

# EVALUATION OF THE QUALITY OF DRAINAGE SLUDGE IN TO LICH RIVER BASIN AND THE PROPOSAL OF SUITABLE MANAGEMENT SOLUTIONS

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## **Abstract**

This study aims to examine the characteristics and to assess the hazardous level as well as the reusability of sewage sludge and river sediment from To Lich River (TLR) basin, which is the largest wastewater catchment in Hanoi. Sludge samples were collected from six manholes along Tran Binh Trong (TBT) and Thai Ha (TH) sewers in rainy and dry seasons. Sediment samples were collected from seven sites near principal wastewater and storm water discharging points along TLR upstream in dry season. Parameters, such as pH, humidity, total ash, zinc (Zn), copper (Cu), lead (Pb), and cadmium (Cd) in sewage sludge were examined. Trace metals in TLR sediment, e.g. arsenic (As), mercury (Hg), lead (Pb), zinc (Zn), chromium (Cr), and cadmium (Cd) were analyzed. The results of sludge and sediment analysis were then compared with national environmental regulations for hazards and aquatic life preservation, and land use purposes, including QCVN 43:2012/BTNMT, QCVN 50:2013/BTNMT, QCVN 03-MT: 2015/BTNMT. The majority of examined parameters of sewage sludge, except ash content, are higher in dry seasons than in rainy seasons. Regarding hazardous level, all the investigated heavy metals in sewage sludge in dry and rainy seasons, respectively, as followings: 644 and 598 mg·kg<sup>-1</sup> Zn, 146.5 and 127.3 mg·kg<sup>-1</sup> Cu, 71.2 and 69.5 mg·kg<sup>-1</sup> Pb, and 1.51 and 1.46 mg·kg<sup>-1</sup> Cd, are below the legislated thresholds, thus, can be considered as nontoxic. Reusability of sewage sludge, however, should be considered since Zn exceeded permissible values for all of land use purposes. The concentration of As (0.659 mg·kg<sup>-1</sup>), Hg (0.03 mg·kg<sup>-1</sup>), Pb (4.07 mg·kg<sup>-1</sup>), Zn (81.3 mg·kg<sup>-1</sup>), and Cd (0.078 mg·kg<sup>-1</sup>) meets national standards on hazardous waste, and sludge from water treatment process, as well as to protect aquatic life and to be reused in anthropogenic activities. However, Cr concentration (157 mg·kg<sup>-1</sup>) is above those legislated thresholds, thus, unsuitable to be reused as land or fertilizer. With high concentration of several trace metals and humidity, drainage sludge from TLR basins should be treated to improve its reusability.

**Keywords:** sewage sludge; river sediment; sludge management; To Lich River; heavy metal; national technical regulation.

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## **1. Introduction**

Yen So landfill, with the area of 14.1 hectare, is currently receiving all of the dredged sludge generated from sewers, canals, rivers, lakes, and wastewater treatment plants in the inner city of

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Hanoi [1]. Sewage sludge, with the large amount of approximately 160,000 to 200,000 tons per year, is the dominant component of Hanoi drainage system. In addition to the above sludge, approximate 1.4 millions tons of dredged sediment from the West Lake will be transported to Yen So landfill site in 2018 [2]. Due to the large amount of the dredged sludge, that site may face to the risk of being overloaded. On the other hand, when being disposed or reused for agricultural purposes, pollutant-containing sludge and sediment may cause the contamination of the surrounding environment of the landfills [3, 4]. Therefore, it is necessary to assess the level of hazards and the reusability of Hanoi drainage sludge before it is transported to Yen So landfill.

To Lich River (TLR) is the main wastewater- receiving river in the inner city of Hanoi. Before discharged into the river, wastewater and storm water in the basin of TLR flow through the combined drainage network consisting of sewers, canals, and regulating ponds. Sludge generated in the basin is composed of two types including sewage sludge from the network and sediment from the river bed. Those types are usually dredged with different frequency and at different time. Sediment in the TLR is dredged every 2 years [1, 5]. Although many previous studies [6–12] focused on the quality of TLR sediment, as far as our knowledge, few researches have evaluated sludge characteristics of sewage sludge from that basin.

