UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL

INSTITUTO DE GEOCIÊNCIAS

PROGRAMA DE PÓS-GRADUAÇÃO EM GEOCIÊNCIAS

ESTRATÉGIAS AMBIENTAIS PARA UTILIZAÇÃO DE MATERIAL DE DRAGAGEM

LUCIANO HERMANNS

ORIENTADOR – Prof. Dr. Iran Carlos Stalliviere Corrêa

Porto Alegre – 2017

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Dedicatória

Dedico esse trabalho as pessoas de perto e de longe, que contribuíram e me apoiaram durante meu amadurecimento. A construção nunca é solitária, os anseios e as expectativas foram divididos e suportados graças ao convívio social e a arte da troca.

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RESUMO

O desenvolvimento da atividade portuária requer melhorias nas vias navegáveis e na configuração dos portos através de dragagens de aprofundamento e manutenção. O estado do Rio Grande do Sul, no Brasil, possui vias navegáveis que liga cidades industriais ao porto internacional do Rio Grande, mas que são subutilizadas devido à falta de investimentos e à necessidade de aprofundamento e manutenção. Associado a isso, os processos de dragagem são caros, complexos e podem impactar o meio ambiente. O objetivo deste trabalho é apresentar uma alternativa de uso aos sedimentos de dragagem na forma de recurso mineral e com isso diminuir os impactos do despejo do material dragado no corpo hídrico. Para auxiliar na definição do melhor uso para o material dragado, foi desenvolvido o Plano de Uso de Material de Dragagem. No intuito de adicionar mais informações aos requisitos legais brasileiros e auxiliar na tomada de decisão sobre a reutilização deste material, este plano busca complementar as exigências da Resolução Conama 454/2012. Para validação do mesmo, o plano foi aplicado durante a elaboração de estudos de licenciamento de um terminal portuário no rio dos Sinos, Canoas – Rio Grande do Sul. Através de uma análise multicritérios, foram discutidas características físico-química do sedimento e a necessidade socioambiental e econômica de recursos minerais. Os resultados mostraram a importância de aplicar um método de decisão que inclua a empresa e as informações técnicas ambientais. A ampla possibilidade de uso dos sedimentos amostrados no rio Sinos, bem como a necessidade social e econômica deste recurso contribuíram para validar o uso de sedimentos como recurso através. Com isso, foi possível concluir que o uso de sedimentos podem ser uma alternativa de recursos durante os processos de dragagem no Rio Grande do Sul. Além de ser uma alternativa à dificuldade encontrada pelos setores público e privado durante a elaboração e execução de planos de dragagem. Aliado a isso, os custos de dragagem podem ser reduzidos através da criação de um banco de sedimentos para atender às necessidades do governo, incentivando a utilização das vias navegáveis do Rio Grande Sul e consequente diminuindo o transporte rodoviário e suas emissões de CO_2 associadas, colaborando com o controle do aquecimento global.

ABSTRACT

The development of the port activity requires improvements through dredging of deepening and maintenance in the navigable ways and the configuration of the ports. The state of Rio Grande do Sul, Brazil, has navigable waterways linking industrial cities to the international port of Rio Grande, but underutilized due to lack of investment and the need for deepening and maintenance. Associated with this, the dredging processes are expensive, complex and can affect the environment. The objective of this work is to present an alternative of use to the dredging sediments in the form of mineral resource and with that to diminish the impacts of the disposal of the dredged material into the water. To define the best use for the dredged material, the Dredging Material Reuse Plan was developed. The plan improve and add more information to Brazilian legal requirements and assist in the decision on the reuse of this material, this plan seeks to complement the requirements of Conama Resolution 454/2012. In order to validate it, the plan was applied during the elaboration of licensing studies of a port terminal in the Rio dos Sinos, Canoas - Rio Grande do Sul. Through a multi-criteria analysis, the physicochemical characteristics of the sediment and the socio-environmental and economic necessities of mineral resources were discuss. The results showed the importance of applying a decision method that includes the company and the technical environmental information. The wide possibility of using the sediments sampled in the Sinos River, as well as the social and economic necessity of this resource contributed to validate the use of sediments as a resource. With this, it was possible to conclude that reuse of sediment can be an alternative resource during dredging processes in Rio Grande do Sul. Besides being an alternative to the difficulty encountered by the public and private sectors during the elaboration and execution of dredging plans. Allied to this, dredging costs can be reduce through the creation of a sediment bank to meet the needs of society and government. The use of waterways must be encourage in Rio Grande Sul, consequently reducing road transport and its associated CO2 emissions, collaborating with global warming control.

SUMÁRIO

1. INTRODUÇÃO

1.1. OBJETIVO DESENVOLVIDO

O presente trabalho tem como objetivo demonstrar a viabilidade de usos de sedimentos oriundos de dragagens e estabelecer o regramento para disposição quanto as melhores alternativas e estratégias de usos.

Neste contexto foram verificadas as atuais possibilidades de manejo desse sedimento dragado e das melhores técnicas e métodos para identificação, qualificação, destino dos sedimentos. Este trabalho avalia os impactos ambientais de dragagem e seus dois fatores importantes (tecnologia de dragagem e característicos de sedimentos) que determinam a magnitude dos impactos através de revisão da literatura, e discute a necessidade de uma gestão ambiental na dragagem mais integrada a ser desenvolvido para o sul do Brasil.

O desenvolvimento das áreas portuárias é histórico e crescente. O amplo uso dessas regiões resultou na contaminação dos sedimentos acumulados nos estuários. A necessidade crescente de aumento de fluxo de cargas e com isso aumento do calado gera a necessidade dragagens constantes e de aprofundamento dos canais.

O uso benéfico não é um conceito novo, durante muitos anos, grandes volumes de material dragado limpo foram utilizados e discutidos em muitos foros como na Conferência Regional do Atlântico Norte em 1987. No Brasil, os usos benéficos de sedimentos oriundos de dragagens são enaltecidos pela Conama 454/2012, entretanto a tomada de decisão da melhor forma de uso não segue regramento padrão e acaba por tornar a despejo do material dragado no corpo receptor como alternativa mais utilizada no Brasil. Embora muitos documentos reconheçam que a tomada de decisão eficaz do ambiente exige considerações ambientais, ecológicas, tecnológicas, econômicas e sócio-políticas relevantes para avaliar e selecionar uma alternativa de gestão, estes fatores raramente são considerados em conjunto e as decisões são muitas vezes impulsionadas por apenas um aspecto do problema.

Os resultados que serão apresentados mostram a importância de aplicar um método de decisão que inclua a empresa e as informações técnicas ambientais do sedimento e da área de estudo. A Figura 01 apresenta um resumo das estratégias de uso descritas para sedimentos de dragagem. A ampla possibilidade de uso dos sedimentos, bem como a necessidade social e econômica deste recurso contribuíram para validar o uso de sedimentos como recurso. Com isso, foi possível concluir que o uso de sedimentos como recursos no Rio Grande do Sul pode ser uma alternativa à dificuldade encontrada pelos setores público e privado durante a elaboração e execução de planos de dragagem. Aliado a isso, os custos de dragagem podem ser reduzidos através da criação de um banco de sedimentos para atender às necessidades do governo, incentivando a utilização das vias navegáveis do Rio Grande Sul e consequente diminuindo o transporte rodoviário e suas emissões de CO2 associadas, colaborando com o controle do aquecimento global.

Figura 01 – Estratégias de uso para sedimentos de dragagem.

1.2. SOBRE A ESTRUTURA DESTA TESE

Esta tese de Doutorado está estruturada em torno de artigos publicados em periódicos ou publicações equivalentes. Consequentemente, sua organização compreende as seguintes partes principais:

a) Introdução sobre o tema e descrição do objeto da pesquisa de Doutorado, onde estão sumarizados os objetivos e a filosofia de pesquisa desenvolvidos, o estado da arte sobre o tema de pesquisa.
b) Artigos publicados em periódicos ou submetidos a periódicos com corpo editorial permanente e revisores independentes, ou publicações equivalentes (capítulo de livro de publicação nacional ou internacional com corpo de revisores independentes), escritos pelo autor durante o desenvolvimento de seu Doutorado.
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2. ARTIGOS

Os artigos são apresentados conforme lógica de desenvolvimento e aplicação de estratégias para o uso benéfico de sedimentos de dragagem.

2.1. THE NECESSITY OF DREDGING MANAGEMENT IMPROVEMENT IN BRAZIL

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THE NECESSITY OF DREDGING MANAGEMENT IMPROVEMENT IN BRAZIL

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THE NECESSITY OF DREDGING MANAGEMENT IMPROVEMENT IN BRAZIL

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ABSTRACT

The necessity for development in countries such as Brazil is directly linked to infrastructure improvements. Consequently, the improvement of the port system and maintenance of waterways by dredging are required. The **objective** of this work is to evaluate the environmental management of dredging in order to reduce operational costs and potential environmental impacts. The **methodology** applied in this study discusses information on regulation, supply, supervision and management. The data are presented, organized, discussed and compared with each other and with the Brazilian reality. The **results** presents that national policy seeks for decentralization of trade and suggests the alternative use of dredging sediments. However, dredging not present a wide discussion to reuse sediments, prioritizing disposal in water. To reduce dredging costs and minimize impacts on water, this work **concludes** that it is necessary to improve the discussion on sediment reuse in dredging in Brazil, through a multi-criteria analysis.

Keywords: MCDA; Environmental Management; Sediment; Multi-criteria.

Introduction

Dredging is essential for the maintenance and development of ports, harbours and waterways for navigation, remediation of contaminated sediment and flood management. However, other environmental impacts are produced by the dredging process and include the removal, transport and placement of sediments within the existing physical, social, economic and biotic structures of the public and the environment (Balchand and Rasheed, 2000; Crowe et al., 2010). The dredging of sediment replaces the indigenous subtidal benthic species and communities with species and communities that can inhabit the altered conditions in the dredged channel and during suspension of less dense sediment components can also affect pelagic organisms. In addition to the environmental impacts of the dredging operation, the dredging of these waterways produces large volumes of dredged material that need to be handled while reducing the quality of water for human consumption or ecosystem not only at the dredging site but also at the site where the dredged material is placed (PIANC, 2009). Manap and Voulvoulis, 2015, suggest conditions to developing nations, where the impacts from dredging also coexists with conflicting issues. Cost, public perception, rules and regulations, socioeconomic, interference with alternative uses at the dredging and placement sites, and management of dredging have received attention over the past few years (Agius and Porebski, 2008; Wang and Feng, 2007; Alvarez et al., 2010). Managing conflicting uses and public perception at dredging and dredged material placement sites are key aspects of conducting successful projects.

Prior to making a decision about dredging processes and the preferred alternative uses of the dredged material it is necessary to conduct environmental and socioeconomic assessments (Dwarakish and Salim, 2015). Different tools have been created and tested throughout the world to increase the ports performance (Madeira et al, 2012). A dredging process hazard analysis (PHA), analysis of multi criteria (MCDA), Life Cycle Analysis (LCA) Environmental Impact Assessment (EIA), and risk assessment analysis are good examples of alternative approaches (PIANC, 2016; Bates, ME et al, 2015; Gomez, A.G. et al, 2014). Coincident with these analyses is the need to obtain pre-dredging data and cartographic measurement which can then be entered into and analyzed through a Geographic Information System (GIS) (Nemec, and Raudsepp-Hearne, 2013). GIS can then be used to demonstrate the effectiveness of the project by post dredging monitoring of the dredged and the placement sites.

The legal rules in developing countries as in the case of Brazil have evolved over the years (Drummond, and Barros, 2005). However, simplistic analysis of the results may hinder the public and governmental acceptance and execution of dredging but may also miss important environmental or socioeconomic considerations. In this sense the tools to be used for understanding the best dredging processes for each environment should consider multiple potential short and long-term effects of conducting or not conducting the project as well as those same types of factors for the proposed alternative uses of the dredged materials (Andersson et al, 2016).

This article presents the considerations to be made by Brazil stakeholders and discusses the potential impacts of dredging coupled with the use of available technologies for dredging as well as placement of the dredged materials in coastal environments and the potential suite of alternative uses of dredged material other than water disposal. This paper is designed to provide information for consideration and to generate discussion on the best strategy to ensure port development while conserving and potentially enhancing coastal ecosystems.

Methods

In order to evaluate the necessity for improvement in the environmental management of dredging in Brazil, the main factors involved in dredging management were discussed e compared to reality. The results will be presented and discussed by: a brief survey of the Brazilian port legislation; existing and applicable dredging technologies; potential impacts caused by dredging; and environmental dredging management tools.

Thereby, the Brazilian reality is discussed as the need for development of the port system and its waterways. As well, the associated legislation and governmental programs that seek to improve logistics in Brazil. On the other hand, the existing dredging techniques, the environmental impacts inherent in the process and the measures for mitigation and monitoring are also evaluated. In a comparative way, management tools used in different countries will be presented and their applicability to the Brazilian reality will be discussed.

Results

Brazil is not an exception, and needs to optimize the use of ongoing research for more efficient harbor and waterway development while employing less direct labor in routine tasks while producing more coherent environmental solutions to current reality (Boldrini, et al, 2007; Boldrini, et al, 2008). This is the search that ventures have follow from the beginning, where the ports brought and led the global economy. Today, the reality of port development is not a single, simple solution to implement what is needed by the port but ports must now depend on economic, environmental and political social factors to create ongoing port development. This mixture of different perceptions of realities require understanding of other concerns and honest negotiations among stakeholders (Gac et al, 2011).

The ports that have the best conditions have increased traffic flow allowing the highest profits resulting in the best conditions to managers of the ports and the country. In this context, the marine industry has increased the size of the supply vessels allowing increased transport of a larger number of loads/vessel resulting in an increase in productivity. Thus, it is necessary to alter Brazilian port infrastructure to match the globalization of vessel sizes. Brazil implemented legislation to reform of the port system in 1993/96, by the “Law of the Ports” (Law nº 8.630/93). This law granted port authorities to allow private terminals and to implement the new regime of hand-work management. Supplemented by the Additional Act of 1996 which focused on decentralization. These laws and supplements (Law nº. 8630/93/96) proposed to promote the necessary changes in ports in order to achieve the minimum international parameters so we could take advantage of the regional locations of each port terminal (Gilbertoni, 2015).

