

Anthropogenic Pollution Impact on Microbial Contamination of Lake Kivu, Rwanda

O.J. Olapade

Department of Aquaculture and Fisheries Management, School of Forestry and Horticulture, Njala University, Njala, Sierra Leone

Email: Julius.olapade@yahoo.co.uk/fem66@hotmail.com

Abstract

Investigation of the anthropogenic pollution impact on microbial contamination of Lake Kivu, Rwanda was carried out in Gisenyi, Kibuye and Cyangugu over a period of 24 months. Total coliforms (TC), total heterotrophic bacteria (THB) and fecal coliforms (FC) counts were monitored. Indicator bacteria were enumerated by membrane filtration while pathogenic bacteria were recovered by broth enrichment of water samples. Microbial load did not differ significantly with season and locations but fecal coliform (FC) had positive significant correlation ($r = 0.36^*$; $P < 0.05$) with season. Mean total coliform (TC) (cfu/100 ml) was highest 7.7×10^5 at Gisenyi and lowest 1.7×10^5 at Cyangugu. These values exceeded the zero faecal coliforms counts/100 ml recommended by WHO for water considered safe for human consumption. Total heterotrophic bacteria (THB), fecal coliforms (FC), total coliforms (TC) and *Fecal streptococcus* (FS) were widespread with abnormally high values at the sampling locations, signifying poor water quality. Microbial isolates from the water samples were of wide range of groups, and their occurrence and distribution varied from location to location. *Bacillus* sp., *E. coli*, *Citrobacter freundii*, *Klebsiella pneumonia* and *Proteus* sp. were the dominant microbial species in the lake water. The microbial quality of the water was poor, suggesting contamination of the lake water by animals and human domestic wastes and other anthropogenic activities, such as laundry, swimming, farming, transportation, etc. The lake water is unfit for human domestic use without any form of treatment.

Introduction

Lake Kivu, which is one of the Great Rift Valley lakes, supports very important fisheries that provide livelihood to hundreds of people and contribute significantly to food supply as a prime source of animal protein (Fishbase, 2003). Livelihood activities around this lake include hotel businesses, fishing, tannery, farming, boating, methane gas extraction, mineral mining and localized sand mining. An estimated two million people who live around the lake draw their drinking water from the lake without treatment. The major environmental concern in the lake area are erosion, siltation and pollution of the water through garbage, human wastes and excreta deposition and effluents from industries, restaurants, motor

garages and mechanical shops. Agricultural activities also contribute to the pollution of the lake. Investigation conducted by Green Vision (2004) at 24 sites around the lake revealed that latrine of houses are emptied into the lake, and mud, caused by erosion, creates a garbage in a big part of the littoral zones, and, at certain places, the lake is used as dump site.

Polluted water is an important vehicle for the spread of diseases. In developing countries, 1.8 million people, mostly children, die every year as a result of water related diseases (WHO, 2004). Okhawere, cited by Adama & Kolo (2006), reported that water bodies are reservoir for micro-organisms, and that contamination of water by sewage or excrement from human or

animals is the greatest danger associated with water. According to Okhawere, cited by Adama & Kolo (2006), transmission through contaminated water supply is by far the most serious source of infection that is responsible for the massive epidemic outbreak of the most serious enteric diseases (especially cholera and typhoid fever).

The major causes of faecal contamination of water sources, such as rivers, dams, groundwater, as well as drinking water, according to Isobe *et al.* (2004), are release of partially treated sewage or sewage leakage, leaching of poorly maintained septic tanks, and improper management of farm wastes and run-off of faecal matter during rainy periods. Human excreta have been implicated in the transmission of many infectious diseases including cholera, typhoid, hepatitis and cryptosporidiosis (WHO, 2001). Ingestion of faecally polluted water has long been recognized as a primary cause of diarrhoea. It is estimated that 2.1 million people die every year from diarrhoeal diseases and the majority of these deaths are among children in developing countries (WHO, 2002).

Wastewater pathogens that most frequently cause disease include *Salmonella* spp., *Shigella* spp., pathogenic *Escherichia coli*, *Vibrio cholerae*, *Yersinia enterocolitica*, *Campylobacter jejuni*, Hepatitis A viruses, *Giardia* spp., *Cryptosporidium* spp. and *Entamoeba histolytica* (WHO, 1993). Most of these pathogens are distributed worldwide but outbreaks occur more frequently, and endemicity is higher in areas, where access to good quality water supplies and sanitation is limited (UNEP, 2002).

