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How Can Lime Help Izmir Bay? Two Promising Marine Applications

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Abstract

City of Izmir has been suffering from rotten odors emitting from anoxic river mouths, which are located in the innermost part of the Izmir Bay. An extensive research program has been conducted to control the noxious smells by inhibiting the anaerobic sulfate reducing bacteria at the sediment surface. In this respect, hydrated lime – *in the form of milk of lime* - has been spread close to the interface of the sediment and water to increase pH values. First, appropriate lime doses were investigated in the laboratory, and then pilot applications were performed both in the estuary and downstream segments of a creek, accordingly. The results- *both in the laboratory and in the field* - indicate that waterborne H₂S levels decrease significantly, and odor control efficiencies of 40 - 50 % remains even after 10 days from the time of lime addition

Another problem of the Izmir Bay is disposal of dredged material due to the expansion of harbor facilities. According to Ministry of Environment, this sediment can only be used as filling material for the construction of container terminals. Laboratory tests have shown that plasticity index of the soils stabilized with lime significantly reduces, and a remarkable increase occurs at the uniaxial pressure resistance.

1. Introduction

Izmir Bay is situated on the west coast of the Anatolian peninsula, and is connected to the Aegean Sea. The inner bay is surrounded by the residential and industrial areas of Izmir, which is the third largely populated city in Turkey.

Izmir Bay has suffered severe environmental damages for the past three decades as a result of the rapidly developing urbanization and industrialization. In fact, the master plan of the wastewater collection and treatment systems of the Izmir city has been on the agenda since 1968, and treatment system has started to operate for only few months. However, significant portion of wastewaters are still discharged into the bay without any treatment or after a limited pre-treatment due to lack of collection systems in many regions. Therefore, domestic and industrial effluents created by the city of Izmir and its vicinity keeps the bay under pollution stress. Also Gediz River and a number of creeks are significant point sources carrying diffuse pollutants to the Izmir Bay (Akyarli, 1996) (Figure 1).

Innermost part of the bay is an ideal harbor location due to the natural sheltering facilities that she presents for the ships. Izmir harbor has been among the most important nodal points in eastern Mediterranean since 16th century. She was the largest export port of the Ottoman Empire, and also followed Istanbul as the second largest

import port. The importance of Izmir harbor for the economy of Turkey is still valid, and she has been included among seven major ports of the country.

A vital recent problem of the Izmir Bay is disposal of dredged material due to the expansion of harbor facilities. Preliminary evaluations indicate that total of some 6.0 million m³ material comprising 2.4 million m³ from approach channel and 3.6 million m³ from the maneuvering areas has to be dredged for the construction of this channel and turning basins (Figure 1).

