels of trace metals in samples collected from surface water and came to the conclusion that such concentrations were most likely derived locally from the water–mineralized rock interaction. The findings also agree with Nganje *et al* (2010) who employed similar protocol to assess the impacts of mine water drainage on water quality in a river proximal to the mines and established that total water hardness exceeded the WHO (2006) standard guide values. The elevated concentration of total hardness was suspected to be a product of the dissolved host minerals (USDI, 2000). The overall results are demonstrated in Tables 1 and 2.

TABLE 1: WATER QUALITY PARAMETERS FOR GROUND WATER

Parameter	Units	Mean	Median	Min.	Max	WHO Val.	EMCA Val.
PH	pH Units	8.3 ± 0.156	8.240	7.97	8.7	6.5 – 8.5	6.5 – 8.5
Turbidity	N.T.U	0.3 ± 0.029	.270	.260	.38	5	-
Conductivity	□S/cm	1138 ± 3.1	1135	1133	1146	NS	-
Total Hardness	mg/L caCO3	933 ±3.86	931	925	942	300	-
Nitrates	mg/L NO3	1.74 ± 0.278	1.47	1.3	2.45	10	10
TSS	mg/L	0	0	0	0	NS	1200
Total Coli	/100 ml	0	0	0	0	03	-
E- Coli	/100 ml	0	0	0	0	Nil	Nil
Zinc	Zn mg/L	0	0	0	0	3	1.5
Cadmium	Cd mg/L	0	0	0	0	.003	0.01
Lead	Pb mg/L	0	0	0	0	.01	0.05
Copper	Cu mg/L	.020 ±0.005	.030	.01	.03	2	0.05

Source: Research Data 2015

Generally, the results shown in Tables 1 and 2 indicate insignificant elevation in the concentrations of trace metals pollutants in ground water samples. However, the concentration of the assessed parameters in surface water samples was much higher than in ground water samples and exceeded the WHO (2006) and EMCA (2006) recommended guideline values for the specific parameters. For instance, the mean concentration of nitrates in surface water samples was 10.1 mg/L ranging from 6.8 mg/L to 12.7mg/L, while the concentration of nitrates in the ground water samples ranged from 1.3 to 2.45 mg/L. Copper concentration ranged from 0.01 to 0.03 mg/L. These were safely below the WHO guide values of 10mg/L and 2mg/L respectively.

This finding is consistent with observations by Al-Harthi (2001) who noted that ground water at the Maqna area was free of contamination by the gypsum extraction processes, safe for the high concentration of soluble salts. This further agrees with Margutti (2009) who used water chemistry characterization techniques to examine the impact of gypsum mining on ground water sources and established that gypsum quarrying activities seemed not to affect ground water quality. Further, Gyang and Ashano (2010) adopted similar chemical parameters in an analysis of the effects of mining on waters of the Jos plateau in Nigeria and also arrived at results comparable to these findings. They affirmed that the chemical concentration levels for copper (0.05 mg/l), Zinc (0.03mg/l), Lead (0.00). Nitrates (0.00 - 10 mg/l) and PH (6.63 – 7.99) were below the WHO guide values. They recorded total hardness at 61.25 which was below the WHO guide value. Nevertheless, they noticed above normal levels for turbidity (478.79 NTU) which was attributed to the use of pond water for domestic purposes and watering of livestock that were always allowed to walk right into the water ponds to drink (Gyang and Ashano, 2010).

TABLE 2: WATER QUALITY PARAMETERS FOR SURFACE WATER BODIES

Parameter	Units	Mean	Median	Min.	Max.	WHO Value	EMCA Value
PH	pH Units	8 ± 0.08	8.010	7.400	8.660	6.5 – 8.5	6.5 – 8.5
Turbidity	N.T.U	80.10 ± 0.57	121.5	1.380	156	5	-
Conductivity	□S/cm	28203 ±3664	27422	2429	48830	NS	-
Total Hardness	mg/L $caCO_3$	1102 ± 24.29	1124	952	1252	300	-
Nitrates	mg/L NO_3	10.12 ± 0.41	10.3	6.800	12.7	10	10
TSS	mg/L	878 ± 189.25	598.5	100	2370	NS	1200
Total Coli forms	per/100 ml	555 ± 167.93	180	75	2400	03	-
E-Coli	Per/100 ml	47.8 ± 10.16	30	7	150	Nil	Nil
Zinc	Zn mg/L	0.033 ± 0.01	.015	.01	.002	3	1.5
Cadmium	Cd mg/L	0	0	0	0	.003	0.01
Lead	Pb mg/L	0	0	0	0	.01	0.05
Copper	Cu mg/L	.024 ± 0.02	.015	.01	.03	2	0.05

Source: Research Data 2016

Bacteriological Contamination

To determine if the water samples were free from dangerous bacterial and other pathogens, bacteriological analysis was carried out based on a common group of bacteria found in the human gut called Coliform. The research used multiple tube fermentation technique where sample water was exposed to MacConkey broth, a nutrient specific to Coliform and allowed the Coliform to multiply and indicate presence by colour change and evolution of gas. The results as indicated in Tables 1 and 2 revealed that Coliform concentrations in surface water samples were many times higher than those observed in ground water samples. The concentration of Total Coli forms and faecal Coli forms (E-Coli) was undetectable in the ground water but high in the surface water samples.

