Environmental and health concerns regarding the quality of water in a poor suburb of Kinshasa in the Democratic Republic of Congo

R. M. K. Vala, L. Tichagwa, D. E. Musibono and V. M. Lukanda

ABSTRACT

In many developing countries, the scarcity of potable water is an ongoing challenge. Even when water is plentiful, its quality may be unsuitable for household use such as in the city of Kinshasa in the Democratic Republic of Congo (DRC) which is the study area for this investigation. Shortage of potable water has forced inhabitants in the city to rely on water wells dug without adherence to regulations or specifications within perimeters of their homesteads. The water from such wells is often polluted with household waste being generally disposed by burning and burying in shallow pits, thrown in pit toilets or into rivers. Such practices have led to contamination of ground water. This study examines the water quality of drinking water drawn from wells in Fer-bois, which falls under the Kimbanseke municipality in the South East of Kinshasa. The dynamics of well design/location, sources of possible contamination with respect to water treatment and water quality as well as its possible impact on health are examined. The area was shown to have poor groundwater quality with significant amounts of pollutants such as NO₃, Pb and Cd leading to environmental and health concerns.

Key words | contamination, groundwater, physicochemical parameters, waste, water quality, WHO guidelines

INTRODUCTION

Inadequate water and sanitation is the major cause of disease in developing nations (Xu & Braune 2009) and the population of Kinshasa in the Democratic Republic of Congo (DRC) is counted amongst the 2.6 billion people deprived of improved sanitation services (Unicef 2008). Even in a country like DRC with many rivers and where rainfalls are often plentiful (averaging 1,529 mm per annum), the provision of potable water is a major problem. In one study, DRC had one of the lowest rates of access to drinking water and sanitation in sub-Saharan Africa (USAID 2008)

This is because the country has been devastated by years of war and political instability which has affected the capacity of the relevant Government departments to install and maintain an efficient water supply.

In the DRC, municipal water is supplied by ‘Régie des Eaux’ or better known as Regideso, the only enterprise in charge of water supply for cities and towns within the country, while some rural areas are sometimes supplied with borehole water by non-governmental organizations (NGOs). Regideso faces many challenges in its duty to provide water to the over 60 million population including those in capital city of Kinshasa. Efforts have been made to drill deep boreholes to meet the needs of an increasing population (afd 2008) but still many inhabitants are not served with a supply of water. Therefore, these inhabitants are forced to dig their own wells without adhering to standards, specifications or inspections by government. There is also a lack of an appropriate sewage disposal system. In this area there is generally no running water and most
of the inhabitants rely on latrines. An assessment of the impact of latrines on groundwater quality studied by some researchers in Zimbabwe resulted in findings that groundwater is negatively affected up to 25 m lateral distance (Dzwairo et al. 2006).

The water table in most areas of Kinshasa is typically at a shallow depth of less than 2 m while the environment around is polluted due to a haphazard approach to dumping brought about by the lack of official dumping sites. Contamination of groundwater is made likely by seepage of residues from the burning of plastic and organic waste which people end up doing to reduce accumulated waste. The area has poor drainage resulting from a low topographic slope with a shallow water table. This situation means that the unsaturated zone attenuation capacity is very limited (Singleton et al. 2007). In Kinshasa, many other areas have the same environmental characteristics as Fer-bois suburb.

This study aims to examine the physicochemical properties of water from household wells during rain and dry seasons with respect to variations in well characteristics such as location, design and depth. The current methods of water treatment used by the population of Ferbois are also examined to determine their adequacy or inadequacy. It is hoped that such information can help empower Fer-bois inhabitants make informed choices regarding use of well water for household use and also when they seek to improve their water system whenever they get the means to do so. Lack of national guidelines has led DRC authorities to use World Health Organization (WHO) guidelines for drinking water standards wherever possible. These provide a target for treated water.

**STUDY AREA, MATERIAL AND METHODS**

**Description of the study area**

Fer-bois (±504.800 km²), the area of this study illustrated in Figure 1, is located about 2 km from the main Ndjili airport to Kinshasa town road. In Fer-bois, streets lie perpendicular to the main road (Route de Mokali). In this study, there were 25 operational wells in the Fer-bois area but only a selection of four wells (W₁, W₂, W₃ and W₄) considered for water sampling.

