Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.12, No.11, 2022

A Comparative Study of the Physiochemical and Bacteriological Parameters of Potable Water from Different Sources in Kitui County, Kenya

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Abstract

Developing nations are experiencing an ever-increasing demand for safe water due to climate change and the ever-increasing human population. Various strategies including construction of shallow wells, boreholes and sand dams along the river are done to make water available to various households. However, availability of water sources near are faced with challenges of pollution from a variety of sources. The aim of this study was to determine the levels of selected bacteriological and physico-chemical parameters in three potable water sources namely Kiembeni borehole, Mwitasyano River and Kalundu Dam in Kitui County. The quality of this water was compared to the standards for potable water prescribed by Kenya Bureau of Standards (KEBS). Representative sampling was conducted during the wet season (October 2019) and the dry season (August 2020) in the three sampling sites. The samples were analyzed for physico-chemical parameters: pH, color, turbidity, alkalinity, conductivity, iron, calcium, magnesium, hardness, chloride, fluoride, sulphates, ammonia, total dissolved solids and bacteriological parameters: total and fecal coliform. The analysis was performed at the Kenya Water Institute (KEWI) laboratory using standard procedures. The values obtained for the different water sources in the wet season and dry season were pooled and mean values calculated to determine the overall quality of drinking water. The results indicated that all the water sources had fecal coliform levels unsuitable for drinking water. Most of the values obtained for pH, color, alkalinity, conductivity, calcium, fluoride and sulphates in all sources of water were within the recommended potable water standards by KEBS. However, turbidity, iron and total coliform obtained values for borehole water samples were not within the recommended KEBS standards. The river and dam water samples were within the recommended standards for magnesium, hardness, chloride, ammonia and total dissolved solids. Although results indicate that some of the physico-chemical parameters were in conformance with the recommended standards, the overall bacteriological parameters render the water unsuitable for drinking. Thus, public health intervention programmes should be focused on addressing various sources of water pollution including regular disinfection of water.

Keywords: Water quality, Physico-chemical, Kitui County, Assessment
DOI: 10.7176/JEES/12-11-05
Publication date: November 30th 2022

1. Introduction

Good water quality is fundamental for the sustainability of life (WHO & UNICEF, 2017). Special consideration is given to drinking water because of its impact to human health. Some of the health issues associated with the intake of contaminated water include increased risk of water related and health care associated infections such as enteropathy and diarrheal illnesses (Ashbolt, 2015; Edokpayi, 2018), the rise of antimicrobial resistant bacteria (Hayward, 2020) and increased exposure to carcinogenic substances such as lead (Naidenko, 2019). The quality of drinking water obtained from surface waters is predominantly compromised by human activities such as industrial and agricultural activities including geologic conditions (Balthazard-Accou, 2019).

It is estimated that 1.1 billion people worldwide lack access to safe drinking water. This is equivalent to one person out of every six people (UNDP, 2015). An estimated 1.8 billion people in developing nations are also exposed to drinking water contaminated with fecal matter (WHO & UNICEF, 2019). It is also estimated that about 50% of the population in Africa lacks access to safe drinking water (Davis, 2013).

Ideally, drinking water should be pure and free from pathogens, impurities and all contaminants that may pose a threat to human health. Therefore, it is extremely important to control and monitor the quality of drinking water (KEBS, 2014). The suitability and quality of drinking water is determined by testing several essential physiochemical, chemical and biological water quality parameters (Ma, 2020). The World Health Organization(WHO), has developed guidelines for potable water (Fewtrell, 2001) which have been adopted by the

Kenya Bureau of Standards (KEBS) (KEBS, 2014).

In developing nations such as Kenya, the ever-increasing water demand and the inability of the government to provide safe piped water supply to all people especially those residing in rural areas in arid and semi-arid lands has forced most people in these areas to resort to the use of water from sources that may not be safe. These sources include shallow wells, boreholes and surface waters such as rivers and dams (Olajuyigbe & Emmanuel, 2012).