Law 12,815 / 2013, would modernize Brazilian ports. It establishes new criteria for the operation and lease (through assignment agreements for use) for the private cargo handling terminals in public ports. In addition, the new rules facilitate the installation of new private port terminals. Already NORMAN-11 provides that, before starting the process of environmental licensing, by the competent environmental agency, the entrepreneur must ask: through Application Captain of Ports, via Police or Agency of the Province of the dredging area of jurisdiction, one dredging

Preliminary Request for the Maritime Authority to ascertain whether, in principle, the dredging project will compromise the safety of navigation or the planning of maritime space (Diretoria de Portos e Costas, 2003).

Despite the efforts to put Brazil in the forefront, many environmental aspects need to be considered. The big ships which reduce costs and become more competitive need access channels with greater depth. For this the Secretariat of Ports (SEP) through the Institute of Waterways Research has conducted studies for the National Dredging Program 2 - PND2. According to SEP's information there are now 34 Public Ports Maritimes where 16 are delegated, granted or have authorized operation to state and local governments and the other 18 are directly managed directly by the Dock Company (situation that must be changed with the annexation of companies docks by DNIT, scheduled on 2015).

Technologies for dredging

According to Goes-Filho (1979), the choice of dredgers and dredging equipment is very complex, and in many cases is determined by the dredged area's physiographic location. The main elements to be considered when choosing the equipment are as follows:

• physical characteristics of the material to be dredged;

• the volume of material to be dredged;

• dredging depth;

• distance from the placement site of the material;

• environmental conditions of the area to be dredged and placement site (housed displaced or local);

• agitation of the water level;

• level of contamination of dredged sediments;

• Placement method of dredged material;

• Estimated production of equipment used; and

• types of equipment available.

Literature available indicates the existence of four main types of dredging processes: These include 1) Dredging to deepen or develop a new location; 2) Maintenance dredging, 3) remediation or environmental dredging and 4) mining dredging. In this context, there are three categories of equipment, mechanical, hydraulic and pneumatic dredges (Antipov et al, 2006; Du Li, 2010; Honmagumi and Chiyoda Kenki, 1995; Klein, 1998).

The material from the dredging can be stored for later use or removal, placed in barges for transport to disposal or reuse site, directly discharged into water or on land usually in nearby areas using a pipeline (Zhang et al., 2014). In Brazil, the most widely used placement method is in-water disposal after mechanical or hydraulic dredging. However, any type of disposal must be previously licensed for corrent disposal (CONAMA 454, 2012).

National legislation (eg. CONAMA 454, 2012) and international (eg. EPA, 2008) assessment methods requires knowledge of the physical and chemical characteristics of the sediment, and slurries of sediment and their ecotoxicological potential. These assessments help in making decision on the methods of dredging, transport and disposal of dredged sediments. CONAMA - National Environment Council, through Resolution CONAMA nº 454/2012 establishes minimum guidelines and procedures for the assessment of dredged material in Brazilian waters, in order to support and harmonize the activities of environmental agencies in the environmental licensing of activities dredging, defining the locations for final disposal from sediment contamination levels. The focus of this resolution is the management of the material to be dredged, in which the sediment rating levels are set as reference values should be taken as another line of evidence for the definition of the dredged material disposal. The main objective of Resolution No. 454/2012 is the establishment of national classification levels of sediment, detailing some reference determinations on environmental management of dredged material, clearly explain the steps to be followed for the characterization and classification of the sediment, and indicate that dredged material may be used in a beneficial way without necessarily disposal in water (Morton, 2001; Su, 2002; and Thibodeaux Duckworth, 2001; Calixto, 2012).

The disposal of contaminated sediments is generally not allowed, based on physicochemical characteristics and ecotoxicological tests (Lapota et al., 2000). Some forms of sediment contamination can be easily handled with mechanical methods such as mixing and aeration (Akcila et al, 2015). As well as some positive or negative for contaminants should be better evaluated, indicating the possibility of confunding factors and assisting in the decision making regarding the disposal of this material (Lapota et al., 2000). Other remediation techniques include sequential extraction techniques, pretreatment physical separation processes, containing, washing, thermal extraction, bioremediation, electro kinetics solidification / stabilization, vitrification, and chemical oxidation (Akcila et al, 2015). However, the remediation of sediment can be costly and destination of this treated material not offset the expenses. On the other hand, the use of contaminated sediment should be evaluated for their real toxicity to human health and the ecosystem destinations. In this sense reuse can be a solution, provided that the necessary steps are taken (Wang et al, 2015; Cappuyns et al, 2015; Junakova, 2015).

The sediment contamination is directly related to the type of target sediment and land uses in the surrounding areas. Fine sediments tend to retain higher concentrations of contaminants and nutrients as in consolidated port areas and near urban areas have the potential risk of the presence of noxious compounds to the ecosystem (Bebianno et al, 2015). Contaminant enter the water through runoff over contaminated soils, industrial effluents, agricultural areas, domestic sewage, mining or natural apport as like from organic and chemistry decomposition of rocks and organisms (Kenishi, 1994). As contaminants do not degrade (or degrade slowly), they can be a source of environmental chronical or acute impacts, even if they are not frequently resuspended.

Sediments may have high levels of contamination when municipal sewage generated are not efficiently treated (Garrett, 2000; Holt, 2000). On the other hand, the health of rivers needs of sediments as a source of life and appreciation of these stems from the fact that they have different functions. From the point of view of aquatic ecology, as well as water, sediments are an integral and active part of the watershed. They constitute the major source of nutrients for many organisms and microbiological processes that trigger the regeneration of nutrients and operation cycles of nutrients throughout water providing favorable conditions for the development of a wide variety of habitats (Cruvinel et al., 2008).

In this context, quality guidelines sediments (Guidelines) have been used for classification of the sediments as potentially or not contaminated, although this is not a regulatory requirement for all countries (Wenning, 2005). Currently in the US, European Union, Canada and Brazil are used quality guidelines to determine the sediment contamination level in a local dredging. The guidelines are used to assess the quality of dredged sediments in order to help protect the environment and humans from exposure to contamination (Burton, 2002; Wenning, 2005). This means that if the sediments exceed the reference values, it is necessary to adopt alternative technologies to deal with them (PIANC, 2009). Along with guidelines, water reference values (quality standards) are used to monitor chemical parameters of the water column affected by dredging. The quality standards of water can be determined from two perspectives: the water quality in aquatic water systems; and quality of water intended for drinking use. The guidelines are based on human or animal toxicity studies (MacGillivray and Kayes, 1994).

Potential impacts of dredging

Even using the best technologies available for dredging and taking the necessary precautions are expected environmental impacts. It is important to note that any change environments generates a certain impact on the ecosystem. Thus, the positive impacts (beneficial) and negative (adverse) are evaluated for their forms and incidence of time (whether direct or indirect, immediate or mediate), as to their distributive (local or regional) and especially on their stay (reversible or irreversible).

Through the knowledge of the impact assessments indicate to the preventive and mitigating measures, and ways to monitor the impacts being identified for each impact their respective measures and environmental programs. However, when these impacts are irreversible, proposals for mitigation and monitoring programs, compensation measures are necessary to the affected environment.

The activity of the dredger cause physical disorders associated with the removal and relocation of sediments with consequent destruction of benthic habitats, increasing the mortality of organisms caused by mechanical action during dredging or by suffocation. These environmental changes are responsible for reducing the abundance of benthic organisms associated with these sediments.

The response of benthic fauna in dredging's events is widely studied. For example, Newell et al. (1998) showed that dredging operations determine significant falls in univariate descriptors (density and number of charge). The dredging expose subsurface sediments which typically exhibit low oxygen concentrations. Moreover, the dredging determine an increase in turbidity due to the increase of the suspended material content, and may cause a decrease in the penetration of solar radiation, which may result in a reduction of primary productivity rates of benthic and pelagic system (Rabalais et al., 1995).

The dredging process will involve resuspending the pellets which in turn will increase the water turbidity and may also resuspend contaminated sediments. The sediments of aquatic environments, especially their organic fraction, perform nutrient exchange with the overlying water column (DeNobili et al., 2002; Moss et al., 1996). In general, the sediments are not only a deposit of products that are, or who come to the water column, but represent a compartment that recycles compounds involving biological processes (bioturbation, action oxidizing bacteria and reducing, among others), physical- chemical (adsorption, desorption), chemical (precipitation, oxidation, reduction, complexation) and transport processes (diffusion, advection).

It is also clear that the dredging cause changes in aquatic fauna, to a lesser intensity induce less temporary displacement of nektonic species (Fogliatti, 2004). The influence of dredging activity by reducing the diversity and abundance of fish fauna species has been studied and confirmed by several researchers, including, Torres (2000) and Antunes (2006). Moreover and Freitas (2005) suggests that dredging can enable new colonization these environments and contribute to the growth of new species, since disturbances release new niches. Furthermore, nektonic species, with natural high mobility, rapidly depart the appearance of sediments plume, returning to the site dissipate the impact.

Regarding the impact that dredging can cause escape and mortality of fish fauna from these environments, has been also identified that habitat disturbance and physiological problems related to the accumulation of sediments in the gills can cause suffocation, causing your scaring and scattering (Table 1). However, because they are nektonic organisms, they must be able to get away once identified changes in the environment. This clearance is momentary, while there is a disturbance in environment, and once paused the interventions, the fauna has full capacity to return.

Table 1 presents some examples of dredging environmental impacts, the possible causes and alternative mitigations.

Table 1. Examples of Principal Environmental Impacts of Dredging			
Impacts	Chemical (1, 2, 3, 4, 5, 6, 7, 10, 12, 17, 20 and 21)	Physical (1, 2, 6, 13, 14, 16, 25, 26)	Biological (1, 2, 3, 4, 8, 9, 10, 14, 15, 17, 18, 19, 22, 23, 24, 25, 26, 27)
	Increase of chemical contaminants in water and sediment after dredging	Decreased transparency	Uptake of contaminants by the fauna
	Increased Oxygen Demand	Hydrossedimentological Changes	Increase or decreased in the number organisms
Possible cause	Dispersion of contaminants in the water during the excavation or deposition - and return of these contaminants to the natural sediment layers. The exposure of contaminants increases the need for oxygen for decomposition	Change the rivers, estuaries and coastal sediments, hydrodynamics and patterns of erosion and accretion margins	Dispersion increases chemical contamination. And there are no mitigating alternatives to changes in the bentic organisms directly affected.
Mitigations for these impacts	Use of low dispersion dredging systems; Disposal of dredged material n soil or in the water, which allows high turbidity dilution.	Previous studies of modeling and creation of structures to ensure the maintenance natural characteristics	Previous studies can guarantee the choice of areas with lower impact. The environment should be specifically evaluated, and specific social and environmental demands must be adopted, such as the completion of dredging out the fishing periods and reproducing organism communities
	They should also be applied to monitoring programs that assist in decision making during the process.		

Reference: (1) Davis, Macknight e Imo 1990; (2) Bray, Bates e Land 1997 (3) Ponti et al., 2009;(4) Toes, 2008, (5) Mackie, 2007, (6) Messieh et al., 1991, (7) Piou, 2009, (8) Munawar, 1989, (9) Constantino, 2009, (10) Balchand and Rasheed, 2000, (11) Thibodeaux and Duckworth, 2001, (12) Shigaki et al., 2008, (13) Su, 2002, (14) Bonvicini Pagliai et al., 1985, (15) Ellery and McCarthy, 1998, (16) Sergeev, 2009, (17) Rasheed and Balchand, 2001, (18) Padmalal, 2008, (19) Kenny and Rees, 1996, (20) Ljung, 2010, (21) Cappuyns, 2006, (22) Ware et al., 2010, (23) Crowe et al., 2010, (24) CruzMotta and Collins, 2004, (25) Powilleit et al., 2006, (26) Wilber et al., 2007; (27) Padmalal, 2008.

The dredging has different impacts on the natural environment, but is important to consider the socio-economic positive impacts of the activity to sustainable development. New employment opportunities, income generation and improvement in efficiency of transport are impacts arising from the dredging. That through the improvement of these factors tends to improve the coexistence of man and the environment. However, the high cost of dredging is an important point to correct execution procediment. The cost of dredging varies according to the technology and equipment used, the estimated volume of sediment to be removed, type of dredged material, distance of excavation for disposal site, the time and distance of mobilization and demobilization, and disposal method (Xavier, 2009). The high cost has always been the main problem for the port operators, who are responsible for dredging and maintenance of deep channels, but also need to spend money to expand or build new terminals in order to meet the growing commercial activities (Gibb, 1997, BMVBW, 2004).

Despite the fact that developing countries should become the largest dredging markets in the world over the coming years, stiff competition from foreign dredging contractors increases the need to reduce costs for contractors of local dredging (Anderson and Barkdoll, 2010; Williams, 2008). This, along with poor facilities and poor environmental expertise, increases the risk of environmental neglect in developing countries. In addition to the problems faced in developed countries, dredging operators, for example in Brazil, face an even greater challenge because of the limited funds of port entrepreneurs. Although the maritime industry of Brazil has been treated as a priority for his government through different programs like PAC – Growth Acceleration Program, PROMEF - Program for Modernization and Expansion of the Fleet (TRANSPETRO, 2014; SINAVAL, 2014; PAC-2, 2015). Brazil has the challenge to increase the impacts monitoring during dredging. The environment sensitivity, which is deteriorating, makes a critical point to investigate and reduce the dredging impacts at national level.

In an attempt to reduce costs by optimizing work and reducing impacts, different management tools have been created and is being used around the world (BMVBW, 2004; PIANC, 2009). As well as remediation techniques of sediment and reuse of dredged material alternatives show alternatives to aggregate value to material from dredging and bring income to the activity.

Environmental dredging management

Environmental management is a response to human actions considering the increasing seriousness and significance of human impact on natural ecosystems. It is comforting to know that evolution of the technology and the environment resilience might be able to recuperate habitats from the past mistakes and abuse. Nevertheless, it is now widely recognized fact that in many cases positive intervention is necessary to recover environment for economic growth and to preserve the natural ecosystems.

