Environmental Screening Method for Dredging in Contaminated River
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Abstract. Dredging in a contaminated river has been widely accepted to have an impact on the environment; however environmental risk assessment analysis could be costly, time-consuming and difficult to perform. Therefore, a screening method acting as a preliminary risk assessment analysis to screen potential contaminated areas is necessary. The aim of this study is to demonstrate a new screening method for risk assessment analysis in a scenario where economy, time and simplicity factors had been a concern. The development of this method is based on a variation of standard Ecological Risk Assessment. An analysis will be performed on two elements. Firstly, the level of contaminants in the water, groundwater and air (known as the media) and, secondly the behavior of environmental indicators during monitoring of historical dredging. This analysis is performed in order to establish the degree of contamination in an area that is about to be dredged, in where the publicly accessible contamination level in the media and the historical dredging monitoring data will be utilized. Eight dredged sites in Peninsular Malaysia are selected as the case studies of this research. This research showed that Sungai Perlis has a very high total risk value, which could have a fatal impact on its biodiversity if dredging is performed with negligence at this location. This research could provide an opportunity for Malaysia to increase its efforts to avoid dredging impacts without being constrained on time, cost and simplicity factors.

Introduction

Dredging, which is performed in a highly contaminated site but has not been identified as a risk, could prove fatal for biological resources. Such cases have been observed in the developing country of Malaysia [1-4]. This could be due to current understanding of low number of contaminated sites owing to its slower development rate in comparison to countries like the US and the UK, in that their contaminated land requires strict environmental rules and regulations [4]. Moreover, it has been generally accepted that assessing environmental risks and providing mitigation measures is costly [5-7], which is a discouraging factor for many developing countries to use the already developed tools and assessments. In fact, a research which explored dredging issues in the developing country of Malaysia, confirmed that it lacks efficient tools and practices to assess the environmental risks of dredging [8]. Therefore, the need remains for an efficient tool or assessment, which takes into account a country’s economic capability, to be developed in order to identify possible risks of dredging.

Ecological Risk Assessment (ERA) has been widely used to assess impacts of chemical exposure on endangered biological resources [9-11]. This analysis involves simplistic phases of risk assessment and three phases of ERA have been suggested by the United States Environmental Protection Agency (US EPA) (1998) namely: problem formulation, extent of impacts from exposure to chemicals over toxicity levels, and characterization of risk [10, 12].

The ecological impacts caused by exposure to contaminated sediments have generated considerable research interest in the US and the UK and many frameworks have been developed in order to characterize the risks of the presence of contaminated sediments for biological resources.
This includes assessment of ecotoxicological risks related to the depositing of dredged materials on soil and assessment of ecological risks of sediments dredged from ports and estuarine zones [7, 13]. Unfortunately, these frameworks can be time-consuming and are often difficult to perform, which is unfavourable to middle income countries, which are currently in the state of rapid development [7]. Therefore, an alternative approach that is easy to perform and not time-consuming is a necessity.

This paper introduces a new screening method and demonstrates its application to identify dredging-related risks in an area by using a simplified variation of ERA framework. This method utilizes the publicly accessible data and the historical monitoring of dredging data by using Malaysia as its case studies. As a result, this research will determine a location that is having a very high degree of contamination level.

Methodology

1st step. The objective of this first step of the screening method is to identify historical dredging risk values through three distinct stages; assessment of exposure level (namely; concentration level of mercury, cadmium, arsenic, lead, copper, zinc, dissolved oxygen, biochemical oxygen demand, total suspended solids, and chemical oxygen demand) from historical dredging activities, assessment of toxicity level associated with exposed substances, and characterization of the risks found. The execution of this step can circumvent the unnecessary sediment analysis, which can often be costly.

Eight maintenance dredging projects performed between 2006 and 2011 in Peninsular Malaysia were selected as the case studies for this paper. The reason for using historical dredging data lays in the fact that previous research indicates that concentration levels of metals in sediments increased after dredging. This means that contaminants dispersed by dredging are deposited back onto the new layer of sediments, exposed after excavation [14-16]. This creates a potential for future dredging to disperse the contaminants that have been re-deposited. Additionally, critical changes in indicators, monitored after historical dredging in an area, indicated its high contamination levels, which could have been initially caused by contaminants inputs from neighbouring land. Therefore, it is vital to analyse the behaviour of contaminants and the risk of re-contamination from adjacent land and therefore utilized in this step.

2nd step. The objective of this second step is to assess and quantify contamination level in media (the water, groundwater and air) as a total risk value using three types of data, namely number of rivers with polluted and slightly polluted status of Water Quality Index, number of days with very unhealthy and unhealthy status of Air Pollution Index and number of sampling points exceeding the standards of groundwater levels.

The reason behind the selection of this data to screen for ecological risks lays within the contaminant pathways. The contaminant originates from point and diffuse sources and penetrates sediments, which are about to be dredged, through precipitation, emission and dissipation from various media, including air, groundwater, and surface and marine water [17-19]. Therefore, it is necessary to assess these media (air, groundwater, and surface and marine water) to indicate its quality that determines the degree of contamination in an area.