The mean total coli form in the surface water samples was 555/ 100 ml, with a minimum of 75 and maximum of 2400. This is several times higher than the recommended maximum of 3 (WHO, 2006). The mean concentration of E-coli in the surface water samples was 47.8, compared to the WHO (2006) and EMCA regulations (2006) requirements of zero presence of faecal coli. The detection of significant bacterial pollution in water provides evidence of recent faecal pollution resulting from contamination from run-off containing cattle and human excreta and therefore, confirms the influence of anthropogenic activities near the mine ponds (WHO, 2006; Attia, 1999). This is in agreement with Odira *et al* (2012), who in evaluating the effect of climate change and anthropogenic activities at Tudor, suggested that the water contaminants could have a devastating effect on the local population. Presence of Escherichia Coli in parts of the body other than the intestinal flora of humans and animals can cause serious diseases such as Urinary Tract Infections (UTI), diarrhoea and meningitis. The implicit contamination of water resources at the study area is likely to further compromise accessibility to safe drinking water by increasing the cost of water treatment for household consumption, which is consistent with Afroz, *et al* (2014). In this study, we examined the relationship between probable water contamination and disease incidence through scrutiny of outpatient medical consultation records at the Isinya Health Centre as shown in Table 3.

Table 4.3 shows that waterborne diseases including diarrhoea, dysentery, typhoid fever and intestinal worms accounted for 20.3% of the under 5 year old cases reported at the health centre while the older population (over 5 year olds) in the same category accounted for 18%. There is no significant difference in the disease burden for children aged below 5 years and the rest of the population ($p \leq 0.206$). The bacteriological analysis results are thus reinforced by the medical examination results and consistent with existing literature (Obiekezie, 2006; Amankwah, 2013; Fink *et al*, 2011) to the effect that water samples collected from mine pits, confirm presence of bacterial organisms including Escherichia Coli. The water resources near mining sites were so unsafe that they escalated disease outbreaks in the affected communities.

TABLE 3: OUTPATIENT CONSULTATION RATES AT ISINYA HEALTH CENTRE

Disease	**Under 5 Oct 2015**	**Over 5 Oct 2015**	**Under 5 Jan 2016**	**Over 5 Jan 2016**
Diarrhoea	201	176	278	149
Dysentery (Bloody Diarrhoea)	0	12	3	4
Tuberculosis	0	3	0	41
Poliomyelitis	9	0	0	0
Fevers	6	0	1	5
Malaria	5	10	10	46
Urinary Tract Infections	4	0	4	168
Bilharzias’	0	16	0	0
Typhoid fever	0	8	0	3
Intestinal Worms	2	115	4	5
Eye Infections	24	3	22	24
ear Infections	5	24	5	8
URTI	284	11	543	354
Asthma	0	11	1	13
Tonsillitis	21	656	10	75
Pneumonia	36	10	22	45
Other disorders of the respiratory system	237	48	10	75
Skin disorders	34	20	102	106
Brucellosis	1	2	0	9
Cardiovascular conditions	0	5	0	5
All other diseases	131	600	46	407
TOTAL	**1000**	**1730**	**1061**	**1542**

Conclusion and recommendations

From the findings, it is realistic to conclude that water quantity was significantly influenced by mining operations. The prevalence of waterborne diseases associated with mining implied reduced participation in livelihood activities by the affected Kajiado residents. Financial resources spent on the treatment of the waterborne diseases by the affected households unnecessarily increase the households' budget and diverts household resources away from productive livelihood activities. This calls for measures to be put in place to safeguard the water quality availability to the residents. The elevated bacterial concentration levels are more of an indirect impact of gypsum mining on water resources than a direct one since they arise from the human settlement attracted to the mining sites. The resultant anthropogenic activities associated with Gypsum mining coupled with poor hygienic and sanitation standards lead to further water contamination.

It can also be concluded that the study area population has not embraced safe waste disposal practices so as to control the effects of some of the waterborne diseases. The study recommends training and extension services aimed at prevention of diarrheal and other waterborne diseases.

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