SEDIMENT CHARACTERIZATION OF MEXICO CITY'S COLLECTOR NETWORK IN AREAS WITH DIFFERENT LAND USE

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ABSTRACT

The aim of this study was to characterize the sediments extracted by maintenance activities of the wastewater collector network in nine sites with different land use in Mexico City. For all sampling sites, the following parameters were determined: particle size, density, total solids, organic content, fats and oils, chemical oxygen demand, biochemical oxygen demand and orthophosphate. In addition, for four of the samples were determined: lead, cadmium and chromium. The characterization was carried out based on the methods of the American Public Health Association and the American Society for Testing and Materials in the United States. The sediments sampled in Mexico City are classified as poor graded sands with gravel and few fines (SP) according to the Unified Soil Classification System, their densities are placed in the area between 2246-2628 kg / m^3. It was determined that the organic content can reach maximum values of 29%. The lead concentration in the sediments varies from 43 to 125 mg / kg on dry basis and concentrations of COD and BOD are in the area between 1920-7404 mg / kg and 100-1280 mg / kg on wet basis, respectively. It is concluded that the variations in the concentrations of pollutants in sediments depend on the land use in urban areas where the collectors are placed.

Keywords: Testing, Sediments, Collectors Network, Land Use.

INTRODUCTION

Wastewater and storm water contains solids dissolved and suspended of both organic and inorganic nature so, when poured into drains, a fraction of the solids form sediments.

Existing sediment in a sewer can generate various effects, including the following: a) loss of hydraulic capacity of the pipes, which could cause flooding during the rainy season; b) in the event of natural washing by rains, sediments can reach the treatment plants, affecting wastewater treatment operation, or water bodies directly; c) during sewerage system maintenance the sediments are removed and, if they are not treated before disposal, they cause environmental impact.

However, nowadays there is little information on the characteristics of the sediments extracted from the sewer, so the effect they have on the environment is unknown.

In a field study [8] some characteristics of sediments were analyzed (BOD , COD, total solids , ammonia nitrogen and percentage of organic content) and it observed that in peak flows , washing sediment increased the pollution load up to 90 %.

Because of the previous reasons, sediment samples were obtained in areas with different land use and the sediments extracted from sewage systems in Mexico City were characterized.

SEWAGE IN MEXICO CITY

The sewerage system in Mexico City is a complex system; it drains an endorheic hydrological basin which consists of more than 7,800 square kilometers. It is composed of culverts, collectors, interceptors, issuers, treatment plants, sewage pumping stations, dams, open channels, ancillary works and final discharges.

The system is combined, that is to say, both wastewater and storm water are transported in sewers. It starts in the sewer networks which, in turn, flow into the collectors and those continue to the General Drainage System or Deep Drainage System.

Sewer networks collect wastewater and stormwater discharges from homes and storm drains existing in the streets. These sewers are 0.2 to 0.4 m in diameter and discharged into the collector network for subsequent eviction; the length of Mexico City's sewer system is more than 10, 237 kilometers.

The collector network consists of sewers of 0.4 to 4.0 m in diameter, it is integrated for 2,038 kilometers long and in its development has 86 pumping plants and 91 overpasses.

The General Drainage System consists of lakes, ponds and check dams with a capacity of 11 million cubic meters, open channels with a total length of 123.8 kilometers, including the Grand Drainage Channel and the Canal de Chalco, the San Javier rivers, the Remedios river, Tlalnepantla and Canal Nacional, as well as encased rivers as San Buenaventura, Churubusco, La Piedad and Consulado. The total length of these is 47.2 kilometers [9].

Meanwhile, the Deep Drainage System covers thirteen interceptors in addition to the Central Outlet and the Canal Nacional - Canal de Chalco. The East Outlet Tunnel is currently under construction and it is planned to build the Poniente 2 Outlet Tunnel, the Chimalhuacán-Rio de Los Remedios Tunnel, the Chimalhuacán II Tunnel and the General Canal Semi-Deep Collector.

All the water collected by the Mexico City's sewerage system, either wastewater, storm water or combined, is evacuated by any of the four artificial outlets: Tajo de Nochistongo, Tequisquiac First Tunnel, Tequisquiac Second Tunnel, Central Outlet; and is conducted to the Endhó dam or Tula River located in the Mezquital Valley, belonging to the Panuco River watershed which is 60 km from the city.

