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RESEARCH ARTICLE

ASSESSMENT AND DETERMINATION OF SELECTED PHYSICAL PARAMETERS OF SURFACE WATER IN CEMENT FACTORY, WESTERN PROVINCE, RWANDA

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ABSTRACT

Cement is by far the most widely used man-made material. This study aimed at assessing and determining physical parameters of surface water in cement factory in Western Province of Rwanda. CIMERWA Ltd Plant is using the dry process method to produce cement. Water samples were collected from nine stations along the water course of CIMERWA Ltd Plant. The water samples were examined for physical analysis in WASAC Ltd laboratory using coloration methods, conductometric method and photometric method for pH, total dissolved solids, conductivity and turbidity. Temperature is measured using the digital thermometer. The results indicated that most of the physical parameters were within the recommended limits by Rwanda Standards Board for drinking water and discharged wastewater. It is recommended to regularly monitor of quality and quantity of wastewater produced by CIMERWA Ltd plant using the appropriate water treatment facilities.

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INTRODUCTION

Cement is a powdery substance made by calcining lime and clay, mixed with water to form mortar or mixed with sand, gravel, and water to make concrete (Loubana, 2013). Cement is a basic ingredient for the construction industry. It is the most common and widely used building material in the world and its by-product concentrate is the second most consumed substance universally after water (Lasserre, 2007). World cement demand was 2,283 million tons in 2005; the expected demand for 2010 was estimated at 2836 Mt. From 2005 to 2010, in North America, Western Europe, Asia/Pacific, other regions; the growth in cement demand growth rate was 2.9 percent, 2.2percent, 5.2percent, and 4.7percent respectively (Wang, 2008). China will increase its demand by 250 million tons during the period, an increase higher than the total yearly European demand; thus cement constitutes over 95 percent inputs of basic infrastructural developments in USA (Lasserre, 2007). Many analysts have pointed out that after the petroleum industry in some countries, the cement industry is the most controversial and most politicized because of the policy somersaults that relate to the proportional allocation to importation and domestic production (Ade-Ademilua and Obalola, 2008).

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In West Africa, the production was driven by Ghana, Nigeria and Senegal with approximately 2.1 million tons each in 2004 (World Bank, 2009). Rwanda is currently a cement deficit market. Cement consumption is concentrated in and around Kigali, which being the capital is seeing the maximum development, both in terms of infrastructure development and residential and commercial complexes/ buildings (African Development Bank, 2010).In Rwanda, the cement is used in infrastructural development such as construction of roads; manufacturing of bricks and housing. The cement industry and its associations continuously hinder the environmental performance by consuming a significant amount of natural resources and energy. The most dominant in Bugarama, Rusizi District environmental issues are the land degradation; carbon dioxide (CO_2) emissions and wastewaters (Rwanda Environmental Management Authority, 2009). Therefore, the World Bank/International Finance Corporation (2007) declared that the environmental issues in cement manufacturing projects primarily include air emissions (air pollution); energy consumption and fuels; wastewater; solid waste generation and noise pollution. Specifically, the natural environment (air, soil, water and natural vegetation) surrounding CIMERWA Ltd plant are becoming increasingly vulnerable to the effects of cement production through cement manufacturing processes and methods. Besides, there is evidently little understanding of the impact arising from cement production in Rusizi; there is a need to analyze the water physical parameters in order to inform on the best intervention and enhance existing living condition and environmental sustainability.

MATERIALS AND METHODS

Description of the study area

CIMERWA Ltd plant is geographically located at $2^0$35'43''Southof latitude and $29^0$02'16''Eastof longitude. It is positioned in Muganza Sector, Rusizi District of the Western Province. The location is about 350kilometers from Kigali and 60 kilometers from Kamembe town. The clay mining area is located in Muganza Sector; about 2 kilometers from the plant and the limestone and sandstone mining areas are located in Nyakabuye Sector at about 3 kilometers from the plant site (African Development Bank, 2010). The topography of the study area and the surrounding consists of plains, mountains and valleys. The drainage of the study area is governed by the catchments of Rusizi and Rubyiro rivers. The region has known a series of tectonic movements and has an important network of geological fractures resulting in a number of thermal water points on the ground surface like Mashyuza near the limestone quarry. Furthermore, the study area experiences tropical climate, characterized by an average temperature of24^{o}C and a dry season of three months starting from June to September. The total annual rainfall is about 1,050millimeters. There are two rainy seasons, the short wet season lasts from October to November and the main rainy season lasts from mid-March to end May.