Previous studies showed the contamination of TLR sediment with high concentration of trace metals [6–9]. These concentrations exceeded acceptable values for sediment and were considered toxic for aquatic life in the river [10–12]. TLR sediment was also considered to be unsuitable for land use purposes in agriculture, forestry, industry, commerce and service, or for crop fertilizers [13]. Heavy metals in TLR sediment were mostly generated from anthropogenic activities, such as the discharge of untreated domestic and industrial wastewater from residence and industrial clusters upstream [9, 11]. However, those conclusions based on the analysis of sediment samples collected before recent activities to improve the quality of sediment and river water are being implemented. Since 2012, the new system of environmental protection regulations has been tightened together with the relocation of industrial facilities out of the river basin and embankment of the river banks. Therefore, the current quality of TLR sediment may be different from previous studies.

This study focuses on the characteristics of the dredged sewage sludge and river sediment from TLR basin recently. Analysis results of sludge quality will clarify the possible toxicants and the reusability of the sludge and sediment for various purposes. Understanding the characteristics of drainage sludge provides the basis for the proper sludge management and reduces the risk of overload and pollution for Yen So landfill site.

## 2. Materials and methods

### 2.1. Study area and sample collection

TLR originates from the West Lake and runs through Hanoi inner city before merging with Kim Nguu River downstream and flowing into Nhue River. It has a length of 14 km and covers the basin of 77.5 square kilometers, which is the largest drainage catchment in Hanoi. The total amount of wastewater discharged into TLR is approximately 290,000 m<sup>3</sup> per day [9]. The drainage network in the TLR basin was built to collect wastewater both from the ancient city, where there are no new construction activities and in the new urban areas, where the infrastructure is still being completed.

Sampling locations of sediment and sludge were illustrated in Fig. 1. Sediment samples were collected from seven points near the crossing bridges along 7-km TLR upstream which receives wastewater and storm water from the main sewers. Two targeted sewers in this study were Tran Binh Trong