**Selection and characteristics of wells**

In the current study, the selection of a well for water sampling was carried out according to the following criteria: the well was to be used during the rain and dry season; had to serve at least three families; was to be accessible at any time for sampling and field research and had to be a reasonable distance from the other wells selected.

In W₄, the water was mechanically pumped from the ground while water from wells W₁, W₂, W₃ was hand-drawn using a container tied to one end of a long thick rope. Additional characteristics of the wells were:

**Well W₁** – This well was more than 20 years old, and was located in a non-enclosed courtyard and was accessible to anyone during the day. Sometimes water had a green colour and was smelly (during both the rain or dry season). There were 9 other wells found within a 200 m radius of this well.

**Well W₂** – This well was more than 40 years old. Access was limited to a few people. There were 7 other wells within a radius of 200 m of W₂.

![Figure 1](https://iwaponline.com/ws/article-pdf/11/3/266/416501/266.pdf)
Well W3 – This well was 24 years old and was located in a plot with free access to the public. There were 10 other wells within 200 m of W3.

Well W4 – This was a borehole 6 years old which was drilled by Oxfam NGO (Canada) and was located in a Missionary Parish.

Characteristics such as depth, distance between wells and any source of pollution, well-curb, type of water treatment (if any), materials used for construction, well dimensions (type, size and wall thickness), surface mounding (slope around the well) and type of covering while the well was not in use were also recorded and summarized in Table 1.

Some potential contaminant sources

The locations of latrines, metal works and a common dumping site and distances of the wells from each other are illustrated in Figure 2.

Dumping sites

A major environmental concern in Fer-bois is that waste is often burnt or buried in the courtyards of homesteads because of insufficient dumping sites. Many homesteads bury rubbish within courtyards because of infrequent garbage collection by the municipality which collects only about 20% of all household rubbish.

### Table 1 | Summary of well characteristics

<table>
<thead>
<tr>
<th>Well</th>
<th>Construction material</th>
<th>Depth</th>
<th>Diameter or dimensions</th>
<th>Well-curb</th>
<th>Distance from pit latrine</th>
<th>Distance from next well</th>
<th>Covered or not covered</th>
<th>Water treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>Cement</td>
<td>1.5 m</td>
<td>Rectangular 45 cm</td>
<td>55 cm</td>
<td>6 m</td>
<td>20 m</td>
<td>Not covered day &amp; night</td>
<td>671 g NaCl at the end of August</td>
</tr>
<tr>
<td>W2</td>
<td>Cement</td>
<td>2.5 m</td>
<td>Rectangular 64 cm</td>
<td>45 cm</td>
<td>6 m</td>
<td>60 m</td>
<td>Rarely covered</td>
<td>25 tablets of ‘Micropur’ (chlorine dioxide) in September</td>
</tr>
<tr>
<td>W3</td>
<td>Steel</td>
<td>3 m</td>
<td>Rectangular 50 cm</td>
<td>30 cm</td>
<td>15.7 m</td>
<td>&gt;20 m</td>
<td>Usually covered</td>
<td>578 g NaHCO3 (end of dry season)</td>
</tr>
<tr>
<td>W4</td>
<td>Steel</td>
<td>22 m</td>
<td>Rectangular 50 cm</td>
<td>30 cm</td>
<td>&gt;20 m</td>
<td></td>
<td>Covered</td>
<td>400 g of granular chlorine at the end of August</td>
</tr>
</tbody>
</table>

![Figure 2](https://iwaponline.com/ws/article-pdf/11/3/266/416501/266.pdf)
Metal industries

Another environmental concern is the illegal discharge of different types of waste at any open unoccupied space in the area, exposing the ecosystem to harmful pollutants such as metallic waste. In one study by Oluyemi et al. (2009), high contents of Pb and Cu in water were recorded for a well dug near scrap iron and metal recycling facilities. As much as 13–26 g of Pb per kg used and 22 grams of Cu per kg used was found to have leached into the water at 40 cm depth. Table 2 shows the number of metallic industries in the area which illustrates the degree of metallic waste contamination affecting the area’s ecosystem.

