Study on Regions Non-point Source Pollution at Different Management Level in Longgang District of Shenzhen

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Abstract. In order to understand the regional non-point source pollution at different management level in Longgang District of Shenzhen City, the commercial and residential zone, the cultural and educational zone, the transportation zone, the industrial zone and the urban village were chosen as sampling sites. The surface street dust and rainfall runoff samples were collected after investigating the management levels and the correlation between the management level and street dust or rainfall runoff was analysed. The results showed that the street dust accumulation was the highest in the transportation zone (25 g/m²), which was at the lowest management level. However, the best-managed commercial and residential zone and the cultural and educational zone had a street dust accumulation of about 8 g/m², which was higher than those in the industrial area and urban village (3.5 g/m²). This may be due to the different size of the crowded flow. In each zone, the large-sized particles contribute a major proportion of the street dust. The N and P contents in the dust was highly correlated with the particle size, but showed no correlation with the management level. The correlation was also observed between the pollutant contents in rainfall runoff and the management level. The low-managed transport zone had the highest pollutant contents, with most of the indicators exceeded the values limited by the Environmental Quality Standard for Surface Water (GB 3838-2002, class V criteria)

1. Introduction
The street dust is an important carrier of pollutants on impervious surface when considering the non-point source pollution in the city. By studying the street dust accumulation and its pollution characteristics such as pollutant species and quantity, the effects of life and production activities on the environment in specific areas can be analysed. Thus, the street dust characteristics could be used as good indicators in regional environmental pollution studies. The contribution of street dust on the non-point source pollution is mainly derived by the rainfall event. Along with the afflux of runoff on the impervious surface, the pollutants were gathered and lead to a rainfall runoff pollution. Furthermore, these pollutants can be flushed into the receiving waters and posed a potential risk to the water environment [1].

In the rapid development of urbanization, some parts of the city cannot fully become economically developed regions. Such regional population is not in the minority, and the degree of education is also
uneven. In such urban areas, therefore, large differences emerged at the management levels between different regions and functional areas, and this might result in obvious effects on the characteristics of street dust [2-7]. Since street dust is a complex mixture of pollutants and has complicated sources, it is affected by various factors, such as tires wear, vehicle emission, roads aging, industrial production, residential activities, atmospheric precipitation, and cleaning method and frequency, etc [8-10]. The street dust can be washed into the receiving water along with rainfall after daily accumulation, resulting in the pollution of urban water environment. Therefore, it will be helpful to the research of urban non-point source pollution by studying the pollution of urban street dust and rainfall runoff at different management levels [11-12]. The results also have reference meaning on improving the management mode in the economically underdeveloped regions, and thereby improving the conditions of urban non-point source pollution.

In view of the problems that the urban non-point source pollution of street dust and rain runoff are various caused by different management levels, this study chooses the Longgang district of Shenzhen city as study area. The management levels of different regions were investigated, while the street dust and rainfall runoff were sampled and assayed. According to the results, the relationship between the regional management level and street dust or rainfall runoff pollution were analysed.

2. Material and methods

2.1. Study area
Five different functional areas were selected as the research regions in the Pingdi street of Longgang district, Shenzhen, including commercial and residential zone, culture and education zone, transportation zone, industrial zone and urban villages. In each functional area, one or two sampling sites were selected. The location of the selected sampling sites were as follows: the Dingshanghuating housing estate in commercial and residential zone, the Lanling School in cultural and educational zone, the Jiaoyu North Road and Xinghua Road in transportation zone, the Jixiang 3rd Road factory and the industrial area in industrial zone, the Liyuan New Village and Gaoqiao Village in urban village.

2.2. Sampling methods
The street dust was sampled with vacuum cleaner sampling method. After removing leaves and garbage, the samples were packed into a sealed bag and stored at a cool and dry place for analysis. In the sampling process, the low-lying areas beside the road should be avoided, and the sampling area should be recorded.