Water borne transmission of pathogenic

E. coli has been well documented for recreational waters and contaminated water. A well-publicized waterborne outbreak of illness, caused by *E. coli* and *Campylobacter jejuni*, occurred in the farming community of Walkerton in Ontario, Canada. The outbreak that took place in May 2000 led to the death of seven people and caused more than 2300 illness. According to O'Connor (2002), the drinking water supply was contaminated by rainwater runoff containing cattle excreta.

Cholera occurs worldwide. Cholera is an extremely virulent disease. It affects both children and adults and can kill within hours. Cholera epidemic occurred in Bangladesh in 1991 which resulted in the death of an estimated 8000 people within a period of 12 week (Siddique *et al.*, 1995). Between 1992 and 1993, 21 countries in the Western Hemisphere, mostly in coastal areas, reported 800,000 cholera cases with more than 8000 cases resulting in death (Tauxe *et al.*, 1994). Forty two percent (42%) of all cholera deaths reported globally were in Africa. The first reported cholera case from the seventh pandemic in Africa's Great Rift Valley Lakes region (bordered by Zaire, Burundi and Rwanda) occurred in May 1978. In July 1994, 14000 deaths from cholera were reported in refugee camps in Rwanda (Siddique *et al.*, 1995).

Recent cholera outbreaks started in February 2006 in Luanda, Angola. Further cases have been detected and confirmed in the provinces of Bengo, Benguela, Bie, Kuanza Norte, Kuanza Sul, Huambo, Huila, Malange and Democratic Republic of Congo (UNICEF, 2006). Out of the 384403 cases and 10692 cholera deaths reported in 1994 to WHO, an estimated 58057 cases and 4181 deaths resulted from the explosive epidemic

of *Vibrio cholerae* in Rwandan refugees camp around Goma, near Lake Kivu in DRC. Numerous factors have been implicated to increase the risk of cholera outbreaks in a given area, where cholera is already circulating among the population. The main environmental risk factors identified include heavy rainfall, blooms of plankton, and an increase in sea surface temperatures. Daubner (1969) reported that stream bacteria numbers is affected by factors such as temperature, BOD and flow rate.

The extensive use of the Great Rift Valley lakes for transport, drinking, and bathing may encourage rapid and widespread dissemination of *V. cholerae*, resulting in continued risk of unpredictable, explosive and short-lived cholera epidemics among communities situated along these lakes and their connecting rivers (Maureen *et al.*, 1997). There are no serious management approach put in place to control the pollutant lading erosive waters from the neighbouring towns and the wastes from the tiny houses on the thousands hills. Consequently, it is imperative to constantly monitor the microbiological characteristics of the lake water in a bid to determine its suitability for human use. The study was, therefore, undertaken to investigate the impact of anthropogenic activities on the Lake Kivu pollution status and provide information on the microbial load of the lake.

Materials and methods

Study area

Lake Kivu is a mountain lake located between 1° 84' 38" and 22° 30' S and 28° 50' and 29° 23' E. It developed as a result of

volcanic activity in the region. It has a surface area of 2,370 km², of which about 1000 km² (42%) belong to Rwanda and 58% to Democratic Republic of Congo (Fig. 1). It is a deep (maximum 489 m), meromictic lake, with oxic mixolimnion up to 70 m and a deep monimolimnion rich in dissolved gases, particularly methane (Tietze, *et al.*, 1980; Schmid, *et al.*, 2005). Due to its great depth and very steep shores, the littoral area of Lake Kivu having access to oxygenated waters represented only 12% (Beadle, 1981). The average daily temperature in the lake area is 23 °C; relative humidity ranges between 59–83% while the average yearly rainfall is 1300 mm.

Water sampling

The lake was sampled bi-monthly for a period of 24 months at three major towns, namely Gisenyi, Kibuye and Cyangugu. These towns were chosen based on anthropogenic activities going on in them, such as fishing, farming, tannery, laundering, mining, localized sand mining, boating, etc (Fig. 2). Major anthropogenic activities include but not limited to farming, mining, fishing, laundry. 500 ml sub surface water samples for microbiological analysis were collected at a depth of 30 cm into 500 ml capacity sterilized sampling bottles. The samples were collected every 2 months, transported to the laboratory in an ice chest and kept in a refrigerator at 4 °C prior to analysis.