Depending on the location of the metals industry, waste produced from small enterprises is dumped into the sewage system, open areas or in workyards which results in metal contamination of groundwater through reactions and/or dissolution. Also, environmental weathering of waste has polluted groundwater passing through areas with a sandstone soil texture (Robles-Arenas et al. 2006; Kulabako et al. 2007).

Water sampling and analysis

Water sampling was done at 30 cm below the water surface in the well for W1, W2, and W3 and directly at the pump for W4 after 3 min of water flow. Before sampling, bottles were washed and rinsed with water to be analyzed. Plastic bottles of 0.5 to 1.5 L were completely filled, immediately stoppered and kept for analysis as practiced in other studies (World Health Organization 1985; Tomar 1999). Samples were collected twice weekly between 06:00 and 07:00 in July–August (dry season: no rainfall) and in January–February (rain season with a lot of rainfall). Samples were analyzed on the day of sampling to avoid unnecessary chemical degradation of the constituents.

<table>
<thead>
<tr>
<th>Type of metal industry</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car battery repair</td>
<td>15</td>
</tr>
<tr>
<td>Saucepan foundry</td>
<td>10</td>
</tr>
<tr>
<td>Brazier makers</td>
<td>5</td>
</tr>
</tbody>
</table>

Each analysis was done in triplicate. Nitrite, nitrate, sulfate, phosphate, calcium, magnesium, suspended matter, colour and turbidity were analyzed by using a UV spectrophotometer at 507, 500, 450, 890, 522, 810, 455 and 450 nm. Conductivity and total dissolved solids (TDS) were determined using a Hach Conductivity Meter while pH was measured (at 25 °C) using a Hach pH-meter. Biochemical Oxygen Demand (BOD) and alkalimetry were determined by titration while Chemical Oxygen Demand (COD) was determined by a Fisher Bioblock COD-meter. Heavy metals were analysed by UV–Vis spectrophotometer Hach 2400: Cd (at 595 nm), Pb (at 283 nm) and Zn (at 620 nm). The average from the triplicate analyses was recorded for each parameter measured or determined and the results given in Tables 3, 4 and 5.

RESULTS AND DISCUSSION

Analyses were done for physical and chemical parameters on water from wells W1, W2, W3 and W4.

Physicochemical parameters of groundwater

Analysis results of physicochemical properties of water are presented in Table 3.

Electrical conductivity

The electrical conductivity is a useful parameter of water quality for indicating salinity hazards. Sensitive variation of electrical conductivity of groundwater in W1 and W3 observed indicates an extra contribution which may be due to the surface water runoff during rainfall. These values are lower than those found in groundwater such as was reported in Mozambique (Cronin et al. 2007)

Total dissolved solids (TDS)

TDS comprised mainly of inorganic salts with some small amounts of organic matter that are dissolved in water and provide a qualitative measure of the amount of dissolved ions. The presence of a high amount of TDS in drinking
water affects its organoleptic properties. In this study, TDS values ranged between 180–710 mg/L. WHO suggests water quality as: Excellent TDS < 300 mg/L; Good 300/C20 TDS/C20 600 mg/L; Fair 600/C20 TDS/C20 900 mg/L; Poor 900/C20 TDS/C20 1200 mg/L; and Unacceptable TDS > 1200 mg/L. The results show that water from well W2 had the lowest TDS followed by the borehole water from W4 while W1 and W3 had fairly high TDS values.

Colour and turbidity

Colour affects the aesthetic quality of water and raises doubt as to its purity when deeply coloured. Still, all water analyzed presented high colour values which were more than the 50 platinum–cobalt colour units recommended by the World Health Organization (WHO 1997). Colourless water is water exhibiting a platinum–cobalt colour value that is less than 50 colour units when measured at 455 nm using ultraviolet spectroscopy. The well with the nearest colourless water from the 4 tested was the water from well W4

Table 3 | Physicochemical analysis of groundwater during both dry and rain seasons

