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Gross Fecal Pollution of a Rural Watershed in Kenya: Research Identifying Cattle as a Major Source in the River Njoro Watershed

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Elevated levels of fecal pollution in surface water pose significant health risks for humans as well as livestock, and degrade aquatic ecosystems. This brief presents preliminary findings on pollution research in the River Njoro Watershed and explores actions to reduce gross pollution found throughout. We conducted an extensive survey and launched a year-long program to measure fecal coliform bacteria in river water to quantify pollution levels across the watershed, pinpoint problem areas and identify major sources. Genetic methods were applied to track fecal sources and test for Cryptosporidium spp., *a water-borne pathogen causing severe diarrhea in young, old, and immuno-compromised human and cattle populations. A common pattern of fecal pollution peaking in August, significantly higher levels detected when cattle were present at a site, and widespread detection of cow fecal genetic markers, point to livestock, in particular cattle, as the most likely cause of gross fecal pollution and probable source of* Cryptosporidium *risk in the Njoro Watershed. Elimination of the widespread practice of in-river livestock watering through provision of watering troughs would quickly reduce gross levels of fecal pollution, bringing immediate health benefits for humans, livestock, and ecosystems. Tackling the complex web of human-livestock-animal, resident-migratory, and rural-urban combinations of sources and actors contributing fecal pollution in this and similar rural watersheds throughout Kenya requires a long-term multi-pronged engagement process of joint local community and government action.*

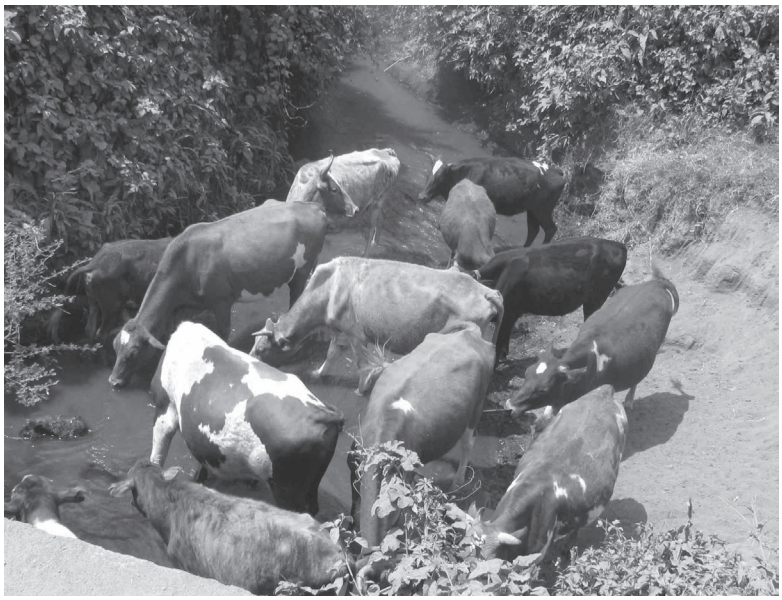
Background

Historically, the earliest concerns with water pollution have been with the transmission of pathogenic diseases, such as typhoid. When large amounts of excreta from humans, livestock, or wildlife are allowed to enter a water system, environmental exposure to and spread of infectious enteric pathogens increases for humans, animals and wildlife, while the organic matter and nutrients (nitrogen and phosphorous) in excreta degrade aquatic environments, causing algal growth, reduced oxygen levels and eutrophic conditions. Fecal water pollution and the increased exposure to water-borne infectious pathogens have immediate negative health and economic consequences in Kenya, especially for marginalized communities where clean water is acutely scarce, improved water supply coverage low, health services strained or out-of-reach, and livestock assets an important component of livelihoods.

At about 3000 msl (meters above sea level) in the eastern Mau Escarpment, the River Njoro descends through high elevation indigenous forest and pasture down through agricultural and urban lands into the Rift Valley, passing along the city of Nakuru, and terminating at Lake Nakuru (1750 msl). The 50 km river and 280 km^2 watershed are an important source of surface and groundwater supplies for growing domestic, industrial, commercial, livestock, irrigation, and environmental water requirements in and around the watershed. Massai herdsmen move their livestock into the watershed for grazing and watering during the dry season. Dramatic increases in small-scale agriculture and livestock populations in the upper watershed have been documented, with numbers of cattle and sheep rising by over 250% and 200%, respectively, in the last five years (GL-CRSP, 2005).