ENTERING AND LEAVING OF SEDIMENTAL SOLIDS IN THE SEWAGE

The formation and movement of sediments in sewers is a multi-step complex process. The solids deposited on the streets are: a) removed in part by the city cleaning service, b) re-suspended in the atmosphere by wind, or c) washed away by runoff into the gutter and enter the sidewalk storm drains which, in turn, are poured into the sewer lines. A percentage of solids is retained in the sand trap of the drain sidewalk by sedimentation and the rest is transferred to the receiving sewer. Once in the sewer, the material is deposited or is transported by an open channel as bed load or suspended. The suspended solids are carried in the main body of the flow while the bed load travels in contact with the pipe and more slowly. Part of the material may be deposited to form sediments and / or re-suspended as it moves downstream.

In Mexico City there are other important sources of solids that may enter the sewer system; these are the 24 areas naturals protected of the city. As it is a closed basin, the flow of precipitation is encased and ejected by the sewer system. Rainfall drags organic matter and solids, part of them are deposited in the regulation dams and the other part manages to enter the system forming sediment.

Another potential source solid is aquifer infiltration into the sewer at sites that have had landslides and displaced joints, because in some parts of the city, groundwater level is above the sewer system.

Once the solids are deposited they form sediments in sewers and can be: a) dragged by maximum flows to wastewater treatment plants or to receiving water bodies; or b) extracted by maintenance activities and taken to landfills or dumpsites.

OBJECTIVE

The sewer in Mexico City is a complex system with operating difficulties due to counterslopes, obstructions and landslides, so the desilting of networks is a fundamental activity for operation. The public company called "Sistema de Aguas de la Ciudad de México" draws 140 m^3 of sediment per day, but it is estimated that up to 947 m^3 can be drawn per day.

However, there is little information on the characteristics of the sediments, and the effects when they are extracted, transported and dumped in disposal sites are unknown.

This research on the characteristics of the sediments aims to assess the environmental impact of the management of sediments extracted from the sewer systems due to maintenance work.

METHOD

The study was conducted in Mexico City and consisted of extracting sediments from sewers in 9 points located in areas with different land use for analysis in the laboratory in order to characterize and determine whether there is a relationship between pollutant content and land use of the area where the samples were extracted.

Sediment samples were obtained with dumbbell and winch equipment, which are used by workers who do the collector desilting. Sampling was carried out only in collectors for the samples to be representative of large areas of wastewater and storm water. Sampling was deterministic, that is to say, the location of the sampling points was coordinated with the Mexico City's Water System maintenance program.

Moreover, based on the study by Dr. Crabtree [8] on sediment from sewage, in this study two samples were taken (Fig. 1), trying to discriminate bottom sediments (type B) from the surface sediments (type A).

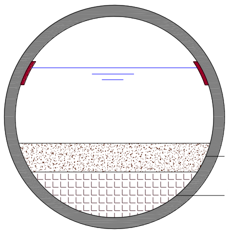

Fig. 1- Sampled sediment deposits.

The determined parameters were: total solids, organic content, density, grain size, BOD, COD, orthophosphate, and fats and oils, also, for 4 samples was determined: chromium, cadmium and lead.

SEDIMENT CHARACTERIZATION FROM THE SEWER

Deposits of type A and type B are the most important sources of pollutants, since the re-suspension of sediments of type B can be the cause of high pollution loads associated with extreme precipitation events. Type A deposits are washed during average storm events in sewer systems [15].

Type A sediments are gritty, granular, compact, dark colored and without garbage; sediment type B are viscous, sticky, less granular than type A, dark colored and have some garbage which mostly consists of plastic bottles.

Physical Characteristics

The particle size analysis of the samples was conducted by sieving the dry mineral residue. Results are expressed as percentages of dry weight and are shown in Table I. Type A and B sediments are a reflection of the solids existing in the catchment basin and flow conditions in the sewer, therefore, it is expected high variability among samples from each site. However, it is expected that from every single culvert a deposit type A and type B will be distinguished. Sediment type A and B are on average 80% sand and 3% fines, based on the Unified Soil Classification System (USCS) sediments can be classified as poorly graded sands (SP).

The percentage of gravels in sediment is relatively low, 16%. This was expected because large solids settle in the sand traps of stormwater drains.

Table I Particle size of sewer sediments by type.