Improving environmental performance actually reduces costs (Wang, 2006). Dredging companies have found that it is possible to save money, sometimes large sums of money, by improving their environmental performance and reuses of materials (Junqua, 2006).

To improve environmental performace and assist in decision making, management tools have been used around the world. In Brazil the most commonly used are the auditing and monitoring, environmental impact studies, life cycle analysis, risk analysis, geographic information system and more recently multi criteria analysis.

Environmental auditing is a tool for checking how the process are been done and how it should be doing. For instance, a legislative compliance audit checks if those activities covered by environmental legislation actually comply with the Brazilian legislation. An environmental audit will confirm if the dredging management practices are be doing conform the industry best practice guidelines and if it has committed itself to following.

Auditing is an important part of an environmental management system. ISO 14001 requires an audit to be undertaken to check whether management system meets its requirements. That means, a critical analysis and thorough process, could found faults and maintaining the standardization process.

Environmental Impact Assessment (EIA) is a tool used to identify the environmental, social and economic impacts of a project prior to decision-making of viability. It aims to predict environmental impacts at an early stage in project planning and design, find ways and means to reduce adverse impacts, shape projects to suit the local environment and present the predictions and options to decisions. By using EIA both environmental and economic benefits can be achieved, such as reduced cost and time of project implementation and design, avoided treatment/clean-up costs.

As described by Nec 2011, although legislation and practice can vary around the world, the fundamental components of an EIA would necessarily involve the screening to determine if the project require a full or partial impact assessment study. Investigate to identify which potential impacts are relevant to assess (based on legislative requirements, international conventions, expert knowledge and public involvement), and alternative solutions that avoid, mitigate or compensate (including the option of not proceeding with the project), and finally to derive terms of reference for the impact assessment. Assessment and evaluation of impacts and development of alternatives. And reporting the Environmental Impact Statement (EIS) or EIA report, based on the terms of reference (scoping) and public (including authority) participation. The decision-making on whether to approve the project or not, and under what conditions; and at last the monitoring, compliance, enforcement and environmental auditing.

Life cycle assessment (LCA) is a tool for identifying and assessing the various environmental impacts associated with a particular process. LCA takes a “cradle to grave” approach looking at the impacts of the product throughout its life cycle. For example, the choice of different sediment management options through the compilation and evaluation of the environmental consequences of each choice. LCA allows to find ways of cost-effectively reducing the environmental impact of a product over its life-cycle and to support their claims about the environmental impact of their products.

The life-cycle method considers the air, water and solid waste pollution that are generated when materials are extracted. It examines the energy used in the extraction of materials, and the pollution that results from manufacturing the material. It also accounts for environmental harm that might occur during the distribution and use of the product. The valuation of the environment is fundamental to the understanding of the cost benefit of environmental projects, the ex duction of dredging and the reuse of sediments (Pearce & Seccombe, 2000)

Management approaches to environmental and risk assessment issues are increasingly being used at all levels of policy and regulation. These techniques have a wide range of application, including: design of regulation, for instance in determining societally "acceptable" risk levels which may form the basis of environmental standards; providing a basis for site-specific decisions, for instance in land-use planning or siting of hazardous installations; prioritization of environmental risks, determination of which chemicals to regulate first; comparison of risks, for instance to enable comparisons to be made between the resources being allocated to the control of different types of risk, or to allow risk substitution decisions to be made.

An ecological risk assessment is the process for evaluating how likely it is that the environment may be impacted as a result of exposure to one or more environmental stressors such as chemicals, land change, disease, invasive species and climate change (Chapman, et al. 2002; Linkov, et al. 2006).

Risk characterization includes two major components: risk estimation and risk description. "Risk estimation" combines exposure profiles and exposure-effects. "Risk description" provides information important for interpreting the risk results and identifies a level for harmful effects on the plants and animals of concern (Deliman et al., 2002).

Geographic information system (GIS) technology is used to support and deliver information to environmental managers and the public. GIS allows the combination and analysis of multiple layers of location-based data including environmental measurements. The environmental application areas of GIS varied in terms of potential users, environmental spheres, and the specific environmental issue being investigated (Larsen, 1999).

GIS can be used as a strategic tool to automate processes, transform environmental management operations by garnering new knowledge, and support decisions that make a profound difference on our environment. A dredging modeling techniques system based on GIS and GIS geostatistical model to identify contamination (Vianna, 2004) also to support the design of judicious and effective remedial actions such as dredging and capping in large complex sites.

Multi-Criteria Decision Analysis (MCDA) support a complex decision-making with different possibilities and situations. The groups of stakeholders with different desires are assisted by MCDA to find the best economic, ecological and social solution for potential conflicts of uses. The performance of the alternatives with respect to the criteria (scoring) with subjective judgements about the relative importance of the evaluation criteria in the particular decision-making context (weighting) (Kiker, 2007). This method needs to require subjective judgement about the normalization/scaling of impacts. However, also expert opinions can be disputed in conflicting environmental management situations (Martin et al, 2011; Ban et al, 2015). Therefore it is important to engage the participants also in the impact assessment stage and not only in the weighing stage (Saarikoski et al., 2013).

Overall, to control the adverse effects of the dredging process were analyzed the environmental impacts of dredging, and some tools of environmental management have been identified. However, these tools have individual weaknesses which could limit their effectiveness. It has been noted that the management tools and environmental practices that allow the integration of conflicting issues during the decision-making dredging should be put in place in order to make a sustainable decision and avoid its adverse effects. Moreover, the sources, routes and dredging impacts must be taken into consideration when identifying measures to reduce the impacts of dredging. The concept of integrated environmental management has a definition that covers everything; Wang (2006) defined this concept as "a process of achieving sustainable development and maximize the benefits to human and ecosystem society, balancing exploitation of resources, socio-economic activities, and protection of the environment through cooperation and coordination of entities and relevant administrative and governmental parties ". Consequently, integrated environmental management could provide a structure to accommodate different views of stakeholders, and identifies the most appropriate range of actions to address multi-criteria and conflicting issues as faced by many countries (PIANC, 2009). Successful applications of this concept were seen in Integrated Coastal Management and Integrated Coastal Zone, which is among the Environmental Management Integrated tools (IEM).

In Brazil, the Constitution of the Federative Republic of Brazil, in Art. 225, § 4, considers the Coastal Zone a National Heritage, providing for their use in accordance with the law, with a view to preserving the environment and the sustainable use of it's natural resources (BRASIL, 1988). The Law No. 7,661 / 88 which established the National Coastal Management Plan - PNGC, national public policy that mandated the states the delimitation of its Coastal Zone. With PNGC II, approved by Resolution CIRM No 05 of 12.03.1997, proceeded to the delimitation of the coastal zone using political boundaries for terrestrial band and established Baselines according to the United Nations Convention on Law of the Sea (1982) for the marine strip (BRASIL, 2004). The PNGC has, as its primary purpose, the establishment of standards for environmental management of the country's coastal zone, laying the foundation for the formulation of policies, plans and state and local programs. In this connection was also established Project Management Integrated Maritime Orla (Projeto Orla), aimed at a joint action between the Ministry of the Environment - MMA, through its Secretariat for Climate Change and Environmental Quality - SMCQ, and the Ministry of Planning, Budget and Management, within its National Union Heritage Secretariat - SPU / MPOG trodden in the following items (MMA, 2014):

- Strengthening the performance capacity and articulation of different actors in the public and private sector in the integrated management of the edge, improving the legal framework for the use of land and occupation of this space;
- Development of mechanisms for participation and social control to integrated management;
- Valuation innovative management actions aimed at sustainable use of natural resources and occupation of coastal areas.

Knowledge of the conceptual model of sources of impacts is a first step to help and develop environmental management. MCDA studies offer different opportunities to reduce, avoid or mitigate environmental impacts. These measures can be implemented by controlling the levels of contaminants from point and diffuse sources, proper new management process, environmentally friendly technologies, remediation of sediment prior to disposal and use these material from dredging as a resource. Engineering uses such as: for construction materials, isolation, flood defence and beach nourishment; Environmental Enhancement including habitat creation and enhancement, maintenance of sediment supply, aquaculture and recreation. They can bring value to the sediment and assist in the implementation of more appropriate management tools to environmental conservation.

In Brazil it is necessary to balance dredging problems involving economic and social issues. On the other hand, methods requiring the search for expensive data are difficult to implement in countries with scarce monetary resources, so the use of dredging material as a resource for other purposes may be more appropriate. The economic view of derived material from dredging by developing countries could put greater emphasis on developing environmental issues. In addition, Brazil is currently undergoing major economic development as part of a government plan to become a fully developed country. Dredging is an important component of this, and how observed in previous studies, Brazil is facing difficulties in effectively monitor the dredging impacts. The lack of a structured database and temporal relevance, have become even more evident the need for this country to develop an effective tool for environmental management to prevent further deterioration of the environment and any distortion of the real impacts of dredging.

Conclusion

The choice of optimal environmental management tool that links the environment and the broader issues of dredging is the way to reduce the impacts and increased economic growth as necessary social sustainability of developing countries. Through the choice of tools and reuse of dredged materials developing countries have the opportunity to learn from their practices. Examples from other countries shows that the use of dredging sediment to economic and ecological purposes decreases the impacts, improves the ecosystem and reduce the compliance costs (BMVBW, 2004; PIANC, 2009).

An environmental management tool for dredging and the best use of dredging material is clearly needed to improve the economic and environmental performance of dredging in Brazil. This tool should incorporate process implications and environmental and social needs with the aim of reducing the dredging impacts.

Considering the properties of sediments and the technology avalable, as well as economic considerations which would otherwise dominate the process. And essentially seeking to decrease the costs and monetary economy during the dredging process, ensuring economic improvement and the participation of society in decision making.

Despite the Brazilian national policy, through CONAMA 454/2012 to indicate preferentially the beneficial use of dredged sediments, it is necessary to create a flow chart to assist decision-making based on the potential impacts of sediment and local needs through a multi-criteria analysis.

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2.2. DETERMINATION OF ALTERNATIVE USES OF DREDGING MATERIAL THROUGH MULTI-CRITERIA ANALYSIS

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Determination of alternative uses of dredging material through multi-criteria analysis

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ABSTRACT

Alternative uses for dredging sediments is not a new concept. In Brazil, the alternative uses of sediment from dredging are extolled by legislation, however, the best alternative use does not follow a standard rule and ends up making the disposal of the dredged material in water, the most used in Brazil. While many documents recognize that effective environmental decision-making requires relevant environmental, ecological, technological, economic, and sociopolitical considerations to assess and select an alternative management, these factors are rarely considered together and decisions are often driven by only one aspect of the problem. In this sense, the objective of this work is to provide information necessary for the creation of a Dredging Material Reuse Plan. The method used by Hermanns, L. et al. 2017, to create the plan was the compilation and structuring of secondary information, legal aspects, community consultation and consequent multi-criteria into an integrated analysis, through a flowchart of the stages for Dredging Licensing, complying with current legislation. The stakeholders' consultation seeks to understand the need for local uses for material from dredging and generate involvement among individuals, to seek inclusion of the social, environmental and economic segments of the process. The analyzes result pointed to the importance of beneficial uses and the prioritization of social and environmental uses to economic ones. Moreover, it is possible to verify that there are few restrictions to the use of the materials, being the restrictions related the size of the grains and contaminated sediments related to the purpose of use. Finally, this study concludes that it is necessary to establish the elaboration of a Dredging

Material Reuse Plan as a public instrument for decision-making. Noting that local use needs, technological risks and associated costs are essential to validate the most appropriate use for the material.

Keywords: Environmental Management, MCDA, Dredging, and Sediment.

1 INTRODUCTION

Dredging may be considered as the removal of material from the bed of water bodies for a specific purpose by means of equipment called a "dredge", which is generally a vessel or floating platform equipped to remove the sediment. The most common dredge types used in Brazil and in the world are divide into two groups, the mechanical and the hydraulic (ALAD/CBD, 1972, Bray et al., 1997). Mechanical dredges are used for the removal of gravel, sand and very cohesive sediments, such as clay, peat, and highly consolidated silt. These, remove sediments through the direct application of a mechanical force to excavate the material, regardless of its density. Hydraulic dredges are better used for the removal of loosely consolidated sand and silt by removing and transporting the sediment while suspended in a liquid form. They are in general centrifugal pumps, driven by diesel or electric motors, mounted on boats and that discharge the dredged material through pipes. When sediment is remove in this manner, it results in a great amount of water that also needs to be processed.

The importance of dredging procedures is also important and essential for the maintenance and development of ports, waterways for navigation, remediation of contaminated sediments and flood management (Soares, 2006; CL, 1972, Goes, 2004; Brighetti *et.al* 1993). The growth and development of ports leads to greater trade activity, increased supply, greater foreign reserves and reduced prices for commodities as a whole (Dwarakish, and Salim, 2015).

The sediments are move from the bed of rivers, lakes, estuaries and coast zones, by the dredging activity. The sediment composition consists of particles ranging from coarse to fine sand, silt and clay. They also contain organic matter and different types of materials like stones, wood, pieces of metals and glass as well as having a potential contain contaminants.

In line with legislation, dredging as well as for all activities, causing environmental impacts, require measures to eliminate or mitigate possible negative effects on the affected region (PIANC, 2009).

In projects that requiring dredging, these measures are implemented at all stages. In the deposition phase, the dredged material can be place directly to water, which involves possibility of impact on the benthic community, navigation, fishing activity and may even interfere with water quality (Davis, Macknight e Imo 1990; e Bray, Bates e Land 1997). The dredged materials may also be disposed on land, which would involve suctioning and recharging of the dredged material directly to the disposal site and continuous monitoring during the operation (BMVBW, 2004; PIANC, 2009). In addition, the legal, technical and environmental implications are also relate to land use and land use legislation. Table 1 presents correlations between factors associated with the dumping of dredged material in water and soil, taking into account some important information in the decision making as the probable environmental impacts, legal protection, the forms of control and the time of occurrence for each one compartment.