Microbiological analysis

Indicator bacteria such as faecal coliforms and *E. coli* were collected by membrane filtration and plated on Levine eosine methyl blue agar while faecal streptococcus was

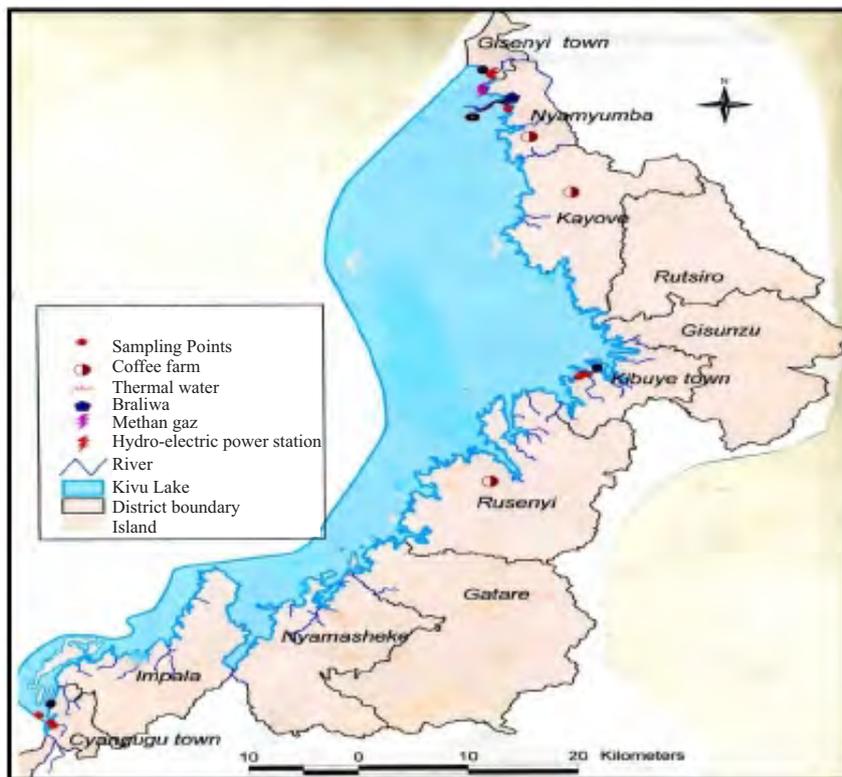


Fig. 1. Map of Lake Kivu (dotted points indicate sampling locations)



Fig. 2. Shoreline of Lake Kivu in Gisenyi (one of the sampling locations)

plated on Slanets agar and enumerated on IMVIC, and TSI test was conducted. Pathogenic bacteria – salmonella and shigella – were collected by broth enrichment (APHA, 1998), and incubated on brilliant green (BGA) and xylose lysine desoxycholate (XLD) agars. Total heterotrophic bacteria were enumerated by plating technique (Jones, 1979). *Vibrio cholerae* was inoculated on thioglucolate and TCBS media.

Data analysis

Results obtained from the study were analysed using mean, standard deviations, correlation coefficients (SAS, 1998), and were presented in tables and graphs.

Results and discussion

The mean and standard deviation of total heterotrophic bacteria (THB), total coliforms (TC), faecal coliforms (FC) and faecal streptococcus (FS), obtained from the different sampling locations, are presented in Table 1. The correlation matrix of indicator bacteria examined is presented in Table 2. FC correlates positively and significantly ($r = 0.36^*$) with season of sampling. TC and FS were more pronounced in Gisenyi and Cyangugu than at Kibuye, while FC was more in Kibuye than at Cyangugu and Gisenyi, respectively. The result is a reflection of the anthropogenic activities taking place in the three sampling zone. THB, FC, TC and FS were wide-spread in the

TABLE 1
Means of bacterial density measured at sampling locations (cfu/100 ml)

<i>Parameters/Locations</i>	<i>Gisenyi</i>	<i>Kibuye</i>	<i>Cyangugu</i>
Total heterotrophic bacteria	168930	82060	75710
Total coliforms	76950	60115	66780
Faecal coliforms	12360	24893	12798
Faecal streptococcus	532.3	6.30	122.2
Mean	64693.08	41768.58	38852.55
Standard deviation (±)	525.59	309.03	301.74

TABLE 2
Correlation matrix of X-values of mean data of bacteria at the lake locations (P < 0.05)

<i>Parameters</i>	<i>Months</i>	<i>Season</i>	<i>THB</i>	<i>TC</i>	<i>FC</i>	<i>FS</i>
Months	1.00					
Season	0.22					
THB	-0.10	-0.10				
TC	0.16	0.13	0.05			
FC	0.19	0.36*	-0.24	0.30		
FS	-0.05	0.27	-0.05	0.08	-0.03	1.00

Legend:

0.36* = Faecal coliforms significantly correlate with season; THB = Total heterotrophic bacteria; TC = Total coliforms; FC = Faecal coliforms; FS = Faecal streptococcus.

three locations sampled with very high values, suggesting poor water quality. THB, FC, TC and FS, however, were not significantly different ($P > 0.05$) with months, seasons and locations.

