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A Review on Tar-Ball Pollution on the Beaches of Goa and Environmentally Safe Methods Available for Tar-Ball Disposal

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Abstract

This research investigates the sources and impacts of primary marine pollution, with a particular focus on offshore oil pollution along the West Coast of India and proposes solutions to mitigate these effects while preserving marine ecosystems and promoting sustainable economic growth. Marine pollution, notably through tar ball deposition, adversely affects local flora, fauna, and the tourism industry, which indirectly impacts the regional economy. The research highlights that while significant oil spills trigger immediate response measures, routine small spills often remain unreported and unmanaged, exacerbating environmental damage. The study examines the seasonal deposition of tar balls on the beaches of Goa, noting their transport and accumulation due to oceanic conditions. Through fingerprint analysis of tar balls from 2015, this research identifies their considerable calorific value, suggesting that these byproducts could be repurposed as a fuel source for cement industries. This approach not only addresses the challenges of hazardous waste disposal but also promotes sustainable practices. The paper advocates for the implementation of effective policies for oil spill management and tar ball reuse, aiming to restore affected beaches, conserve marine ecosystems, and support sustainable development.

1. Introduction:

The coastline of India spans approximately 8110 km. The states of Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Orissa, West Bengal, and Tripura share the same coastline. Coastal zones are vulnerable to pollution because of increasing anthropogenic activities like fishing, recreation, transport and aquaculture. Beaches have turned out to be dumping sites of domestic wastes, industrial effluents, hydrocarbons and solid waste materials (Kaladharan et al., n.d.). Presently, oil spills and tar-ball pollution have become a global issue, particularly in industrialized and developing countries such as India (Rekadwad & Khobragade, 2015a). Millions of liters of oil are discharged into the ocean yearly from routine ship and car maintenance activities, offshore oil drilling operations, and ship spills. Serious oil spills and tar-ball deposition on the seashore from these activities accelerate the degradation of marine ecosystems. In recent years, due to activities like routine ship maintenance, underwater drilling operations, and destructive fishing operations, more than thousands of liters of oil spill problems was observed. (PRIYANKA et al., 2019)

The negative impact of oil spills and tar-ball pollution was first reported in the 1970s by the director of the National Institute of Oceanography (NIO), Goa. On 2 July 1994, NIO reported an oil spill of approximately 2 tons from cracks on the starboard side of oil ships (Rekadwad & Khobragade, 2015). The NIO also found oil slicks, partially degraded petroleum hydrocarbons, and residual tar in seawater and on beach sand. Although oil spill incidents have decreased globally, the number of spillage reports is on rise along the Indian coastline notably along the West Coast of India. (Neethu et al., 2019)

The beaches in Alibaug do not have the problem of an oil spill and pollution of tar balls up to 2009. But because of collision between two ships namely, MSC CHITRA, and MV KHALIJIA in 2010, tar balls have appeared on the beaches of Alibaug (Raigad District) up to 2013, which was reported by National Environmental Engineering Research Institute (NEERI). This report has been submitted to the Maharashtra Pollution Control Board (MPCB). (PRIYANKA et al., 2019).

2. Tar balls

The tar balls are dark-coloured, sticky balls of oil that form when crude oil floats on the ocean surface. The West Coast of India is prone to receive Tar Balls deposits during the southwest monsoon season (Suneel et al., 2014). When crude oil (or a heavier refined product) floats on the ocean surface, its physical characteristics change. During the first few hours of a spill, the oil spreads into a thin slick. Winds and waves tear the slick into smaller patches that are scattered over a much wider area. Various physical, chemical, and biological processes change the appearance of the oil. These processes are generally called "weathering".

Figure 1. Tar balls deposited on Vagator beach, Goa, India in May 2018. (Fernandes et al., 2020)

3. Sources of Tar balls

The sources of spills in the sea surface are offshore oil exploration, oil tanker accidents, oil-well blowouts, accidental and deliberate release of bilge and ballast water from ships, river runoff, discharges through municipal sewage and industrial effluents.