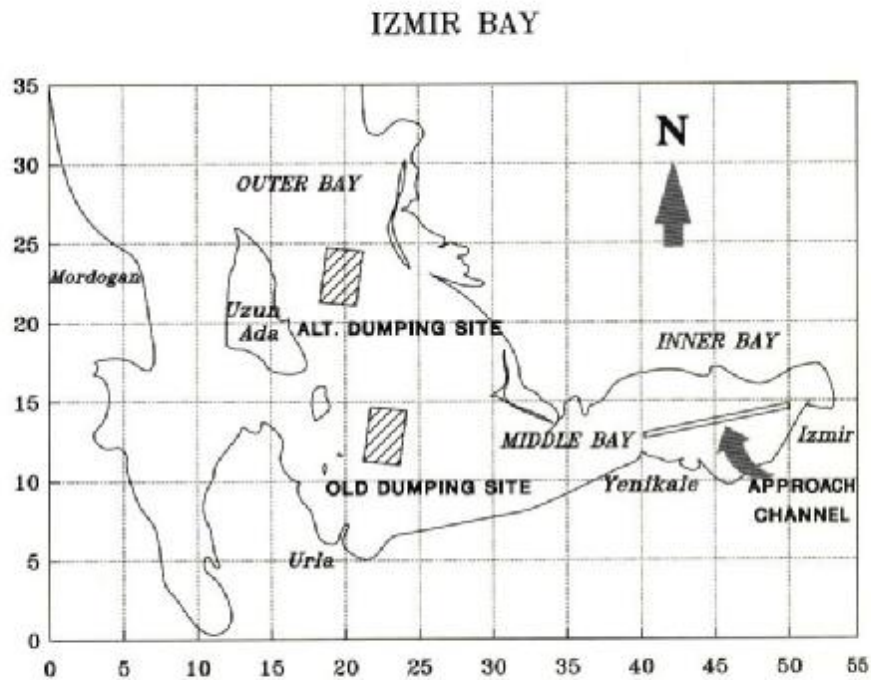


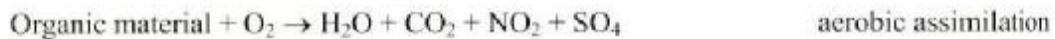
Fig. 1: Map of the Izmir Bay and locations of dredging and dumping sites

During previous dredging operations, some parts of the inner bay and old dumping area were used for aquatic dumping of dredged material. However, as a result of increasing environmental sensitivity and tightening legal requirements, environmental impacts of recent dredging operation have been carefully investigated (Akyarli, 1995). Finally, Ministry of Environment decided that dredged sediment could only be used as filling material for the construction of container terminals. According to laboratory tests, plasticity index of the soils stabilized with lime significantly reduces, and a remarkable increase occurs at free pressure resistance up to two times of the actual value.

2. First Promising Application – Odor Control in the Inner Bay

2.1. Source of Odor

City of Izmir has been suffering from rotten odors emitting from anoxic river mouths, which are located in the innermost part of the Izmir Bay. Anaerobic conditions occur after the consumption of dissolved oxygen (DO) in the water for the assimilation of organic wastes:



If the amount of organic material is excessive, assimilation process continues after the complete consumption of DO – *which means anaerobic conditions occur* - according to following formula:



Three products of anaerobic assimilation – *hydrogen sulfur, methane and ammonia* – release different odors among which the first one (H₂S) is more disturbing than the others. It is also H₂S being responsible from the typical odor in the Izmir Bay.

2.2. Phases of Odor Control Program and Measurement Methods

An extensive research program has been conducted to control the noxious smells by inhibiting the anaerobic sulfate-reducing bacteria at the sediment surface. In this respect, pH values at the interface of the sediment and water increased by spreading hydrated lime following Japanese experience (JLA, 1995).

First, appropriate lime doses were investigated in the laboratory, and then pilot applications were performed both in the estuary and downstream segments of a creek, accordingly (Koken, et al, 1998).

Airborne and waterborne free H₂S measurements were made by Dräger – Liquid - Extraction method (German Environmental Monitoring Institute, 1990). This technique consists of sucking a pre-determined volume of air through the Dräger tube by using a standard hand pump. During the sucking phase, a chemical reaction takes place between released free H₂S and the dry sorbent reagent in the Dräger tube. As a consequence of this reaction, originally white color of the tube becomes brownish. Here, the colored length of the tube is an indication of the exact amount of free H₂S in the sucked gas. Table 1 summarizes the other parameters involved during the laboratory and field investigations and relevant methods applied to measure them.

Table 1: Measured parameters and their test methods

Parameter	Method
H ₂ S (both water and air borne)	Drager tube method with water phase extraction system
Total suspended particles	APHA/AWWA/WPCF, 1985
Total nitrogen	Spectroquant kit method
Total phosphorus	APHA/AWWA/WPCF, 1985
PH	Portable pH meter and probe
Temperature	Portable digital thermometer and probe
Salinity and conductivity	Portable salinity and conductivity probe
Total bacteria	Dilution plate count (nutrient agar, Pelezar, <i>et. al.</i> , 1972)
Ammonium producing bacteria	MPN from Mc Cardy Table (mineral medium containing organic nitrogen source, Pelezar, <i>et.al.</i> , 1972)
Anaerobic bacteria	MPN from Mc Cardy Table (anaerobic broth containing Na-thioglicollate, Shank, 1988)
Sulphate reducing bacteria	MPN from Mc Cardy Table (mineral medium containing sulfate source and lead acetate paper sheet, Postgate, 1980)