The Water Quality Index, Air Pollution Index and groundwater level that have been monitored annually on a national level, can be good indicators of the quality of media [20-23]. Moreover, the utilization of this publicly accessible data can save cost and time to screen the dredging risks for the environment. Quantification of these indicators can be used in accordance to their indexes, however it should be noted that the lower the Water Quality Index becomes, the worse the water quality is. This is in contrast to the Air Pollution Index, which denotes that the risk increases, as the index itself increases. A stable quantification of risk is required to relate these indexes, which can signify the environmental risks. Therefore, it is suggested that the number of rivers in the river basin of the area to be dredged, that have a polluted and slightly polluted status of Water Quality Index, the number of days in the area, which have a very unhealthy and unhealthy status of Air Pollution Index and the number of sampling points, which exceed standards of groundwater levels in the area,
should be used for this step of the screening. It should be noted that the duration of data monitoring depends on data availability; however, a similar the monitoring should have a similar duration in each location in order to ensure a fair comparison between areas.

3rd step. The final step of this screening stage is to combine risk values found in previous steps for a total risk value and to determine the degree of contamination of an area. The terminology for the degree of contamination can be found in Table 1 [11].

<table>
<thead>
<tr>
<th>Total risk ratio (Y)</th>
<th>Degree of contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y&lt;7</td>
<td>Low</td>
</tr>
<tr>
<td>7≤Y&lt;14</td>
<td>Moderate</td>
</tr>
<tr>
<td>14≤Y&lt;28</td>
<td>Considerable</td>
</tr>
<tr>
<td>Y≥28</td>
<td>Very high</td>
</tr>
</tbody>
</table>

Result

1st step results. Sungai Perlis has been found to have the highest average total risk value of historical dredging, compared to other locations Fig 1.

![Figure 1. Average of total historical dredging risk value at location of case studies](image)

2nd step results. The results for the second step in the screening stage can be found in Fig 2 which shows media risk values for each case study location. Sungai Muar has the highest average total of contamination level in media.

![Figure 2. Average of total media risk value at the location of case studies](image)

3rd step results. The results have been illustrated in Fig 3. It was found that the river, which has a very high degree of contamination, was Sungai Perlis.
Discussion

Prior work highlighted the environmental impacts of dredging and many tools and assessments to identify dredging risks have been developed, but remain difficult to utilise, costly and time-consuming. This becomes the discouraging factor to use them by party that seeks for economic, simplicity and time benefits. In this paper, a newly developed method that utilizes free publicly accessible data and already available data in order to initially identify risks of dredging has been demonstrated in the scenario of a developing nation. This method corroborated the ERA phases suggested by US EPA (1998), well matched to the behavior of indicators, when being dredged by utilizing historical dredging monitoring data, and well suited to the contamination level in media into sediments, when using media contamination level data.

This method was demonstrated in Malaysia using eight case studies. It has been found that Sungai Perlis has the highest value of total historical dredging risk, whereas Sungai Muar is the location with the highest value of total media risk. The analysis of total risk value (addition of total historical risk value and total media risk value) found that Sungai Perlis has a very high degree of total risk value. This indicates that the contamination level at Sungai Perlis is categorized as very high.

However, it should be noted that this result is arguable due to the fact that it was not possible to retrieve groundwater data prior the execution of this study. Nevertheless, the research highlights the insufficiency of monitoring of this vital environmental indicator (groundwater data) on a national level in this country. At the same time, this becomes a good indicator to demonstrate how this country deals with the issue of contaminated land. It should be stressed that contamination from point and diffuse sources can dissipate into groundwater and be transferred from one area to another. Therefore, the lack of monitoring on a national level for this vital pathway shows that the issue of contaminated land has not been recognized in Malaysia.

It should be highlighted that ERA was initially suggested to protect endangered species and there can be tolerance for its risk values, only if they do not affect the entirety of populations and communities [30]. For example, Sungai Perlis has been characterized as having a very high degree of contamination, but if its biodiversity is not endangered and is highly mobile, the very high degree of contamination of this area can be tolerated with caution.

As countries like Malaysia are well-known for their biodiversity, which has become one of its sources of income, proactive action towards protecting them from the harmful effects of dredging is strongly needed. The results from this study should be looked upon as an opportunity for countries like Malaysia to improve their efforts to protect their environment from harmful dredging impacts. Thus, a detailed analysis on biodiversity composition and mobility should be further analyzed.
This screening method enables the accurate initial prediction of environmental dredging risks and it is straightforward and efficient in terms of time and cost. This could encourage parties that stress upon benefits in cost, simplicity and time, like Malaysia, to take proactive actions toward protecting their environment, whilst increasing their economic strength.

Conclusion

Dredging has been proven to have an impact on the environment and many tools and assessments have been developed. However these are difficult to perform, costly and time-consuming. This study demonstrated a newly developed screening method for the environmental risks of dredging, using publicly accessible data and available historical dredging monitoring data in its variation of ERA phases suggested by US EPA (1998). This method was demonstrated in a scenario of a developing country, Malaysia, where economic impact has always been a concern. It has been found that Sungai Perlis has the highest value of total historical dredging risk, whereas Sungai Muar is the location with the highest value of total media risk. The analysis of total risk value (addition of total historical risk value and total media risk value) found that Sungai Perlis has a very high degree of total risk value. This indicates that the level of contamination at Sungai Perlis is categorized as very high. However, this result is arguable due to the fact that it was not possible to retrieve groundwater data prior the execution of this study. Nevertheless, this research highlighted the many insufficiencies of environmental monitoring in this country, where this method could provide an opportunity to improve current efforts to prevent environmental damage due to dredging. This improvement should be reflected in future dredging projects, when this method is used, in order to benefit from its low cost, time efficiency and straightforwardness.

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