Table 1. Relation of associated factors in the choice of disposal site for material from dredging

CHOICE OF DISPOSAL		
ASSOCIATED FACTORS	**DISPOSAL AREA**	
Compartment	In Water	Land Based
Potencial Impacts	Burial of benthic fauna (1, 2 e 3); Change in biodiversity (4); Acute and Chronic effects on organisms (5); Change in water quality for irrigation, supply and recreation uses (6); Provision of compounds stored in the sedimentary layers (8).	Alteration of hydrogeology (7); Groundwater quality change (8); Alteration of soil quality (9); Habitat change (10); Erosion of deposited sediment; Air Quality.
Brazilian legislation (CONAMA*)	CONAMA 454/2012 CONAMA 357/2012	CONAMA 420/2009 CONAMA 396/2008
Impact área	Scattered, transported away from placement site	Localized
Impact Control Form	Dredging methods and impact monitoring.	Physical containment, dredging methods and impact monitoring (11).
Time of occurrence	Locally short term, unspecified long term	Short-term, but will depend on the isolation method
Cost to control (12)	Hight	Average
Operational cost (13)	Low	Average
Financial Return (14)	Null	Average
Environmental impact (15)	Hight	Low

Reference: (1)ROSENBERG, 2001;(2)SOARES et al., 1996;(3)DAY et al., 1989;(4)VASCONCELOS, 2002;(5)PATCHINEELAM, et al, 2008; TEIXEIRA, 2009;(6)TORRES, 2000;(7)PATCHINEELAM et al, 2008;(8)BERBERT, 2003;(9) DEGTIAREVA, 2001; (10) KENISHI, 1994;(11) SIMOES, 2009;(12) BRAY ET AL. 1997;(13) BROADUS, 1990; (14) MERICO, 1996; (16) PIANC, 2009.

As presented, the disposal of the dredging material in water and soil have different impacts, but mainly are verifie that the extent of occurrence of impacts on soil is more easily controlled. Allied to this fact, there are a variety of alternative uses for the dredged material, depending on the physical and chemical characteristics, and can be used in socio-environmental improvements or even in dredging ventures, reducing implementation costs and assuring the dredging process (Planágua, 001; BMVBW, 2004;). Alternative have been used and discussed in many forums such as the North Atlantic Regional Conference in 1987, for many years large volumes of clean dredged material. According to Winfield and Lee (1999), the dredged material can also be combine with other ingredients to create specific products such as block construction, capping material and others (PIANC, 2009)

When assessing the need for dredging, it is necessary to investigate the feasibility of the application of combined actions for the reuse of the dredged material, seeking previous proven technical experiences. In case there is no alternative for immediate use, a program should be develope for the future use and management of disposal and / or reuse alternatives (Planágua, 2001). The goal should be to use the dredged material in the most useful, environmentally and socio-economically feasible manner in the most cost-effective approach.

This article undertakes to present an alternative method to assist in choosing the most appropriate use for dredging material. Multicriteria analysis is part of the decision-making process, which simply and efficiently guides different decision-making (Cavalcante, et al., 2005). The development of an alternative method aims to assist in the planning of projects, besides subsidizing security in the decision making to the environmental agencies.

1.1. BRAZIL CONTEXT

Brazil is one of the richest countries in natural environmental resources of the planet and, in this context, the minerals have a prominent position, however, generally, the production of the mineral, of sand for example, occur in backwater and river beds, together to forest areas, which according to the Brazilian Forest Code, Federal Law No. 12.651 / 2012, are considered Permanent Preservation Areas (APP), which require caution in the use of resources to ensure the preservation of ecosystems. However, CONAMA Resolution No. 369/2006, which deals with the exceptional cases that allow interventions in the APPs, considers sand mining as a permitted activity and of "social interest".

Primary source sand mining is one of the fastest growing sectors in the world, being recognize as an important activity for economic and social development (Halmeman; Souza; Casarin, 2009). Sand represents a large-scale raw material used in this industry, average prices vary by up to 30% from the competition, with the highest prices being quoted for the materials with the highest particle size, coming from the areas located upstream of the river, according to data compiled by the National Department of Mineral Production - DNPM (2014). In Brazil, 70% of the sand is produced and extracted in river beds and 30% in backwaters (Valverde, 2006). By market factors, transport corresponds to about 1/3 to 2/3 of the final price of the product, the production of sand imposes its action close to the consumer centers, being a limiting factor, and typical activity is characterize in the less urbanized regions (BMVBW, 2004). In 2006, the national production of this resource was 358 million tons, of which 146.0 million tons correspond to crushed stones and 212.0 million tons of sand (Valverde, 2007).

Fernando Valverde (2014) of the National Association of Entities of Producers of Aggregates for Construction (ANEPAC), in an interview, argues that sand production in the main markets does not meet the real demand, the material has to be brought from other regions, because municipalities, responsible for land use, have created laws to prevent the installation of new mines, which also hinders the operation of those in operation. On the other hand, sands and other materials of less commercial interest are extracte during dredging processes and wasted dumping them into the water. This loss to commercial interests is due to the lack of information from the entrepreneur, legislator and due to the difficulties in licensing, the timing of availability of the resource and choosing the most appropriate alternative use for the sediment dredged. Therefore, the planning of dredging and the use of dredged material seems strategic for the sector and for the government.

2 MATERIALS AND METHODS

In order to assist in decision making for the beneficial use of dredging material, Resolution No. 454 of 2012 of the National Environmental Council (CONAMA) establishes general guidelines and referential procedures for the management of the material to be dredge in waters under national jurisdiction. And defines in its Article 2 item XVI "Beneficial use of dredged material" where the use of the material, in whole or in part, as a material resource in productive processes that results in environmental, economic or social benefits, thus without generating environmental degradation, as an alternative to its mere disposal on land or water. In Article 15 it is stated that the entrepreneur must consider, beforehand the decision on the disposal, the possibility of the beneficial use of the dredged material, according to its characterization and classification, As well as the environmental assessment and analysis of the economic and operational feasibility of the disposal options, according to the specific and pertinent regulations. In paragraph 1, is point out that the possible beneficial uses, among others, are the following:

I. Engineering works - creation and improvement of the terrain, artificial resurfacing and reinforcement of beaches, stabilization of the coastline, riverbanks and erosion control, offshore berms, material for capping and filling sediment cells, landfill for ports, airports, anchorages, construction of dams, dams and highways;
II. Construction and industry;
III. Uses in agriculture and aquaculture; AND
IV. Environmental improvements - restoration and establishment of wetlands, nesting islands, fishing, soil recovery, recovery of degraded areas, recovery of eroded margin.

Subsequently, paragraph 2 shows that proposals for the beneficial use of dredged material may be elaborated by the entrepreneur in partnership with other institutions, public entities, universities, companies and civil society organizations.

However, the entrepreneur's assessment of the best disposition can be carried out in different ways and due to the lack of objective in the analysis and the scientific support for the beneficial use of the dredging material, the most commonly used option is the one with the greatest potential impact, discharge into the water. As already mentioned, it will be presente the use of the integrated, multicriteria method associated with technical analysis and consultation of society. In this sense, the assessment of potential uses of dredging material, including possibilities of disposal on land, will be called the 2.1 Dredging Material Reuse Plan.

With regard to dredged material, their disposal should follow procedures aimed at identifying, characterizing and minimizing the likely environmental impacts and comparing these to the benefits of alternative uses.

For these reasons, the implementation of the Dredged Material Reuse Plan will follow a constructive process, which must be approved by the responsible environmental agency, controlled and monitored by competent companies or institutions, in order to mitigate potential impacts and ensure the perfect execution of the work. Figure 1 presents a flowchart describing the suggested steps for the Dredging Material Reuse Plan to choose the most appropriate use of the material resulting from the activity.

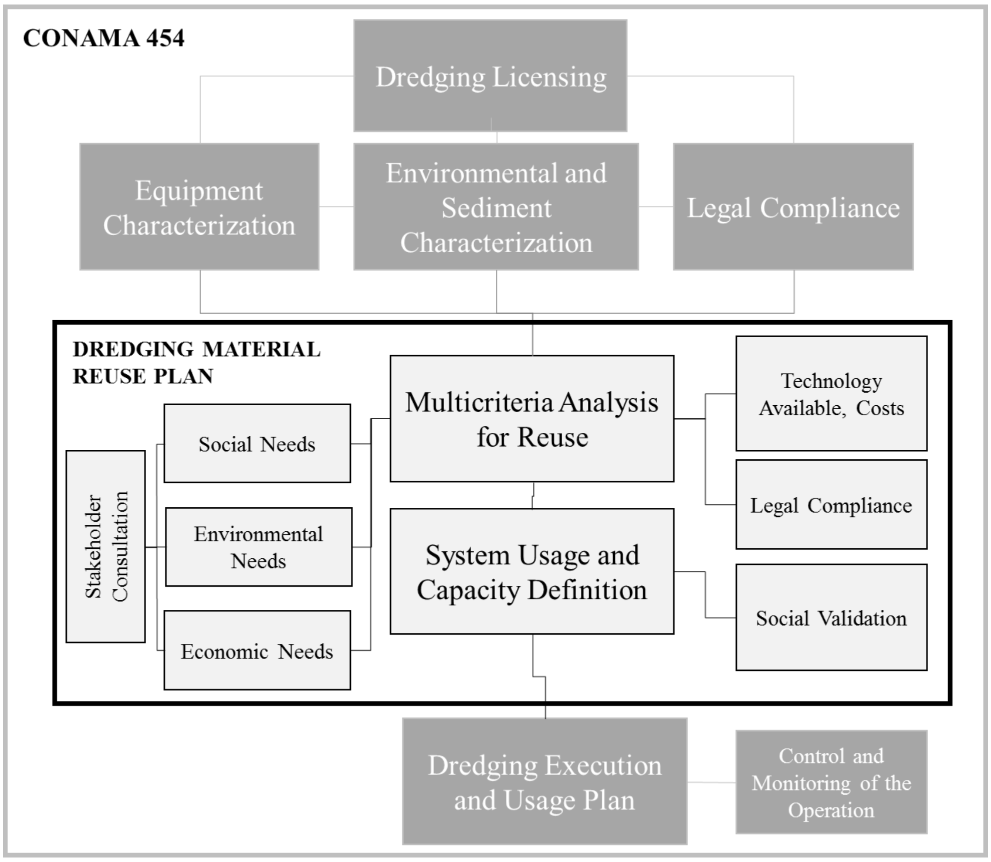

Figure 1. Flowchart of the stages for Dredging Licensing, complying with current legislation, and the phases of implementation of the Dredged Material Reuse Plan.

Assuming that Dredging Licensing occurs, there is a need to comply with CONAMA Resolution 454/2012, which requests the presentation of a conceptual dredging plan, containing the following items and other paragraphs described in the legislation:

I - Bathymetric survey of the area to be dredged;

II - Presentation of the desired quotas and quotas of any previous project;

III - Delimitation of the area to be dredged with georeferenced coordinates;

IV - Volume of sediments;

V - Delimitation of the proposed disposal areas, with their georeferenced coordinates.

VI - Implementation schedule;

VII - Characteristics of dredging equipment;

With this information, steps are taken to technically evaluate the use needs in the surrounding area, with the application of the steps suggested by the Dredged Material Reuse Plan. Where the first step is through the *Stakeholders Consultation*, generating involvement among individuals, to seek inclusion of the social, environmental and economic segments of the process and the timing of necessity. Also expert opinions can be taked in conflicting environmental management situations (Martin et al, 2011; Ban et al, 2015). Then, following the other steps presented in the flowchart for each of these spheres - the social, environmental and economic potential uses. Followed by the analyzes of the Multicriteria Evaluation for Reuse of dredged material where the evaluations for *Technology Available* of the process and respective *Costs* should be contemplated, In addition to ensuring *Legal Compatibility* and subsequent *Definition of Use and Capacity of the System*, and consequent *Social Validation*. These stages enable the Execution of the Dredging, and subsequently the Plan of Reuse of the Dredged Material. Finally, we arrive at the *Operation Control and Monitoring stage*, where this total flow of information, at all stages, becomes an effective management tool.

3 RESULTS

3.1Stakeholders Consultation

Consultation with the community seeks to understand the need for local uses for material from dredging. The consultation has two main approaches: (1) the collection data from previous studies; And (2) data sampling. Previous studies should be collecte in official agencies. On the other hand, the sampling data consists of conducting qualitative field surveys, through semi-structured interviews with three main segments of social actors, namely: (1) government managers; (2) leaders and residents; (3) representatives of the economic sector.

For all the analyzes it is necessary to seek the basis of technical and scientific articles, dissertations and theses developed in different thematic ones about the region under analysis, in order to confirm, whenever possible, with the sampling data. Eventually, data from the demographic, economic and infrastructure characterization, with emphasis on data provided by IBGE (Brazilian Institute of Geography and Statistics), by the United Nations Development Program (PNUD) can help in understanding the local reality.

The qualitative character of the surveys that should be carried out is highlighted. As Michelat points out (in Thiollent, 1987), in a qualitative survey, only a small number of people are questioned. People are chosen based on criteria that have nothing to do with probabilists, and are by no means a representative sample in the statistical sense, but which on the other hand allow the deepening of information on points of view.

The suggestion is that the questionnaire's implementation script is through semi-structured questions, which consist of pre-established questions that have flexibility during the interview, allowing "a more intimate contact between the interviewer and the interviewee, thus favoring the exploration in depth of their knowledge "(Laville and Dionne, 1999). According to Thiollent (1987), "the preformulation of the questions, especially when it comes to subjective subjects, forces the respondents' choices because they refer to problems whose access or relevance are not the same for all, as indicated by the Differences between modes of communication ". Thiollent (1987) emphasizes that the subject can respond for or against a given utterance, without being able to produce the statement of the question, nor to know the problematic from which it is formulate.

In addition, semi-structured questions allow for greater flexibility and freedom of response, making it possible, when necessary, to redirect questions and / or to deepen issues according to the answers that respondents provide, something that is not an objective interview, with closed answers. It aims to obtain complete answers, detailed in depth, making its analysis more complex than those obtained in objective interviews, which are of better treatment and analysis, but with a more superficial feedback.