The results of the bacteria analysis obtained for the three sampling locations (Gisenyi, Kibuye and Cyangugu) suggest that the general sanitary qualities of the water, as indicated by the total coliforms count, were unacceptable while the faecal coliforms results imply that the water poses a serious health risk to consumers of the water. According to WHO, cited by Karikari & Ansa-Asare (2006), for fresh water to be considered as posing no risk to human health, the faecal coliforms count per 100 ml should be zero. The poor microbial quality of the lake might be due to contamination caused by human activities and livestock. It is a common practice for people living along the lake catchments to discharge their domestic and agricultural wastes, as well as human excreta, into the lake. In addition, these people use the lake for bathing, washing of clothes and for recreational purposes such as swimming, thus, contaminating the lake.

Salmonella, Shigella and *Vibrio cholerae* were not detected in the ambient water. Shigella infection is spread mainly through contaminated human stools, and, also, by flies and through contaminated food and water, while Salmonella is mostly through contaminated food, but also through contact with pets' contaminated faeces (<http://www.livestrong.com/article/212944>). *V. cholerae* can be found as free swimming cells, attached to surfaces provided by plants, filamentous green algae, copepods, crustaceans, insects, and egg masses of

chironomids (Sack *et al.*, 2004). The main reservoirs of *V. cholerae* are people and aquatic sources, such as brackish water and estuaries, and often associated with algal blooms (<http://www.who.int/mediacentre/factsheets/fs107/en/>).

Bacteria isolates from the water samples cut across diverse groups such as enteric gram-negative and pyogenic cocci. Their occurrence and distribution vary from location to location (Fig. 3–5). *Bacillus* sp. and *E. coli* were present in all the locations. *Bacillus* sp. *Citrobacter freundii*, *Klebsiella pneumonia* and *Proteus* sp. showed the most relative percentage abundance while enterobacter were least occurring in Cyangugu (2%). *Bacillus coli* and the coliforms groups, as a whole, are most commonly used as indicators of sewage pollution. The presence of such bacteria in water is a valid evidence of contamination by faeces. Since the disease spreading organisms belong to coliforms group of bacteria, their presence in any water body clearly indicates that it is unhygienic. Presence of *Streptococcus fecalis* in the three locations confirms faecal pollution of the lake water. The sources of effluents in lake Kivu include herbicides and pesticides application by farmers around and near the lake and human and animal faeces, sewage, bathing, laundry, effluent from industries and mines majority of which are concentrated in the Democratic Republic of Congo; oil and metallic wastes from mechanic workshops (car washing) and mineral releases from volcanic bedrocks.

The results of the study agreed with the findings of Adama & Kolo (2006), who reported prevalence of pathogenic bacteria in Gurara river, caused by the inflow of effluent