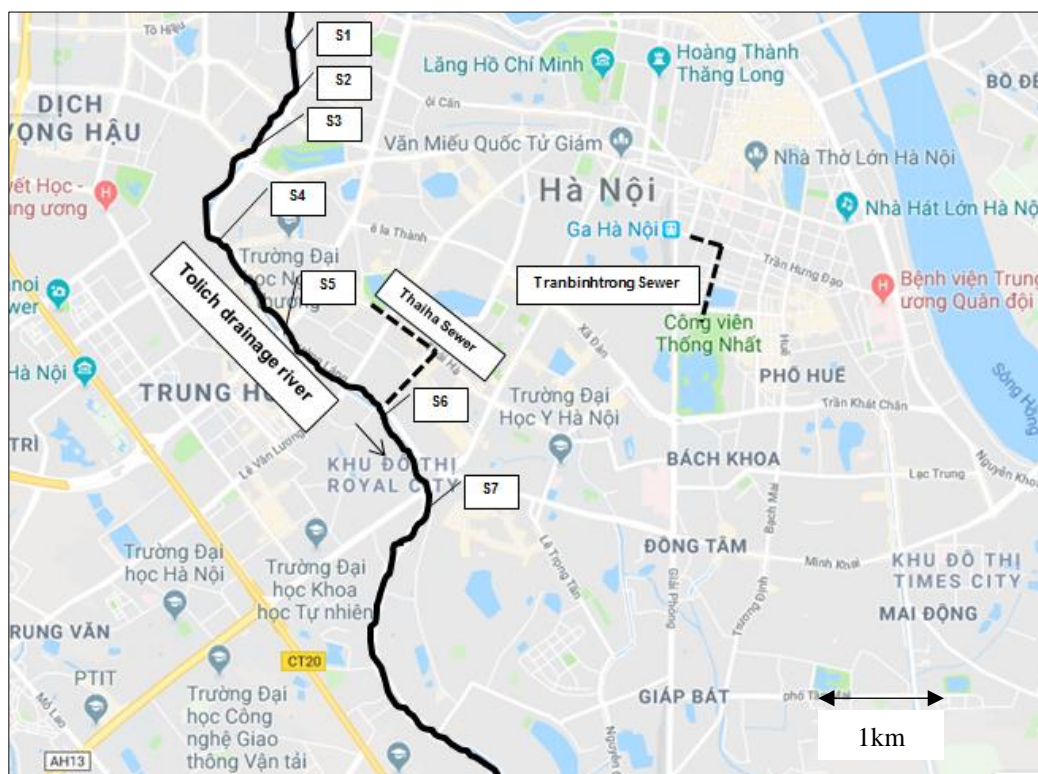


Figure 1. Sampling sites along TLR basin in Hanoi, Vietnam

S1: Buoi Discharger; S2: Dichvong Bridge; S3: Caugiay Bridge; S4: Cot Bridge;  
S5: Trunghoa Bridge; S6: Moc Bridge; S7: Moi Bridge

(TBT) sewer from the old urban area and Thai Ha (TH) sewer from the new urban area. TBT sewer was built by French during the French colonial period while Thai Ha sluice was built in 1985, during the Renovation period. These two 600-meter sewers have been built in different stages of the Hanoi drainage network, making them representative to others sewers which were built at the same period. Sewerage sludge was collected from six manholes consisting in the sewer.

Sewage sludge was collected in the rainy season (June, 2016) and another time in dry season 2017 (January, 2017) while the sediment samples were collected in November, 2016. Sludge samples were collected and preserved in accordance with current Vietnamese technical standards including TCVN 6663 - 3:2008 - Water quality - Sampling - Part 3: Guidance on the preservation and handling of water samples (ISO 5667-12:1995 Part 12: Guidance on sampling of bottom sediments) and TCVN 6663 - 15: 2004 (ISO 5667-15: 1999) Water quality - Sampling - Part 15: Guidance on preservation and handling of sludge and sediment samples. Particularly, sediment samples were taken by buckets at the depth of 10-30 cm, then placed in 250 mL plastic bags, stored in dark box at two to five degree Celsius [14, 15]. The preservation time for analysis parameters were in accordance with the above Vietnamese technical standards [14, 15].

## 2.2. Sample analysis

Sludge samples from two sewers were analyzed for physical characteristics such as pH, ash content, humidity and chemical components including total nitrogen, total phosphorus, and heavy metal

concentrations including zinc (Zn), copper (Cu), Cadmium (Cd), and lead (Pb). In addition, sludge thickness along the sewers was also measured. For To Lich River sediments, heavy metals such as arsenic (As), mercury (Hg), lead (Pb), chromium (Cr), cadmium (Cd), zinc (Zn) and copper (Cu) were examined. Samples are analyzed in an accordance with Vietnamese standards (c.a. TCVN 4196:2012: Soils - Laboratory methods for determination of moisture and hygroscopic water amount; TCVN 8467:2010 (ISO 20280:2007): Soil quality - Determination of arsenic in aqua regia soil extracts with electro thermal or hydride-generation atomic absorption spectrometry; TCVN 8246:2009 (EPA Method 7000B): Soil quality - Flame atomic absorption spectrophotometry; and TCVN 8882: 2011 (ISO 16772 : 2004): Soil quality - Determination of mercury in aqua regia soil extracts with cold-vapour atomic spectrometry or cold - vapour atomic fluorescence spectrometry) [16–19]. The samples were analyzed no later than eight days for total ash, and Hg. The preservation time for sludge and sediment samples were less than four months for other heavy metals [14, 15]. Each sample was measured for at least three times.