The evapo-transpiration has been calculated as 51.9 millimeters, the runoff is 27.6millimeters with the resultant storage being 13.7millimeters. Considering the flow of water in Njambwe River, which has been measured as 141,313 cubic meters/day, the withdrawal of about 1200cubic meters/day surface water to meet the water requirement of the proposed CIMERWA Ltd plant and the local population shall not adversely affect the hydrological conditions of the area. CIMERWA Ltd is the only cement company in Rwanda that mines the raw materials, produces the clinker concentrate, packs and sells cement for general and civil construction. Some of its products are exported to the Democratic Republic of Congo and Burundi. CIMERWA Ltd has invested USD 170 million in a new modern dry process production plant at its head office in Bugarama with a capacity to turn out 600,000 tons of cement per year. The plant was commissioned in August 2015.CIMERWA Ltd is 51 percent owned by Pretoria Portland Cement (PPC) Company Ltd, Southern Africa's largest cement producer. The PPC Ltd has been in the cement business for more than 100 years and is a public company listed on the Johannesburg Stock Exchange. CIMERWA plant is committed to building strong partnerships with leaders and members of the local community. In the process, the firm has helped set up a number of initiatives geared at improving the livelihoods of the people. These include a nursery and primary school, medical clinic, an ambulance and providing them with clean, piped water.

Field works, sampling and analytical procedures

The water samples were taken in CIMERWA Ltd plant zones and the surrounding areas.

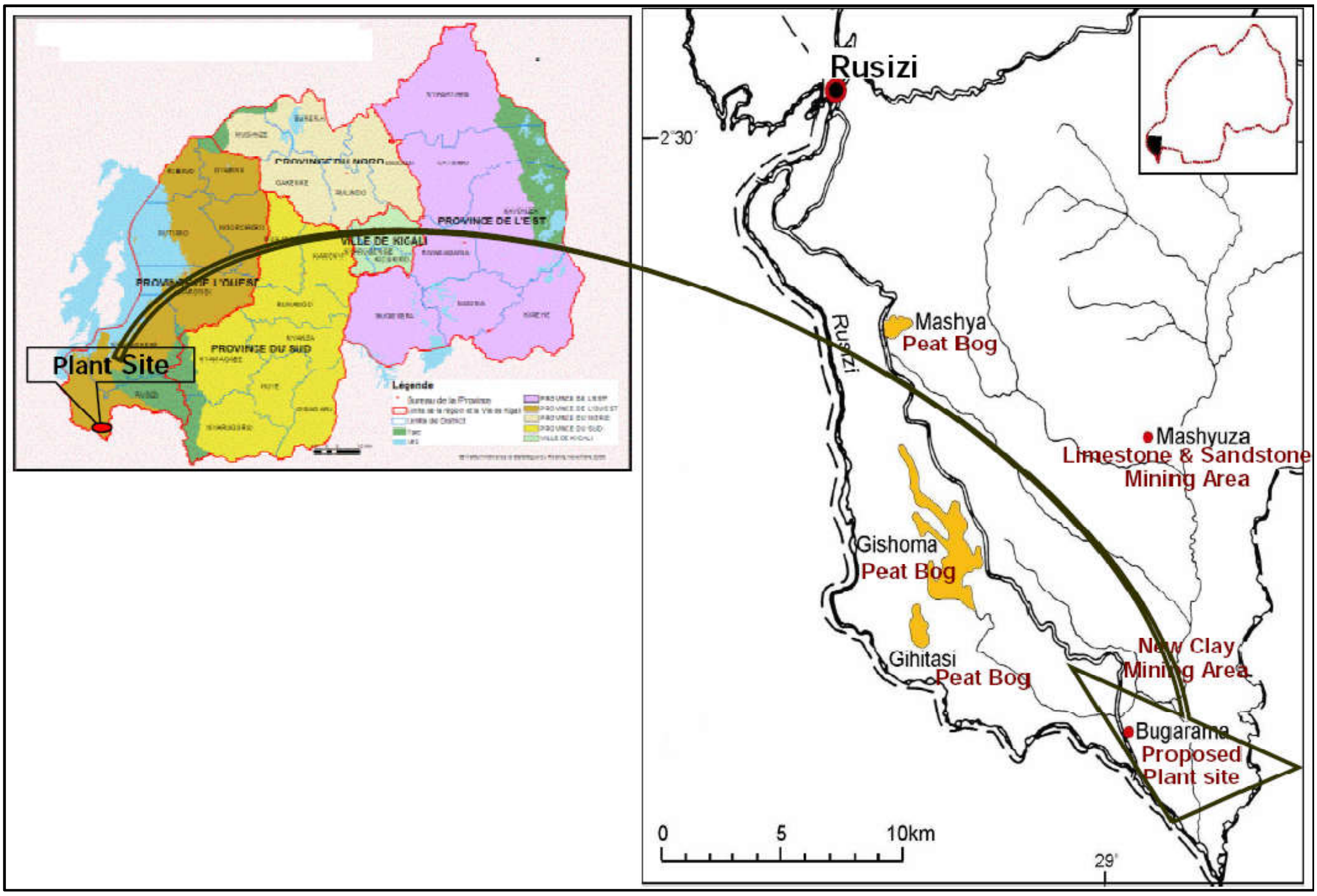

Figure 1. Localization of CIMERWA Ltd plant (Source: AfDB, 2010)

