Sewage Sludge Management
A Case Study of Monrovia, Montserrado county Liberia

Victor Emery David Jr [a,*], Jiang Wenchao [b] ,' Yasinta John [c], Md Sahadat Shawpan [c]
[*] (College of Urban Construction and Environmental Engineering, Chongqing University, 400044 – China)
Email: (emerydavid2011@gmail.com)

ABSTRACT: Sewage sludge management has been a problem faced by most developing cities as in the case of Monrovia. The management of sewage sludge in Monrovia is still in its infant stage. The city is still struggling with poor sanitation, clogged pipes, shortage of septic tanks, lack of resources/human capacity, inadequate treatment facilities, open defecation, absence of clear guidelines etc. The rapid urban population growth of Monrovia has severely stressed Monrovia's marginally functional urban WSS system caused by the civil conflict which led to break down in many sectors as well as infrastructure. The sewerage system which originally covered 17% of the population of Monrovia was down to serving about 7% because of bursts and blockages causing back flows in other areas. Prior to the Civil War, the average water production for Monrovia was about 68,000 m3/day, but has now dropped to about 10,000 m3/day. Only small parts of Monrovia currently have direct access to the piped water supply while most areas depend on trucked water delivered to community collection points or household tanks, and/or on water from unprotected dug wells or hand pumps. There are only two functional treatment plants; The Fiamah Treatment plant and the White Plains Treatment Plant.

Keywords - Fiamah Treatment plant, Management, Monrovia/Montserrado County, Sewage, Sludge,

1. Introduction

Sewage sludge can be characterized in terms of its chemical, physical, and biological components. The sludge brings to the sewage treatment plants all the wastes sent into the sewer from drains, toilets, industrial wastes, hospital wastes, commercial wastes, human excreta, storm water runoff, and every other kind of hazardous, toxic, and biological waste material. All these are carried away from their source via the sewer. (J. et al., 2011). Sewage sludge is a produce of municipal waste water treatment. It is a heterogeneous mix of hazardous materials containing high concentrations of toxic contaminants, heavy metals etc. However, sludge treatment issues are often neglected in comparison with water-related parameters such as the outgoing load and the degree of removal of different waste water compounds. Sludge is a potential threat to the environment if not properly managed. This however involves the treatment of sludge. Sewage treatment is focused on reducing wastewater discharges, conventional pollutants: oil, grease, organics like nitrogen and phosphorous (measured by biological oxygen demand), total suspended solids, and settleable materials. To retrieve the precious water, the sewage is then 'treated at the treatment plant. During this process, the water is cleaned in the degree to which the pollutants which had turned the water into sewage are removed by treatment-primary, secondary, or tertiary-and concentrated in the sludge (Borchardt, J.S., Jones., & Redman., 1981)

1.1 Composition of sewage sludge

Sewage sludge can be regarded as a multi substance mixture. Due to the inhomogeneity and tremendous differences in the concentrations of its components, it is difficult to determine or define a standard composition for sewage sludge, which is mainly composed of organic substances.(Judith Oliva et al., 2009).

+Substance	Unit of measure	Value range according to DWA
pH value	-	7.7*
Dry solids (DS	wt %	30.5*
Loss on ignition (LOI)	%	45–80**
Water	wt %	65–75
Volatile matter	wt %	30
Net calorific value (NCV	MJ/kg DM	10–12
Carbon (C)	%	33–50
Oxygen (O2)	%	10–20
Hydrogen	%	4-Mar
Nitrogen	%	6-Feb
Sulphur (S)	%	0.5–1.5
Fluorine	wt %	<0.01
Chlorine	%	0.05–0.5
Phosphorous (P)	g/kg	2–55
Antimony (Sb)	mg/kg DS	Feb-55
Arsenic (As)	mg/kg DS	30-Apr
Lead (Pb)	mg/kg DS	70-100
Cadmium (Cd)	mg/kg DS	1.5-4.5
Chrome (Cr)	mg/kg DS	50-80
Copper (Cu)	mg/kg DS	300-350
Manganese (Mn)	mg/kg DS	60-1,500
Nickel (Ni)	mg/kg DS	30-35
Selenium (Se)	mg/kg DS	5-Jan
Thallium (Th)	mg/kg DS	0.2-0.5
Vanadium (V)	mg/kg DS	10-100
Mercury (Hg)	mg/kg DS	0.3-0.5
Zinc (Zn)	mg/kg DS	100-300
Tin (Sn	mg/kg DS	30-80
AOX	mg/kg DS	350
PCDD/F	mg/kg DS	0.000035
Molybdenum (Mo)	g/kg TS	3.9*
Cobalt (Co)	g/kg TS	6.53*
Calcium (Ca)	g/kg TS	71*
Potassium (K)	g/kg TS	2.63*
Magnesium (Mg)	g/kg TS	9.17*

Fig. 1. Sewage sludge composition showing organic substances (Judith Oliva et al., 2009).