### 2.3. Comparisons of sludge quality and national regulations

The results of the analysis were compared to Vietnamese environmental regulations on hazardous thresholds in soils, aquatic life protection, and sludge reuse including QCVN 43:2012/BTNMT- National Technical Regulation on Sediment Quality, QCVN 50:2013/BTNMT - National Technical Regulation on Hazardous Thresholds for Sludge from Water Treatment Process and TCVN 03-MT: 2015/BTNMT- National technical regulations on the allowable limits of heavy metals in the soils to determine the hazardous level and assess the potential reuse [20–23].

## 3. Results and Discussion

### 3.1. Characteristics of sewage sludge and sediment in TLR basin

#### a. Characteristics of sewage sludge

The average humidity of TBT sewer in dry and rainy seasons (83.5% and 87%) are higher than these values of TH sewer (81% and 84%). The ash content in the old urban areas was lower than that in the new areas. In the new urban areas with ongoing key building sites, dust from anthropogenic activities on the surface, together with wastewater from road washing, and constructing in dry season, as well as with storm water in rainy season will be swept into the sewers. However, the flow rate of wastewater in the drainage system in both rainy and dry seasons is insufficient to clean up sediment according to the report from HDSC [1]. Consequently, it is essential to use mechanical measures to remove the sludge deposited in the sewer.

Sludge from sewers contained low organic concentration and high heavy metal contents in both seasons as shown in Table 1. Those results were consistent with previous studies [23, 24] on sewage sludge in Hanoi.

Because most of the organic matters decompose in the onsite septic tanks, and gradually in the sewer, the differences in concentration of those substances between two seasons are not significant. However, ash content in rainy season is slightly higher than that in dry season since surface dust is swept by storm water into the sewers. For heavy metals, storm water is continuously added to the sewer, thus, remove metals from the deposited sludge into water. Therefore, the concentration of trace metals in sewage sludge is higher in dry season than in rainy season.

Table 1. Physical characteristics and heavy metal contents of sewage sludge from sewers in TLR Basin and comparison with Vietnamese environmental regulations

	pH	Humidity, %	Ash content, %	Zn, mg·kg <sup>-1</sup>	Cu, mg·kg <sup>-1</sup>	Pb, mg·kg <sup>-1</sup>	Cd, mg·kg <sup>-1</sup>
Dry season <sup>(1)</sup>	6.64±0.35	85.2±4.5	78.2±2.5	644±23	146.5±11.4	71.2±2.1	1.51±0.12
Rainy season <sup>(1)</sup>	6.52±0.27	84.7±3.9	79.6±3.1	598±23	127.3±12.5	69.5±1.7	1.46±0.11
Hazards <sup>(2)</sup>	NA	NA	NA	5,000	NA	300	10
Agr. <sup>(3)</sup>	NA	NA	NA	200	100	70	1.5
For. <sup>(3)</sup>	NA	NA	NA	200	150	100	3
Com. and Ser. <sup>(3)</sup>	NA	NA	NA	250	200	200	5
Ind. <sup>(3)</sup>	NA	NA	NA	250	300	300	10

<sup>(1)</sup> Pooled data from sewers in both old and new urban areas.

<sup>(2)</sup> Thresholds for toxics in Vietnamese standards for Hazard [22].

<sup>(3)</sup> Acceptable value for sludge and soils to be reused as land for various purposes [23].

Arg. - Agricultural land, For. - Forestry land, Com. and Ser. - Commercial and Service land, and Ind. - Industrial land, NA - not available.

#### b. Characteristics of TLR sediment

The concentration of heavy metals according to six parameters regulated in Vietnamese environmental standards [23] is relatively high. Those concentrations decrease gradually in the order of Cr > Zn > Pb > As > Cd > Hg in accordance with Report on feasibility study for Hanoi Drainage Project-Phase 2 [25]. Chromium content is noticeably large, ranging from 156 to 158 mg·kg<sup>-1</sup>. However, the concentration of heavy metals in the present study is lower than that reported in [8, 9, 13]. The difference can be explained by the change in the nature of the refill of TLR sediment including rainwater and wastewater from the sewers, and canals in the catchment. In the past few years, heavy metals in wastewater must be treated before discharged into the city's combined drainage network. In addition, sewerage sludge (from the drains, canals, and ditches) must be regularly dredged. Consequently, the concentration of pollutants, including heavy metals, in wastewater and sediment is significantly reduced and competent with those predicted in the previous report [26] (see Table 2).