Table 1. National Standards for Drinking Water (RS EAS 12:2014) and National Tolerance Limits for Discharged Wastewater (RS 110:2009)

Parameters	pH	Temperature (ºC)	Turbidity (FTU)	TDS (mgL^{-1})	Conductivity (μScm^{-1})
RS 110:2009	5-9	25	30	2000	≤2500
RS EAS 12:2014	6.5-8.5	25	-	700	1500

-: missing values; *FTU: Formazin Turbidity Unit.Source: EAC, 2015.

Table 2. pH water interpretation norms

pH	Strongly acid	Highly acidic	Acidic	Moderately acidic	Neutral	Alkaline
Interval	3.5 – 4.2	4.2-5.2	5.2 – 6.2	6.2 – 6.9	6.9- 7.6	7.6 – 8.5

Pietrowiez, 1982.

Table 3. Selected physical properties of surface water samples used in the study

Parameters	Locations								
	Raw water	Treated water	Room 44	Kiln discharge	Storm water	Cement mills	Sewage plant workshop	Small sewage plant	Educateur effluent
pH	7.5	5.0	5.5	7.0	10.0	10.0	5.0	7.5	10.0
Temperature (ºC)	22.2	22.4	24.3	30.3	27.0	25.4	23.0	22.4	22.1
Turbidity (FTU)*	654.0	9.6	159.0	35.4	88.7	37.1	69.1	48.7	222.0
TDS (mgL^{-1})	63.7	85.4	83.5	86.7	189.0	781.0	185.0	186.0	171.0
Conductivity(μScm^{-1})	126.6	171.1	167.1	173.6	384.0	1555.0	370.0	371.0	345.0

Author, 2018.

The samples were randomly collected from nine different locations. After sampling, samples were packed in bottles and labelled with respect of their origin. The samples were transported in Water and Sanitation Corporation Limited (WASAC Ltd) laboratory for analysis of physical properties. The physical parameters of the samples were determined by the standard operating procedures. The pH of water was determined using the coloration method. We compared the colors on the pH paper package in order to determine the pH of the sample. We used water solutions to test the pH paper and practice determining colors on the color scale. Using different solutions could help visualize the different colors on the scale and determine the exact pH range (Schafer, 2006).The total dissolved solids and conductivity were determined using the conductimetric method. We dipped the TDS probe into water and TDS meter measured how well water conducts electricity. It then converts that to concentration of total dissolved solids (Howard, 1933). The turbidity was determined using the photometric method as described by Fog, 1952.

RESULTS AND DISCUSSION

The physical properties of the samples are shown in the Table 3. The pH of storm water, cement mills and Educateur effluent is high (10.0) compared to other zones. The lowest pH value (5.0) has been found in treated water. The pH in plant ranged from 5.0 to 10.0 while in Njambwe River (7.5) was above the range suggested by RS EAS 12:2014 (6.5-8.5). The pH in storm water, cement mills and Educateur School is exceeding the RSB drinking water guidelines ranges (5.0-9.0). The pH of water in CIMERWA Ltd plant varies from highly acidic (4.2-5.2) to alkaline (7.6-8.6) which is in agreement with the interpretation norms of Pietrowiez, 1985.Water surrounding cement factories, especially downward areas, exhibit elevated pH levels (Ade-Ademilua and Obalola, 2008). When these acidic compounds that are deposited to the earth's surface, they can impair the water quality of different water bodies and acidify lakes and streams in the surrounding areas of cement factory. Acidification (lowpH) and the chemical changes result in making it difficult for some fish and other aquatic species to survive, grow, and reproduce (Shraddha and Siddiqui, 2014).

