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Water quality issues in West and Central Africa: present status and future challenges

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Abstract An overview of freshwater quality in West and Central Africa is proposed by reviewing recent selected literature. Water quality degradation in the region is mainly attributable to: anthropogenic activities, communities' socio-economic conditions and natural sources. Surface and groundwater contamination by organic matters, *Escherichia coli*, nitrates, phosphates, pesticides, hydrocarbons, heavy metals and fluorine ions are reported. In cash crop production areas, the large quantities of pesticides and fertilizers used explain residues in the ground and surface water in many countries. Unsafe domestic wastes are an important source of water pollution in capital cities due to overcrowding, poverty, and low sanitation in precarious neighbourhood areas. Eutrophication is seasonally observed in lakes or lagoons with high concentrations of nitrates in urban areas. The challenges to overcome are a promotion of strategic research with a high diffusion level, pollution prevention measures which include the behaviours of all communities through the application of laws and respect of norms, an allocation of financial support for water analysis and treatment, and suitable sanitation for health preservation. To face the pollution of freshwater by pesticides residues, fluorine and arsenic ions, intensive research based on local natural materials for cheap and easy water purification technologies is a priority.

Key words freshwater; quality; pollution; present status; future challenges; West Africa; Central Africa

INTRODUCTION

Water resources face increasing pressure from human needs, climate change and pollution, major environmental problems in Africa. Due to rapid urbanization, agricultural practices and industrialization, water pollution is responsible for many premature deaths and diseases due to pathogens and toxic pollutants. West and Central Africa nations are developing countries with a lack of clean drinking water and limited access to sanitation facilities. Although access to water supply and sanitation in Sub-Saharan Africa has been steadily improving over the past two decades, rising respectively from 49% to 60%, and 28% to 31% between 1990 and 2008, the region still lags behind all other developing regions. Access to improved water supply in Sub-Saharan Africa is unlikely to meet the Millennium Development Goals (MDGs) of halving the share of the population without access to safe drinking water and sanitation between 1990 and 2015. There are, however, large disparities among Sub-Saharan countries, and between urban and rural areas. In the entire Sub-Saharan region, water supply and sanitation coverage in urban areas is almost double the coverage in rural areas, both for water (83% in urban areas, 47% in rural areas) and for sanitation (44% *vs* 24%) (WHO/UNESCO, 2010). Yet, the rural areas improve at a fast pace, whereas in urban areas, the extension of water supply and sanitation infrastructure can barely keep up with the fast urban demographic growth.

In a context of climate change, with increasing pressure on water resources, there is a need to identify new challenges for a regional solution to achieve the MDGs. This paper provides a review of the literature covering the issues related to freshwater resources quality in West and Central Africa. The objective is to understand the level of pollution in these regions for a good management beneficial to population's needs.

METHODOLOGY

The literature review concerned recent selected papers, the websites of institutions with water as a subject or interest (UNESCO, WHO, FAO, PAN-Africa, Water and Sanitation Program-Africa), and information from reports of conferences held in Africa. A great amount of water quality monitoring is done by water suppliers' laboratories, students from universities and in reports by experts. Some of these documents are only available at the local level. Many documents are from

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institutions, or networks such as Water and Sanitation for Africa (WSA) (ex-CREPA), SOACHIM. The main indicators for water quality used in this review are those investigated for a pollution profile of water, i.e. constituents which are toxic and seen as active pollutants. They belong generally to the following common groups: microbiological pathogens (bacteria, viruses and protozoa), heavy metals (cadmium, chromium, lead, mercury, arsenic and nickel), oils, organic compounds, pesticides, anions and cations (nitrates, phosphates, sulphates, Ca^{+2}, Mg^{+2} and F^{-}). For bacteriological pollution *E. coli*, total coliforms and faecal streptococcus (WHO, 2003) are the usual indicators.

WATER POLLUTION SOURCES

West Africa and Central Africa comprise 16 and 11 countries, respectively. All are Sub-Saharan countries (Fig. 1) and deal with similar challenges in the following context: (i) Low economic development, (ii) fast growing population particularly in big cities, (iii) low education level of the population, (iv) low social conditions in terms of accommodation, energy, sanitation, health, drinking water, (v) growing need for food security, and (vi) increasing demand for water for drinking and agricultural purposes. The transboundary waters of the West African coast are defined by the Guinea Current Large Marine Ecosystem, the Niger (about 4200 km long), Volta and Congo (about 4700 km long), rivers discharging into the greater Guinea Current region (Ukwe & Ibe, 2010).

