Toxicity on *Anabas Testudineus*: a case study of sanitary landfill leachate

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Abstract

In many parts of the developing world, leachate treatment system is not properly installed and managed that landfill leachate usually flows into existing water bodies. Consequently, heavy metal in leachate could lead to biomagnification of heavy metals as the components travel higher within the food chain. Thus, it is necessary to understand the characteristics of leachate and its toxicity potential prior to its release to the water bodies. This paper aims to determine the toxicity effect of different types of landfill leachate on *Anabas testudineus*. Also, the behavioural changes towards leachate toxicity will be recorded. To achieve the objectives, toxicity tests were conducted on *A. testudineus*. It involved three main stages namely acclimatisation, range finding test, and short-term definitive test. For the purpose of the study, leachate samples were collected from an active sanitary landfills and a closed sanitary landfill. Ten *A. testudineus* with average weight of 4.2g and average length of 4.0cm were introduced into leachate with five different concentrations ranging from 3.125% to 5.625%. The mortality rate was observed and recorded after 96 hours exposure. The LC$_{50}$ of *A. testudineus* was calculated using EPA Probit software. Leachate from non-active landfill is alkaline (pH 8.2) as compared to that of the active landfill (pH 7.35). As expected, COD from the closed landfill is much lower (10,000mg/l) than the active landfill (24,800 mg/l) while the BOD$_5$ was 3,500mg/l and 12,500mg/l, respectively. However, the result of ammoniacal nitrogen was highly different between these landfills, where closed landfill is releasing higher concentration of ammoniacal nitrogen (880mg/l) than the active landfill (0.085mg/l). The toxicity test indicated that both landfill leachates are highly toxic to *A. testudineus*. In fact, leachate from the closed landfill was more toxic than leachate from the active landfill. Results indicated that the LC$_{50}$ of the leachate from closed landfill on *A. testudineus* was 4.71% v/v while LC$_{50}$ of the leachate from active landfill was 5.1%. Discolouration of exposed fishes was observed in the study, and it could be due to the loss of colouring pigment caused by ammonia poisoning. Other observation of behavioural changes included swimming disorder, loss of equilibrium, unusual leaping action, and declination in the general activities. These are most probably due to neurotoxin effect inflicted by the leachate exposure. In conclusion, leachate from active and non-active landfills is toxic to *A. testudineus* based on the behavioural changes and the high mortality rate.

Keywords: MSW disposal; Landfill leachate; toxicity effect; Anabas tetudineus

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1. Introduction

Rapid human growth has resulted with the emergence of various environmental problems ranging from depletion of natural resources to environmental pollution. In many countries in the ASEAN region, improper waste management has been reported to be one of the three main contributors to environmental degradation [1]. This is due to the fact that the increase in waste generation is not in line with the advancement in waste management system. For example, Malaysia landfills 95% of the approximately 30,000 tonnes of waste generated daily into existing waste disposal sites, while Indonesia and Nepal landfills more than 70% and 63% of the waste collected, respectively [2-4].

1.1. Municipal solid waste disposal

Economic development has pushed environmental concern such as constructing sanitary landfill to a lower priority due to the low standard of living of the people. As a result non-sanitary landfill with no engineered technologies is being extensively utilized in developing nations. Consequently, this improper waste disposal practice will bring about various environmental issues namely environmental degradation and risks to human health to many developing nations in the world.

Municipal solid wastes (MSW) generally are highly heterogeneous in nature that the separation can be almost impossible [2]. This is occurring in the many parts of the world particularly the developing nations that the whole of this waste stream will be dumped into disposal sites. As a result, it is necessary to have a dumping ground to cater the need of disposal within a designated area. In Malaysia approximately 300 disposal sites have been recorded where 111 were mere-open-dumps. Several of these open-dumps have been closed after the passing of the Solid Waste and Public Cleansing Management Act 2007 due to their negative impacts to the surrounding area [2]. Without proper lining system, open-dumps can leach out highly polluting liquid to the adjacent surface water bodies while penetrates through the soil layers into the groundwater system. Thus, landfilling activities generally pose risk of leachate contaminations to the aquatic ecosystem.

1.2. Landfilling and leachate generation

Leachate is the liquid percolated through the waste layers within a landfill cell. It contains high level of organic pollutants in the form of high COD, TOC while dissolving various heavy metal elements [5]. The leachate generation is highly dependent on soil types, waste composition, degree of compaction of the waste disposed, amount of landfill received, evapotranspiration and also type of landfill and the age of landfill [6]. Leachate generation begins as soon as the disposal site receives its first batch of waste, where the liquid sourced from the moisture that exists in the waste, water from degradation of putrescible waste and rain. This will continue until the disposal sites cease its operation and no longer receive additional waste. At this instant, leachate will be produced mainly from the degradation of the waste within the waste cells. Due to this factor, characteristics of leachate will vary from time to time. Normally, the concentration will be the highest during the first 3-8 years when biodegradation is occurring very rapidly [6]. Table 1 depicts the characteristics of landfill leachate samples obtained landfills in Malaysia.