The results (Table 3) are in agreement with Ade-Ademilua and Obalola, 2008 that the pH of the control and cement-polluted water were alkaline but that of the polluted water was more alkaline. Similar studies on cement dust pollution show elevated levels of soil and water pH (Adamson *et al.,* 1994; Mandre, 1997; Mandre *et al.,* 1998). The results (Table 3) showed that the temperature in CIMERWA Ltd plant fluctuates between 22.1^{0}C to 30.3^{0}C. The highest temperature has been observed in kiln discharge whereas the lowest temperature was observed in Educateur effluent. The temperature also varies depending on the activities conducted in each region. Considering the guidelines of RSB (2009) on the temperature of water in Njambwe River, treated water, Room 44, Sewerage 1, Sewarage 2, Educateur School is below to the range suggested by RSB (2009) (25^{0}C) while in kiln discharge, storm and cement mills the temperature is 30.3^{0}C; 27^{0}C and 25.4 ^{0}C respectively. Rani *et al.,* (2005) recorded the peak temperature of 30^{o}C and 32^{o}C in waste water samples of Ariyahur and Reddipalayam cement industrial zones in India. These results are in agreement with the findings in CIMERWA Ltd plant.

Moreover, Meme *et al.,* 2014 reported that the water temperature in North Cement factory waste water varies from 24-27^{o}C which is in agreement with the temperature in CIMERWA Ltd plant kiln discharge, storm water, cement mills and Room 44.The turbidity varies 645 FTU to 9.6 FTU with respect to the zones. The raw water has 645FTU as the highest value while the treated water has 9.6FTU as the lowest value. However, with reference to the RSB (2009) guidelines we observed that the turbidity is behind the recommended levels in all zones of CIMERWA Ltd plant. According to Meme *et al.,* (2014) found that the turbidity in Nigeria, cement factory in north central region ranged between 14 to 22.7 FTU which is in agreement with the results of the turbidity of treated water in CIMERWA Ltd plant. The highest value of TDS has been observed in cement mills (781mgL^{-1}) while the lowest value has been observed in raw water (63.7mgL^{-1}). The TDS varies depends upon the manufacturing activity that is happening. The TDS values are 63.7mgL^{-1}; 83.5mgL^{-1}; 85.4mgL^{-1}; 86.7mgL^{-1}; 171mgL^{-1}; 185mgL^{-1}; 186mgL^{-1}; 189mgL^{-1} and 781mgL^{-1} which correspond to raw water, room

44, treated water, kiln discharge, Educateur effluent, sewage plant workshop, small sewage plant, storm water and cement mills parts. Moreover, it has been remarked that the TDS in CIMERWA Ltd plant zones is behind the recommended levels by RSB (2009 and 2014) which are $1500mgL^{-1}$ in discharge effluent; $700mgL^{-1}$ in raw water and treated water and $\leq 2000mgL^{-1}$ in waste water or industrial discharge. However, the cement plant located in Nigeria near Kogi State presented the TDS of 52.7 to 108.8 mgL^{-1}; in fact, there is very high variation for some other parameters (Meme *et al.,* 2014 and Rani*et al.,* 2005).

The EC varies from $1555\mu Scm^{-1}$ to $126.6\mu Scm^{-1}$. The highest value was observed in cement mills whereas the lowest value has been observed in where the raw water is present. With reference the RSB (2014 and 2009) guidelines, we have observed that the EC in CIMERWA Ltd plant is below the recommended value depending on the zones and the activity that is being done there. The recommended EC in raw water and treated water is $1500\mu Scm^{-1}$; discharge effluent is $\leq 2500\mu Scm^{-1}$and in waste water or industrial waste is $\leq 2500\mu Scm^{-1}$.In addition, Meme *et al.,* 2014 stated that the electrical conductivity in Nigeria cement surrounding areas varies from 110.9 to 209.0 μScm^{-1}while in CIMERWA plant is 126.6; 171.1; 167.1 and $173.6\mu Scm^{-1}$ of raw water; treated water; room 44 and kiln discharge respectively.

CONCLUSION

The waste water produced by an industrial unit will depend upon the type and size of the industry, the process being used, and the extent of its reuse within the industry. The wastewater should be completely segregated and separately treated physically, chemically and biologically. Therefore, one concern which was observed in the laboratory results for water quality is that the conventional water treatment method used to treat Njambwe River is not complete; the coagulation process is not performed well with accurate doses. The way the lime is injected to adjust the pH is not well enough to be reliable. If the coagulation process is not performed well it affects all treatment processes and leads to the deviation of some parameters to the recommended limits of drinking water. On the side of sewer water most of measured parameters do not comply with the National standards for effluent discharge, the quality present harm to the environment as many of measured parameters do not comply with the standards even microbiologically. These results confirm that the efficiency of the treatment in removing the measured pollutants needs improvement on bacteriological removal thus will improve the microbiological quality of the effluent. For industrial discharged water, majority of measured parameters exceed the recommended limits. The discharged water are not treated and this can cause harm to the surrounding population and to the environment.

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