Research to assess the magnitude, extent, and causes of fecal pollution in the Njoro Watershed was initiated in 2004 as part of the Sustainable Management of Watersheds (SUMAWA) project. SUMAWA is demonstrating a science-based approach to rural watershed management that tackles degraded water quality and declining quantity problems facing watershed residents, stakeholders, water resources users, and resource managers. Community outreach early in the project revealed scarcity of clean water, river water pollution, water-borne diseases, and animal health as priority concerns among watershed residents dependent on river flow for some or all of their human and livestock water requirements (Jenkins et al., 2004).

Dr. Marion Jenkins, US Co-PI, University of California, Davis, working with Dr. Charles Maina-Gichaba at Egerton University, began with an extensive field survey of the River Njoro stream network and adjacent land use to inventory potential fecal pollution sources. Thirty-



Cattle watering at open access points along the River Njoro stream network are a common sight throughout the watershed. Photo by Sian Mooney.

eight public access watering points where domestic water supplies are collected, livestock watered, and other activities occur, and numerous other non-point and point sources of potential fecal pollution were identified. A year-long monitoring program along the length of the main River Njoro and Little Shuru tributary was launched in October 2005. UC Davis environmental engineering PhD student Sangam Tiwari provided technical training and oversight for students and technicians at Egerton University, who were trained and equipped to collect water samples, record site activities, and measure fecal coliform concentrations in labs at Egerton University. Following a baseline assessment, 15 sites were selected for monthly monitoring, including 3 un- or least disturbed sites and 12 watering points.

Fecal coliform bacteria is the most common standard microbiological indicator of fecal contamination from human, livestock, or other warm-blooded animals in environmental water samples, but it is unable to distinguish between these sources and unable to accurately identify if human fecal pollution, the most dangerous for human health, is present. Given these weaknesses, a variety of new microbial source tracking and pathogen detection methods have emerged in the last 10 years to improve scientific ability to identify sources of fecal pollution in watersheds (Simpson, et al., 2002). The overwhelming number of non-point direct (in-river, i.e., at watering points) and diffuse (land-based) human and animal source activities potentially contributing fecal contamination along any given section of the River Njoro makes it difficult to establish which activities, locations, and fecal source activities should be prioritized in developing an abatement program. New gene-based qPCR TaqMan detection methods (Kildare, et al., 2007), developed at UC Davis and elsewhere to identify specific pathogenic species and track or fingerprint fecal organisms by their animal or human source, were used to help identify priority sources and risks. To our knowledge, this is the first time a gene-based fecal source tracking method has been applied in a developing country. With the help of Dr. Stefan Wuertz, at UC Davis, we tested five established fecal source marker assays designed to detect universal, cow-specific, and human-specific 16s rRNA Bacteroidales (a gut organism excreted in the feces of warm-blooded animals) against Kenya fecal samples of known origin to establish assay validity in Kenya. We then used the validated TaqMan assays and another designed to detect *Cryptosporidium spp.,* a water-borne pathogen harmful to humans and livestock, on a subset of river water samples.

Research Findings

High levels of fecal water pollution occur throughout the watershed. Out of 162 water samples collected monthly along the river from October 2006 through September 2006, fecal coliform levels in just three met the surface water pollution threshold of 200 cfu/100 ml considered acceptable for human contact or use as a raw water source by the US EPA. River water averaged 8,000 cfu/100 ml of fecal coliforms across all sites during the year. Fecal concentrations at watering points in the upper watershed were lower than those in rest of the watershed but still always exceeded 200 cfu. Contamination levels at watering points in middle reaches exceeded 10,000 cfu/100 ml 30% of the time, and at lower watershed watering points, 65% of the time. Fecal loading throughout the watershed has persistent and cumulative effects on water quality, reaching particularly elevated levels in the lower watershed just prior to entering Lake Nakuru National Park.

Incidents of gross pollution exceeding 100,000 cfu/100 ml occurred at 10 of the 15 monitored locations. These occurred periodically during the dry season at several sites in the upper watershed and were associated with the presence of large herds of Massai cattle watering at the time of sample collection. Gross pollution was also evident nearly everywhere in the watershed during August, the wet season month when effective rainfall and runoff are historically greatest.

We compared mean log 10 fecal coliform concentrations for river water samples grouped according to types of activity occurring at the site at the time of sample collection and found statistically significant differences in the quality of

water when cows were present compared to no activity or non-cow activity present. A more than four-fold increase in mean fecal contamination at sites with cow activity (n=34 was measured compared to sites with no activity (n=45) (18,501 vs. 4,075 cfu/100 ml). At sites with non-cow activity (including human and other animals; n=71), the concentration was half of that with cow activity (9,715 versus 18,501 cfu/100ml).