<table>
<thead>
<tr>
<th>Parameters</th>
<th>W1 Dry season</th>
<th>W1 Rain season</th>
<th>W2 Dry season</th>
<th>W2 Rain season</th>
<th>W3 Dry season</th>
<th>W3 Rain season</th>
<th>W4 Dry season</th>
<th>W4 Rain season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical conductivity (mV)</td>
<td>0.63</td>
<td>1.36</td>
<td>0.37</td>
<td>0.41</td>
<td>0.91</td>
<td>1.43</td>
<td>0.416</td>
<td>0.41</td>
</tr>
<tr>
<td>Total dissolved solids (mg/L)</td>
<td>310</td>
<td>680</td>
<td>180</td>
<td>200</td>
<td>450</td>
<td>710</td>
<td>210</td>
<td>200</td>
</tr>
<tr>
<td>pH</td>
<td>4.96</td>
<td>7.01</td>
<td>5.38</td>
<td>6.94</td>
<td>5.05</td>
<td>6.73</td>
<td>4.74</td>
<td>5.25</td>
</tr>
<tr>
<td>Colour (in platine cobalt)</td>
<td>197</td>
<td>190</td>
<td>100</td>
<td>58</td>
<td>123.5</td>
<td>108</td>
<td>51.6</td>
<td>60</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>29</td>
<td>37</td>
<td>14.6</td>
<td>10</td>
<td>21.3</td>
<td>20</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 4 | Some Chemical components of groundwater during both dry and rain season

<table>
<thead>
<tr>
<th>Parameters</th>
<th>W1 Dry season</th>
<th>W1 Rain season</th>
<th>W2 Dry season</th>
<th>W2 Rain season</th>
<th>W3 Dry season</th>
<th>W3 Rain season</th>
<th>W4 Dry season</th>
<th>W4 Rain season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended matter (mg/L)</td>
<td>33</td>
<td>38</td>
<td>26.6</td>
<td>18</td>
<td>29.6</td>
<td>27</td>
<td>27</td>
<td>26</td>
</tr>
<tr>
<td>Phosphates (mg/L)</td>
<td>0.53</td>
<td>4.6</td>
<td>1.13</td>
<td>14.64</td>
<td>4.6</td>
<td>10.75</td>
<td>0.20</td>
<td>3.6</td>
</tr>
<tr>
<td>Nitrites (mg/L)</td>
<td>0.04</td>
<td>3.7</td>
<td>0.03</td>
<td>0.05</td>
<td>0.12</td>
<td>0.11</td>
<td>0.06</td>
<td>4.8</td>
</tr>
<tr>
<td>Nitrates (mg/L)</td>
<td>76</td>
<td>136</td>
<td>76.6</td>
<td>147</td>
<td>105</td>
<td>97</td>
<td>117.5</td>
<td>198</td>
</tr>
<tr>
<td>Sulfates (mg/L)</td>
<td>69</td>
<td>5.4</td>
<td>33</td>
<td>13.46</td>
<td>20</td>
<td>8.65</td>
<td>7</td>
<td>4.5</td>
</tr>
<tr>
<td>Total alkalinity (mg/L)</td>
<td>169</td>
<td>41</td>
<td>65</td>
<td>12</td>
<td>207</td>
<td>15.5</td>
<td>210</td>
<td>10</td>
</tr>
<tr>
<td>Magnesium (mg/L)</td>
<td>1.65</td>
<td>0.40</td>
<td>1.65</td>
<td>0.15</td>
<td>1.45</td>
<td>0.61</td>
<td>4.53</td>
<td>0.80</td>
</tr>
<tr>
<td>Calcium (mg/L)</td>
<td>5.2</td>
<td>1.06</td>
<td>5.22</td>
<td>0.75</td>
<td>4.45</td>
<td>1.08</td>
<td>4.13</td>
<td>2.05</td>
</tr>
<tr>
<td>Hardness (meq/L)</td>
<td>2.56</td>
<td>0.54</td>
<td>2.57</td>
<td>0.34</td>
<td>2.20</td>
<td>0.61</td>
<td>2.97</td>
<td>1.05</td>
</tr>
<tr>
<td>BOD (mg/L of O2)</td>
<td>27.03</td>
<td>5.50</td>
<td>10.8</td>
<td>7.50</td>
<td>6.16</td>
<td>18</td>
<td>33.5</td>
<td>15</td>
</tr>
<tr>
<td>COD (mg/L of O2)</td>
<td>39.6</td>
<td>14</td>
<td>14.8</td>
<td>10</td>
<td>8.16</td>
<td>12</td>
<td>47</td>
<td>17</td>
</tr>
<tr>
<td>Lead (mg/L)</td>
<td>0.04</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
<td>0.02</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Cadmium (mg/L)</td>
<td>0.13</td>
<td>0.17</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc (mg/L)</td>
<td>0.04</td>
<td>0.09</td>
<td>0.02</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5 | Average concentrations of some of the parameters and WHO guidelines