These countries face similar water pollution patterns, mainly due to: (i) intensive use of pesticides and fertilizers in agriculture, (ii) improper dumping of solid wastes, (iii) discharge of untreated wastewaters from households and industries, and (iv) some natural pollutants of geological origin. In the region of focus, high fluorides and arsenic are documented in different parts. Thus, there is an urgent need to map the water quality for both microbial and other pollutants before any attempt is made to treat or preserve the water resources.

Fig. 1 Area of the present investigation.

1 Pollution due to domestic activities

Unsafe solid wastes from domestic activities are an important source of water pollution in many capitals, such as Yaoundé (Cameroun), Lagos (Nigeria), Abidjan (Ivory Coast) and Dakar (Senegal) due to overcrowding, poverty and low sanitation in precarious neighbourhood areas. Rural to urban migration has led to rapid development in African towns in relatively small areas under poor conditions of sanitation. The impact is that the municipalities cannot provide water supply and sanitation. For example, in 2000, urban areas of Ghana generated about 763 698 m^3 of wastewater each day, resulting in approx. 280×10^6 m^3 over the entire year. In addition, during the

rainy season, wastewaters and non-disposed wastes were washed and drained to surface water in place with a favourable topological context (Agodzo & Huibers, 2011).

In areas of high population density and near rivers and dams, a large proportion of household wastes are disposed of with high contents of biodegradable organic matter leaching out of the wastes. Depending on the type of waste, the resulting leachate may be highly acidic, have a large organic load or contain a high concentration of ammonia, toxic metals or various organic compounds, all of which may contaminate underlying groundwater (Morris *et al.*, 2003). Their discharges contribute to increased organic load of water and sediment promoting eutrophication of rivers or dams as well as heavy metals contamination (Scheren *et al*., 2004; Kouamé*et al*., 2006; Ajeagah*et al*., 2010; Bouvy *et al*., 2010; Dibi*et al*., 2010; Segbeaya, 2012).

Along the Sub-Saharan Africa coast, notably in the Gulf of Guinea, many capitals or cities have developed without concomitant development of wastewater treatment. Consequently, near-shore activities and poorly managed coastal development pose a rapid degradation of vulnerable coastal and offshore habitats with a direct threat to human health and the environment. In Cotonou in particular, motorbike taxis and vehicles use poor quality fuel, which worsen pollution by lead, and has led to the slump of crustaceans on the European market (Fanou *et al.,* 2006).

2 Agricultural activities pollution

In Sub-Saharan Africa (SSA) countries, a large proportion of the population depend on rainfed agriculture, mainly in rural areas, butalso in urban areas where growing population pressure is resulting in increased irrigation and market garden cultures. Cash crop cultivation of cacao, cotton, coffee, pineapple, bananas and palm oil represent real sources of direct pollution due to intensive use of fertilizers and pesticides, which increase productivity but threaten the environment and crop quality.

For cotton culture in West Africa, pesticides were applied from the 1950s until the 1980s with a mixture of DDT, endosulfan and methylparathion. Due to increasing resistance of the cotton bollworm (*Helicoverpa armigera*), application doses increased and the mixture was replaced by pyrethroids. With new resistance from cotton bolm worm in the 1999/2000 cropping season, many West African countries again allowed the use of endosulfan with organophosphates, pyrethroids and carbamates. Herbicide application also increased in the region (Martin *et al*., 2000).

Studies in Burkina Faso show pesticide contamination in soils, water and aliments (Toé *et al*., 2004; Savadogo *et al.*, 2006; Tapsoba *et al.*, 2008). In this country, intensive garden market cultivation is located next to dams and boreholes drilled for irrigation water, mainly in urban and peri-urban areas. Investigation of soil contamination in the Pendjari biosphere (northwest of Benin), highlight the importance of a buffer zone to protect the park from pesticide contamination. The biosphere reserve is divided into three distinguish zones, i.e. Agricultural zone, Protected Park zone, and the buffer zone between the agricultural zone and the park zone. Due to the banning of agricultural activities in the park zone, no residues of endosulfan were detected in water and pool sediments in the park. In the agricultural zone as well as the buffer zone, pesticides residues were detected (Pare *et al*., 2013).