1.3. Leachate toxicity

In many parts of the developing world, leachate treatment system is not properly installed and managed that landfill leachate usually flows into existing water bodies. The heavy metal in leachate will cause toxicity and heavy metal accumulation in aquatic organisms. Consequently, it could lead to
biomagnification of heavy metals as the components travel higher within the food chain [8]. The risk of leachate contamination can also due to the present of high concentration of ammoniacal nitrogen [5]. Thus, it is necessary to understand the characteristics of leachate and its toxicity potential prior to its release to the water bodies.

Table 1. Characteristics of Raw Landfill Leachate [7].

| Parameter          | Jeram Sanitary Landfill | Bukit Tagar Sanitary Landfill | Panchang Bedena Disposal site (Rural) | EQA 1974 Standard 2009 |
|--------------------|-------------------------|-------------------------------|--------------------------------------|------------------------|
| BOD5 (mg/l)        | 27,000                  | 26,379                        | 348                                  | 20                     |
| COD (mg/l)         | 51,200                  | 36,413                        | 5,056                                | 400                    |
| pH                 | 7.35                    | 6.6                           | 8.1                                  | 6.0-9.0                |
| TSS (mg/l)         | NA                      | 14                            | 1.6                                  | 50                     |
| Cd (ppm)           | NA                      | 7                             | ND                                   | 0.01                   |
| Cu (ppm)           | NA                      | 7                             | 1.0                                  | 0.20                   |
| Pb (ppm)           | NA                      | 13                            | 41.7                                 | 0.10                   |
| Zn (ppm)           | 827.7                   | 31                            | 675.7                                | 2.0                    |
| Mg (ppm)           | 32                      | 59                            | 36,533.3                             | NA                     |
| K (ppm)            | 1130                    | 923                           | NA                                   | 0.05                   |
| Ammoniacal-N (mg/l)| 0.085                   | 4,329                         | NA                                   | 5                      |
| Hg (ppm)           | 0.05                    | NA                            | NA                                   | 0.005                  |
| Fe (ppm)           | 97.76                   | 74.0                          | NA                                   | 5.0                    |

NA- Data not available   ND- elements not detected

This paper aims to determine the toxicity effect of different types of landfill leachate on *Anabas testudineus* while the behavioural changes towards leachate toxicity will be recorded. *A. testudineus* is among the most vigorous freshwater fish in the tropical region which have high tolerance to unfavourable water condition.

2. Materials and Methods

2.1. Leachate characteristics

For the purpose of the study, leachate samples were collected from an active sanitary landfills and a closed sanitary landfill. Fresh leachate samples were collected from the inlet point of the leachate treatment pond. Samples were pretreated with acid preservation prior to the transport to the laboratory for analysis and toxicity trials. Leachate characteristics were analyzed and determined. The analysis conducted includes COD, BOD5, TOC, Ammoniacal-nitrogen, TDS, Heavy metals and Oil and Grease.

2.2. Toxicity tests

Toxicity tests were conducted on *A. testudineus* involving three main stages namely acclimatization, range finding test, and short-term definitive test.
2.3. **Acclimatization**

During acclimatization, *A. testudineus* with average weight of 4.2g and average length of 4.0cm were kept in an aquarium with continuous aeration. The water was flushed and refilled daily for at least 14 days. *A. testudineus* were fed with commercial pellet once per day during the acclimatization period. Feeding was stopped 48 hours prior to the introduction to leachate.

2.4. **Range finding test**

Range finding test were conducted to determine the best range of concentration for the definitive test. Duplicate groups of 10 fishes were added into containers with five different concentrations and monitored every 12 hours. The number of mortality within 96 hours of exposure was recorded to determine the most appropriate concentration for the definitive test.

2.5. **Definitive test**

For the definitive test, the concentration used range from 3.125% to 5.625% v/v of leachate. Similarly, for each concentration namely 5.625%, 5.00%, 4.375%, 3.750% and 3.125%, 10 fishes were introduced. A control was set-up without the addition of leachate. The mortality and change in the fish behavior were recorded for every 12 hours. The LC50 of *A. testudineus* was calculated using EPA Probit software.