<table>
<thead>
<tr>
<th>Parameters</th>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>W4</th>
<th>WHO guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate (mg/L)</td>
<td>106.00</td>
<td>112.00</td>
<td>101.00</td>
<td>178.00</td>
<td>&lt; 50</td>
</tr>
<tr>
<td>Pb (mg/L)</td>
<td>0.04</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
<td>0.01</td>
</tr>
<tr>
<td>Cd (mg/L)</td>
<td>0.13</td>
<td>0.15</td>
<td>0.20</td>
<td>0.015</td>
<td>0.003</td>
</tr>
</tbody>
</table>
which had a reading of 51.6 colour units while the most coloured water was from W1 with a reading of 197 colour units. This was an indication of extra contribution of organic or inorganic ions in water, which influence the turbidity (OMS 1986) and colour of groundwater making it unsuitable for drinking. This meant that borehole water looked cleaner in colour and the least turbid followed by W2 while W1 was the worst.

**pH**

For drinking water, a pH range of 6.0–8.5 is recommended (WHO, 1997). The pH values in the study ranged from 4.74 to 7.01 showing a general trend towards acidic water. These pH values are lower than those reported for groundwater in Zimbabwe (Love et al. 2006) which were closer to the WHO values. Consumption of water from such an environment can introduce risk of disease. These pH results necessitated an analysis of some heavy metals in the water from all the 4 wells. The heavy metals analysed were Pb, Cd and Zn in addition to the other metals Mg and Ca. The results of the analyses of the metals and other chemical parameters are summarized in Table 4.

**Chemical parameters of groundwater**

**Suspended matter**

Some pollutants do not dissolve in water; they settle and form a thick suspension at the bottom. As much as 18–38 mg/L of suspended matter were recorded in samples from the wells with W1 showing the highest value. This parameter affects water turbidity which is confirmed by turbidity measurements which also showed that W1 had the highest value. These concentrations raise concern on the quality of water used in households. Well W2 had the least suspended matter.

**Phosphates**

The phosphate content of the groundwater was found to be in the range 0.20–14.64 mg/L. The highest value of 14.64 mg/L was recorded in water samples from well W2 which was undesirable for household water. This could have been a specific phosphate contamination which occurred at the well during the rainy season because other than this, well W2 was one of the least polluted.

**Nitrites and nitrates**

In groundwater, nitrate is often an indicator of fecal or sewerage system pollution. Despite the fact that nitrite concentration in all the wells is normal as recommended by WHO (<10 mg/L), all the groundwater remained inappropriate for drinking because of the high levels of nitrate (recommended < 50 mg/L), the highest being 198 mg/L in well W4. Nitrate can be converted to nitrite by reductive microorganisms in an infant’s stomach causing hemoglobin destruction (methaemoglobinemia), a condition responsible for many deaths in developing nations (Comly 1945; Walton 1951; Agarwal et al. 1981; Roberts & Dainty 1991; Hill 1999; World Health Organization 2004). Nitrate can also be converted to nitrosamines which are carcinogenic substances and yet such contaminated water is used by many households in Fer-bois. It is not advisable to cook babies’ and infants’ food with nitrate content of more than 50 mg/L in water. All the water from the 4 wells had more than this value and nitrate content ranged from 76 to 198 mg/L which raised serious concern.

**Sulfates**

The sulfate content of groundwater was found in the range of 4.5–69 mg/L. These concentrations do not raise any concern because the WHO drinking water limit is 250 mg/L.

**Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)**

BOD gives a general idea of the extent of pollution. In this study BOD was found in the range of 5.5–27. Groundwater samples from well W1 and well W4 showed high degrees of organic pollution with concentrations of 27.03 and 33 mg/L of O₂, respectively. The COD test is helpful in indicating toxic conditions and the presence of biologically resistant organic substances. In the range of 10–47, the maximum COD value was recorded in samples from W4 which was the borehole. The long distance between any source of
pollution and the borehole suggests pollution could have come from a decay of organic matter, such as observed in Cameroon (Mafany et al. 2006).

**Alkalinity**

The alkalinity of water is its capacity to neutralize acids. The maximum alkalinity was recorded as 210 mg/L in samples from the borehole (W4). Alkalinity of groundwater depends on the soil structure and chemical composition of the aquifer. The 4 wells had wide-ranging values of alkalinity (10–210 mg/L).

**Hardness**

Although not a pollution parameter hardness indicates water quality being influenced by the amount of calcium and magnesium ions. In the present study water samples showed values ranging from 0.34–2.97 meq/L.

**Heavy metals**

All the groundwater samples contained considerable concentrations of Pb (0.04–0.09 mg/L) and Cd, (0.13–0.20 mg/L) compared to WHO guidelines (Pb 0.01 mg/L and Cd 0.003 mg/L) (WHO 1997). Similar heavy metals concentrations were found in Nigerian groundwater (Adekunle et al. 2007). Concentration of zinc was not a worry because of the low amount and the fact that it is a nutrient. The high lead content could have leached from car batteries from old cars such as found by Oluyemi et al. (2009).

It was noticed that electrical conductivity, dissolved solids, pH values and nitrates were higher in the rain season than in the dry season for all wells (except for W3 which showed a slightly lower value). For most of the wells including W4, parameters such as water colour, sulphates, alkalinity, water hardness, Mg, BOD and COD were less in the rain season. It was surprising to note that the borehole water of W4 was as highly contaminated as the other wells and had the highest concentrations of nitrates and nitrates in the rain season because with rising water levels in the rain season the dilution factor may have been expected to reduce the nitrite and nitrate concentrations in W4. The COD and BOD were the highest in W4 in the dry season even though it was deeper (22 m) as compared to (1.5–5 m) for the wells W1–3 which suggests that pollution may have been from underground sources such as decaying organic matter. The fact that W1 (the only well uncovered at all times) showed the highest dissolved solids, colour contamination and turbidity may suggest that some of the contaminants may have been introduced through the opening to the well.

Among different parameters studied and comparing with WHO guidelines, nitrates, lead and cadmium attracted the most attention because of their toxicity raising health concerns. Table 5 summarizes the pollutants concentration and WHO guidelines.

The high concentrations of the above pollutants recorded gave reason for concern.

**CONCLUSION**

Physicochemical analysis of groundwater from wells in Fer-bois, a poor residential suburb of Kinshasa in the DRC showed that the household water in use exposed this area’s population to various pollutants which included unacceptable high levels of nitrates, lead and cadmium which are potentially very harmful to health. There was no significant influence from well design e.g., surface mounding. Covering on some of the wells did not seem to help the situation much confirming that much contamination occurred through underground reactions or transport. In some cases rain seems to provide a medium for transporting contaminants as indicated by higher incidents of pollution during the rainy season as compared to the dry. Some of the heavy metal pollution will probably have come from the metal industries around Fer-bois.

The distance of 6 m between pit latrines and wells surprisingly seemed adequate in this particular study contrary to the results of other researchers such as Dzwairo et al. (2006). This could perhaps be due to the differences in soils, slopes and the diluting factor of rains (Chidavaenzi et al. 2000) since Fer-bois has low topography. Without adequate dumping sites provided by the municipality, the population might continue digging pits in their backyards to dispose of household waste which raises serious health and environmental concerns.
The results of this study lead to concerns about future negative impacts on the health of the population of Fer-bois. It is recommended to seek solutions by developing more efficient ways for waste disposal in the city in addition to applying more effective water treatment methods as those applied in W1 to W4 were not adequate.

REFERENCES


First received 1 November 2010; accepted in revised form 4 May 2011