The sampling of rainfall runoff were conducted at the Dingshanghuating housing estate (commercial and residential zone), the Jiaoyu North Road (transportation zone), the Jixiang 3rd Road factory (industrial zone) and Liyuan New Village (urban village).The surface runoff was sampled at the rainwater wellhead at intervals of 5 minutes in the beginning 15 minutes, and then at intervals of 10 minutes. When the surface runoff decreased obviously, the sampling was conducted at intervals of 30 minutes. The volumes of runoff and the sampling times were recorded. The runoff samples were mixed in a sampling barrel, part of the samples was stored in a 1L polyethylene bottle for analysis. The precipitation data was measured by automatic rain gauges installed near the sampling sites.

2.3. Analysis methods
The street dust samples were separated into seven particle sizes by a sieve analyser: 450-1000μm, 250-450μm, 150-250μm, 105-150μm, 62-105μm, 44-62μm, and < 44μm. The weight of each particle was determined, and TN and TP in different particles of part of the dust samples were analysed.

The runoff samples were prepared to analyse total suspended solids (TSS), total nitrogen (TN), total phosphorus (TP), chemical oxygen demand (COD) and ammonia nitrogen (NH3-N). All the chemical indicators were determined in accordance with the “National Standard of the People's Republic of China” and “National Environmental Protection Standards of the People's Republic of
China”. The TSS was determined using weight method (GB 11901-89). The TN was determined using ultraviolet spectrophotometric combined with alkaline potassium per sulfate digestion (HJ 636-2012). The TP was determined using ammonium molybdate spectrophotometric method (GB 11893-89). The COD was determined by dichromate method (GB 11914-89). The NH3-N was determined using the sodium reagent spectrophotometric method (HJ 535-2009). The runoff water quality in each study area was analyzed using event mean concentration (EMC), and compared with the class V criteria of the Environmental Quality Standard for Surface Water [8,11].

3. Results and discussion

3.1. Street dust accumulation and particle size distribution

Previous studies have shown that the accumulation of street dust no more increased after rainfall event over 14 days [8]. Thus, the sampling of the street dust in the present study was carried out over 14 days after the rainfall, which were conducted in November 2016 and January 2017, respectively. The result of dust accumulation was showed in Fig.1 and Fig.2. The accumulation of street dust is not increased day by day, but was more influenced by the external factors.

![FIGURE 1. Street dust accumulation (2016.11)](image1)

![FIGURE 2. Street dust accumulation (2017.1)](image2)

Note: XQ, the Dingshanghuating housing estate in commercial and residential zone; XX, the Lanling School in cultural and educational zone; R1, the Jiaoyu North Road in transportation zone; R2, the Xinghua Road in transportation zone; F1, the Jixiang 3rd Road factory in industrial zone; F2, the 2nd industrial area in industrial zone; C1, the Liyuan New Village in urban village; C2, the Gaoqiao Village in urban village.

![FIGURE 3. The average amount of street dust in sample sites](image3)

The street dust samples collected from two periods are analyzed, and the cumulative amount was shown in Fig. 3. The amount of street dust per unit area, as well as the range of the dust, was highest in the sites from transportation zone, where received the lowest level of management. This is mainly because of the uncertainty and complexity of the human flow, traffic flow and cleaning condition in these areas. The best-managed commercial and residential zone and cultural and educational zone had low street dust amounts. However, the range of the dust in commercial and residential zone was larger than that in cultural and educational zone, because of the more complicated surrounding environment.
of the former. The industrial zone and the urban village, with the medium management levels, had generally higher street dust amounts than the commercial and residential zone and cultural and educational zone, even though the 2nd industrial area (F2) and Gaoqiao Village (C2) showed lower dust amounts due to the lower human flow. The Jixiang 3rd Road factory and the Liyuan New Village also had large dust range.

The particle size distribution of street dust was analyzed using samples collected in January 2017. After dividing the street dust into seven particle sizes, the percentage of each particle size was shown in Fig. 4.

