

Sedimentary Environments of the Inshore Pemangkat Region Sambas, West Kalimantan

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Abstrak

Lingkungan Sedimen di Perairan Pemangkat, Sambas, Kalimantan Barat

Peningkatan produk-produk perikanan melalui industrialisasi dengan menekankan pada pengembangan perikanan budidaya laut yang membutuhkan data pendukung lingkungan laut termasuk sedimen dasar laut. Penelitian lingkungan sedimen di Perairan Pemangkat bertujuan untuk mendapatkan informasi mengenai komposisi sedimen permukaan dasar laut, konsentrasi mineral logam dan total padatan tersuspensi. Beberapa sampel sedimen permukaan telah diambil pada transek yang telah ditentukan di sekitar Pantai Pemangkat dan telah dilakukan analisis mengikuti prosedur analisis granulometri, sedangkan metode AAS diterapkan untuk menentukan konsentrasi mineral logam. Selain itu, beberapa sampel air laut juga telah diambil menggunakan botol Nansen untuk mendapatkan total padatan tersuspensi. Informasi tersebut sangat bermanfaat bagi manager dan atau pemerintah daerah dalam menilai, merencanakan dan mengelola kawasan peisir dan lingkungan laut. Standar kualitas air yang dikeluarkan oleh Kementerian Negara Lingkungan Hidup digunakan sebagai acuan untuk mengkalibrasi hasil penelitian. Studi ini menunjukkan dominasi sedimen lumpur dan tingginya konsentrasi TSS, mengindikasikan bahwa Perairan Pemangkat tidak direkomendasikan untuk pengembangan kawasan perikanan budidaya laut.

Kata kunci: sedimen, mineral logam, total padatan tersuspensi

Abstract

Increasing fisheries products through industrialisation with emphasizing on marine aquaculture development requires supporting data on marine environments including seafloor sediments. Research on sedimentary environments of the inshore of Pemangkat region was aimed to obtain seafloor sediment composition, heavy metal and total suspended solid (TSS) concentrations. Some surface sediments samples were collected in transects across the selected Pemangkat coast and analysed following the procedure of granulometric analysis, whilst AAS (Atomic Absorption Spectroscopy) was applied to determine heavy metal concentrations (e.g. Hg, Pb, Cd, Cu, and Zn). Additionally, water samples were also collected using Nansen bottle to derive TSS concentrations. This sort of information will be valuable for manager and/or local government to assess, plan and manage coastal zone and marine environment. A standard of water quality issued by the State Ministry for Environment was then used as a reference to calibrate the results. This study showed silt (mud) sediment dominance and high TSS concentrations, indicating that the inshore Pemangkat region was not highly recommended for marine aquaculture development.

Keywords: sediment, heavy metal, total suspended solid

Introduction

The inshore Pemangkat region is located at Sambas Regency, West Kalimantan, extending

approximately between 1°–1.5°N and 108.5°–109° E (Figure. 1). This region is one of contributing areas in West Kalimantan that produces fisheries products both capture and marine aquaculture. Recently, the

government of Indonesia through Ministry of Marine Affairs and Fisheries (MMAF) delivered the fisheries industrialisation program purposing the increase of fisheries production with draw more attention to marine aquaculture and value-added products rather than capture fisheries (Solihuddin *et al.*, 2010). In this regard, researches on marine environments are essential to be conducted in order to support the government reaching the target and to provide scientific base for better marine and coastal resources assessment, planning, and management. This recent study, therefore, focuses on sedimentary environments comprising sediment composition and distribution, heavy metal and total suspended solid (TSS) concentrations.

Previous studies discussing sedimentary environments to support fisheries management have been carried out to provide insight on marine aquaculture development based on sediment characteristics (Radiarta *et al.*, 2003). Likewise, study of heavy metal concentrations in water and sediment samples in relation to marine aquaculture development was conducted by Tarigan *et al.* (2003), involving Pb, Cd, Cu, Zn, and Ni elements analysis. Similarly, reported by Rubio *et al.* (2000) about major and trace element, as an assessment on metal pollution through sediment. Whilst Hardjojo and Djokosetiyanto (2005) demonstrated study of TSS concentrations linked to an understanding of seawater quality and productivity for marine biota.