4. Types of Tar balls

Marine tarballs can be classified as pelagic or benthic. Pelagic tar balls are those which float on the sea surface as shown in figure 2(a). While Benthic tar balls are observed on the sea floor as shown in figure 2(b). Both these types of tar balls are transported to the shore by the action of wave and tidal movements. (Warnock et al., 2015)

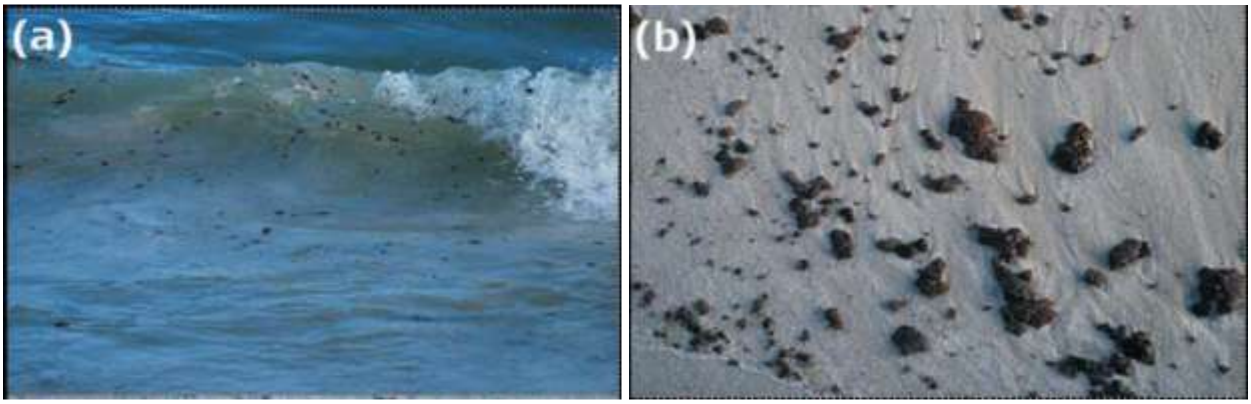

Figure 2. Pelagic tar balls (b) Benthic tar balls (Warnock et al., 2015)

5. Formation of tar balls

Some sources like oil transportation from the ships, drilling operation, emission from oil exploration, ship accidents, etc., have led to the entry of oil in Marine environment. (PRIYANKA et al., 2019) Initially, the lighter components of the oil evaporate much like a small gasoline or diesel spill. In the cases of heavier types of oil, such as crude oil or home heating oil, much of the oil remains behind. At the same time, some crude oils mix with water to form an emulsion that often looks like chocolate pudding. This emulsion is much thicker and stickier than the original oil. Winds and waves continue to stretch and tear the oil patches into smaller pieces, or tar balls. While some tar balls may be as large as pancakes, most are coin-sized. Tar balls are very persistent in the marine environment and can travel hundreds of miles.

In addition, tar balls can incorporate inorganic materials like sand, sediment, minerals, and salts from their surrounding environment, further altering their composition. Over time, microorganisms such as bacteria and fungi can colonize tar balls, breaking down oil components through biodegradation processes and changing their composition and appearance.

Moreover, tar balls may contain toxicants and contaminants, including heavy metals, trace elements, and persistent organic pollutants (POPs) such as PAHs, which pose environmental and health risks. The degradation of tar balls not only facilitates the physical adhesion of different microbes but also the residual products from this degradation process may further encourage microbial growth. (Shenoy et al., 2024)

To evaluate the weathering of the tar balls, the samples were analyzed for their levels of polycyclic aromatic hydrocarbons (PAHs) according to EPA 8270(D):2007 and EPA 3550(C):2007. The results reveal a predominance of chrysene, benzo(b,k)fluoranthene, dibenzo(a,h)antracene and benzo(a)pyrene. The biodegradation of high-molecular weight PAHs such as chrysene, benzo(b)fluoranthene and benzo(a)pyrene is difficult, whereas lower- molecular-weight PAHs such as phenanthrene and naphthalene are efficiently degraded. (Baptista Neto et al., 2014)

Saturates are the predominant class of hydrocarbons in most crude oil. Saturates include straight chain and branched chain (also called paraffins) and cycloalkanes (also called naphthenes). Biomarker terpanes and steranes are branched cycloalkanes consisting of multiple condensed five- or six carbon rings. (Wang et al., 2006). From this observation, pH value test was performed on tar balls and conclusion is that tar balls found on Kihim beach are acidic in nature. (PRIYANKA et al., 2019).

The Carbon Preference Index (CPI) is one such method, which gives information on composition of tar balls. The CPI value is approximately 1.0 for floating tar balls and petroleum oil. The CPI values of the present samples also range from 1.09 to 1.11, which indicates that the present tar ball samples contain petroleum, and they have floating tar ball characteristics. (Suneel et al., 2013).