Kitui County is located in an arid and semi-arid region in eastern Kenya. The county is vulnerable to droughts and the annual average precipitation ranges from 400-1000mm. The long rains, which occur in the months of March to May, are less reliable as compared to the short rains that occur in the months of October to December (Kitui, 2018). Kitui Water and Sewerage Company (KITWASCO) is the major water supply agency in the county. However, demand exceeds supply, forcing inhabitants of the county to resort to alternative sources of water such as boreholes, dams and rivers that may not be safe. Other studies have indeed determined the bacterial and physicochemical properties of potable water in Kitui County (Abila et al., 2012; Nzeve & Matata, 2021). This study assessed and compared the physicochemical and biological parameters of water obtained from different sources in and around Kitui town, which is a major urban center of Kitui County. This study highlights the parameters of concern in the different sources of water and may advice on the most suitable water treatment strategies.

2. Materials and methods

2.1 Study Area

This study was carried out in Kitui town, Kenya and its environs. The town is situated at latitudes 0°10 South and 3°0 South, longitudes 37°50 East and 39°0 East. The area experiences semi-arid climatic conditions. The urban center with an approximate population of 29,062 people serves as the county headquarter of Kitui County. Kitui County is one of the largest Kenyan counties by land with an area of 30,429 km2 and a population density of 37 people per km2 .48% of the population remains poor and access to water is a challenge. (Kitui, 2018) Only 53% of residents have access to improved water sources (KNBS, 2017).