The main objective of this study is to obtain a detailed characteristic of seafloor sediment in combination with heavy metal and TSS concentrations. This will involve addressing these following issues: 1) what are the sediment compositions and how have these distributed regionally, 2) what are the concentrations of the heavy metal and to what extent they affect the marine environment capacity, and 3) what are the concentrations of TSS and how can they influence marine living organisms.

Material and Methods

Sampling were conducted at Pemangkat region, Sambas, West Kalimantan, Indonesia (Figure 1.). Some 26 sediment samples were collected using a grab sampler in transects across the inshore Pemangkat region (Figure 2.). Textural group were then defined following the triangular diagram classification proposed by Folk (1980).

Every single sediment sample was separated from organic materials after being washed by tap water and dried using a warm oven. An initial sample weight of 100 gr was then sieved

using a set of sieves (each sieve diameter equating to the Wentworth grain size boundaries) and a sieve shaker to obtain a ratio of gravel, sand, and mud. Following this, Gradistat version 6.0 was also applied to derive grain statistical parameters comprising mean size, standard deviation, skewness, and kurtosis which are determined by both graphical and mathematical measures (Poppe *et al.*, 2004). In this software, all grain size analysis were measured using logarithmic method .

Sediment samples were also subject to analyse heavy metal concentrations such as Hg, Pb, Cd, Cu, and Zn using an AAS (Atomic Absorption Spectroscopy) method. Whilst some 26 seawater samples collected by Nansen bottle were examined using gravimetric technique to derive TSS concentration (measured as mg.L⁻¹).

Results and Discussion

Regional geology

The regional geology of the inshore Pemangkat region is predominantly covered by Quaternary Alluvial deposits which consist of mud, sand, and gravel from Sambas and Paloh River systems. This covers almost 50% of the study area and is widespread along the littoral zone forming a major geomorphic feature along the Pemangkat coasts (Rusmana *et al.*, 1993), whilst the seabed is sloping north-westward from the shoreline and composed of submerged Pleistocene Alluvium (Thorpe *et al.*, 1990).

The geological structures are not obviously exposed in the study area due to widely spreading of alluvial deposits. However, anticlines, normal and strike faults developed in eastern part of Pemangkat, enabling mineralisation processes and geomorphic formation. The Sintang Intrusive Rocks which consist of dikes, diorite, and granodiorite spread locally at southern part of Pemangkat and are believed as main sources of gold mineralisation in this area and across Kalimantan.

Oceanographic setting

The regional oceanography of the inshore Pemangkat region is significantly influenced by South China Sea which has characteristic shallow bathymetry, averaging 200 m maximum in depth. The average sea surface temperatures are from 22 to 30 °C, whilst salinity ranges from 28 to 34 ‰. The high rainfall and freshwater input from rivers give contribution to the impressive salinity changes in this region (Masrikat, 2010).