The results showed that the 450-1000μm sized particle contributed most to the total dust weight, with a proportion of 30-50%. The large proportion of this particle size was mainly observed in the transportation zone and might be attributed to the roadside green belts and cleaning methods. The street dust was difficult to be cleaned up by sweeping vehicle, since the coarse particles was easy to settle down to the road during the cleaning process. Moreover, the leaf falling from roadside trees will produce a large amount of wood residues and increase the coarse particles. The commercial and residential zone such as Dingshanghuating housing estate had more fine particles (< 44μm) than other zones, with a proportion of more than 20%. This might be attributed to the dust derived from human flow. The tiny sized dust was difficult to be wiped off by simply manual cleaning. The urban villages such as Liyuan New Village and Gaoqiao Village also had a high proportion of fine particles (10-20%) in the case of unstable and unrestricted human flow.

3.2. TN and TP contents in particle size fractions
The TN and TP contents in particle size fractions were analyzed in part of the collected dust samples.
The results showed that the TN contents increased with decreasing particle size in all dust samples (Fig. 6). Among the different sampling sites, the TN content in coarse particles was highest in the dust samples collected from the Xinghua Road (R2, 9.95 μg/g), and that in fine particles was highest in the dust samples collected from the 2nd industrial area (F2, 14.58 μg/g). The lowest TN content was observed in coarse particles sampled from the Jixiang 3rd Road factory (F1, 6.82 μg/g), and followed by that in coarse particles sampled from the Gaoqiao Village (C2, 7.00 μg/g). The TP contents also increased with decreasing particle size in all dust samples (Fig. 6). The highest TP content was observed in fine particles sampled from the Liyuan New Village (C1, 1096.89 μg/g), and lowest was in fine particles sampled from the Dingshanghuating housing estate (XQ, 6.29 μg/g) and the Jiaoyu North Road (R1, 6.29 μg/g), respectively.

3.3. Characteristics of runoff pollution

In this study, two complete rainfall events were monitored and the runoff samples were collected. The two rainfall events can be identified as moderate rain according to the precipitation, and the data were shown in Table 1.

| Duration of rainfall (min) | Precipitation (mm) | Ave. rainfall intensity (mm/min) | Max. rainfall intensity (mm/min) |
|---------------------------|-------------------|----------------------------------|----------------------------------|
| 2016-08-26                | 33                | 13.6                             | 0.41                             | 1.5                              |
| 2016-09-11                | 68                | 17.3                             | 0.25                             | 0.7                              |

The EMC is normally expressed as the mean concentrations of pollutants in surface runoff during a rainfall event; the land is widely used to evaluate the pollution load of the urban rainfall runoff, the validity of the management, and its effects on the receiving water. Actually, the EMC is a average value of the instantaneous runoff pollutant concentration weighted by the flow rate during a rainfall event, and could be calculated as follows [10]:

\[
EMC = \frac{M}{V} = \frac{\sum_{i=1}^{n} Q_i c_i dt}{\sum_{i=1}^{n} Q_i dt}
\]

Where EMC is the event mean concentration of rainfall runoff (mg/L); M is the total pollutant contents during the rainfall event (g); V is the total runoff volume (L); t is the runoff time (min); Qt is...
the runoff rate (L/min); Ct is the pollutants concentration (mg/L) that varied with time. n is the sampling frequency during period t; Qi and Ci represent the runoff rate (L/min) and pollutant content (mg/L) of sampling i. In condition of multiple rainfall events, the EMC was expressed as the arithmetic mean value of the EMCs in each rainfall events.

The runoff water quality in each study area was analyzed using EMC method and compared with the class V criteria of the Environmental Quality Standard for Surface Water (GB3838-2002) (Table 2).
exceeded the class V criteria of the Environmental Quality Standard for Surface Water in all regions. This might be attributed to the pollution from the surrounding residential and industrial areas. The sampling sites of industrial zone and urban village, which had similar management levels, showed similarly higher rainfall runoff pollutant concentrations. The highest runoff pollutant concentration was found in the worst-managed transportation zone. The pollutant concentrations of the rainfall runoff can reflect the relationship between management level and runoff pollution. On the whole, the rainfall runoff pollution increased with the reducing management level.

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