### 3.2. Assessment of potential hazards and reusability of drainage sludge from TLR basin

#### a. Potential hazards and reusability of sewage sludge

Heavy metal, including Zn, Pb, and Cd, as shown in Table 3, was below the allowable limits of hazards in the soils [23], thus, considered nontoxic. Regarding the reusability, sewage sludge is not suitable for all of land use purposes due to exceeded concentration of Zn in both of dry and rainy seasons. The reusability of other heavy metals differs between two seasons. Particularly, Cu, Pb, and Cd do not satisfy the thresholds for agricultural activities but can be reused for other types of land use in dry season. In rainy season, those metals meet the permissible values for lands in forestry, commerce and service, and industry.

Table 2. Concentration of heavy metals in sediment from sampling sites

Sampling site	Concentration (mg·kg <sup>-1</sup> )					
	As	Hg	Pb	Zn	Cr	Cd
S1	0.661	0.03	3.91	81.1	156.8	0.079
S2	0.659	0.03	4.07	81.2	157.5	0.077
S3	0.657	0.03	3.96	81.3	157.6	0.078
S4	0.661	0.03	4.12	81.3	157.6	0.076
S5	0.659	0.03	4.09	81.3	157.9	0.078
S6	0.659	0.03	4.16	81.3	157.7	0.081
S7	0.660	0.03	4.17	81.4	156.7	0.076
Mean ± SD	0.659±0.001	0.03±0.00	4.07±0.10	81.3±0.1	157.4±0.5	0.078 ± 0.002

Table 3. Comparisons of heavy metal concentrations in TLR sediment with permissible limits in Vietnamese environmental standards

Value	Concentration (mg·kg <sup>-1</sup> )					
	As	Hg	Pb	Zn	Cr	Cd
This study, Mean ± SD	0.659±0.001	0.03±0.00	4.07±0.10	81.3±0.1	157.4±0.5	0.078±0.002
Hazardous Waste Threshold [20]	40	4	300	5000	100	10
Hazardous waste for sludge from Water Treatment Process [22]	40	4	300	5000	100	10
For aquatic life preservation [21]	17.0	0.5	91.3	315	90	3.5
Agr. [23]	200	NA	70	200	150	1.5
For. [23]	200	NA	100	200	200	3
Com. and Ser. [23]	250	NA	200	300	250	5
Ind. [23]	250	NA	300	300	250	10

Arg. - Agricultural land, For. - Forestry land, Com. and Ser. - Commercial and Service land, and Ind. - Industrial land, NA - not available.



### b. Potential hazards and reusability of TLR sediment

To assess the risk of TLR sediment, we compared the result of sludge analysis with Vietnamese standards for hazardous waste, sediment hazards to protect aquatic life in fresh water [20, 21]. Among analyzed metals, Chromium content exceeds the allowable values in both of those standards. However, if considering TLR sediment as the sludge from water treatment process to assess the hazard threshold under the corresponding standard [22], the Cr(VI) composition should be evaluated. Ha *et al.* [26] showed that Cr(VI) ratio of total Cr in drainage sludge is extremely small. Marcussen *et al.* [9] also agreed that Cr(VI) in TLR sediment is not significant since Cr is affected by the reduction of Fe(II) in pore water.

Due to deposition process in sewers and wastewater-receiving river, concentrations of some heavy metals such as As, Zn, Pb, Cr... exceeded the threshold for freshwater sediment for aquatic life protection [21]. It is therefore necessary to remove the sediment from TLR.

Overall, the concentrations of heavy metals in TLR meet the requirements for land used, c.a. agriculture, forestry, agriculture, forestry, service and commerce, and industry. This result is contrary to the conclusion of Ingvertsen *et al.* [13] when they claimed that the To Lich River sediment was not suitable for any purpose of land use. However, for Cr, its content in sediment exceeds the allowable limit for agricultural land.