1.1.2 Sludge treatment

The treatment of sludge encompasses all processes that improve the suitability for usage, transportation or storage of sewage sludge. The methods of sludge treatment includes thickening, hygienization, biological stabilization, dewatering, drying and incineration.

- Thickening involves the reduction of the sludge volume by removing as much water as possible.
- The process of hygienization is to reduce the concentration of pathogens such as virus and worms eggs in the sewage sludge. The aim of this method is to minimize the risk of human and animal contamination whenever the sludge is used as a fertilizer.
- Biological stabilization of sludge is carried out to reduce the concentration of organic substances that break down rapidly in order to avoid odors.
- Sludge dewatering is done mechanically thereby reducing the volume of the sludge mixture and its water content. It is important in settings where the sewage sludge is transported to another site for treatment or disposal (Judith Oliva et al., 2009).
- Sludge drying has a number of advantages which includes the reduction of sewage sludge volume therefore making it conducive to store and transport. Its advantage also lies in microbiological stabilization and health safety. However, additional energy is needed
- The economics of incineration depend to a great extent on fuel requirements to ensure an autogenous combustion.

2. Materials and methods

Liberia, a country located in West Africa, borders Sierra Leone to its west, Guinea to its north and Ivory Coast to its east. It covers an area of 111,369 square kilometers with a population of about 4 million people. It is a low-income country with an estimated GDP per capita of USD 454 in 2013. Although the real GDP growth in 2014 had been projected at 5.8%, it was estimated to have declined to 2.5% or less by the end of 2014 due to the Ebola crisis. The country is geographically divided into five regions and 15 counties, with populations ranging from 57,913 in Grand Kru County to 1,118,241 in Montserrado County.(Liberia, 2015). Monrovia is the capital city of Liberia situated in Montserrado County and has the highest population of 1,118,241 compared to other counties (LDHS, 2013). Before the civil war, approximately 75 percent of the population lived in rural areas. The conflict forced hundreds of thousands of people to flee into cities. Consequently, Monrovia has experienced rapid urban population growth. This has severely stressed Monrovia's marginally functional urban WSS system (USAID, 2010). Due to the increasing population of Monrovia caused by the civil conflict which led to break down in many sectors as well as infrastructure, the researcher thought it necessary to conduct a study on sewage sludge management in line with best practices so as to have a clear picture of the management process and give recommendations in line with best practices. Montserrado County, being the capital of Monrovia was chosen due to its difference in size and population compared to other counties. Review of past and present policy documents, visits to ministries and agencies involved in the management of sewage sludge as well as site visits to the treatment plant were carried out.

Fig. 2. Map showing the population of Montserrado 1,118,241

3. Sewage sludge management in Monrovia

Poor sanitation is associated with Monrovia, a city with sprawling neighborhoods hosting people from rural areas, most of whom were displaced during the civil crisis or moved to the city in search of a better life. As a city grappling with an increase in population of over one million people, it is also seriously overwhelmed with the problem of clogged and leaking sewage lines. The blockage of the stem drainage, the secondary sewage collection facility that receives primary sewage from homes and businesses, has not only caused the pouring of feces on busy Streets, but subjected the city to constant outflow of sewage. Monrovia water supply and sewerage system had largely ceased functioning by the end of the war because of vandalization, illegal connections and high water losses. The sewerage system which originally covered 17% of the population was down to serving about 7% because of bursts and blockages causing back flows in other areas (sanitation, 2010). Prior to the Civil War, the average water production for Monrovia was about 68,000 m3/day, but has now dropped to about 10,000 m3/day. In Monrovia, the water supply service is mainly based on a surface water source from the nearby St. Paul's river. The raw water is pumped to the White Plains Treatment Plant (WTP) and treated water distributed to the population through a distribution system. Only small parts of Monrovia currently have direct access to the piped water supply while most areas depend on trucked water delivered to community collection points or household tanks, and/or on water from unprotected dug wells or hand pumps AWF (AWF, 2008) (AWF, 2008). Prior to the civil war there were a number of sanitation facilities. The White Plains treatment which had a production capacity to 30,000 m3/day (8 mgd); 60,000 m3/day Caldwell treatment plant ,Newport Street Booster Stations; Mamba Point Reservoir and Fiamah Treatment plant. The Fiamah treatment plant and the White Plains Treatment Plant are the only functional plants in Monrovia. In 2008 the World Bank and EU agreed to fund the project of rehabilitating the Monrovia water supply system to at least 50% pre-war status to serve a target population of 350,000 and rehabilitate existing onsite sanitation facilities to serve a target population of 150,000 .The White Plains Treatment Plant covers only 17% of Monrovia serving the center of the city including Bushrod Island and Sinkor areas. The network is connected to a waste stabilization pond, which discharges to the ocean through concrete outfalls. At present, the sewerage system is in disrepair and the outfall is damaged. Most people use open defection due to the limited number of public and household latrines and the Liberia water and sewer company having only one desludging truck.((OWAS), 2007). The Fiamah Treatment Plant is currently being used for the discharge of the sewage from various septic tanks, latrines, and holding tanks located at various Ebola treatment centers by means of a truck to the discharge point- Fiamah treatment plant. Limited information could be found on the management of wastewater sludge from waterborne sewage treatment systems. To date, there is no evidence for transmission of Ebola viruses via drinking-water contaminated by feces or urine but we are not certain what the future holds as research has shown that the virus has the ability to mutate. On the other hand, 90% of deaths linked to diarrhea are directly attributed to poor water, sanitation and hygiene in Monrovia. In 2012, E. coli was present in 58% of Monrovia's water due to public defecation and mining has been linked to river pollution as has the rubber industry (Government of Liberia, World Bank, & Program, 2012. In Monrovia, a significant population of the city is not served by the piped supply system nor the sewerage system, including central areas of the city near Mamba Point. Existing infrastructure has not yet been restored to its pre-war capacity, which itself is inadequate because of the expansion of the city over the past decades. Most people in all urban areas defecate in the open or use the limited number of communal or household latrines. Data on water supply quantities is limited (WASH, 2013).