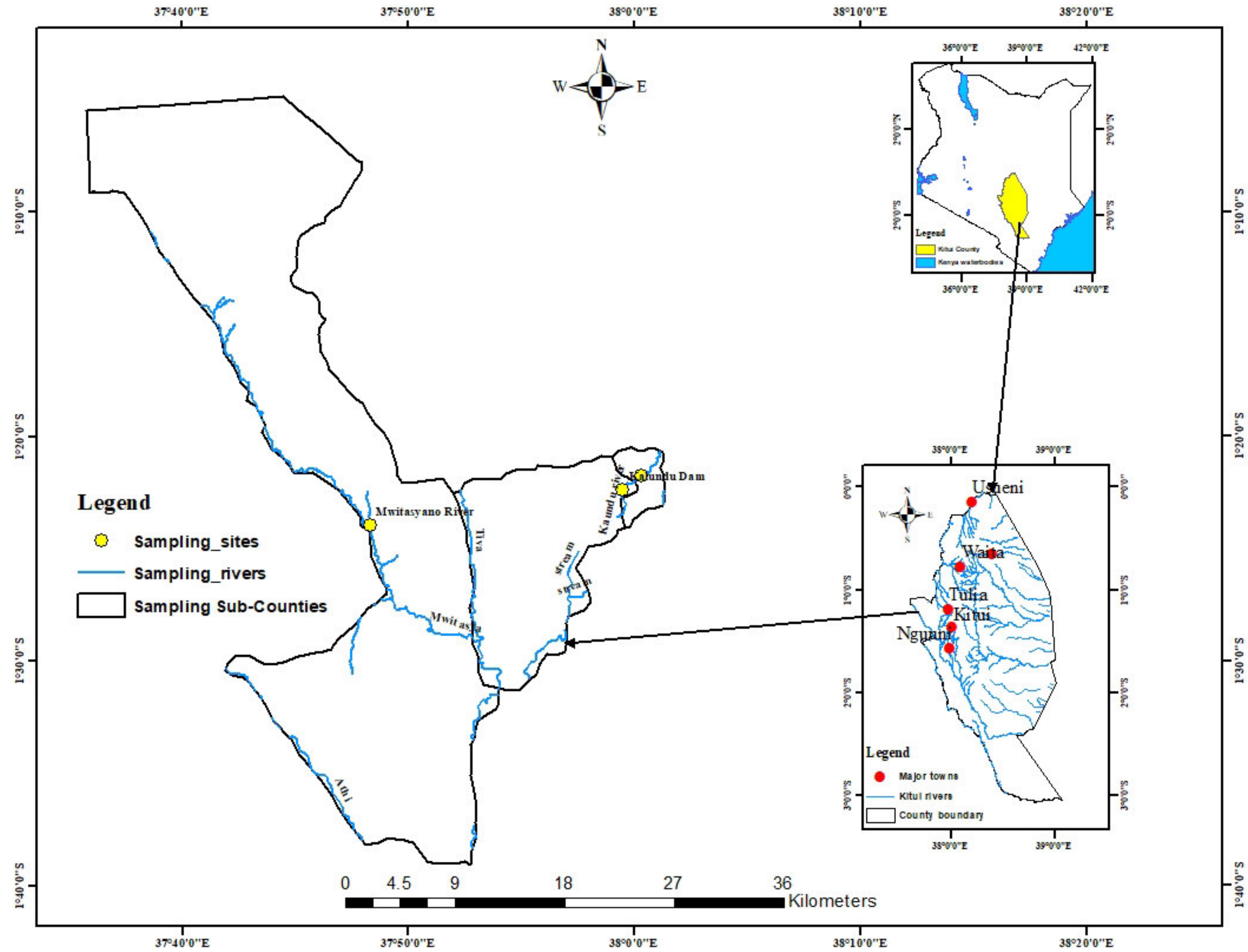

Figure 1. Map of Kitui County indicating the sampling sites

2.2 Selection of sampling sites

The sampling sites were selected purposively. The locations were Mwitasyano River at Kwa Vonza, Kalundu dam at Eco park resort and Kiembeni borehole at Kiembeni slaughterhouse.

2.3 Water Sampling and Analysis.

Water samples were collected in triplicate using sterile one-liter glass bottles in a period of one week. The glass bottles were sealed, covered with an aluminum foil and placed in a dark ice cooler box where the temperature was maintained at 4 - 10oC to avoid contamination. The samples were ferried to the Kenya Water Institute (KEWI), Nairobi County for analysis as soon as they were collected. Representative sampling was carried out from each location during the wet season (October 2019) and the dry season (August 2020) for a period of one year. The average temperature at the time of sampling during the dry season was 25°C and 18°C during the wet season. For purposes of tabular representation and analysis, the average values of duplicate samples in the two seasons were used to determine the overall annual quality of potable water.

2.4 Physicochemical analysis

The values of all parameters were determined using standard methods of test validated and cross-checked against KEBS standards for potable water specifications (KEBS, 2014). These methods were in line with standard methods as described in Standard Methods for the Examination of Water and Wastewater (Rice, Baird, & Eaton, 2017) The analysis of data was carried out using Microsoft excel 2016 database and Origin Version 16 software.

2.5 Bacteriological analysis

The detection and enumeration of total and fecal coliform, Escherichia coli (E.coli) bacteria in various samples was carried out using multiple tube fermentation (MPN) technique of analysis. The results obtained after the test were interpreted using the MPN table following the procedure as outlined in ISO 9308 standard (KEBS, 2014).

2.6 Data analysis

To compare the quality of water from the three different sources and determine its suitability for drinking, the data obtained was analyzed using Statistical Package for Social Sciences (SPSS IBM version 21). The Mean ± Standard error deviations and range of physicochemical and bacteriological parameters were obtained. Fisher's least significance difference test was performed in order to identify the sources of water with significant differences in their means at a confidence level of 95%. The results were subsequently compared with KEBS water quality standards for potable water (KEBS, 2014). These results were represented in table 1 and table 2 respectively.

3. Results

3.1 Physicochemical properties

The physicochemical properties namely pH, color, alkalinity, conductivity, Calcium, Sulphates and Fluoride for all the sources of water were within the recommended KEBS standards (Table 1). Kiembeni borehole water had turbidity and iron levels within the recommendations with Mwitasyano River and Kalundu Dam having unacceptable levels. Interestingly, Kiembeni borehole water had unacceptable levels of total dissolved solids but not Mwitasyano River and Kalundu dam (Table 1). This means that although the river and the dam water was cloudier than the borehole water, the total dissolved solids were higher in the borehole and unsuitable for drinking water.

Magnesium, Chloride, hardness and ammonia levels in Kiembeni borehole were outside the recommended standards. Similarly, Mwitasyano River had unacceptable levels of magnesium.

3.2 Bacteriological parameters

All of the water sources had total coliform values higher than the recommendations (Table 1). However, Kiembeni borehole water had no observed fecal coliforms but Mwitasyano River and Kalundu dam had observed levels of fecal coliform (Table 1).

Table 1: Mean ± Standard error deviations of the physicochemical and bacteriological parameters of sampled potable water sources in Kitui County, Kenya.