3.2 Material Request

The community consultation should focus on the local needs for the use of the material to be dredged. It is also emphasize in relation to the needs of uses the dredged material, that information regarding social interests should be collected together with representatives of society and specific bibliography. Social and environmental uses should be prioritize, preferably for recovery of degraded areas. A key need is to balance the availability of these resources with the needs – tighter connections between dredging activities and social-environmental needs.

In the social sphere, one can cite actions such as elevation of the protective barriers in urban areas to minimize the risk to flood and to repair eroded port areas. The Netherlands, the Dutch Criterion, complies with the Evaluation of Water Act (March 1994), which incorporates, to a large extent, the procedures prescribed in the London Convention the methodology of preventive operation, the dredged material, if inert, is almost always seen as a natural resource to be harnessed, thus, the granular coarse material is used whenever possible in flood protection dikes, or in the construction of roads. The Dutch criteria methods are respecte worldwide as they are extremely proactive in these operations as more than half of their population lives below sea level or are at risk of flooding. The United States, on the other hand, is a slightly different example, with the purpose of creating or recovering flooded areas, restoring these lands flooded with dredged material and is the most accepted alternative in the country. In most cases, the restoration of an area is more often considere than the creation of new areas. Dutch thinking is different from the US, because damage in the United States is more important than avoiding catastrophic events, said Wim Kuijken, a senior official with the Dutch government for water control policies. The United States excels in disaster management, but working to avoid them is completely different from working after they happen "(Higgins, 2012). In other words, the mechanisms for applying guidelines that address social, environmental and economic follow-up do not follow a worldwide standard, the authors lack a tool that provides a stable contribution to planning and decision-making.

In the environmental field, the growth of ecosystem concern has substantially altered the management of dredged materials found in aquatic resources. We can cite positively the dredging for recovery of degraded areas, where the method when well practiced, benefits the environmental conditions of a certain place as well as the improvement in the protection of human health. For Goes Filho (2004) it basically consists of the cautious withdrawal of the corrupted material together with a process of revitalization, relocation of the same. Maintenance dredging is mainly aimed at maintaining the depth of existing works such as ports and canals, thus maintaining good navigability. In addition, environmental dredging focuses on the removal of contaminated sediments from riverbeds. (Kobayashi et al., 2008). Contrary to the popular belief that dredging and mining activities exclusively cause damage to society and nature appropriately used dredged materials can be valuable resource.

In the economic and infrastructure sphere, it is common to use the material for the placement at the margins near the dredging site, avoiding costs in the displacement and purchase of materials from other deposits. The creation of a bank of dredging material can be use for different purposes (Kerstner, 2003). In civil construction, for example, works prioritize the noblest uses for material and aggregates. The term aggregates are use in Brazil to identify segment of the mineral sector that produces the raw material and its employment in construction. Within this category are the mineral substances sand, gravel and crushed rock that enter into mixtures to produce concrete, asphalt and mortar or are use *in natura* in base of pavements. According to the United States Geological Survey (USGS), aggregates are the most accessible mineral resources to humanity.

According to Sachs (2002), for the balance between technology and environment to be achieved, environmental protection must be understood as an integral part of the development process and cannot be considered in isolation. That is, for sustainable development to be effective in our reality, the information management and the planning of the actions must lead with admitting and recognizing that the natural resources are finite. Becker et.tal (1999) states that this is a concept that represents a new form of economic development, which takes into account the environment.

However, while many documents recognize that effective environmental decision-making requires environmental, ecological, technological, economic, and socio-political considerations relevant to assessing and selecting an alternative management, these factors are seldom considered together and decisions are often driven by only one aspect of the problem (Linkov et al., 2006).

3.4 Multicriteria Analysis

By following the steps in Figure 1, it is possible to apply the analysis to the choice of the best material destination. The multicriteria analysis aims to determine a qualitative factor comparing the existing alternatives and the needs for each situation. The use of this method for interactive decision-making is based on the hierarchical analytical process (Saaty, 1980) is an impact assessment method and supports individuals and organizations to make judgments under the influence of a multiplicity of criteria. The application of the method depends on the choice of problem solving alternatives, which are often complex (Gomes et al., 2004). The advantage of applying methods that assume a constructivist approach is to consider in the model both the decision maker's values system (subjective) and quantitative data (objective aspect), while a rationalist approach only appreciates objective elements (Madeira Junior, A.G., et al, 2012).

The actors chosen for the evaluation of the matrices that must be knowledgeable about the subject or have somehow experienced the problem, to avoid as much as possible the subjectivity of the results, to obtain a judgment as realistic as possible. This logic has been used in several segments of the environmental area, such as environmental impact assessments, from different human activities: treatment and final destination of domestic and industrial sewage in coastal lagoons (Moraes and Gomes, 1994); Controlled landfills (Marmello; Moraes, 2007); (Chowdhury and Rahman, 2008), in which multiple-criteria decision-making is required, involving different opinions and interests. It is categorical to remember that the application of the multicriteria method will be directly linked to the local need of the use, that is, the choice of the method to be used will depend on the information obtained to choose the most appropriate system. The form of reuse should consider process costs preferably following the hierarchical order: social security, environmental and infrastructure. The timing is key, a less efficient use of the resource could result if the material is dredged after it is needed. Timing for production of the resource (dredged material) and its alternative uses has to be blended to be sure it gets used.

When the objectives of the process are very clear, and of objective measurement, even if qualitatively, the real reliability, mastery and assertiveness are inferred under the multi-criteria tool, thus establishing satisfaction in decision-making. For the evaluation criteria: particle size / grain (physical characteristics), chemical composition, technology available, costs and validation with society.

The physical characterization of the dredged material is fundamental for the overall planning of a dredging project, influencing not only the operation, but also the transportation and final disposal of the material. The granulometry is the basis for the classification of the material (Table 3). In Brazil, the particle size distribution is usually classified according to the Brazilian Standard NBR 7181 of 1984, being:

Table 3. Standard Brazilian Standard of granulometric classification.

MATERIAL	PARTICULE SIZE
Sand	0.05 to 4.8mm
Coarse Sand	2.0 mm to 4.8mm
Average Sand	0.42mm to 2.0mm
Fine Sand	0.05mm to 0.42mm
Silt	0.005mm to 0.05mm
Clay	Less them 0.005mm

Sands provided by dredged material are generally considere valuable for use in many types of construction projects. They are suitable for filling voids, in general, without the need to process the material. The silts are common in maintenance dredging works in rivers, canals or ports. These materials are best suited for agricultural purposes and for the development of natural habitats. When appropriate, silts and clays are ideal in the composition of surface soil layers and the development of habitats for wildlife. The most valuable agriculture lands are those that received fine-grained materials deposited during flood events.

Depending on the legislation in force in each region, this type of material, when moderately contaminated, can be use in applications such as bricks, tiles, ceramics and some applications in engineering (Teixeira and Dias 2009). Consolidated clay is usually derived from virgin dredging and, therefore, is usually free of contamination. The possible uses of the consolidated clay include the use as bricks and ceramics and their use for the formation of dikes and berms. Sands, Silt and Clays have as possible beneficial uses to: Creation of land strips; Offshore berms; Coastal protection; Capstone; Construction Materials; Aquaculture; Habitats on land; Creation of marshy areas; And Fisheries Development.

The differential in decision-making will be the identification of future use for the most appropriate destination. Evaluations of other physical aspects may also be requested, such as specific gravity, density; Viscosity (viscous tension), water retention characteristics, sedimentation speed, consolidation, compaction, matter and other characteristics of the grains.

In terms of chemical composition, the parameters usually required to ensure the quality of the sediment are pH due to its usefulness in evaluating the mobility of contaminating metals and is a good indicator to determine the beneficial use and disposal of the material. In case these dredged reuse materials are intended for agricultural use or soil fertilization, there is an adequate degree of nutrients that should be considered as a prerequisite for chemical analysis. There are the parameters required in the legislation and depending on the use that will be attributed to the dredged material, extra analyzes may be requested in addition to biological parameters such as microorganisms, contaminants, toxicology assessments, among others, so that unforeseen events do not happen in the planning and execution of the activities.

In this sense, the multicriteria analysis can be develope in different formats, which will allow the coherence and interpretation of the different consequences for each action. Table 5 presents the simplification and unification of the characteristics of the dredged material for placement on land, taking into account aspects of deposition infrastructure and environment. Table 6 presents the application of the multicriteria analysis, defining the destination and use priorities of the dredged material.

Table 5 was divided into uses of economic interest and uses of socio-environmental interest and classified as the characteristics of the sediment, particle size and concentration of contaminants (Level 1, Level 2, Level 3) in the scale of Conama 454/012 that regulates Soil sedimentation.

The use of Economic Interests can be divide into direct land uses is free from contamination and sediments with containment to use in confined areas, due to the potentially toxic characteristics (Barbosa and Almeida, 2001). In relation to Economic Interests, the subdivisions are according to the form of packaging, being in Confined Environment and Free

Environment, for these, the forms of structures are presente being WC with containment and NC without containment. Particle size regulates the construction of structures for containment.

Socio - environmental use was divide for geological recovery of the water body, ecosystem recovery for the recovery of communities of organisms suppressed by the intense use of the water body and for social recoveries, in order to assist communities located in areas at risk.

Table 5 – Definition of destination and use compatible with the characteristics of the dredged material

SEDIMENT CHARACTERISTICS		ECONOMIC NEED				SOCIO-ENVIRONMENTAL		
		Confined Environment		Open Environment		Geological Recovery	Recovery Ecosystem	Social Needs
		WC	NC	WS	SE			
Particle Size	Clay (<0.004 mm)	X	X	X	X	X	X	X
	Silt (0.004–0.064 mm)	X	X	X	X	X	X	X
	Sand (0.064–2 mm)	X	X	X	X	X	X	X
	Granule (2–4 mm)	-	X	-	X	X	X	X
	Bigger than 4 mm	-	X	-	X	X	X	X
Contamination (level during disposal)	Level 1	X	X	X	X	X	X	X
	Level 2	X	X	-	-	-	-	-
	Level 3	X	X	-	-	-	-	-

WC- WHITH CONTAINMENT / NC- NO CONTAINMENT

The definition of destination and use compatible with the characteristics of the material dredged is shown above. The physical characteristics of the material dredged in relation to the size of the particles or grains is according to levels for each of these placement options. As shown, it is possible to verify that there are few restrictions to the use of the materials, being the restrictions related to large grains for the construction of structures and contaminated sediments to be use without due treatment and free form in the objective purpose.

As shown in Table 5 the possibilities of beneficial use of the material are broad, in this sense Table 6 presents the comparative prioritization between potential uses. The alternative use options are compared and prioritized on the scale of 1 to 5, classification 5 being the most necessary and classification 1 being the least necessary. Prioritized by Table 6, the result should be compared with the data collected from need of use, legal compatibility and technological risk and costs, and only then, the decision to make the best use of the dredging material.

Table 6 – - Definition of destination and use priorities for the sediment.

DESTINATION / USE			ECONOMIC NEEDS				SOCIO-ENVIRONMENTAL		
			Confined Environment		Open Environment		Geological Recovery	Social Needs	Recovery Ecosystem
			WC	NC	WC	NC			
Economic Needs	Confined Environment	WC	=	1\2	1\3	1\2	1\3	1\4	1\5
		NC	2\1	=	2\3	2\3	2\3	2\4	3\5
	Open Environment	WC	3\1	3\2	=	3\2	3\3	3\4	3\5
		NC	2\1	3\2	2\3	=	1\3	2\4	2\5
Social-Environmental	Geological Recovey		3\1	3\2	3\3	3\2	=	3\4	3\5
	Social Needs		4\1	4\2	4\3	4\2	4\3	=	4\5
	Recovery Ecosystem		5\1	5\3	5\3	5\2	5\3	5\4	=

WS- WHITH CONTAINMENT / NS- NO CONTAINMENT

In general, the maintenance of life should be prioritize. Therefore, if there are no legal emergencies or impediments, recovery of the degraded ecosystem should be prioritized by society as a way of reducing the effects of ecosystem change on local communities and reducing local and global impacts.

In this premise, social protection seeks to maintain the safety of communities at risk, and geological recovery to maintain the natural characteristics of aquatic systems. Only in case it is not possible to apply dredging material for these purposes the economic use should be prioritize. Even so, we will have differentiations regarding economic uses for placement. Where, must be considere fine particles for areas with infrastructure uses because the presence of a lot of organic matter that can generate gases. Alternatively with the larger particles, for stabilization of slopes or highways, where there is need of less dilation of the soil layer.

It is observe that, in compliance with legislation, and identifying the real need for use in accordance with the three social, environmental and economic spheres, there are several possible uses for the use of material from dredging activities. The multicriteria analysis emerges as an alternative to consolidate the information needed to aid this planning.

3.5 Technology Available and Costs

In parallel with the evaluation of the need for uses, it is necessary to evaluate the technological risks and the costs involved in the process. Such factors may prevent a preferential use, due to the absence of technologies applicable to the process, or the excessive cost, making the project impracticable.

Risk analysis is recognize internationally as a scientific method (Stonehouse and Munford, 1994) and is used in studies that identify possible flaws associated with operations and subsidize information to implement measures, administrative procedures or techniques for prevention and control of activity. Slovic (1987, quoting Sjoberg et al) states that research on risk perception can guide policies and assist in decision-making by analyzing how people evaluate and judge certain dangerous activities and technologies. In this sense, the existence of technology for the execution of local needs must be evaluate, for example: the pumping capacity of a given material at a given distance; the use of certain dredges at certain depths; and construction of particle containment systems or contaminant remediation. All the alternatives of use should be analyzed as to the possibility of execution by the applicability of the method.

In relation to costs economics, the use of dredged sediments will, in most cases, lead to transportation and handling costs as the most significant. It seeks to account for the economy through the use of dredged material, rather than the use of rocks from quarries and their transportation. The feasibility, which takes into account the cost to execute the service in relation to the benefit generated by its execution. In the case of valuation of the benefit to the ecosystem, ecological valuation should be evaluated (Martinez, 1991; Nijkamp, 1984). Due to the complexity of the ecological valuation, a simplified alternative is the discussion in society as to the preponderant use in the area.