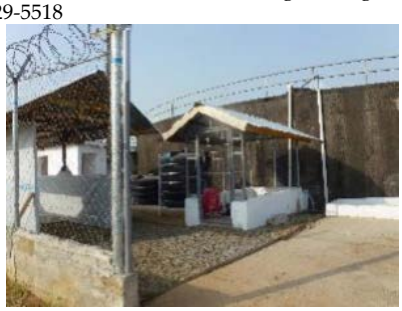

Figure 3. Holding retention tank at Fiamah treatment plant

Figure 4. Sewer truck containing inlets/outlets connections, pump mode and control panel used for transporting sewage to the Treatment plant

4. DISCUSSIONS

4.1 Legislations regarding sewage sludge

Although a number of laws, rules, and a regulatory framework existed in the past, i.e. prior to the civil war, currently laws specifically pertaining to the regulation of water resources are not clearly defined except an amendment to the Public Utilities Law in 1973 establishing the Liberia Water and Sewer Corporation (LWSC). With the assistance of donor organizations, the Government of Liberia (GOL) is currently drafting WSS sector policy and preparing an Integrated Water Resources Management Policy (IWRMP). Other agencies involved are:

- The Ministry of Lands, Mines and Energy which is responsible for water and sanitation sector development and the formulation of policies and guidelines.
- Liberia Water and Sewer Corporation (LWSC) which is a public institution responsible for providing water and sewer services to urban areas.
- The Monrovia, the Monrovia City Corporation is responsible for on-site waste management of toilets and latrines
- Rural Development Authority (RDA) to the Ministry of Public Works which works closely with the Monrovia City Corporation in rural areas.

There are number of challenges faced by these sectors which include absence of specific policies or guidelines, lack of human resource capacity, weak financial position, poor water service characterized by disruptions and breakdowns. This has led to break down in the sewage systems in parts of Monrovia and the government having to rely on pump trucks to remove wastewater that was collected in low spots since lift station pumps and the wastewater treatment plants became inoperable with only one functional one. A large portion of those residing in Monrovia rely on septic-tank or pit latrines. The septic tanks however are in short supply and people tend to defecate in plastic bags that are then deposited onto trash heaps or thrown into open drainages (G. & Foundation, 2009). Solid waste management in Monrovia is the responsibility of the Monrovia City Corporation. In 2007, 55% of Monrovia's solid waste was not been collected while the remainder was being discarded in wetlands, rivers and streams around Monrovia. South Africa being a developing country like other developing countries has developed a guideline regarding the handling and management of sludge. The guideline is known as the South African Guidelines for the Utilization and Disposal of Wastewater sludge. This guideline serves as a working tool for the utilization of sludge in land application, brick manufacturing, composting and fertilizer manufacturing plus its economic benefits when applying sludge beneficially (C., 2008). However guidelines regarding the utilization and management of sludge in line with best practice as seen in the case of South Africa is still in its developmental stage in Liberia.