3 Industrial activities pollution

As in developed countries, there is a great effort in SSA countries to promote industrialization. Unfortunately, these industries generate wastewaters without respect of local laws and population security. Wastewaters contaminate surface water by transfer of pollutants (heavy metals, dyes, POPs; Mérimo *et al*, 2008; Voegborio*et al*., 2011). Furthermore, West Africa has been one of the world's most important gold mining regions for centuries (Hilson, 2002). Today mining activity is undergoing expansion in many countries: Burkina Faso, Guinea, Niger, and with Ghana as the leader in gold mining. It is known that gold exploitation, mainly artisanal and small-scale gold mining, contribute to water pollution by mercury and cyanide leading to serious water and soil pollution and health problems (Sracek *et al*., 2012). In petroleum industry areas, thermal centrals and at distribution stations, there is no respect by the companies or by local administrations and

population of regulations causing a great deal of oil pollution. This mainly concerns the Niger Delta in Nigeria, the largest drainage basin in Africa, with real visible pollution of surface water in wetlands (Omo-Irabor *et al*., 2008).

4 Natural pollution

Many sites face arsenic pollution as a major problem for groundwater quality. The inorganic metal in the forms of arsenite AsO^{2-}(III) and arsenate AsO_4^{3-}(V) oxidative form are natural products of oxidative weathering and geothermic reactions (Smedley *et al*., 2002).

Fluoride, more toxic than lead but less so than arsenic, is an accumulative toxin in humans and increases bone/tooth and skeletal defects (fluorosis). High concentrations of fluorine were observed in water used by populations in south central Senegal and the Maradi area in Niger (Partey *et al*., 2008).

PRESENT STATUS

Water resources are supposed to be of good quality when populations have been drinking from them through generations without any major health problems. When hot spots are identified as direct sources of pollution (crowded areas, industrial and agricultural sites), monitoring plans are required to confirm the real state of the water resources, and define the best strategy to overcome the problems. In this context, several reports showed surface and groundwater polluted with organic matter, pathogens, nitrates, phosphates, pesticides, pharmaceuticals products, heavy metals and hydrocarbons. Table 1 reports data recorded in water quality investigations. Bacterial contaminations are reported in many studies in Cameroon (Table 1; Ajeagah *et al*., 2007; Kenmogne *et al*., 2011). Groundwater has in general excellent natural microbiological quality and adequate chemical quality for drinking and other uses. But some polluted areas are noticed, whether natural or through anthropogenic activities (Nola *et al.*, 2002; Bosque-Hamilton 2006; Ohou *et al.*, 2008; Bosque-Prosun *et al*., 2012; Douagui *et al*., 2012).

Eutrophication with invasion of water hyacinths in famous lakes or lagoons, dams and rivers in Africa is observed in Abidjan, Cotonou, Lomé, Yaoundé, Ouagadougou and Niamey. Water hyacinth proliferation in surface waters in capital cities reflects a conjunction of many anthropic activities with uncontrolled population growth without adequate sanitation facilities. In Cotonou, due to air pollution by lead, water quality monitoring showed levels around 900 mg/kg of Pb in shrimps (Fanou *et al*., 2006). In agricultural areas, surface water contamination by pesticides depends on the agricultural seasons, while groundwater contamination has a stronger persistence with a continuous toxicological effect for human health. There are few data for the specific circumstances of small-scale farms in West Africa (Kütting *et al*., 2003). Manirakiza *et al.* (2003) determined DDT residues in water with a concentration of 0.23 µg/L and in soil with 71 µg/kg. Savadogo *et al.* (2006) evaluated pollution of soils by pesticides that were used in cotton production during 2003 and 2004 in Burkina Faso. Soils were contaminated with endosulfan at a level of 1–22 µg/kg, and by dimethoate with a concentration of 1.7–5 µg/kg. Tapsoba*et al.* (2008) found endosulfan residues in soil from conventional cotton fields in Burkina Faso at concentrations of 21–69 µg/kg between the beginning of the cotton-growing period to the end of the rainy season. Within some bio-cotton fields, endosulfan residues were found at levels of 10–23 µg/kg in June and July. Smedley *et al*., (2007) make a study on arsenic in groundwater in the northern part of Burkina. Although most analysed groundwaters have As concentrations of less than 10 µg/L, they have a large range from <0.5 to 1630 µg/L. The high-As groundwaters observed derive from zones of Au mineralization in the Birimian (Lower Proterozoic) volcano-sedimentary rocks.

For nitrate, due to its source from agricultural activities and domestic activities, abundant literature is available (Table 1). High nitrate concentration is particularly dangerous for babies.

Table 1 Some selected data on water quality from the Sub-Saharan Africa region.