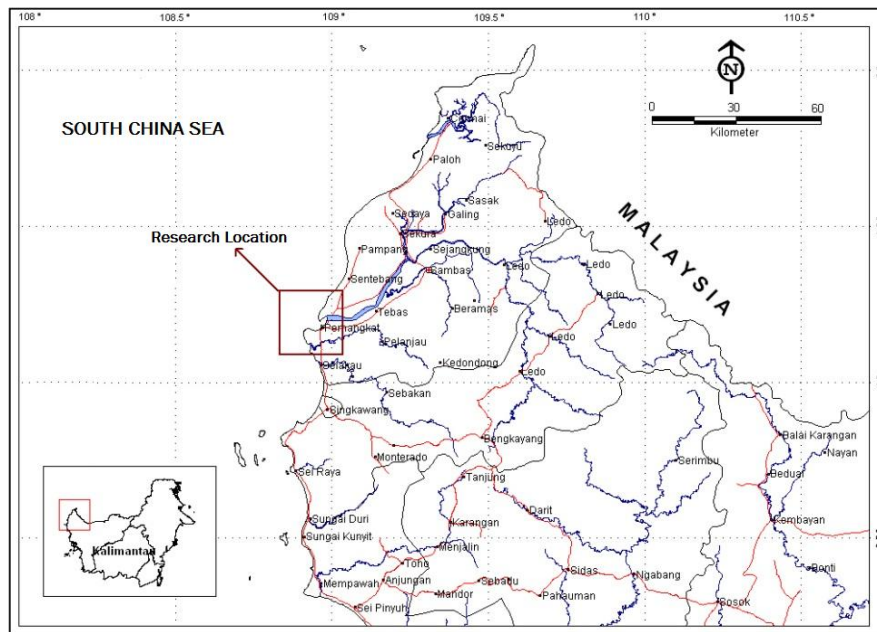


Figure 1. Research location Pemangkat region, Sambas, West Kalimantan, Indonesia

The region lies in the monsoonal belt which prevailing westerly rain-bearing winds induces intense precipitation from December to February with an average rainfall of 300 mm.y⁻¹, and dry easterly trade-wind occurs from June to August with an annual average of 150 mm (Masriat, 2010). Also, the inshore Pemangkat region has mixed mainly semidiurnal tides with a maximum tidal range of 1.6 m and experiences both high and low tides twice a day with various ranges of tides. This condition leads to remarkable differences of current speed and direction, which flows south-eastward with a speed of 0.1 m.s⁻¹–0.2 m.s⁻¹ during high tide and from a low of 0.05 m.s⁻¹ to a high of 0.18 m.s⁻¹ north-westward at low tide (Solihuddin *et al.*, 2011).

Sediment textures

To classify seafloor sediment textures, 26 sediment samples have been collected using a grab sample in transects across the inshore Pemangkat region (Figure. 2). Visual estimation and description is the first stage to obtain sediment characteristics with the aid of a hand lens. Based on grain size analysis (Table 1), sediment textures of the inshore Pemangkat region can be grouped into two units (Figure. 3) i.e. silt (Z) and sandy silt (sZ).

Silt (Z)

The silt (Z) was widespread along the Pemangkat coast constituting around 90% of the study area and deposited in range of 0–25 m deep. Visually, the silt was blackish gray in colour, slightly grain, and composed of rock fragments and shells.

This texture unit is classified as fine – very coarse silt mixed with fine sand and largely transported, suspended, distributed from inland to the sea through Sambas River, and redeposited in the inshore Pemangkat region by tidal currents and waves.

Sandy silt (sZ)

The sandy silt (sZ) was locally distributed in South Jawa Coast, northern Sambas River estuary. This texture unit only represented ± 10% of the study area and was deposited in the depth of 0–2.5 m. The sediment, which consist of very slightly reefal sand, shells, and organic materials, was dark brownish gray in colour, forming a sandbar morphology in the nearshore and this was emergent at low tide.

Based on this sediment composition, it can be inferred that most sediment materials were originally derived from Sambas River. This means that fluvial processes were dominant than marine processes. Moreover, the high turbidity level in combination with shallowing processes in the mouth of Sambas River and adjacent Nusantara Fisheries Port (NFP) of Pemangkat showed high sediment input from rivers.

However, the existence of reefal sand and shells in sediment samples is evidence that marine processes particularly tidal currents and waves also play important role in eroding and distributing the bioclastic sediment such as coral, shells, mollusc and foram.