3.6 Social Validation

Defining the best method for using material from dredging is advisable to check the main social actors about the chosen method. The society must be heard, during the collection of information of social, environmental and economic needs and for validation of the determined use. In general, the main actors to be heard will be the municipal and state secretariats, basin committees, non-governmental organizations, conservation units, residents' associations, industry federations, agriculture, commerce, and other institutions that have relevance in the area of study and influence.

3.7 Sediment treatment alternatives according to the need for use

Dredging needs generally occur in areas close to urban centers, that is, potentially contaminated areas (CETESB, 2001). The use of contaminated materials requires the reduction of impacts to the ecosystem, which may be reduce by use in confined spaces as discussed above or by treatment of contaminated sediment (Barbosa and Almeida, 2001).

Among the possible environmental problems arising from the disposal of contaminated sediment on land is the possibility of contamination of the water table and surface waters around the disposal site by effluent percolation or other transport mechanisms of contaminants; Natural or anthropogenic action that breaks down the containment of contaminants; Risks the material may offer to the ecosystem of the disposal area or area of influence; And restrictions on current uses and future uses of the area (Planágua, 2001). However, these dredged sediments may be treated and the final product may not pose any risk to the health of people, flora or fauna, together with the ecological risk analysis that the social, environmental and economic spheres (Philomena, 1989) and will also indicate the possibilities of use of free form or even be used in buildings after the satisfactory legal levels have been reached.

The dredging material can be adapted to the needs of use. In this case, the cost of treating the material in relation to the cost of obtaining a material from the field will be the limiting factor of use. However, it is advisable that the environmental cost be considere in the cost sheet, since the transportation of the material from the deposit to the area of use, generates impacts on the highways and the emission of particles and Co2. As well as, the nonuse of the dredging material, that is, the dump in the water body, increases the impacts of the dredging in the water.

The grain size will directly influence the type of material usage, thus the coarser materials can be processed into finer particles by grinding (Alhadas, 2008). Already very fine particles, they do not present enough resistance for the construction of structures and they present / display great density of interstitial water (PIANC, 2009). This water can be drained through the construction of settling basins and the thinner material can be incorporated into structures, or barriers that guarantee the increase of its resistance.

Calcium carbonate is related to pH because it allows us to indicate the amount of lime needed to neutralize the acidity present in the dredged material, the addition of lime, for example, can reduce the bioavailability and toxicity of acidic materials (Burt et al, 1995). Cation exchange capacity is also analyzed because this parameter can alter physical properties and also corrects acidity and basicity, and can be used to purify or alter percolated water, which can lead to reduction of impacts (Phillips and Burton 2002). Salinity should also be analyzed because this parameter can inhibit the movement of water and air through the material and decrease the availability of nutrients, as well as salinize environments and hinder the natural occurrence of vegetation (Fassbender and Bornemisza, 1987). Total organic carbon and dissolved organic carbon, nutrients (nitrogen compounds and phosphorus) that are essential constituents of living organisms can, in excessive amounts, accelerate biological processes and may even cause problems in water and soil quality (Souto, 2009; Figueirêdo et al., 2007).

However, sediments contaminated with organic parameters can be treated directly at the disposal site, such as isolation (Palermo et al., 1998), with the premise of monitoring the soil conditions and impacts on the water table. Compounds of lower toxicity such as nitrogen and phosphate can be degraded by planting specimens to form plant curtains or garden areas (Embrapa 1986, Roderjan et al., 2002, Curcio et al., 2007 and Lorenzi, 2002). Already compounds with toxicological hazards, can be treated in the place, however, isolated from contact with the soil and groundwater *in natura* (PIANC, 2009). The treatment will depend on the compounds present in these sediments. Studies demonstrate the efficiency of fungus use for the degradation and breakdown of organic compounds, such as PCBs and organochlorine pesticides (EPA, 2004; EPA, 2012) and plant species for the removal of metal compounds (Mulligan, C.N., et al, 2001; YAO, et al. 2012).

In this sense, there are no impediments to the use of dredging materials, which are not relate to local needs, legal compatibility, and technological risks and associated costs. Where the aggregate value of the dredging material and its impacts on the environment must be compare to obtaining material from the quarry and its inherent extraction and transport impacts.

4 Conclusions

The alternative uses of materials from dredging is extolled by Brazilian legislation, however due to lack of methods, technical debate and lack of governmental incentive the most common destination of dredging material is disposal in the water. The dredging process presents inherent impacts to the execution of the work, the impacts increase when the sediments are place in water. In this sense, altering the disposal of this material by using it in an alternative way, reduces the impact caused in water and reduces the impact in obtaining new materials by other methods.

The present study indicates the need to create a Dredging Material Reuse Plan, associated with the requirements of Conama 454/2012 to assist in the decision-making of the environmental, community and entrepreneur must be presente and validate with the environmental agency.

The analysis of sediment variables allowed us to visualize that much of the sediment can be use for one or more beneficial purposes. Among the alternative uses should be prioritized the socio-environmental uses and the economic uses that are most useful. Noting that local use needs, technological risks and associated costs, as the timing of use are essential to validate the most appropriate use for the material.

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2.3. DREDGE SEDIMENT AS A RESOURCE - SINOS RIVER / BRAZIL

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[ALB] Agradecimento pela Submissão Inbox x

Antonio Fernando Monteiro Camargo <noreply.ojs@scielo.org>
to me

Portuguese > English Translate message

Luciano Hermanns,

Agradecemos a submissão do seu manuscrito "Dredge Sediment as a Resource - Sinos River / Brazil" para Acta Limnologica Brasiliensia. Através da interface de administração do sistema, utilizado para a submissão, será possível acompanhar o progresso do documento dentro do processo editorial, bastanto logar no sistema localizado em:

Dredge Sediment as a Resource - Sinos River / Brazil

(Sedimentos de Dragagem como Recurso Mineral – Rio dos Sinos / Brasil**)**

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Abstract: The development of the port activity requires improvements in the waterways and the design of the ports through deepening and maintenance dredging. The state of Rio Grande do Sul, Brazil, has a waterway that connects industrial ports to the international port of Rio Grande, but is underutilized due to the need for maintenance. However, dredging processes are expensive and potentially impacting the environment. The **objective** of this work is to present an alternative to the use of dredging sediments as a resource. For this, the **method** used applies the Dredging Material Usage Plan To add more information to the Brazilian legal requirements and assist in the decision making regarding the reuse of this material. Through a multi-criteria analysis the physical-chemical analysis of the sediment and the socio-environmental and economic necessity of materials were discussed. The **results** showed the importance of applying a method of decision that includes the company and technical information. The wide possibility of uses of the sediments sampled in the Sinos River, as well as, the social and economic necessity of this resource contributed to validate the use of sediments as a resource. With this, it was possible to **conclude** that the use of sediment as resources in the Rio Grande do Sul may be an alternative to the difficulty encountered by the public and private sectors during the drafting and execution of dredging plans. Allied to this, dredging costs can be reduced by setting up a sediment bank to meet government needs, encouraging the utilization of the waterways of the Rio Grande Sul and consequent decrease in road transport, and its associated CO2 emissions, collaborating with global warming control.

KEYWORDS: Dredging; MCDA, Reuse, Environmental Impact

Resumo: O desenvolvimento da atividade portuária requer melhorias nas vias navegáveis e na configuração dos portos através de dragagens de aprofundamento e manutenção. O estado do Rio Grande do Sul, no Brasil, tem uma via navegável que liga cidades industriais ao porto internacional do Rio Grande, mas é subutilizada devido à necessidade de aprofundamento e manutenção. No entanto, os processos de dragagem são caros e podem impactar o meio ambiente. O **objetivo** deste trabalho é apresentar uma alternativa de uso aos sedimentos de dragagem na forma de recurso mineral. Para isso, o **método** utilizado aplica o Plano de Uso de Material de Dragagem em sedimentos do rio dos Sinos. No intuito de adicionar mais informações aos requisitos legais brasileiros e auxiliar na tomada de decisão sobre a reutilização deste material. Através de uma análise multi-critérios, discutimos caracteristicas físico-química do sedimento e a necessidade socioambiental e econômica de recursos minerais. Os **resultados** mostraram a importância de aplicar um método de decisão que inclua a empresa e as informações técnicas ambientais. A ampla possibilidade de uso dos sedimentos amostrados no rio Sinos, bem como a necessidade social e econômica deste recurso contribuíram para validar o uso de sedimentos como recurso. Com isso, foi possível **concluir** que o uso de sedimentos como recursos no Rio Grande do Sul pode ser uma alternativa à dificuldade encontrada pelos setores público e privado durante a elaboração e execução de planos de dragagem. Aliado a isso, os custos de dragagem podem ser reduzidos através da criação de um banco de sedimentos para atender às necessidades do governo, incentivando a utilização das vias navegáveis do Rio Grande Sul e consequente diminuindo o transporte rodoviário e suas emissões de CO2 associadas, colaborando com o controle do aquecimento global.

PALAVRAS-CHAVE: Dragagem; MCDA, Reuso, Impacto Ambiental

Inroduction

The mainly aimed dredging is to create and maintaining the depth ports and canals. To increase the development of ports to greater trade activity, increased supply, greater foreign reserves and reduced prices for commodities the ports have to receive bigger vessels (Dwarakish & Salim, 2015). The dredging procedures is important and essential for the maintenance and development of ports, waterways for navigation, remediation of contaminated sediments and flood management (Soares, 2006; CL, 1972, Goes, 2004; Brighetti *et.al* 1993).

According to Christofoletti (1981), the main factors that control the morphological characteristics of river banks and sediment transport are the amount and distribution of precipitation, geological structure, topographic conditions and vegetation cover. Christofoletti (1981) also determined that the granulometry of fluvial sediments decreases in the downstream direction, which represents a decrease in river competence, with no shoreline erosion data associated to shipping in Rio Grande do Sul.

In the last two curves of the Sinos River of the bells the sinuosity increases, causing the deposition of the sediments to occur according to the meandering pattern, excavating in the concave margin and depositing in the convex margin and, consequently, carrying sand fraction sediments downstream.

However, environmental impacts are produced by the dredging process and include the removal, transport and placement of sediments within the existing physical, social, economic and biotic structures of the public and the environment (Balchand & Rasheed, 2000; Crowe *et al.*, 2010). In addition to the environmental impacts of the dredging operation, the dredging of these waterways produces large volumes of dredged material that need to be handled while reducing the quality of water for human consumption or ecosystem, not only at the dredging site but also at the site where the dredged material is placed (PIANC, 2009). The dredged materials may also be disposed on land, which would involve suctioning and recharging of the dredged material directly to the disposal site and continuous monitoring during the operation (BMVBW, 2004; PIANC, 2009).

The study area in Sinos River, close to the Jacuí Delta, inside the portion of the river basin district of the South Atlantic, which is inserted into the Rio Grande do Sul state, has an extensive waterway network consisting of rivers, lakes and navigable lagoons (Figure 01).

This region represents the main development area of inland navigation in Rio Grande do Sul, according to the SPH (Superintendência de Portos e Hidrovias), and is integrated by the lagoon complex Patos Lagoon – Guaíba Lake and by the rivers Jacuí, Taquari, Caí, Sinos , Gravataí and São Gonçalo.

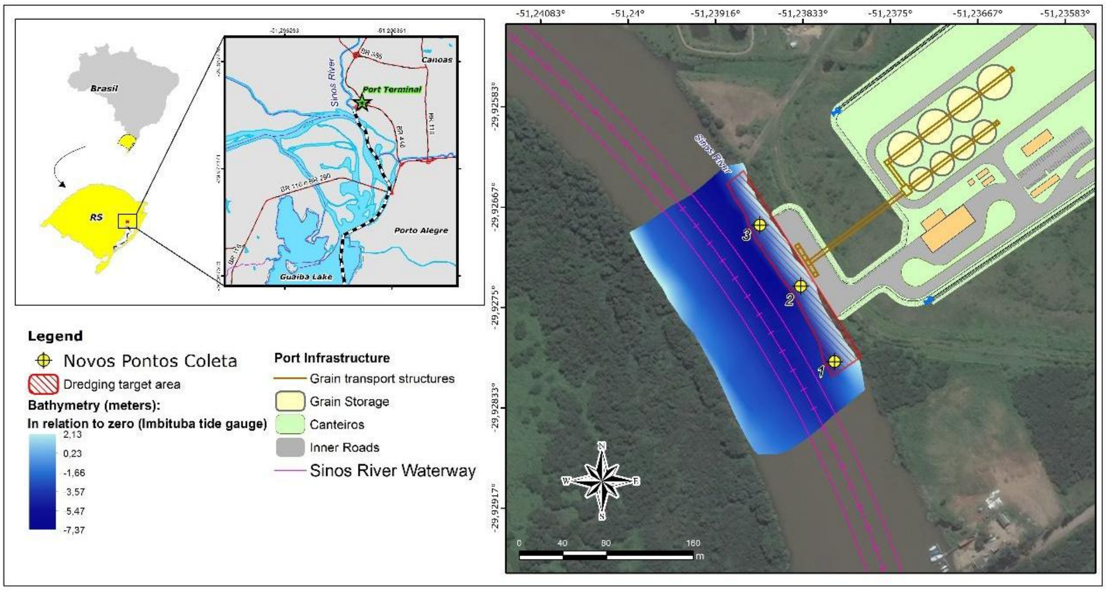

Figure 01- Study Area

This waterway system have strategic importance for the State of Rio Grande do Sul, due to the great potential of inland waterways and the activities that transport commodities, such as grains, minerals and inputs, fertilizers and fuels, as well as products with added value that are transported in roll-on / roll-off vessels.

The hydrographic region of the South Atlantic includes South Waterway, which has 11 state navigation lines, of which four are worthy of note by the amount of cargo handled. These 4 inlcude: Canoas (RS) - Rio Grande (RS); Porto Alegre (RS) - Rio Grande (RS); Guaíba (RS) - Rio Grande (RS); And Triunfo (RS) - Rio Grande (RS). The South Waterway has four organized ports and 15 privately owned terminals in operation, which connect, through rivers, canals and ponds, to the industrial and agricultural production region of Rio Grande do Sul through the Port of Rio Grande, located in the Mouth of the Patos Lagoon, near the Atlantic Ocean. The Bulk Terminal that will integrate the South Waterway, in the Canoas (RS) - Rio Grande (RS) line, is part of the development and improvements needed in Brazilian waterways to meet the national development plan for the (ANTAQ, 2013). The use of waterways generates savings in transport costs, efficiency in logistics and reduction of road accidents and emissions of CO_2 into the atmosphere (Arnold 1999; Chopra & Meindl 2011). However, the navigable waterways in Rio Grande do Sul varying depth and require constant dredging of maintenance.