Cow fecal genetic markers were detected at 10 of 12 locations tested in Fall 2005, including at the highest and lowest points. Four sites in the middle and lower watershed tested positive for human genetic markers. Reliability of the genetic results for the Njoro watershed was estimated to be 100% for positive and 81-91% for negative detections. Genetic source tracking evidence supports the fecal coliform findings which point to cows and the practice of in-river watering and river access as the most widespread likely cause of gross fecal contamination in the Njoro Watershed. These include the large spikes measured at sites when cows were present and the spikes seen across the watershed during the late wet season peak runoff month of August, the most likely cause for the latter being the transport of accumulated still moist cattle fecal deposits in contributing areas along the river's 38 known watering sites during major rainfall-runoff events.

Among negative impacts of widespread contamination of water by cattle is the spread of Cryptosporidiosis, a zoonotic waterborne fecal-oral disease transmitted between humans and cattle, cattle and other animals including wildlife, and between humans and other animals. Cattle are a known major environmental reservoir for this gastrointestinal disease, a leading cause of mortality among AIDS patients, and a recognized cause of childhood and calf diarrhea disease. *Cryptosporidium spp.* was measured with a new gene probe (Miller et al., 2006) able to detect one occyst, a dose sufficient to cause illness in immuno-compromised populations. Genetic markers were found in 50 mL river samples from 10 out of the 12 locations, detected 80% of the time with cow and 30% with human fecal markers. While not definitive, the genetic detection results are strong evidence of the likelihood that this and other waterborne zoonotic pathogens are present in the Njoro watershed at potentially significant concentrations dangerous to health.

Practical Implications

In the Njoro watershed, livestock small-holders have few options but the river for watering their cattle and other livestock. Moving cattle from home to the river each day is the only way livestock are watered. During the dry season, Maasai herdsmen bring their cattle and livestock into the watershed to feed and water at the river for extended periods, notably along the lower Little Shuru tributary. Pathways to and from river watering sites tend to be littered with cow pats, while adjacent riparian areas are attractive grazing spots. Watershed studies of cattle behavior, fecal loading rates, and deposition patterns elsewhere (Tate, et al., 2003) show cattle produce 40-60 kg of fecal matter per day (compared to 0.3-0.5 kg for humans and smaller amounts for other livestock) and are more likely to defecate in and around watering points, preferred food sources, and shade trees.

Eliminating the extensive practice of cattle watering in, and access to, the River Njoro is the single most effect action likely to reduce gross fecal pollution in the Njoro Watershed. Expansion of improved water supplies and construction of off-river watering troughs for cattle and other livestock, with attention to controlling and managing fecal deposits at these sites, are key actions to explore. Successful local models for managing livestock watering facilities in environmentally and financially sustainable ways will need to be developed. Reducing direct and indirect mass loading of cattle excreta to the stream network will also reduce organic, nitrogen and phosphorous pollution for downstream ecosystems in Lake Nakuru.

Engaging communities across the watershed to analyze underlying conditions which lead poorer agricultural and peri-urban households to use the river to water cattle and livestock is crucial in gaining community support and identifying workable solutions. These are thought to include the widespread lack of access to improved water sources in the upper and middle watershed for livestock and domestic needs, frequent rationing and shortages of improved water supplies in the middle and lower watershed, and high prices charged for improved water sold at some kiosks compared to private connections. The Njoro Watershed Water Resource Users Association, a community-based institution supported by SUMAWA, provides a platform for dialogue among communities, livestock-owning households, Massai representatives, water resource managers, water service providers, and agricultural extension agents about fecal pollution problems and mutually beneficial solutions.

Further research is recommended to verify and investigate the extent of *Crytosporidium* contamination of river water and ascertain the prevalence of Cryptosporidosis among neonatal cattle and human populations, and the extent to which cattle health and productivity are impacted by drinking heavily polluted river water in watersheds like the Njoro. Education and extension services to help small livestock owners recognize and prevent the spread of *cryptosporidium* from feces of infected neonatal cattle, a major transmission pathway, and the development of and education on low cost water filtration treatment methods are activities that address the impacts of gross fecal pollution on the human health of large numbers of watershed households who use dangerously polluted river water for their domestic water supplies. (GL-CRSP, 2005).

Further Reading

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The GL-CRSP Sustainable Management of Rural Watersheds (SUMAWA) project was established in 2003 and is a multi-disciplinary research effort focusing on biophysical and human-related factors governing health in the River Njoro watershed in Kenya. Dr. Marion Jenkins, University of California, Davis serves as the project's Co-PI. Email: mwjenkins@ucdavis.edu.

The Global Livestock CRSP is comprised of multidisciplinary, collaborative projects focused on human nutrition, economic growth, environment and policy related to animal agriculture and linked by a global theme of risk in a changing environment. The program is active in East Africa, Central Asia and Latin America.

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