Table 1. Sieve analysis result of the inshore Pemangkat region sediment

Sample ID	Weight percentages (Gr)			Grain statistical parameters(ϕ)				Textural groups (Folk, 1980)
	Gravel	Sand	Mud	Mean	Sorting	Skewness	Kurtosis	
PM-1	0.000	0.3072	88.021	5.987	1.219	0.013	0.719	Silt
PM-2	0.000	0.8697	97.5	5.976	1.227	0.012	0.721	Silt
PM-4	0.000	2.8819	95.5	5.934	1.260	0.006	0.729	Silt
PM-5	0.000	0.8985	87.054	5.974	1.229	0.011	0.721	Silt
PM-6	0.000	0.0573	85.3	5.993	1.215	0.014	0.718	Silt
PM-7	0.000	0.1765	83.689	5.990	1.217	0.014	0.718	Silt
PM-8	0.000	10.0273	87.205	5.764	1.456	-0.061	0.841	Sandy silt
PM-9	0.000	0.0681	97.1	5.993	1.215	0.014	0.718	Silt
PM-10	0.000	0.1011	98.021	5.992	1.215	0.014	0.718	Silt
PM-11	0.000	0.6621	97.021	5.981	1.224	0.012	0.720	Silt
PM-12	0.000	3.1018	95.3	5.929	1.263	0.005	0.730	Silt
PM-13	0.000	0.6920	97.4	5.980	1.225	0.012	0.720	Silt
PM-14	0.000	11.4604	88.021	5.733	1.460	-0.051	0.822	Sandy silt
PM-15	0.000	0.2091	98.245	5.990	1.217	0.014	0.718	Silt
PM-16	0.000	0.1469	97.215	5.991	1.216	0.014	0.718	Silt
PM-17	0.000	0.3994	97.2	5.986	1.220	0.013	0.719	Silt
PM-18	0.000	0.0774	83.015	5.992	1.215	0.014	0.718	Silt
PM-19	0.000	13.1447	86.3	5.689	1.479	-0.046	0.812	Sandy silt
PM-20	0.000	25.6909	72.012	5.236	1.662	0.010	0.621	Sandy silt
PM-21	0.000	0.0494	98.7	5.989	1.218	0.014	0.718	Silt
PM-22	0.000	0.6974	97	5.980	1.225	0.012	0.720	Silt
PM-23	0.000	0.4979	86	5.983	1.223	0.013	0.720	Silt
PM-24	0.000	0.2022	87.542	5.990	1.217	0.014	0.718	Silt
PM-25	0.000	0.5432	97.685	5.983	1.222	0.013	0.720	Silt
PM-26	0.000	1.0517	96.256	5.972	1.230	0.011	0.722	Silt

Environment of sediment deposition

There is a strong correlation between grain size and environments e.g. we rarely find conglomerates in swamps or silts on beaches, but there is a great probability of overlapping. Mean size is a function of the size range of available materials and amount of energy imparted to the sediment which depends on current velocity or turbulence of the transporting medium. Sediments usually become finer with decrease in energy of the transporting medium (Folk, 1980). Based on grain statistical parameters measurement, the mean size ranged from 5.236 to 5.993 ϕ and was grouped as silt. This considerably shows the dominance of fine grained fractions, indicating that the transport agent- energy is low.

Standard deviation (sorting) characterises at least 4 factors i.e. size range of the material, type of deposition, current characteristics, and time rate of supply of detritus. Spreading sheets of sediment will give better sorting than sediment deposited by gravitational flow regime. Also, currents of relatively constant strength whether low or high, will give better sorting than currents which fluctuate rapidly from weak to strong (Folk, 1980). The grainsize analysis resulted sorting in range of 1.216–1.662 ϕ (poorly sorted), designating that the current velocity

was not constant and the time required by sediment to settle was shorter. Skewness is a measure of symmetry of the distribution around the mean and a promising clue to environmental differentiation. For example, island beaches give nearly normal curves, dunes are positively-skewed and Aeolian flats are positively-skewed. Folk (1980) showed that dunes tend to be positive skewed and beaches negative skewed for many areas all over the earth. The skewness of some sediment samples ranged from -0.061 to 0.014 ϕ (near symmetrical), indicating that the whole sediment population has uniform grained fraction.