Prior to making a decision about dredging processes and the preferred alternative uses of the dredged material it is necessary to conduct environmental and socioeconomic assessments (Dwarakish & Salim, 2015). The legal rules in developing countries as in the case of Brazil have evolved over the years (Drummond & Barros, 2005). The material from the dredging can be stored for later use or removal, placed in barges for transport to disposal or reuse site, directly discharged into water or on land usually in nearby areas using a pipeline (Zhang *et al*., 2014). In Brazil, the most widely used placement method is in-water disposal after mechanical or hydraulic dredging. However, any type of disposal must be previously licensed for current disposal (CONAMA 454, 2012). National legislation (eg. CONAMA 454, 2012) and international (eg. EPA, 2008) assessment methods requires knowledge of the physical and chemical characteristics of the sediment, and slurries of sediment and their ecotoxicological potential. In this context, quality guidelines sediments (Guidelines) have been used for classification of the sediments as potentially or not contaminated, although this is not a regulatory requirement for all countries (Wenning, 2005).

In this sense, the objective of this work is to demonstrate the alternative uses for sediments as a possibility to dredging in Rio Grande do Sul, using the multi-criterion evaluation as a tool to aid in decision making.

Methods

This work was conducted by unifying economic and socio-environmental information with physical chemical data of the sediment during a construction a port harbor in Sinos River. The application of this method complements the elaboration of the dredging plan required by CONAMA 454/12 and seeks to meet the necessity for use of dredging sediments as resource.

Firstly, it was necessary to know the need to deepen the river bed. In this sense, the required layer to be dredged and the consequent volume of sediment to be removed were calculated by surface volume tool (ArcGIS®). In accordance with the CONAMA 454/12 rule, 3 samples of surface sediment were collected. The samples were collected with background dredge, preserved and separated into two aliquots. Samples from the first aliquot were sent for chemical analysis in a commercial laboratory and the second aliquot for granulometry analysis.

The use of sediments as a resource was discussed according to the method suggested by Hermanns, et al. (2017), through the creation of a Dredging Material Usage Plan. The results from chemical and granulometry will be discussed, according to the data required to CONAMA 454 and the necessary steps for the development of the Dredging Material Usage Plan. As well, the regional community was consulted on social and environmental needs, as the local economic needs with the entrepreneur and institutions. Also expert opinions can be taked in conflicting environmental management situations (Martin et al, 2011; Ban et al, 2015). To evaluation the reuse, a multi-criteria analysis the particle size and physicochemical data of the sediments and local necessities. The needs and characteristics of the sediments will be compared in order to verify the legal compatibility of the possibilities of use and the compliance with the technologies and costs available to carry out the project.

The analysis of the data try to suggest the type of reuse for the dredge material and the capacity of the chosen use in receive the amount of sediment. In the case of a surplus of material coming from the dredge, it will be necessary to evaluate the combination of alternative uses for dredging sediment. The final stage is the social validation, which must be carried out with the licensing agency and with the actors involved in the chosen method, such as the community and governance in socio-environmental uses and economic cases together with the entrepreneurs.

The process of dredging, as well as the control and monitoring of the operation will not be discussed in this article and must follow the rule determined by the environmental agency.

Results and Discussion

Volume of dredge sediment

In the technical context of the waterways of Rio Grande do Sul, the area of interest is located on the margins of the PK12 + 600 kilometer point of Sublet IV (Sinos River), Section I of the Brazil-Uruguay Waterway. From the bathymetric survey, under authorization No.

188/14, granted by the Hydrographic Center of the Brazilian Navy (CHM / MB), the area of dredging and the volume of sediment to be dredged were determined. To calculate the volume to be dredged, the Surface Volume tool was used, through which it is possible to calculate a volume between each pixel of a raster and a plane with a determined height. Thus, the volume contained between each pixel of the raster resulting from the bathymetric survey with the bottom dots and the nominal level of dredging determined in the previous section (-5.25 meters) was determined (Table 01).

Table 01. Parameters and Results of the nominal dredging level calculation.

DEPTH OF DOCK BERTH, APPROACH CHANNEL AND ACCESS CHANNEL	**DIMENSION (METERS)**	**COMMENTS**
Reference level	0.5749	Level in 95% of the time, considering Tide gauge Imbituba
Maximum depht	-4.56	-
Natural clearance according to terrain	-0.4	As recommended for sandy beds by the cited standard
Squat e Trim	0	Zero for the location object of this Project
Depth Project	-4.3851	
Accuracy of bathymetry	-0,1	-
Settlement between two successive dredging	-0.35	7 cm (ACQUAPLAN, 2015), considering 5 years for successive dredging = 35 cm
Dredging Tolerance	-0.3	Suction dredgers
Depth of dredging	-5.1351	
Nominal Dredging Level	-5.25	Rounding Up

As explained above, the nominal level of dredging was determined at -5.25 meters. After the calculations were carried out using the indicated method, a dredging volume of approximately 18,000 m³ was determined.

It is also worth noting that the dredging of the navigation channels of the South Waterway is the responsibility of the Superintendence of Ports and Waterways (SPH), including the channel of the Sinos River, which already has FEPAM authorization through Operation License No. 1986/2014 -DL.

The hydrographic survey was carried out in the Sinos river, in front of the place where it is intended to install a bulk terminal and also in a section of the Jacuí river adjacent to the Paquetá beach in the municipality of Canoas, Rio Grande do Sul. In order to verify the conditions of the channel of the Sinos River Waterway, the area for mooring vessels in the terminal and to provide information for hydrodynamic and morphological modeling in the region of interest. The feasibility of the project depends on the sedimentary processes in the area to be dredged and on the maintenance needs of the waterway.

According to the data presented above, the reference level adopted for the calculation of the nominal level of dredging is the level with 95% permanence presented, added to the difference between the zero of the Harmony Square Station rule and the average level of Mares (22.49 centimeters), which results in an adopted reference level of 0.5749 meters.

Dredging Material Usage Plan

After the compliance with the Conama 454 rule and the compatibility of the sediment quality data with the Conama 420, was elaborated a Dredging Material Usage Plan using the method suggested by Hermanns, 2017, according to flowchart:

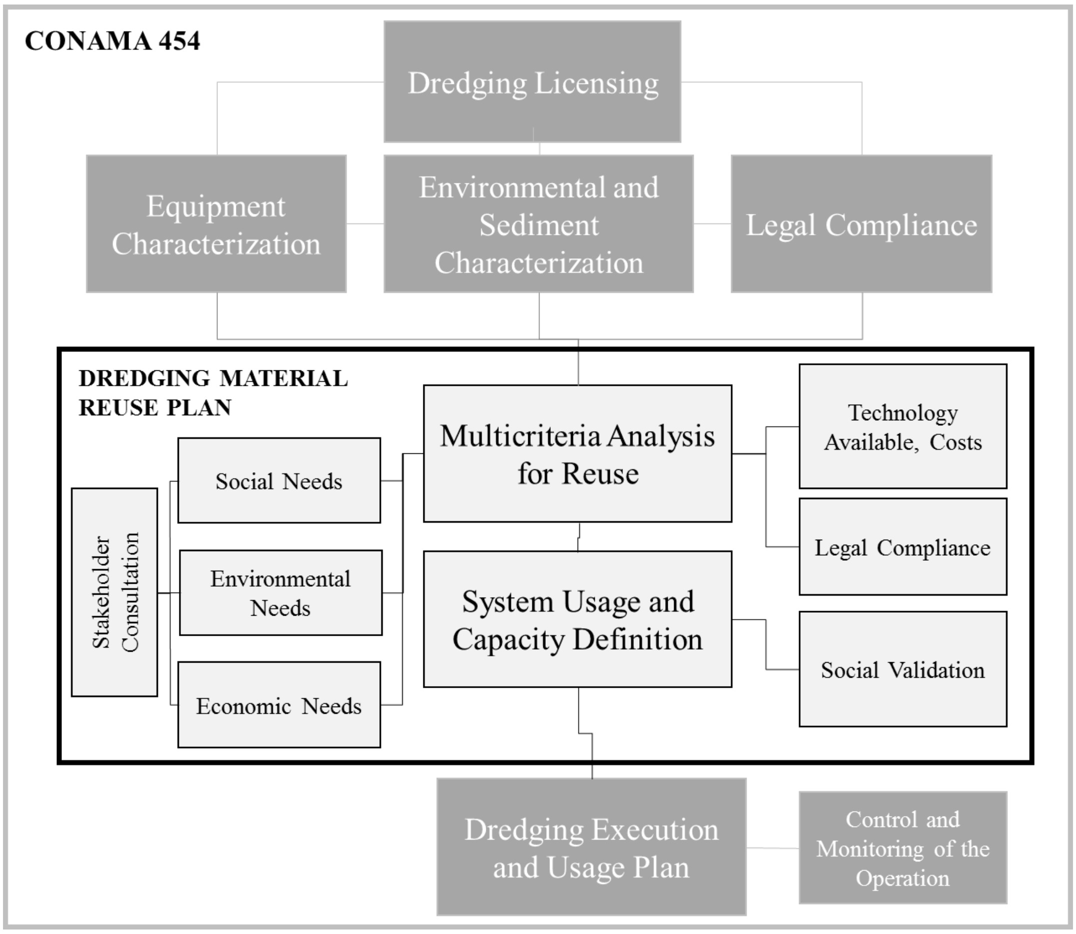

Figure 2. Dredged Material Use Plan Flowchart proposed by Hermanns, *et al*, 2017.

Sediment Parameters

Table 2 presents the results for the chemical analyzes and for total organic carbon (TOC) and nutrients for the samples collected in September 2016, located in the area expected to be dredged as specified in the previous chapter. A total of three samples were collected according to the recommendation of CONAMA Resolution No. 454/2012, which establishes a number of 3 samples for dredging up to 25,000 m³ of dredged material volume. The location of the sample collection points can be seen in Figure 01.

As can be seen in the Table 02, the results for all analyzed chemical parameters of samples # 01, # 02 # 03 were below the guideline values established by CONAMA Resolution No. 454/2012 as well as those established in CONAMA Resolution No. 420/2009.

Table 2. Sediment Quality in Sinos River - Brazil

COMPOUND	UNIT	GUIDELINES				SAMPLES		
		CONAMA 454		CONAMA 420/09		#01	#02	#03
		LEVEL 1	LEVEL 2	PREVANTION	INDUSTRIAL			
METALS								
Arsenic	mg/kg	5.9	17	15	150	**<2.5**	**<2.5**	**<2.5**
Cadmiun	mg/kg	0.6	3.5	1.3	20	**ND**	**ND**	**ND**
Lead	mg/kg	35	91.3	72	900	**<2.5**	**<2.5**	**4.4**
Copper	mg/kg	35.7	197	60	600	**2.6**	**6,6**	**7.1**
Chrome	mg/kg	37.3	90	75	400	**4,7**	**9.7**	**7.7**
Mercury	mg/kg	0.17	0.486	0.5	70	**ND**	**ND**	**ND**
Nickel	mg/kg	18	35,9	30	130	**<2.5**	**3.6**	**8.3**
Zinc	mg/kg	123	315	300	1050	**12.8**	**25.5**	**28.8**
TBT								
Tributyltin	µg/kg	1005	10005	-	-	**ND**	**ND**	**ND**
PESTICIDES								
BHC (alfa)	µg/kg	-	-	-	-	**ND**	**ND**	**ND**
BHC (beta)	µg/kg	-	-	1,1	5000	**ND**	**ND**	**ND**
BHC (delta)	µg/kg	-	-	-	-	**ND**	**ND**	**ND**
BHC (gama) -	µg/kg	0.94	1.38	1	1500	**ND**	**ND**	**ND**
Chlordane (alfa)	µg/kg	-	-	-		**ND**	**ND**	**ND**
Chlordane (gama)	µg/kg	-	-	-	-	**ND**	**ND**	**ND**
DDD	µg/kg	3.54	8.51	13	5000	**ND**	**ND**	**ND**
DDE	µg/kg	1.42	6.75	21	7000	**ND**	**ND**	**ND**
DDT	µg/kg	1.19	4.77	10	3000	**ND**	**ND**	**ND**
Dieldrin	µg/kg	2.85	6.67	43	1300	**ND**	**ND**	**ND**
Endrin	µg/kg	2.67	62.4	1	2500	**ND**	**ND**	**ND**
PCBS								
TOTAL PCBs	µg/kg	34.1	277	0,3	120	-	-	-
PAHs								
TOTAL PAHs	µg/kg	1000		-	-	**ND**	**ND**	**ND**
GERAIS								
Organic Carbon	%	10	-	-	-	**ND**	**0.2**	**ND**
Phosphor	mg/kg	2000	-	-	-	**130**	**236**	**135**
Total Nitrogen	mg/kg	4800	-	-	-	**195**	**334**	**179**

As can be seen in Table 02, the results for all analyzed chemical parameters of samples # 01, # 02 # 03 were below the guideline values established by CONAMA Resolution No. 454/2012 as well as those established in CONAMA Resolution No. 420/2009 for Prevention (safe limit to the preservation of ecosystems - potential destination of use) - socio-environmental use, and for use of material in industrial areas (potential destination of use) - economic use.

In the samples of surface sediments collected in September 2016, a predominance of sandy sediments was observed, as shown in Table 03. The material of sample # 01 was classified as fine area and that of samples # 02 and # 03 as average sand. Thus, it can be considered that the sediments in the dredged area present sand granulometry. This characteristic will be used in the design of the sedimentation basins, by determining the settling velocity that is proportional to the diameter of the particles to be decant. In addition, to determine the best use for this material.