Parameter		Sediment type	
Percentage particle size		A	B
Gravel (9.52 mm - 4.76 mm)	Mean	16.6	15.7
	Maximum	66.8	59.9
	Minimum	1.9	2.5
Sand (2.38 mm - 0.074 mm)	Mean	79.6	81.1
	Maximum	92.7	92.5
	Minimum	32.7	39.8
Silt and clay (< 0.074 mm)	Mean	3.7	3.3
	Maximum	13.2	11.3
	Minimum	0.5	0.3

Type A and B materials have average density of 2,400 kg/m^3 and a total solids content of 65 and 68%respectively (Table II).

Table II Physical characteristics of sewer sediments by type.

Parameter		Sediment type	
		A	B
D_{10}(mm)	Mean	0.30	0.25
	Maximum	1.09	0.82
	Minimum	0.04	0.04
D_{30}(mm)	Mean	0.84	0.75
	Maximum	4.33	3.67
	Minimum	0.14	0.18
D_{60}(mm)	Mean	2.04	1.88
	Maximum	9.52	8.55
	Minimum	0.25	0.28
Total solids (%)	Mean	65	68
	Maximum	92	91
	Minimum	39	46
Dry density (kg/m^3)	Mean	2409	2420
	Maximum	2629	2593
	Minimum	2185	2228

Figure 2 shows the size distribution of the sediment particles. It can be observed that there is no difference between the two types.

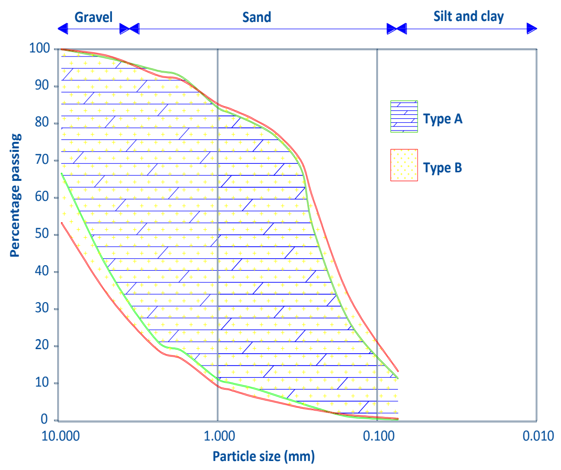

Fig. 2 Particle size of sediments by type.

Chemical Characteristics

Table III summarizes the chemical characteristics of sediments extracted from a sewer. High variability was observed in the results, since the chemical characteristics of sediments are related to the quality of wastewater flowing into the sewer, which is based on the land use of the drained area.

In type A sediments present a higher concentration than in the B type in the parameters: COD, BOD, orthophosphate, organic content, fats and oil, which confirms the existence of two layers of sediments in the sewer.

The low concentration of pollutants in type B sediments is attributed to the degradation of organic matter due to the time spent in the sewer.

The concentration of lead, cadmium and chromium is higher in type B sediments; this is because these elements are not degradable. That is, the concentration of heavy metals in sediments is inversely proportional to the content of organic matter.

The organic content is similar between type A and B sediments, so does the percentage of solids. However, it is important to note that there is a visual difference between the two layers, type A sediments are viscous, sticky, while type B sediments are granular and compact. Is intuited that the visual difference is caused by the content of toilet paper in type A sediments, since it is a lightweight component, it is not detectable in tests of organic content determined by ignition.

Table III Chemical characteristics of sewer sediments by type.

Parameter		Sediment type A	Sediment type B
COD (mg/kg)*	Mean	4715	3878
	Maximum	7316	7404
	Minimum	820	460
	STD	2806	2788
BOD_5 (mg/kg)*	Mean	464	404
	Maximum	1280	680
	Minimum	120	100
	STD	365	204
Orthophosphate (mg/kg)*	Mean	73.3	49.9
	Maximum	166.8	104.0
	Minimum	5.6	2.4
	STD	60.3	43.1
Organic content (%)	Mean	6.5	5.4
	Maximum	17.3	16.4
	Minimum	0.4	0.4
	STD	6.6	5.4
Fats and oil (g/kg)**	Mean	4.5	4.1
	Maximum	8.2	6.9
	Minimum	1.6	1.5
	STD	2.5	2.1
Pb (mg/kg)**	Mean	85.1	93.0
	Maximum	123.7	129.1
	Minimum	43.2	58.6
	STD	37.1	39.4
Cr (mg/kg)**	Mean	12.9	15.0
	Maximum	21.8	27.9
	Minimum	4.8	4.9
	STD	7.6	10.8
Cd (mg/kg)**	Mean	2.0	1.6
	Maximum	2.5	2.5
	Minimum	1.3	1.0
	STD	0.5	0.6

* Milligrams pollutant per kilogram of wet bulk sediment

** Pollutant mass per kilogram of dry sediment

CLASSIFICATION OF DEPOSITS BY LAND USE

Variations of concentration of pollutants in sediments are related to the quality of wastewater flowing into the sewer, which in turn depends on the land use of the area drained.