Parameters	KEBS Standards	WHO Standards	Potable water sources		
			Kiembeni Borehole	Mwitasyano River	Kalundu Dam
			Mean ± StDev	Mean ± StDev	Mean ± StDev
pH	6.0 – 9.0	6.5 – 8.5	8.228±0.018	8.424±0.021	8.186 ±0.028
Color (Hazens)	<15	<15	1.160±0.182	5.000±0.000	10.000±0.000
Turbidity (NTUs)	<5	<5	1.340±0.014	**508.400±5.029***	**361.200±1.304***
Alkalinity(mg/L)	<500	<500	111.200±1.924	142.600±1.673	61.400±0.547
Conductivity(µS/cm)	<2000	<2000	1564.400±2.408	825.600±3.507	191.800±1.483
Iron (mg/L)	0.3	0.3	0.258±0.013	**5.548±0.008***	**5.702±0.015***
Calcium (mg/L)	150	150	14.000±1.225	93.000±1.000	14.800±1.483
Magnesium (mg/L)	100	100	**364.600±0.894***	**101.600±2.074***	40.000±2.236
Hardness (mg/L)	300	500	**377.000±2.236***	193.400±2.408	55.000±0.707
Chloride (mg/L)	250	250	**324.160±0.823***	132.566±1.534	14.969±0.028
Fluoride (mg/L)	1.5	1.5	0.9420±0.019	1.398± 0.069	0.000± 0.000
Sulphates (mg/L)	400	400	74.380±0.454	40.542±0.451	2.582±0.011
Ammonia (mg/L)	0.5	0.5	**1.089±2.211***	0.1288±0.122	0.180±0.198
Total dissolved Solids (mg/L)	700	1000	**970.028±0.446***	514.846±1.306	118.864±0.468
Total Coliform(MPN/100ml)	Nil	<10	**3.000± 0.000***	**2400.000±0.000***	**2400.000±0.000***
Fecal coliform (MPN/100ml)	Nil	Nil	0.0000±0.000	**84.800±114.303***	**68.200±91.088***

NS – not stated. The values outside of the prescribed KEBS standards are in bold and in asterisk (*).

The mean significant differences between and within the water sources were determined as shown in Table 2. Overall, only Ammonia and Fecal coliform values were not significantly different across the water sources. In addition, Calcium levels in the borehole and the dam were also not significantly different (Table 2).

Table 2. A Least Significant Difference (LSD) multiple comparisons table of the physicochemical and bacteriological parameters of sampled potable water sources in Kitui County, Kenya.

Dependent Variable	(I) Source of water	(J) Source of water	Mean Difference (I-J)	Std. Error	Sig.
pH	B.H	River	-.19600*	0.01428	**.000***
		Dam	.04200*	0.01428	**.012***
	Dam	River	-.23800*	0.01428	**.000***
Color	B.H	River	-3.84000*	0.06633	**.000***
		Dam	-8.84000*	0.06633	**.000***
	Dam	River	5.00000*	0.06633	**.000***
Turbidity	B.H	River	-507.06000*	1.89737	**.000***
		Dam	-359.86000*	1.89737	**.000***
	Dam	River	-147.20000*	1.89737	**.000***
Alkalinity	B.H	River	-31.40000*	0.95219	**.000***
		Dam	49.80000*	0.95219	**.000***
	Dam	River	-81.20000*	0.95219	**.000***
Conductivity	B.H	River	738.80000*	1.6452	**.000***
		Dam	1372.60000*	1.6452	**.000***
	Dam	River	-633.80000*	1.6452	**.000***
Iron	B.H	River	-5.29000*	0.00783	**.000***
		Dam	-5.44400*	0.00783	**.000***
	Dam	River	.15400*	0.00783	**.000***
Calcium	B.H	River	-79.00000*	0.79162	**.000***
		Dam	-0.8	0.79162	0.332
	Dam	River	-78.20000*	0.79162	**.000***
Magnesium	B.H	River	263.00000*	1.16046	**.000***
		Dam	324.60000*	1.16046	**.000***
	Dam	River	-61.60000*	1.16046	**.000***
Hardness	B.H	River	183.60000*	1.22746	**.000***
		Dam	322.00000*	1.22746	**.000***
	Dam	River	-138.40000*	1.22746	**.000***
Chloride	B.H	River	191.59400*	0.63592	**.000***
		Dam	309.19080*	0.63592	**.000***
	Dam	River	-117.59680*	0.63592	**.000***
Fluoride	B.H	River	-.45600*	0.02643	**.000***
		Dam	.94200*	0.02643	**.000***
	Dam	River	-1.39800*	0.02643	**.000***
Sulphates	B.H	River	33.83800*	0.23354	**.000***
		Dam	71.79800*	0.23354	**.000***
	Dam	River	-37.96000*	0.23354	**.000***
Ammonia	B.H	River	0.9604	0.81179	0.26
		Dam	0.909	0.81179	0.285
	Dam	River	0.0514	0.81179	0.951
Total dissolved Solids	B.H	River	455.18200*	0.53221	**.000***
		Dam	851.16400*	0.53221	**.000***
	Dam	River	-395.98200*	0.53221	**.000***
Fecal coliform	B.H	River	-84.8	53.36965	0.138
		Dam	-68.2	53.36965	0.225
	Dam	River	-16.6	53.36965	0.761