Table 3. Samples Granulometry

PARAMETER	**SAMPLE – (UNIT - %)**		
	#01	**#02**	**#03**
Clay (< 0.00394 mm)	1.4	0.0	12.7
Silt (0.062 a 0.00394)	30.9	6.0	10.2
Very fine sand (0.125 a 0.062 mm)	1.4	0.8	2.5
Fine sand (0.25 a 0.125 mm)	17.9	30.0	9.6
Average Sand (0,5 a 0,25 mm)	33.2	35.4	29.3
Large sand (1 a 0,5 mm)	8.3	14.0	13.7
Very large sand (2 a 1 mm)	5.2	12.8	9.7
> 2 mm	1.7	1.1	12.4
Class by Sheppard	Fine Sand	Average Sand	Average Sand

Legal Compliance

Based on the Brazilian legislation for the management of dredging material, the following analysis is made as to the feasibility of disposing of dredged material on soil:

Article 10 of CONAMA Resolution No. 454/2012 establishes that:

"Art. 10. After the chemical characterization of the material to be dredged, its chemical classification will be carried out, in order to evaluate the conditions of its disposal observing the following criteria:

I - for the evaluation of soil disposal alternatives, the results of the chemical characterization should be compared with the national guideline values established for soils by Conama Resolution 420/2009 or current state standard."

Article 18 of CONAMA Resolution No. 454/2012 establishes in item I that the disposal of the dredging material must follow the following criteria and conditions:

"I - where the dredged material has concentrations equal to or less than the Prevention Values of the chemical substances indicated by the environmental licensing body, no further studies and groundwater monitoring program for the intended area shall be required, provided there are no environmental and Use and occupation of the soil, in which case the material may be disposed directly on the soil or used in a hydraulic landfill;"

The results for all analyzed parameters of the representative samples of the area to be dredged presented values below the prevention limits of CONAMA Resolution 420/2009. Thus, according to Item I of CONAMA Resolution No. 454/2012, the material to be dredged from the dock berth of the terminal may be disposed directly on the ground or used as a hydraulic landfill provided there are no environmental restrictions and use and occupancy from soil.

Regarding the abovementioned restrictions, the potential location for the disposal of the dredged material must meet the criteria of land use and occupation. The potentiality of use and legal restrictions will be addressed in the discussion as to the need local uses.

With the quality information of the material to be dredged it is possible to indicate which is the best destination for the use of this material. For this, the table 04 suggested by Hermanns (2017) was used as a decision aid through a multicriteria analysis.

In this sense it should be evaluated whether the grain size and the physical-chemical characteristics of the sediment apply the priorities, as well as the weighting of the legal application and the local need.

For the most appropriate definition of uses it is necessary to evaluate and compartmentalize the environment and its needs.

Local Necessity

Dredged material can be used for either social, environmental, or infrastructure purposes. Priority is given to social needs that do not conflict with the environment, environmental needs that maintain the safety of the population and enable the continuity of consolidated environmental services, and the use of dredging material as an input to the improvement of local infrastructure. Priority generalization qualifies use as environmental ≥ social > infrastructure (Hermanns et al, 2017).

Consultation with the local community presented two main approaches: (1) the collection of secondary data; And (2) primary data collection. Secondary data were collected in official bodies. On the other hand, the primary data were obtained through qualitative research in the field, through semi-structured interviews with three main segments of social actors, namely: (1) government managers of Canoas and Rio Grande do Sul; (2) leaders and residents of the community of Praia de Paquetá; (3) and representatives of the economic sector interested in the execution of the project. The results are presented according to socio-environmental context and economic context.

The mouth of the Sinos river is in a low altimetric area that ends in the Jacuí delta, being one of the rivers responsible for the sediment supply that formed the delta, along with the rivers Jacuí, Taquari-Antas, Caí and Gravataí. Downstream of the delta is Lake Guaíba, and afterwards, Lagoa dos Patos, where at the end of this occurs the connection with the ocean. (Menegat & Hasenack, 1998).

To the south and west of the area to be dredged is the State Park and the APA of the Jacuí Delta, Conservation Units that seek to preserve the typical physiognomy of the region, occupying a portion of approximately 210 km2, including in this total the rivers, Canals, bags and emerging lands. It covers five municipalities in the Metropolitan Region - Porto Alegre, Canoas, Nova Santa Rita, Triunfo and Eldorado do Sul, in an area of 17,245 hectares.

This area includes the lower reaches of the Jacuí River, the islands and the floodplain of this river from the town of Porto da Manga on its left bank in the Municipality of Triunfo and the lands in the same direction on its right bank, In the Municipality of Eldorado do Sul; The floodplain of the lower reaches of the Caí River until about 6 km above its mouth with the Jacuí River; The region of the mouth of the Sinos River, the canals and the 18 islands of the delta, which together with the other islands of the lower Jacuí total 28 islands (Oliveira & Porto, 1999).

In the social sphere, dwellings are located mainly on the banks of the islands, on the elevations of the terrain on the marginal dykes, as well as in the continental areas along the highways and in the crossings of the islands. This type of occupation is justified because they are non-floodable areas, in all the islands, the preference of occupation in its periphery is verified. Such residences suffer from the constant inundations of the floodplains of the Jacuí delta. There is a real need to improve the quality of life of these populations (Maffra & Mazzola, 2007). However, the use of dredging materials to increase the shoreline height and consequent improvement in the quality of life of the populations of the islands requires long-term planning and government interest in the construction of a land use management plan (CEDA, 2000; IADC/CEDA, 1997; Monteiro, 2008). The timing of use the resource makes the execution of this work under discussion impossible and excludes the social use of the dredging material of this work as a priority.

Following the relevance of uses, we could use material from dredging to recover degraded areas and protect erosion areas. However, the areas near the dredging site are floodplain areas and do not undergo significant erosive processes to require a geological recovery. As well as the APA Delta do Jacuí conservation unit, there are large areas for the maintenance of local endemic species, guaranteeing the balance of fauna, flora and the source of rivers, canals and creeks (PM/APAEDJ, 2017). Excluding this, the environmental need of the use of the material from this dredging.

Finally, the economic use of dredging material for the infrastructure follows basic assumptions of reuse and recycling of materials that would be discarded in the water body, generating potential impacts to aquatic communities or in landfills, with a cost of transportation and storage. Considering, in isolation, the motivation for the use of dredging material in the local infrastructure would already exist. In addition to this, there is a bottleneck in the production of sand and landfill materials in RS. Due to the sensitivity of the extraction areas and the constantly improving mining rule by the environmental agency and consequent increase in the complexity for the licensing (Prado & Souza, 2004).

The area for construction of the terminal is inside an industrial zone (PDUA, 2015). As for environmental constraints, the disposal site is characterized by an area where irrigated rice was once grown and which is expected after the closure of the material arrangement to be transformed into the useful area of the terminal. Thus, it is possible to confirm the possibility of economic use.

Multi-criteria Analysis

In this context, the material to be dredged is composed of medium to coarse sand and free of contamination, having wide availability of uses (Table 1). The needs assessment pointed to the potential of economic uses for sediment from dredging.

The following point is the comparison between the granulometry and the physical chemical quality of the sediment for the deferred use. As described by Hermanns, 2017 sediments from dredging can be used in different ways in construction. However, coarser sediments limit the uses for building construction and are more suitable for the construction of rolling pavements (Kerstner, 2003).

In this specific case, the characteristics of the material found can be used for landfills with no need of confinement (free) and for the construction of vertical structures, according to Table 4 and discussed in the chemical results of the sediment samples.

The feasibility of the environmental quality characteristics of the sediment and the disposal of the dredging sediment on the ground was analyzed in Table 04 suggested by Hermanns (2017). This analysis confirmed the feasibility of disposal according to the physico-chemical quality results of the sediments. Sediment samples collected in September 2016 are compost bay sands with chemical compounds under Level 1 (CONAMA 454/2012). There is no restriction of use to the sediment dredge.

Table 4 - Definition of destination and use compatible with the characteristics of the dredged material (Hermanns, 2017).

SEDIMENT CHARACTERISTICS		ECONOMIC NEED				SOCIO-ENVIRONMENTAL		
		Confined Environment		Open Environment		Geological Recovery	Recovery Ecosystem	Social Needs
		WC	NC	WC	NC			
Particle Size	Clay (<0,004 mm)	X	X	X	X	X	X	X
	Silt (0,004–0,064 mm)	X	X	X	X	X	X	X
	Sand (0,064–2 mm)	**X**	**X**	**X**	**X**	**X**	**X**	**X**
	Granule (2–4 mm)	-	X	-	X	X	X	X
	Bigger than 4 mm	-	X	-	X	X	X	X
Contamination (level during disposal)	Level 1	**X**	**X**	**X**	**X**	**X**	**X**	**X**
	Level 2	X	X	-	-	-	-	-
	Level 3	X	X	-	-	-	-	-

WC- WHITH CONTAINMENT / NC- NO CONTAINMENT

The importance table determines the type of use but the definition of destination and use priorities for the dredge sediment from Sinos river could be evaluated by comparative prioritization between potential uses. The comparative and prioritized has been made using the scale of 1 to 5, classification 5 being the most necessary and classification 1 being the least necessary. Comparative prioritization between potential uses. In this sense, according to sediment characteristics, the resource should be used primarily for socio-environmental and commercial purposes, and there are no limitations. The result from local necessity must be compared, legal compatibility and technology available and costs, and only then, the decision to make the best use of the dredging material (Hermanns *et al*, 2017).

Technology Available and Costs

The most common dredge types used in Brazil and in the world are divided into two groups, the mechanical and the hydraulic (ALAD/CBD, 1972; Bray *et al*., 1997). Due to the hydrodynamic as well as sedimentological characteristics of the study area (mouth of the Sinos river), as well as to the positioning of the areas for disposal (very close), it is possible to use two (2) types of dredging equipment: one A clamshell dredge or a dragline for dredging of the material located near the quay, and a hopper type hydraulic dredger for dredging material distant from the quay.

Both clamshell type dredgers and draglines are indicated for dredging services near land, shore or mooring structure. The two have very similar operating systems where the bottom material is withdrawn through a system of blades (grab) that is driven through a system of cables, the arrangement of this system is the main difference of these two types of dredgers. Clamshell is the most commonly used dredger in the world, especially in North America and the Far East. It has a crane, equipped with a bucket, which is set on a floating pontoon/barge. The operation of the hopper is controlled by a hydraulic piston located in the control cabinet of the equipment. The vertical structures fixed on the floating pontoon (cigars or spuds) have as function to give support during the act of the excavation.

The dragline is a basic digging tool used in many surface mining, dyke construction, cleaning of canals and dams, etc. The structural configuration of a dragline consists of a steel bucket attached to a moving crane. The shovel is thrown towards the ground, by circular motion of the crane, "subtracting it". Material "subtracted" from the ground is hoisted toward the crane, and usually deposited in trucks (later use in other activities) or in areas adjacent to this excavation.

Drag suction dredgers, hopper type, consist of a self-propelled boat. The dredging system is developed alternately between the suction process of the material, which is pumped to an external storage site, a sedimentation basin or another vessel that will carry the material. The dredging system is comprised of the drag caused by the suction of water, carrying the bottom material into the tank, and the efficiency of this method is greatly increased when there are nozzles in the sediment, shovels or teeth to facilitate the fluidization of the material. The suction is produced by hydraulic or electric pumps specific for dredging, located inside the hull or even coupled in the articulations of the arms of the suction tube. The piping exiting the discharge dump of the dredge pump proceeds by conducting the material through a piping system to the dumping site.

Both types of dredge have the environmental advantage of withdrawing the bottom material with a very low liquid percentage, requiring no settling basin to separate the dredged material from the water as required for hopper dredges. The material to be removed can be directly used in earthmoving works, if there are no environmental quality restrictions.

However, for the provision of dredging sediments on land, dredged with suction dredges and hopper type dams, it is necessary to implement measures so that the dredged sediments do not return to sediment the water bodies, ensuring that the return water presents a low Concentration of solids. For this, the most consecrated method is the construction of sedimentation basins, where the sediments settle to the bottom of the basin and the water returns to the water course after traversing the extension of the basin. Also, based on the results of the particle size analysis, it can be considered that the dredge material presents high sedimentation rates, typical of sands.

This feature helps in the management of dredged material, since sedimentation basins present high efficiency for the separation of this type of material. An efficient separation of the water and the dredged material generates a return water with low amount of solids, reducing the potential of silting and the increase of turbidity in the place of return water throw. Thus, it can be considered that the restrictions cited in CONAMA Resolution No. 454/2012 do not prevent the disposal of the sediment ashore.

Legal Compatibility and Social Validation

The use identified as preferential for the material of this dredging was port construction, without the necessity of confinement or treatment of the quality of the sediments. The legal compatibility analyzes required by Conama 454 were sufficient to ensure the environmental safety of this use. As well as, the social validation of the use in the form of infrastructure, follows the permission issued by the licensing body. Based on the premise of meeting the conditions of execution and monitoring of the process of dredging and dump in soil of the dredged material.

Conclusion

The samples collected in Sinos River are suitable for different forms of use. In this case, the use of the material for dredging should be prioritized for economic purposes. This is due to the fact that the social uses in the region of comprehensiveness need first the intervention of the government.

The multi-criteria analyses from the Dredge Sediment Reuse Plan indicates the possibly to use the sediment as a resource to the port infrastructure. This use guarantee the viability and generates economic to the project, with a lower incidence of impacts on the water and community with a better control of impacts to disposal sediments on the ground. In addition, an alternative to the difficulty encountered by the public and private sectors during the drafting and execution of dredging plans.

The use of sediments as a resource in the construction decreases the necessity of sand mining in the state of Rio Grande do Sul, and seems to be a good alternative, due to the constant need for mining, through dredging, of sedimentary materials for the construction industry. Allied to this, dredging costs can be reduced by setting up a sediment bank to the government supplies.

Associated with this, the present study seeks to encourage the utilization of the waterways of the Rio Grande Sul and the use of dredging material as a resource for different socio-environmental and economic purposes. In addition to contributing to the increase in water transport and consequent decrease in road transport, and its associated impacts from CO2 emissions, collaborating with global warming control.

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