In Mexico City there are different land uses: residential, commercial, services, industrial and green areas. For this study only sediments in areas with residential, commercial and industrial land uses were sampled.

Because the physical characteristics of sediments do not depend on land use, but on the local structural and hydraulic conditions of each culvert, in this study, the sediments were only classified based on their chemical characteristics.

Table IV presents the (mean and standard deviation) statistical analysis of the results of chemical parameters classified by use of soil and by sediment type.

Table IV Chemical characteristics of sediments sewer by type and land use

Parameter		Land use housing		Land use trading		Land use industrialist	
		Sediment type		Sediment type		Sediment type	
		A	B	A	B	A	B
COD (mg/kg)*	Mean	786	809	6043	4448	7004	6366
	STD	576	470	540	2410	441	1468
BOD_5 (mg/kg)*	Mean	160	227	627	447	520	640
	STD	121	170	594	168	226	57
Orthophosphate (mg/kg)*	Mean	27.8	40.1	97.1	65.5	62.8	5.2
	STD	35.7	48.2	77.5	46.3	70.7	4.0
Organic content (%)	Mean	0.5	0.5	8.3	7.7	13.1	9.1
	STD	0.4	0.5	7.8	7.6	4.9	3.2
Fats and oil (g/kg)**	Mean	2.2	2.9	4.2	3.6	7.8	3.8
	STD	1.7	2.4	2.9	2.9	0.6	1.7
Pb (mg/kg)**	Mean	insufficient	insufficient	86.8	91.8	83.4	94.2
	STD	data	data	29.8	47.0	56.9	49.4
Cr (mg/kg)**	Mean	insufficient	insufficient	6.8	6.1	18.9	23.8
	STD	data	data	2.8	1.8	4.0	5.8
Cd (mg/kg)**	Mean	insufficient	insufficient	1.7	1.4	2.3	1.9
	STD	data	data	0.5	0.6	0.2	0.8

* Milligrams pollutant per kilogram of wet bulk sediment

** Pollutant mass per kilogram of dry sediment

SDT - Standard Deviation

Based on Table III , the existence of two layers of sediments into a drain was determined (type A and type B), however, Table IV shows that some parameters do not meet the established, this is due to the high variability of results and decrease of the number of samples analyzed for each zone with different land use.

Notwithstanding the above, in Table IV the difference in the concentrations of pollutants from land use can be observed. The sediments obtained in areas with residential use of land have lower concentrations of pollutants, while the sediments extracted areas of industrial land use have higher concentrations of pollutants.

Concentrations of BOD, orthophosphate, organic content, fats and oil are similar between areas with industrial and commercial uses of land. However, the COD of sediments extracted in industrial areas differs from the residential and commercial areas.

CONCLUSIONS

In stratum A, the concentrations of the parameters: COD, BOD, orthophosphate, organic content, fats and oil are higher than the ones in stratum B.

The re-suspension of the A type deposits may be the cause of high pollution loads associated with precipitation events.

Variations of concentrations of pollutants in sediments are related to the quality of wastewater flowing into the sewer, which in turn is based on the use of land of drained area. Mexico City is mostly composed of three land uses: industrial, commercial and residential. Concentrations of pollutants identified in this study, decrease respectively.

Due to the complexity of the sanitary sewerage of Mexico City, it is impossible to determine the amount of sediments present in the system. However, based on field observations, it is estimated that the amount of sediments in the collector network is about 345.738 m^3.

Sediments in Mexico City are classified as poorly graded sands with gravel and few fines (SP), according to the Unified Soil Classification System (USCS).

Lead concentrations in sediments exceed the established by Nriagu [13] for uncontaminated soils. Moreover, the concentrations of cadmium in sediments exceed levels considered toxic to some plant species [4]. Based on the above, sewer sediments should not be used as soil improvers without prior stabilization treatment.

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