Water type	Sampling Site	No. samples	Parameters	Values found	Country	Reference
Groundwater	Abidjan	-	NO_3^-	>50 mg/L average	Ivory Coast	Soro, (2003)
	Abidjan	127		4–198 mg/L	Ivory Coast	Douagui *et al*. (2012)
	Borekolde/Cotonou	-		75.65 mg/L average	Benin	Boukari *et al*. (2006)
	Well water	40		184–380 mg/L	Nigeria	Adelana, (2006)
	Yaoundé town		*E. coli*	5–9.6 × 10^3 UFC/100 ml	Cameroun	Kenmogne *et al* (2011)
	Abidjan	68	Total coliforms	400–1000 CFU/100 ml	Ivory Coast, mainly found in wet season	Douagui *et al*. (2012)
			Thermo-tolerant coliforms	200–500 CFU/100 ml	Ivory Coast, mainly found in wet season	
	Boreholes	750	Fe	0.69 mg/L average	Ghana	Bosque-Hamilton (2006)
	Borehole/dugwell/ handpump	40	As(Tot), Mn, Fe	17 > than max limit permissible	Western Ghana	Prosun *et al*. (2012)
	Drilled wells	20	As (Tot)	16 with As(Tot) >10 µg /L	Northern Burkina	Guissou *et al*. (2006)
Surface water	Senegal River	-	Inorganic nutrient	Low	Senegal	Bouvy *et al*. (2010)
		-	Chlorophyl -a	Mean of 13.7–20.7	Senegal	
	Yaoundé town	-	*E.coli*	1.1 × $10^3$to 5.2 × 10^4 UFC/100 ml	Cameroun	Kenmogne *et al* (2011)
	Ebrié Lagoon	-	BOD	2/3 of the load from domestic effluent	Ivory Coast	Scheren *et al*. (2004)
	Ebrié Lagoon	-	N (Tot) and P (Tot)	33 $ktyear^{-1}$ load and 2.5 $ktyear^{-1}$ load	Ivory Coast	
	Cotton growing area	-	DDT	489 µg/kg	Benin	Soclo (2003)
	Cotton growing area	-		23 µg/kg	Benin	Yèhouénou (2005)
	Cotton growing area	-		545 µg/kg	Benin	Yèhouénou *et al*. (2006)
	Cotton growing area	-		82 µg/kg	Benin	Agagbé (2008)
	Cotton growing area	-	Organochloride pesticides	9–929 ng/L	Benin	Soclo (2003)
Bottled water	Cotonou		Mineralogy	OK	Benin	Agassounon *et al*., (2010)

FUTURE CHALLENGES

Despite the efforts of the United Nations to focus attention on the importance of freshwater through the annual World Water Day, nearly one billion people still lack safe sources of drinking water, with a third of them living in Sub-Saharan Africa. Future challenges need to be expressed for the MDGs and after the deadline, to reduce the current pollution and avoid future water quality problems. Our suggestions derive from our own experiences and also follow those already mentioned by other authors about water issues.

(a) Research in the sector of water is crucial to provide strong scientific data for policy development and decision-making and to assist strategies in the water sector. This is one of the new challenges of the Water and Sanitation for Africa (WSA) agency, which proposed to improve its contribution ton research after its meeting at Dakar in December 2012. This means high level equipment, certified laboratories, valid procedures to avoid obtaining invalid results,which can occur frequently in water monitoring studies due to the low level of water pollutants and their diversity. As an example, it is crucial in pesticide monitoring programs that samples are properly selected, transported and preserved in order to obtain relevant and

representative samples, worthy of analysis. All these research activities at the local and regional scale need financial support.

(b) Scientific data, good practices and knowledge diffusion. The number of scientific papers or relevant reports from West and Central Africa on water quality is very little in comparison to those from South Africa. This is attributable to the lack of permanent programmes on water quality monitoring, and the high cost of collecting and analysing chemical parameters. Many of the studies done by masters students in universities and reports from expert consultations are only available locally. Today, web technologies can enhance the availability online of all this data for useful purposes. In addition, existing agricultural technologies which limit water pollution need to be disseminated for additional input.

(c) Focus research studies on specific themes. Useful research could be new or to repeat research done elsewhere. Possible topics include pollutant transfer models (from cemeteries, cartography of groundwater quality profiles), residues of endocrine disrupting compounds (EDCs) present in effluents from industries and sewage treatment plants, pharmaceutical active ingredients (PAIs) residues in surface water.

(d) Usage of local cost-effective and available materials for water decontamination. Many studies have focused on naturally available adsorption media for water decontamination (Sajidu *et al*,, 2008; Paré *et al*., 2012). Adsorbents tested abundantly are activated carbon, biomaterials such as cellulose matrixes, chitosan and chitin, alumina clays, activated sludge, and also natural mixed clay. For water microbiological decontamination, promotion of adaptable cheap, easy technologies such as solar photovoltaic disinfection is a priority.