The values that were significantly different are in bold.

3.3 Discussion

KEBS standards on potable water are an important resource as they guide citizens, water supply and water treatment bodies on the quality of water that is safe for domestic use. The increased levels of physiochemical and bacteriological parameters in surface water and ground water can have detrimental effects to human and aquatic life. For example, major variations in pH will cause the water to assume an acidic or basic state that would render it unfit for domestic use (Bell, 1971).

Turbidity is an optical expression of water quality mainly due to colloidal and suspended matter (Soros, Amburgey, Stauber, Sobsey, & Casanova, 2019). High levels of turbidity in dam and river water samples reduce the aesthetic value of water and consequently affects consumer's attitude towards water. It is also an indicator of unsafe drinking water (Gauthier V. , Barbeau, Tremblay, Millette, & Bernier, 2003).

Increased levels of iron in dam and river samples can affect human health by causing medical problems such as liver cirrhosis, diabetes, cancer, infertility and heart diseases. It also changes the odor, taste or color of water thus staining utensils and clothes (Vipin Kumar, 2017). The high levels of hardness caused by increased levels of magnesium in borehole water expose people to the risk of death from hypertension (Yang, 1999). Increased chloride in borehole water is non-toxic to human beings but the effect of long-term intake of chloride is still under study. However, it has a deleterious effect on metallic pipe structures and plants (WHO, Chloride in Drinking-water, 1996).

The increased concentrations of ammonia in borehole waters is toxic to human health as it influences metabolism by shifting the acid-base equilibrium, disturbing the glucose tolerance and reducing the sensitivity of tissue to insulin (WHO, Ammonia in Drinking-water, 1996). The total dissolved solids concentration in borehole is increased due to high levels of soluble solids .Increased concentration of total dissolved solids such as fluoride, sulphate, magnesium, alkalinity calcium, chloride and total hardness has a direct correlation with ischemic heart disease and acute myocardial infarction (WHO, Total dissolved solids in Drinking-water, 1996).

The high levels of total and fecal coliform concentration are an indicator that the water is infested with harmful environmental and other bacteria resulting from the waste of warm-blooded animals. These two parameters are very important markers of water quality as an increase in these affects human beings directly though causing water borne diseases such as cholera, salmonella etc. (Divya, 2016).

3.4 River water

According to the results obtained, samples obtained from river water recorded unacceptable levels of pH, turbidity, calcium, fluoride, alkalinity and fecal coliform. These results are in concordance with results from a study of Mohokare river in Lesotho (Peter, et al., 2019). The high values of these parameters are attributed to surface waters being alkaline in nature and cloudy due to suspended solids (Peter, et al., 2019). The fecal coliform observed are due to animal waste on the river as residents fetch water and animals drinking the water. Calcium and fluoride levels can be explained by the presence of rocks containing calcium and fluorine washed into the river during rock weathering. These results were also consistent with results obtained from a study by Petts in the water quality characteristics of rivers (Petts, 1986).