TSS concentrations

TSS is one of water quality measurements including all particles suspended in water which will not pass through a filter (Wirasatriya, 2011). As levels of TSS increase, a water body begins to lose its ability to support a diversity of aquatic life (Satriadi and Widada, 2004). Suspended solids can also harm fish directly by clogging gills, reducing growth rates, and lowering resistance to disease (Hardjojo and Djokosetiyanto, 2005). To obtain spatial TSS distribution, 26 seawater samples have been collected in transects across the Pemangkat coast with the distance among sample points was \pm 1 minute latitude-longitude grid or about 1.8 km

Figure.2). The samples were collected ± 1 litre each on the depth of 1–2 m and 5–10 m. Laboratory test results (Table 2) showed that the TSS concentrations ranged from a low of 5 mg.L⁻¹ to a high of 414 mg.L⁻¹ and were dominated by high concentrations especially at the mouth of Sambas River and adjacent areas (Figure. 4). This indicates high sediment input from Sambas River and is forming an inhospitable environment for marine organisms, particularly fishes.

Table 2. Laboratory test result of TSS concentration of the inshore Pemangkat region

Number	Samples ID	TSS concentrations (mg.L ⁻¹)
1	PM-1	414
2	PM -2	248
3	PM -3	248
4	PM -4	176
5	PM -5	140
6	PM -6	104
7	PM -7	139
8	PM -8	32
9	PM -9	159
10	PM -10	13
11	PM -11	31
12	PM -12	44
13	PM -13	19
14	PM -14	23
15	PM -15	68
16	PM -16	13
17	PM -17	5
18	PM -18	24
19	PM -19	32
20	PM -20	21
21	PM -21	37
22	PM -22	18
23	PM -23	61
24	PM -24	28
25	PM -25	29
26	PM -26	5

The best range of TSS concentrations for marine biota referring to a water quality standard issued by the State Ministry for Environment (2004) is from 5 to 25 mg.L⁻¹. Whilst Effendi (2003) specifically classified TSS concentrations for fisheries aquaculture into 4 groups i.e. no influence (<25 mg.L⁻¹), slightly influence (25–80 mg.L⁻¹), highly influence (81–400 mg.L⁻¹), and not recommended (>400 mg.L⁻¹). The high TSS concentrations in the inshore Pemangkat region was largely caused by numerous mixed particles transported from Sambas River such as clay, silt, fine grain sand and other organic materials.

Heavy metal concentrations

A heavy metal is a member of a loosely defined subset of elements that exhibit metallic properties. Heavy metals are released into the environment by both natural and anthropogenic sources. The presence of elevated metal concentrations in the environment is usually related to human activities. Mining, smelting and the associated activities are one of important sources by which soils/sediment, plants and waters are contaminated (Morillo *et al.*, 2004; Jung, 2008).

Living organisms require varying amounts of heavy metals such as iron (Fe), cobalt (Co), copper (Cu), manganese (Mn), molybdenum (Mo), and zinc (Zn). However, excessive levels can be damaging to the organism (Tarigan *et al.*, 2003). Other heavy metals such as mercury (Hg), plutonium (Pt), and lead (Pb) are toxic metals that have no beneficial effect on organisms, and their accumulation over time in the bodies of animals can cause serious illness (Najamuddin and Herlina, 2010). In order to obtain heavy metal concentrations in the study area, some 5 sediment samples in selected