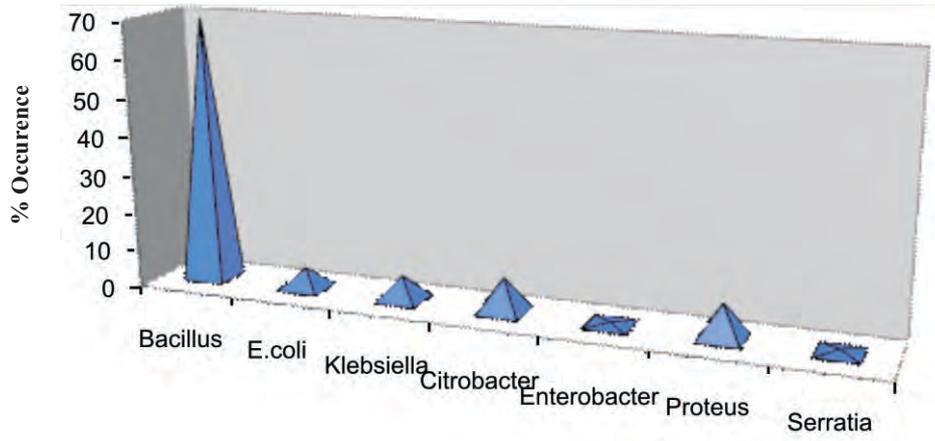


Fig. 3. Microbial isolates in Gisenyi, Lake Kivu

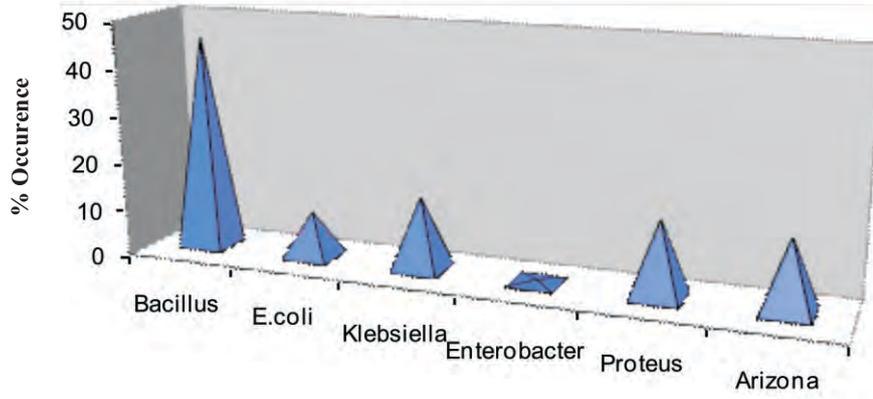


Fig. 4. Microbial isolates in Kibuye, Lake Kivu

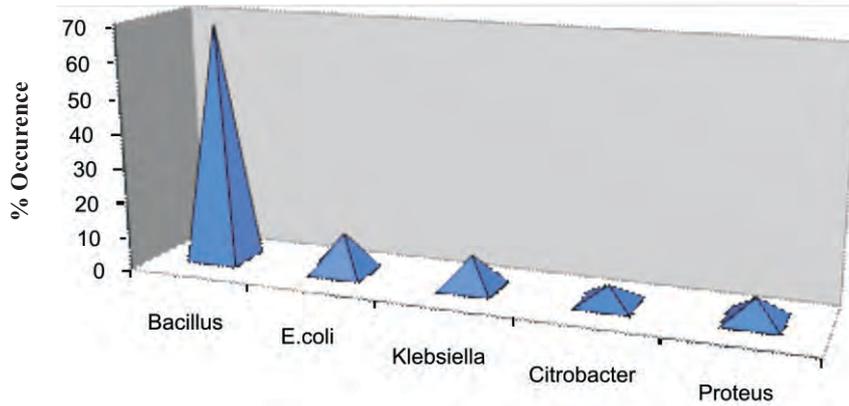


Fig. 5. Microbial isolates in Cyangugu, Lake Kivu

of anthropogenic origin. It also agreed with the findings of Ampofo (1997), in his survey of microbial pollution of rural domestic water supply in Ghana, who said that inadequate availability of water hampers people's efforts to practice personal hygiene, and that frequent fetching, washing and bathing in the river will expose the river to pollution and users to infections.

Conclusion

The results of the study revealed that the microbial status of the lake is very poor and, thus, water from the locations sampled is not suitable for domestic use without treatment, and, also, not suitable for agricultural purposes because of possible contamination of vegetables and crops normally eaten by man in their raw states. The high microbial load obtained in the sampling locations pointed to anthropogenic wastes of organic origin.

The results clearly indicated the need for the control of the quantity and quality of effluents entering the lake in order to reduce the pollution load and enhance suitable environment for sustainable conservation of the aquatic resources. This can be achieved through pre-discharge treatment of wastes, construction of screens across flood water pathways, and the provision of toilet facilities for communities around the lake. Good practices of hygiene (including avoiding bathing and defecating in the lake) also need to be encouraged.