2.3. Results

According to laboratory experiments, when the hydrated lime dose at the sediment surface is 200 gram Ca(OH)₂ /square meter, population of sulfate-reducers drops from 4.5×10^{10} to 1×10^6 per milliliter which corresponds to 99.9 % bacterial kill-out. At the same dose, anaerobic bacteria removal rate becomes 99.83% (Muezzinoglu et al, 1999). These figures are 98.88 % and 66 % – *respectively*- for 114 gram Ca(OH)₂ /square meter dose (Koken et al, 1998).

The results- *both in the laboratory and in the field* - indicate that waterborne H₂S levels decrease significantly just after the lime application, and odor control efficiencies of 40 - 50 % are still reached after 10 days.

Table 2 summarizes the results of field application performed on 17 October 2000.

Table 2: Results of field application performed on 17 October 2000

Location	H ₂ S (ppm)	PH	Temperature °C	H ₂ S reduction %
Control point *				
Start (t=0)	140	7,04	19,9	
7 th day	280	7	23	--
Station 1				
Start (t=0)	80	6,8	19,7	0
After t=10 minutes	0,5	7,3	21,8	99,4
1 st day	10	7	22	87,5
3 rd day	14	7	24	82,5
4 th day	23	6,3	23	71,3
5 th day	62	6,5	22	22,5
8 th day	52	6,5	21	35
Station 2				
Start (t=0)	50	6,7	21	0
After t=10 minutes	10	7,4	22,9	80
1 st day	30	6,7	21,9	40
2 nd day	23	6	20	54
Station 3				
Start (t=0)	240	6,7	19,2	0
After t=10 minutes	24	7	22,7	90
1 st day	56	6,9	21,7	76,7
3 rd day	48	6,5	24	80
4 th day	50	6,5	23	79,2
5 th day	52	7	23	78,3
8 th day	120	6,3	22	50
Station 4				
Start(t=0)	320	6,9	19	0
After t=10 minutes	34	6,8	21,8	89,4
1 st day	42	6,7	21,8	86,9
3 rd day	49	6,8	20	84,7
4 th day	150	6	20	53,1
5 th day	65	6,5	23,5	79,7
8 th day	140	7	22	56,3
Estuarine				
Start (t=0)	280	6,7	19,1	0
After t=10 minutes	41	7,1	22,1	85,4
2 nd day	80	7	22,5	71,4
4 th day	115	6	22	58,9
6 th day	108	7	22	61,4
7 th day	120	6	23	57,1
8 th day	150	6,5	22	46,4

* Since the control point is at the upstream side, lime has no influence on H₂S concentration.

2.4. Conclusion

Odor problem is evident due to excessive organic matter in polluted waters which reach the sea via natural – *creeks and rivers* - or artificial - *sewerage systems* - waterways. In this study, it has been found that when the lime-based chemical is added to the bottom sediments, gaseous sulfides – *particularly H₂S* - decrease significantly, and odor generation is highly reduced. Therefore, sequential feedings of small doses of hydrated lime – *in the form of milk of lime with equivalent dose of 200 gram Ca(OH)₂ per square meter at present case* – close to the bottom will be very effective for odor control due to inhibition of anaerobic and sulfate-reducing bacteria for a certain period which can be determined via monitoring the temporal variation of H₂S concentrations.

3. Second Promising Application – Lime Stabilization of Dredged Material

3.1. Source of the Idea

According to final decision of Ministry of Environment, some portion of the dredged material of Izmir Harbor should be utilized for the reclamation works pertinent to the construction of the new container terminals. It is particularly convenient to consider the sediments from turning basins (3.6 million m³ of total 6 million m³) for this purpose because it will provide remarkable saving as the alternative of aquatic dumping due the elimination of transport costs both for taking away the dredged material (to old dumping area - nearly 17 nautical miles) and bringing the filling materials for reclamation (from Yenikale - nearly 6 nautical miles) (Figure 1).