3. **Results and Discussion**

3.1. **Leachate characteristics**

Analysis showed that the leachate from non-active landfill is alkaline (pH 8.2) as compared to that of the active landfill (pH 7.35). As expected, COD from the closed landfill is much lower (10,000mg/l) than the active landfill (24,800 mg/l), while the BOD5 was 3,500mg/l and 12,500mg/l, respectively. However, the result of ammoniacal nitrogen was highly different between these landfills, where closed landfill is releasing higher concentration of ammoniacal nitrogen (880mg/l) than the active landfill (0.085mg/l). Table 2 details the characteristics of leachate utilized in this experiment.

3.2. **Toxicity test**

No mortality of *A. testudineus* was observed during the first 24 hours in the lowest concentration i.e 3.125%. This probably is contributed by the fact that *A. testudineus* is highly robust, thus have higher capability to tolerate leachate exposure. However, mortalities were recorded after 24 hours in leachate from closed landfill. This could be contributed by the high concentration of ammoniacal-nitrogen in the leachate from the closed landfill. Similar observation was noted for the concentration of 4.375% where no mortality was recorded among fishes exposed to the leachate from the active landfill, while leachate from the closed landfill killed 40% of the fish in the same concentration. However, number of mortality increase to 60% and 45% in the active and closed landfill leachate, respectively at 5.00% concentration. This probably due to the fact that the presence of pollutants in this concentration might be inducing certain biochemical reactions within the cells of *A. testudineus*, thus become toxic to the fishes.

At the highest concentration of leachate exposure (5.625%), the number of mortality ranged from 75%-80% for leachate from active and closed landfills. Therefore, the toxicity test indicated that both
landfill leachates are highly toxic to *A. testudineus*. This is agreeable to the findings of Jaafar et al [8] that leachate from selective landfills in Malaysia was harmful to *Cyprinus carpio*.

Table 2. Characteristics of Leachate Used.

| Parameter       | Active Sanitary Landfill | Closed Sanitary Landfill | EQA 1974 Standard 2009 |
|-----------------|--------------------------|--------------------------|------------------------|
| BOD₅ (mg/l)     | 12,500                   | 3,500                    | 20                     |
| COD (mg/l)      | 24,800                   | 10,230                   | 400                    |
| pH              | 7.35                     | 8.2                      | 6.0-9.0                |
| TSS (mg/l)      | 688                      | 97                       | 50                     |
| Cd (ppm)        | ND                       | <0.001                   | 0.01                   |
| Cu (ppm)        | ND                       | <0.001                   | 0.20                   |
| Pb (ppm)        | ND                       | 0.001                    | 0.10                   |
| Zn (ppm)        | 0.21                     | 0.1                      | 2.0                    |
| Mn (ppm)        | 540                      | 0.12                     | NA                     |
| K (ppm)         | 530                      | 440                      | 0.05                   |
| Ammoniacal-N (mg/l) | 0.085             | 880                      | 5                      |
| Hg (ppm)        | 0.05                     | 0.12                     | 0.005                  |
| Fe (ppm)        | 8.52                     | 3.1                      | 5.0                    |

3.3. Changes in *A. testudineus* behavior and physical appearance

Changes in the behavior of *A. testudineus* included loss of equilibrium where fishes were not able to balance while swimming, aggressive jumps, decline in the general activity and the irregular swimming patterns. These are most probably due to neurotoxin effect inflicted by the leachate exposure. In addition to that, the exposed fishes were also excreting excessive mucosal secretion while having difficulties in breathing. This probably due to the lack of oxygen thus encouraged the fishes to gather at the surface. Similar observation was reported among red tilapia by Daud et al. [9, 10].

Discolouration of exposed fishes was observed in the study, and it could be due to the loss of colouring pigment caused by ammonia poisoning. Other observation of behavioural changes included swimming disorder, loss of equilibrium, unusual leaping action, and declination in the general activities.

3.4. LC₅₀ of *A. testudineus* in tested leachate

As for the toxicity level, leachate from the closed landfill was found to be more toxic than leachate from the active landfill. Results indicated that the LC₅₀ of the leachate from closed landfill on *A. testudineus* was 4.71% v/v while LC₅₀ of the leachate from active landfill was 5.1%. This generally due to the presence of higher concentration of ammoniacal-nitrogen in the closed landfill that the leachate generated is more contaminating and potently harmful to *A. testudineus*. 
4. Conclusions

In conclusion, leachate from both active and non-active landfills is toxic to *A. testudineus* at certain concentration. At higher concentration, the leachate exposure may cause behavioural changes among *A. testudineus* while inducing high mortality rate to the fishes.

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