Figure. 2. Sediment and seawater were sampled at 26 sampling points

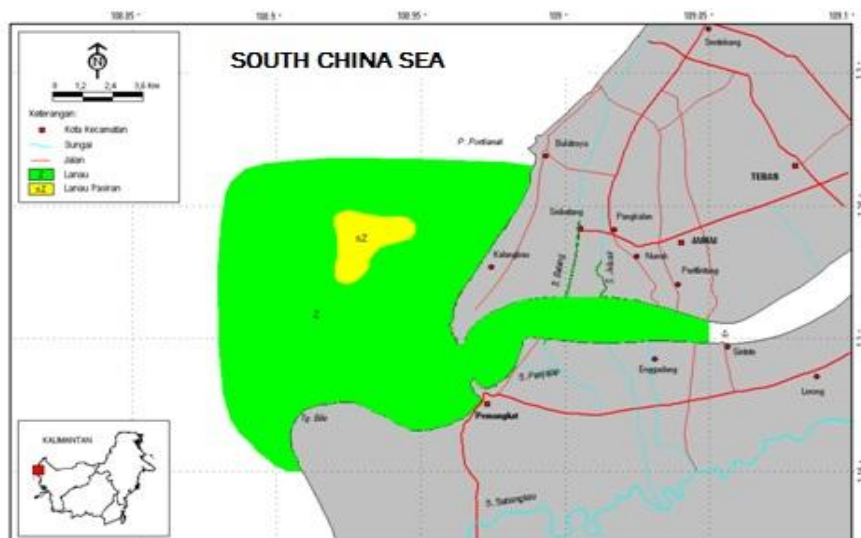


Figure 3. Surficial sediment distribution of the inshore Pemangkat region

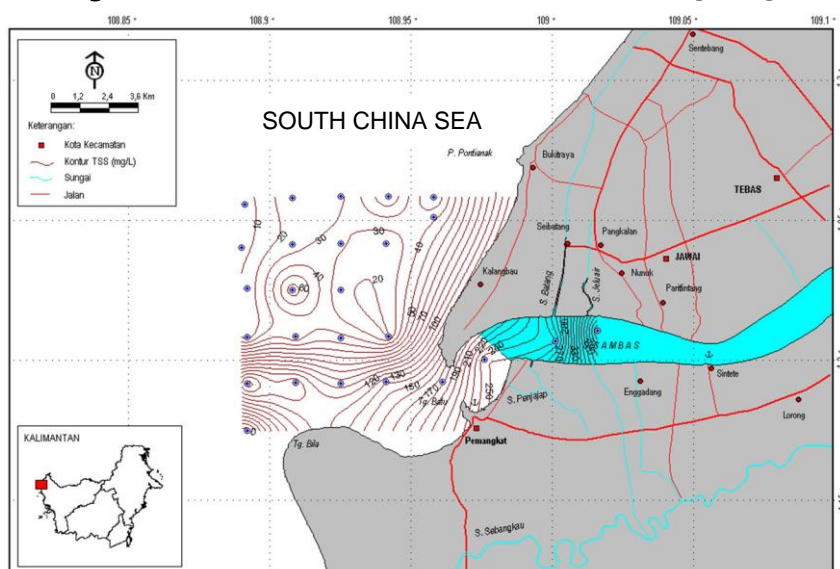


Figure 4. TSS contours showing the distribution of TSS concentrations

sample points (PM-1, PM-4, PM-9, PM-12, and PM-15) were separated to be subject of heavy metal analysis comprising mercury (Hg), lead (Pb), cadmium (Cd), copper (Cu), and zinc (Zn). An AAS method was applied to measure the heavy metal concentrations.

Table 3. Result of heavy metal concentrations of the inshore Pemangkat region (mg.L⁻¹)

Samples Id	Elements				
	Hg	Cd	Cu	Pb	Zn
PM-1	<0.0002	<0.125	0.046	0.15	0.065
PM-4	<0.0002	0.15	0.044	0.15	0.063
PM-9	<0.0002	<0.125	0.043	<0.125	0.061
PM-12	<0.0002	0.15	0.045	<0.125	0.064
PM-15	<0.0002	<0.125	0.047	<0.125	0.047

The results showed that the heavy metal concentrations were relatively low for whole samples analysed (Table 3) and still in tolerable value referring to the standard for marine biota issued by the State Ministry for Environment (2004). The uppermost limit concentrations of Hg, Cd, Cu, Pb, and Zn that are considered safe for marine biota are 0.001 mg/l, 0.001 mg.L⁻¹, 0.008 mg.L⁻¹, 0.008 mg.L⁻¹, and 0.05 mg.L⁻¹, respectively. This indicates that heavy metal released either from natural decay (geological processes) or industrial waste has little impact on heavy metal concentration in sediments of the study area. In other words, the inshore Pemangkat region is not significantly influenced by marine pollutants derived from heavy metal concentrations and this does not inflict direct threat to marine biota. The spatial distribution of heavy metal concentrations is presented in Figure 5.