(e) Understanding and preventing the impact on health. Efforts have been made to evaluate the effects of pollutants in aquatic fauna in order to find specific bio-indicators, particularly for freshwater, to analyse the impact of drinking water quality on health. What is the real part of unclean water consumption on local disease development: amoebiasis, typhoid fever, emergent and re-emergent pathogens, effect on health? The Ecohealth approach promoted by IDRC was appropriate in transdisciplinary research between scientists and medical communities. For example public health observation and diseases prophylaxis could consider effect of nitrate, which can cause hypertension, anemia, infertility, nervousness, cancers in the human body (Yonkeu, 2005).

(f) Water quality governance. To work with subpopulations in a context of low resources, strong governance in water management through the application of rules is needed to prevent water pollution. Regarding environmental management, lack of legislation and/or none respect of laws (in wastewater disposal, environmental impact investigation before any habitat or industry development) is observed because pollution is complicated by the diversity of pollutants and their toxicity variability. The success of action depends on the educational level of the population and democracy level in the country (Clemmens, 2006). It is possible by positive synergies showing combinations of incentives, and enforcement of information on real targeted benefits or subsidies, to promote pollution prevention measures and cross-fertilization of ideas from all key-actors including communities and stakeholders.

(g) Groundwater protective strategies. To face the increasing withdrawal of water and climate change, groundwater protection strategies are important, and cheap, to preserve its natural quality (Biaou *et al.*, 2011). The quality of groundwater is so far evaluated on only an intermittent basis predicting signs of pollution within a 30 m depth. Sub-Saharan Africa uses only 5% of its renewable freshwater resources while the whole world uses 64% of the renewable freshwater resources. In 1999, groundwater use was estimated in billion (10^9) m^3 use per year as 9.5 for Burkina Faso, 20 for Mali, 1 for Niger, and 37.7 for Ivory Coast (NEPAD, 2006). The priorities are to protect the main recharge zones and to encourage aquifer research as an alternative to improve water services in West and Central Africa. The renewed "Roadmap for the Nigeria Water Sector" considered groundwater as a viable alternative for quantitatively and qualitatively reducing water need. Developing capacity in hydrological and hydrogeological knowledge is required to give importance to groundwater.

(h) To face risks of deterioration in the near future, modelling seems to be a powerful tool for preventive actions. One can note the usefulness of this method in climate change studies. To develop water resource protective strategies and establish early warning prevention systems, more simulations are needed to study rivers sedimentation, fluvial erosion, lagoons decontamination from petrol, aquifer recharge, impact of floods on freshwater quality, and mercury transfer to groundwater in small-scale gold mine areas. Some observatories for water quality monitoring could be installed to identify the origins of pollutants and support the modelling.

(i) Transboundary water resources management. Nearly 40% of the world's population depends on river systems shared by two or more countries, leading to political hot spots. An example is the Nile River, which represents 97% of Egypt's freshwater (NBI, 2005). The Volta River basin is spread over parts of six West African countries (Benin, Burkina Faso, Cote d'Ivoire, Ghana, Mali and Togo) covering an estimated area of 400 000 km^2 and the river flows for a total distance of 1850 km. Recognizing the importance of coordinated management of shared natural resources, the governments of these countries signed a convention on the Volta basin and established the Volta Basin Authority (VBA) in 2009 tasked to: promote permanent consultation tools among the basin's stakeholders, promote the implementation of IWRM and the equitable distribution of benefits, evaluate planned infrastructure development that impacts the water resources of the basin, develop and implement joint projects and works and contribute to poverty reduction, sustainable development and socio-economic integration of the sub-region. In a context of vulnerability due to low development, with climatic change effects, the management of such a basin is a challenge for water resources quality.

CONCLUSION

From the available literature, a review of scientific data about water quality showed some hot spots focused in towns with permanent microbial and organic pollution of water. High nitrate concentration produces eutrophication and, at present, surface water quality mirrors the level of development in West and Central Africa. In rural areas, one can note that research focused on pollution due to agricultural activities revealed that due to cash crop cultivation, such as coffee, cacao and cotton, real pollution of freshwater is observed. The impact of unclean water on population health must be evaluated through interdisciplinary research including medical scientists and all stakeholders. In general, significant improvements of the logistics of water quality monitoring and implications for beneficiaries in water management are crucial. To reach the objectives of the Millennium Development Goals in 2015, groundwater seems to retain more potential in its chemical profile, for protection, recharge and modelling to increase the proportion of safe water available for the population's needs.

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