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References

- Adama S. B.** and **Kolo R. J.** (2006). Public health implications of Gurara river around Izom environs, Niger State, Nigeria. *FISON Conf. Proc. Calabar 2006*. pp 167–173.
- Ampofo J. A.** (1997). A survey of microbiology pollution of rural domestic water supply in Ghana. *Intl. J. Env. Hlth Res.* 7: 121–130.
- APHA** (1998). *Standard methods for the examination of water and Waste Water*, 13th edn. APHA Washington D.C. 87 pp.
- Beadle L. C.** (1981). *The Inland Waters of Tropical Africa – an Introduction to Tropical Limnology*. Longman, New York. 475 pp.
- Daubner I.** (1969). The effect of some ecological factors on bacteria in water. *Verh. Int. Verein Theor. Angen. Limnol.* 17: 731–43.
- Fishbase** (2003). Freshwater fish species in Lake Kivu (Rwanda and Zaire). <http://www/mongabay.com/fish/data/ecosystem/lake%20kivu.Htm>.
- Green Vision** (2004). AMARC Africa site, AMARC International Copyright @2004, 2004 AMARC Africa. www.simbani.amarc.org/page.php
- http://www.livestrong.com/article/212944 – Differences between salmonella & shigella. Sep 2, 2010 Cited 27 Oct. 2011.**
- http://www.who.int/mediacentre/factsheets/fs107/en/ – WHO Media Centre: Fact sheets No. 107, August 2011.**
- Isobe K. O., Tarao M., Chiem N. H., Minh L. Y. and Takada H.** (2004) Effect of Environmental Factors on the Relationship between Concentrations of Coprostanol and Fecal Indicator Bacteria in Tropical (Mekong Delta) and Temperate (Tokyo) Freshwaters. *Appl. Envir. Microbiol.* 70 (2): 814–821.
- Jones J. G.** (1979). *A guide to methods of estimating microbial numbers and biomass in freshwater*. Freshwater Biological Association, Ambleside, England.

- Karikari A. Y and Ansa-Asare D.** (2006). Physico-Chemical and Microbial Water Quality Assessment of Densu River of Ghana. *West Afr. J. appl. Ecol.* **10**: 87–100.
- Birmingham Maureen E., Lee Lisa A., Ndayimirije N., Nkurikiye S., Hersh Bradley S., Wells Joy G. and Deming M. S.** (1997) Epidemic cholera in Burundi: patterns of transmission in the Great Rift Valley Lake region. *Lancet* **349** (9057): 981–985.
- O'Connor D. R.** (2002). *Report of the Walkerton Inquiry: Part I – The Events of May 2000 and Related Issues; Part 2– A Strategy for Safe Drinking Water.* Walkerton Public Utilities Commission, Toronto, Ontario.
- Sack D. A., Sack R. B., Nair G. B. and Siddique A. K.** (2004). Cholera. *Lancet.* 2004; **363**(9404): 223–233. [PubMed: 14738797].
- SAS** (1998). *SAS users Guide Statistics ver 7.* SAS Inst. Inc., Cary New California U.S.A.
- Schmid M., Halbwachs M., Wehrli B. and Wuest A.** (2005). Weak mixing in Lake Kivu: New insights indicate increasing risk of uncontrolled gas eruption. *Geochem. Geophys. Geosyst.* **6**(1): 1–11.
- Siddique A. K., Salam A. and Islam M. S.** (1995). Why treatment centres failed to prevent deaths among Rwandan refugees in Goma, Zaire. *Lancet* **345**: 359–361.
- Taxe R., Seminario L., Tapia A. R. and Libel M.** (1994). The Latin American epidemic. In *Vibrio cholerae and Cholera.* (I. K. Wachsmuth, P. A. Blake and Ø. Olsvik, eds), pp. 32–344. American Society for Microbiology, Washington, D.C.
- Tietze K., Geyh, M., Miller H., Schroder L., Stahl W. and Wehner H.** (1980). The genesis of the methane in Lake Kivu (Central Africa). *Geol. Rundschau* **69** (2): 452–472.
- UNEP** (2002). Environmentally sound technologies for wastewater and storm water management. *Technical Report Series No.15.* Division of Technology, Industry and Economics International Environmental Technology Centre (IETC) Osaka/Shiga.
- UNICEF** (2006). Cholera outbreak. *Angola Situation Report, 5th May.*
- WHO** (1993). *Guidelines for Drinking-Water Quality,* 2nd edn. Vol.1. *Recommendations.* WHO, Geneva. ISBN: 92 4 154460 0.
- WHO** (2001). Cholera 2000. *Wkly. Epidemiol. Rec.* **76**: 233–240.
- WHO** (2002). *Water and health in Europe: A Joint Report from the European Environment Agency and the WHO Regional Office for Europe.* WHO Regional Publications, European Series No. 93.
- WHO** (2004). www.who.int/water_sanitation.health/publication ns/facts2004/enindex.html.