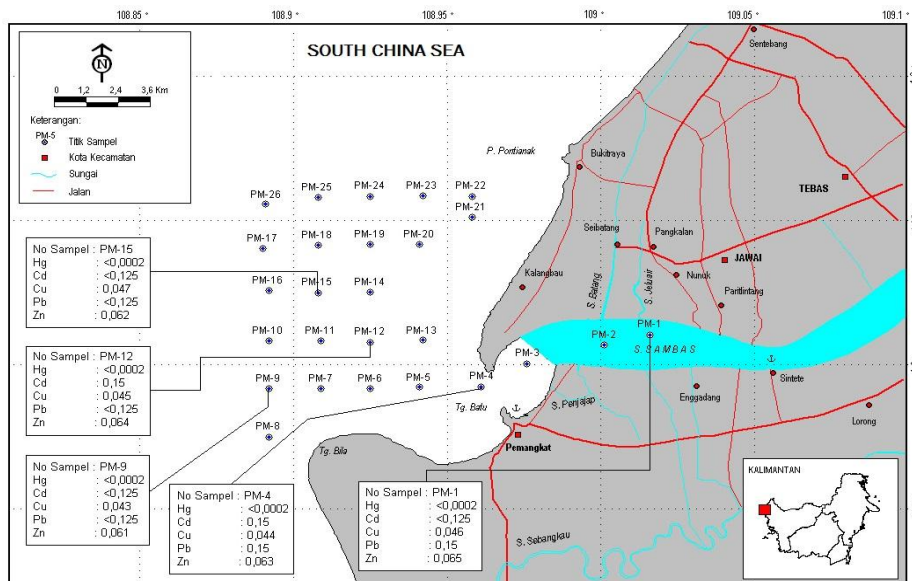


Figure 5. Heavy metal distribution of the inshore Pemangkat region

Sedimentary environment in relation to marine aquaculture development

The characteristic of sedimentary environments alone is not sufficient to determine whether or not a location is feasible to be developed as a marine aquaculture development area. However, the findings of this study at least provide scientific base on marine geological perspective to be applied in fisheries issues. Helfinalis (2005) described that surface sediment play important role in sediment stability and nutrients delivery. Surface sediment, both in size and texture, is one of contributing factors that influences organic material contents and benthic distribution. The finer the grain of sediment textures the higher their ability to trap organic materials. Similarly, Radiarta *et al.* (2005) reported that the best sediment substrate for marine aquaculture development is a substrate which corresponds to each organism habitat.

For example, the suitable surface sediment for oyster is coral reef or sandy coral substrates, whilst sandy and coral rubbles will be suitable for grouper and seaweed. In addition, recognition of heavy metal and TSS concentrations in marine environment will deliver better understanding of seawater quality and productivity and their unbeneficial effects on marine living organism, particularly fishes. However, Das *et al.* (2004) state that sediment which cause load of nutrients at eutrophic level and decrease of soil pH is not good for shrimp culture.

The outcomes of this study showed silt (mud) sediment dominance and high TSS concentrations, indicating that the inshore

Pemangkat region is not highly recommended for marine aquaculture development. Also, the physical properties such as turbidity, temperature, and salinity fluctuate considerably in this region as a characteristic of estuary ecosystem. However, this region is still feasible for marine aquaculture development especially for fishes that have high resistance to remarkable environmental changes such as mud-grouper, tiger-grouper, barramundi, and shellfish (Utojo *et al.*, 2005).

Conclusion

Despite the fact that the inshore Pemangkat region is expected to be one of contributing areas in West Kalimantan to boost fish production, it has inhospitable marine environment due to high sediment input and high fluctuation of physical properties such as temperature, salinity, and turbidity. However, if this region is going to be developed as a marine aquaculture area, the types of fish should have high tolerable level and resistance to the environmental condition changes.

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