3.5 Dam water

Samples obtained from dam water recorded high amounts of color, iron, magnesium, total and fecal coliforms. These levels may be due to dam water being directly affected by human activities upstream (Abila, et al., 2012). Nzeve & Matata, 2021, also observed these results. The relatively low amounts of pH, alkalinity, conductivity, Hardness, Chloride, Fluoride, Sulphates and total dissolved solids are because the water in the dam is not stagnant as it moves downstream to feed Kalundu River (Nzeve & Matata, 2021). Therefore, the movement of this water helps to reduce the levels of salinity of the water and thus the amounts of chemical parameters are reduced. The results obtained for specified parameters were consistent with those obtained in a study by Mohd-Asharuddin et al. (Mohd-Asharuddin S. Z., 2016).

3.6 Borehole water

Samples obtained from borehole water recorded high values of conductivity, hardness, Chloride, Sulphates, Ammonia and total dissolved solids. These results are consistent with an earlier study on the groundwater quality (Nzeve & Mbate, 2021). The high levels of these parameters can be caused by the salinity of this water, which is obtained from deep in the ground, and therefore the salts may originate from geological processes such as rock weathering during infiltration and other processes. The high values of conductivity can be attributed to dissolved ions contribute to the hardness (Nienje, 2017). The relatively low values of color, turbidity, iron, calcium, magnesium, total and fecal coliforms can be attributed to the aquifers on which the water sits and the low number of fecal coliforms indicates that ground water environment is not conducive for growth of microorganisms. The characteristics of the ground water were also consistent with results obtained by Liu in the study of groundwater characteristics (Zhongpei, Jianhua, & Yuping, 2016). These results are also consistent with results obtained by a study that assessed the spatial and temporal variations of ground water quality in Yatta plateau (Fredrick, Johnson, & Peter, 2017).

3.7 Conformance to KEBS potable water standards

All values obtained for pH, Color, Alkalinity, Conductivity, Calcium, Fluoride and Sulphates in all water samples were within the recommended potable water standards by KEBS. For turbidity, iron and total coliform only the obtained values for borehole water samples were within the recommended standards by KEBS. For magnesium, hardness, chloride, ammonia and total dissolved solids only the obtained values for river and dam water samples were within the recommended potable water standards by KEBS. For fecal coliform, no sample-recorded values were within the recommended potable water standards by KEBS (KEBS, 2014). These results are in concordance with the findings of Sila, (Sila, 2018) and Ondieki, (Ondieki, Akunga, Warutere, & Kenyanya, 2021) where the fecal coliform levels rendered the water unsuitable for drinking.

3.8 Comparison of the values from the three water sources.

Analysis of variance and posthoc analysis as seen in tables 2 and 3 respectively showed that there exists significant difference in the quality of water from the different sources of water except for the parameters ammonia and fecal coliform. This is an indication that water from the three different sources is polluted with fecal waste and urea and needs to be treated before drinking. According to studies by Samantha, (Marshall, 2011) Kenya faces drinking water crisis in urban and even rural areas due to rapid increase in population, contamination of water, poor management of agencies tasked with supplying water and droughts. This study confirms these assertions and the further the distance from the urban center the better the quality of water.

4.0 Conclusions and Recommendations

Results obtained from the study suggest strongly that the chemical and bacteriological quality of potable water in the borehole, river and dam do not meet the recommended standards for potable water by KEBS. The findings show that there is a potential threat that looms in the wake of unsuspecting users who may be adversely affected while using the water. Therefore, to ensure their safety it is important to engage intervention measures such as encouraging cheaper methods of water treatment, creating awareness through educating residents on the need for improving sanitation etc. Further studies on identifying and monitoring sources of pollution and the occurrence of water borne infections are also important.

The data used for this study is only from the values of chemical and biological parameters. The data is not enough to form the basis of a comprehensive public health intervention Programme as it does not take into consideration the socio economic factors including treatment of domestic water by residents, data on possible contamination sources and even methods of construction of boreholes. There is therefore need for further studies to establish these aspects before an intervention Programme is launched. However, this study shows that there is need to treat the water from the different sites before use.

Monitoring the quality of water should also be done more frequently to ensure the water sources are evaluated for any changes in water quality. The relevant authorities should enforce legislation already in place.

Acknowledgment

The funding for this study was obtained from South Eastern Kenya University and National Research fund (NRF). We are particularly grateful to the Kenya Water Institute where the lab analysis was carried out and the South Eastern Kenya University team that aided in fieldwork.

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