4.2 OVERVIEW OF SUITABLE SLUDGE HYGIENIZATION METHODS

Sewage sludge can be used in a number of ways. The use of sewage sludge in agriculture may be an effective method for returning plants nutrients to the soil. The foremost importance is

not just to dispose of the sludge but rather use it in cautious ways taking into consideration guidelines for contaminants in accordance with best practices. With regards to pathogens, the focus should be on breaking the chain of environmental transmission and not to introduce new routes of disease transmission. Pathogens are present in waste water and will also be present be in the sludge often in higher concentration. In Monrovia, the only pathogen that has been analyzed and found in water and will potentially be present in sludge is the E. coli (USAID, 2010). There is no evidence to suggest that there is a risk but treatment before use is considered the most efficient barrier towards disease transmission. By applying different treatment methods it is possible to inactivate/kill pathogens present. In Monrovia however, these treatments need to be clearly defined in accordance to experience and best practices as in the case of South Africa. Improper management of sewage sludge can lead to pollution of local water sources with pathogens. Hence this has the ability to cause adverse effects of waterborne and vector borne diseases (Chartier et al., 1999). Wastewater discharged in an uncontrolled manner into the environment can lead to several waterborne diseases that are a threat to human life, especially in developing countries (Chartier et al., 1999).

Groups of WSH risks and interventions	Main diseases impacted
Water supply, sanitation and hygiene	Infectious diarrhoea Malnutrition and consequences of malnutrition on most infectious diseases* Intestinal nematode infections (ascariasis trichuriasis, hookworm disease, other) schistosomiasis Trachoma lymphatic filariasis
Water resources management	Malaria Onchocerciasis Dengue Japanese encephalitis
Safety of water environments	Drownings

Figure 5. Water, sanitation and hygiene-related risks diseases (Fewtrell L et al., 2007).

5. CONCLUSION

Sewage sludge management in Monrovia is still in its infant stage. The city is still struggling with poor sanitation, clogged pipes, shortage in septic tanks, lack of resources/human capacity, open defecation, absence of clear guidelines etc. In Monrovia, Montserrado County, the need for safe and proper management of sludge needs to be acknowledged and regulations aimed at reducing the risks of diseases need to be adopted. The eradication of risk is impossible to achieve but the combination of guidelines/policies for defined management or treatments and restrictions for use will together function as barriers and reduce the risks to what can be considered acceptable in line with best practices. The construction of more treatment plants should be taken into consideration so as to meet the needs of the population. To further reduce the risks from sludge, efficient treatment methods needs to be applied. There is a need for a regulation regarding sludge in relation to process parameters and management of the treatment plant.

6. Acknowledgements

This work was supported by Professor Jiang Wenchao, colleagues from the Department of Urban Construction and Environmental engineering, and the innovative base of Chongqing University. Special Thanks to Miss. Vivian Mustwekwa for proofreading. The authors would like to thank the anonymous referees for their contributions to this research.

REFERENCE

[1] (OWAS), W. a. S. D. (2007). MONROVIA WATER SUPPLY AND SANITATION REHABILITATION PROGRAMME APPRAISAL REPORT-African Development Bank.

[2] AWF. (2008). Study for the expansion of Monrovia water supply and sanitation system and rehabilitation of water supplies of 3 country capitals- Project apprisal report (African Water facility).

[3] Borchardt, J.S., Jones., & Redman. (1981). Sludge and Its Ultimate Disposal. Ann Arbor Science.

[4] C., V. d. W. (2008). South African Sludge Management Guidelines.

[5] Chartier, Y., Emmanuel, J., Ute Pieper, Prüss, A., Rushbrook, P., Stringer, R., . . . Zghondi, R. (1999). Safe management of wastes from health-care activities- 2nd Edition WHO.

[6] Fewtrell L, Prüss-Üstün A, Bos R, Gore F, Bartram, & WHO. (2007). Water, sanitation and hygiene: quantifying the health impact at national and local levels in countries with incomplete water supply and sanitation coverage.

[7] G., B., & Foundation, M. G. (2009). Inclusive Municipal Governance in Monrovia- Annual Report.

[8] J., P., l. Guyer, P.E., R.A., Fellow ASCE, & AEI, F. (2011). Introduction to Sludge Handling,Treatment and Disposal. Engineering.com.

[9] Judith Oliva, Antonia Bernhardt, Hubert Reisinger, Manfred Domenig, Hans-. Jörg Krammer, & Klärschlamm-Materialien zur Abfallwirtschaft. (2009). Sewage Sludge Management in Germany.

[10] LDHS. (2013). Liberia Demographic and Health Survey.
[11] Liberia. (2015). Investment Plan for Building a Resilient Health System in Liberia- Health Sector assessment Report.
[12] sanitation, M. w. a. (2010). MONROVIA WATER SUPPLY AND SANITATION REHABILITATION PROJECT - LIBERIA, PROJECT COMPLETION REPORT

[13] USAID. (2010). Liberia Water and Sanitation Profile.
[14]WASH. (2013). Liberia Water, Sanitation and Hygiene (WASH) Sector performance report, Rural water supply.