### 3.3. Proposals for suitable sludge management

Yen So landfill site is the only place to receive sludge from the sewerage network and wastewater treatment plants in Hanoi. The amount of sludge dredged is expected to increase in the upcoming years, thus, leading to the overload and pollution for that site. Therefore, it is necessary to search for appropriate management solutions for the sludge from the urban drainage system of Hanoi.

Analysis results of heavy metal content in dredged sediment from TLR show that this type of sludge is not hazardous waste which should be managed as other solid wastes. With low content of heavy metals and humidity (75-80%), dried sludge can be used to level the construction or to grow some suitable agricultural crops. Additionally, drainage sludge contains high concentration of N and P, thus, suitable for fertilizers [24]. In case of reuse as fertilizer or soil for agricultural purposes, heavy metal components must be treated by chemical or biological methods on the constructed wetland [26, 27].

Humidity of drainage sludge is relatively high, thus, difficult to transport and easy to contaminate surrounding environment. Ha *et al.* (2012) [28] proposed the use of a hydraulic cylinder at dredging points to reach sludge humidity of 80-82% before sludge is transported. Despite of high nutrient content, sewage sludge is difficult to reuse as fertilizer due to the limited organic contents and surplus heavy metal. The sludge needs to be dried to a level below 60% on a sludge drying bed before transported [26, 29].

Direct dumping on landfill sites has been reduced to less than 1% of the whole waste sludge accumulation [30]. To dehydrate the dredge sludge, the most economical solution is to dry the sludge drying bed by evaporation and filtration [31]. However, this natural method is susceptible to odors and high concentration of heavy metals, and suspended solids, leading to environmental pollution for surrounding areas.

An effective solution for drying and separating heavy metals in sludge is to stabilize sludge in the wetland site. Pollutants in sludge are treated by microorganisms on the roots of rush family trees. Nutrients, such as nitrogen and phosphorus, are converted into plant biomass. Heavy metals are deposited in plant biomass due to root absorption. In the anoxic sludge layer below the wetland, the

activities of microorganisms in sulfate reduction process create low pH environment, generate sulfide ion and convert heavy metals into dissolved forms [26]. The content of heavy metals in sludge, thus, reduces and satisfies requirements of agricultural land or other types of land used for other purposes in accordance with Vietnamese regulations. The sludge leachate is filtered through the limestone underneath and pumped into the reservoir. By adding alkalis, e.g. lime or soda, to raise pH, metal hydroxides are generated and precipitated ready to be reuse or dispose of heavy metals [26].

Additionally, organic components are decomposed and mineralized, leading to the high content of inorganic matters in drainage sludge. Sludge from sewers, canals and the wastewater-receiving river, hence, can be reused as construction material or artificial sand [32]. Sewage sludge contains high contents of construction materials and silt so it can be reused as a source of raw materials for the production of bricks and tiles. Besides, sludge generated from water purification process can contribute to ceramic production [33]. The approach of reused sludge as construction materials is predicted as suitable for drainage sludge management in a city with rapid urbanization process like Hanoi.

#### 4. Conclusions

Sewage sludge and wastewater-receiving river sediment differs in physical characteristics and chemical compositions depending on the location of sewers in urban areas, types of canals, and time of dredge in rainy and dry seasons. Sludge generated from drainage network of a city under construction like Hanoi has high humidity and inorganic content. Although heavy metals in sewage sludge and river sediment exceeds national standards for sediment to protect fresh aquatic life, they are below standards for hazardous wastes. Therefore, sewage sludge and TLR sediment can be reused as industrial, commercial, and service land. In case the sludge is reused as fertilizer or agricultural soil, heavy metal concentration should be lessened. Due to low organic content, sewage sludge can be dried to produce construction materials instead of direct disposal on the landfill site [31]. These are reasonable solutions for dredged sludge to ensure stable operation of Yen So landfill site and to minimize the potential environmental pollution in the surrounding area.

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