There are new technological developments in the world aiming the utilization of dredged material as filler after chemical stabilization with cement or lime (Akyarli, 1999). There is also a promising study – *performed by Calimci (1996) upon the proposal of first author* – based on laboratory tests on lime stabilized dredged material from Izmir Harbor.

3.2. Suitability of Existing Conditions

Dredged material consists of sand, silt, clay and also organic compounds with a spatially variable composition (Table 2). According to these figures, the sediments in the harbor zone include more clay but also high organic matter. In the approach channel, sediment is almost inorganic with the average clay ratio of 34 %. However, since the samples have been collected from the first 1 m of the sea bottom, it is quite possible to have lower organic content at the deeper zones of harbor region – *as well* - which makes dredged material more appropriate for lime stabilization.

Table 2: Geotechnical properties of dredged material

Region	Water Content	Liquid Limit	Plastic Limit	Clay Ratio	Sand Ratio	Grain Density	Organic Matter
	%	%	%	%		gr/cm ³	%
Approach Channel	72	52	26	34	9	2.65	---
Harbor Area	71	86	43	46	-	2.44	11

3.3. Results

The interaction between the dredged material and the lime has been investigated in the laboratory on the samples collected from the harbor area (Calimci, 1996). The results of the experiments are as follows:

- ✓ Samples from the top layer (max 30 cm deep from the bottom) are organic clay with high plasticity, and no positive impact of lime stabilization has been noticed.
- ✓ Samples from deeper levels (> 30 cm) are inorganic silt with high plasticity, and some positive improvements have been observed after lime stabilization with 6 % (by weight) hydrated lime as summarized below:
 - According to standard Proctor test results, optimum water content and corresponding maximum density are 24 % and 1.62 gr/cm³, respectively.
 - For the samples prepared with the figures of Proctor test, the uniaxial pressure resistant is 3.9 kg/cm² before lime stabilization, and it has been 4.9 kg/cm² just after mixing with lime; 7.2 kg/cm² after 7 days curing period, and 8.1 kg/cm² after 28 days curing period.
 - There are significant reductions at plasticity index (= liquid limit – plastic limit) in all cases of the second statement.

These preliminary findings qualitatively indicate that lime helps dredged material to increase its workability and pressure resistance, which are very important in case of using the material for reclamation of container moles. However, it is necessary to carry out more detailed studies to obtain reliable quantitative information.

3.4. Conclusion

Several alternatives have been proposed for safe disposal of the dredged material considering the findings of comprehensive environmental impact assessment (EIA) studies, which are explained in a chronological, humorous, but also scientific manner by Akyarli (1995). However, as a consequence of fundamentalist green actions, even the best alternatives – *both from environmental and economical point of view* – were rejected by some local initiatives – *including some majors* - and could not be applied. The result has been a long delay - *nearly 10 years* - in the realization of the project. Such an incredible delay made it possible to consider newer alternatives which have never been mentioned before - *like lime stabilization that seems to be a promising alternative if Ministry of Environment insists on her final decision.*

4. Final Remarks

We can separate lime market into two main segments as “**Ready to serve**” and “**Create to sell**”. While the first group is based on already available conventional applications, second group requires a real challenge with following actions: first to find a new promising application area for lime (creation of the idea); then to develop methods to perform the application (R&D phase); finally to convince the costumer how reliable and also economic is your proposal. During the final step, it will certainly be very useful to refer similar application(s) – *if any*. Both efforts presented in this paper should be considered in the second group requesting costumer(s) to be convinced.

In other words, we showed that lime is a promising agent to control the odor due to H₂S generation in the extremely polluted parts of the Izmir Bay with the supporting scientific evidences; we developed our methodology to perform the application; and we presented our results to decision-makers to convince how reliable and economic is our proposal. The case is almost similar for lime stabilization of dredged material, as well.

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