The analysis of aliphatic hydrocarbons reveals that the carbon preference index (CPI, defined as the sum of odd over even-carbon-number n-alkanes) is near 1.0 for all samples. This indicates that the tar balls contain petroleum. (Wang et al., n.d.)

The Goa State Pollution Control Board and the Government of India considered this an alarming environmental issue. Moreover, the marine ecosystem was systematically affected by oil spills and tar balls, as they are Hazardous, toxic and carcinogenic, leading to a decline in the coastal water quality and biodiversity health. (Rekadwad & Khobragade, 2015b).

5.1 How they remain sticky?

Weathering processes eventually create a tar-ball or flattened tar patty that can be hard and crusty on the outside and soft and gooey on the inside. Turbulence in the water or beach activity from people or animals may break open tar balls and patties, exposing their softer, more fluid centres. We do know that temperature has an important effect on the stickiness of tar balls. As air and water temperatures increase, tar balls become more fluid and, therefore, sticky--similar to an asphalt road warmed by the summer sun. Another factor influencing stickiness is the number of particulates and sediments present in the water or on the shoreline, which can adhere to tar balls. The more sand and debris attached to a tar ball, the more difficult it is to break the tar ball open. These factors make it extremely difficult to predict how long a tar ball will remain sticky.

6. How to clean?

Once tar balls hit the beaches, they may be picked up by hand or by beach-cleaning machinery. If the impact is severe, the top layer of sand containing the tar balls may be removed and replaced with clean sand by concerned State Pollution Control Board as per Hazardous and other Wastes (Management & Transboundary Movement) Rules, 2016,.

7. Waste Reception

Waste Characterization plays an important part in any treatment process of the waste which may be required before pre-processing and ultimately co-processing into the cement kilns. Upon receipt of the waste, it shall be weighed and property logged. It shall then undergo a visual inspection to confirm the physical appearance. A representative sample of the waste shall be collected and send to the onsite laboratory for finger printing analysis.

Finger print analysis is performed to confirm that a particular waste stream belongs to an offsite waste generation source or not, based on its characteristics. The results of the finger printing analysis should be compared with the results of earlier analysis. Upon confirmation, this shall then be sent for pre-processing or co-processing.

The operator of the pre-processing facility of the cement plant shall perform following finger print analysis for each of the consignment of waste received for pre-processing or co-processing from generation site;

- Moisture content
- Ash content
- Net Calorific Value (NCV)
- Chloride and Sulphur content
- Chemical compatibility
- Any other specific parameter, which may be decided on merit of each case keeping the clinker production process in focus.
- In case of liquid samples, viscosity, pH, suspended particle content etc shall also be performed.
- Heavy metal analysis, Reactive Sulphide, Reactive Cyanide or Halide analysis should be performed if sample comes from a sector which is suspected to have these in the waste material.

The results of this finger print analysis confirm that the waste belongs to already tested and verified waste stream which is suitable for co-processing into the kiln and do not have any side effects on clinker and cement quality parameters.

8. Co-Processing

Co-processing in cement kiln is considered as environmentally sustainable option for the management of different kinds of wastes including hazardous and other wastes. In co-processing, these wastes are not only destroyed at a higher temperature of up to 1450°C and long residence time during which its inorganic content gets fixed with the clinker and becomes part of cement apart from using the energy content of the wastes, thus no residues are left. While in case of incineration, the residual ash requires to be land filled as hazardous waste. Further the acidic gases, if any generated during co-processing gets neutralized in the large alkaline environment available within the kiln system.

This phenomenon also reduces the non-renewable resources requirement such as coal and lime stone etc. Thus, the utilization of wastes in cement kilns through co-processing provides a win– win option of waste disposal. Co-processing of wastes in the cement plants would require a large-scale management of Hazardous and other wastes. This would mean that a large quantum of waste will be received, stored, handled and pre-processed in the cement plants or TSDFs or stand-alone pre-processing facilities so as to make a homogenised mixture of wastes suitable for co-processing in the cement kilns. It may require installation of different systems for feeding such homogenised mixtures into cement kilns. Fig 1 given in Annexure 1 provides an overview of the pre-processing of the waste in a facility and co-processing in cement kiln. Hence, there is a need to define appropriate methodology with which, necessary authorization can be granted by SPCBs to cement plants or pre-processing facilities apart from TSDFs for collection, transportation, receipt, storage, handling & pre-processing of wastes and also for co- processing operation in cement kilns.

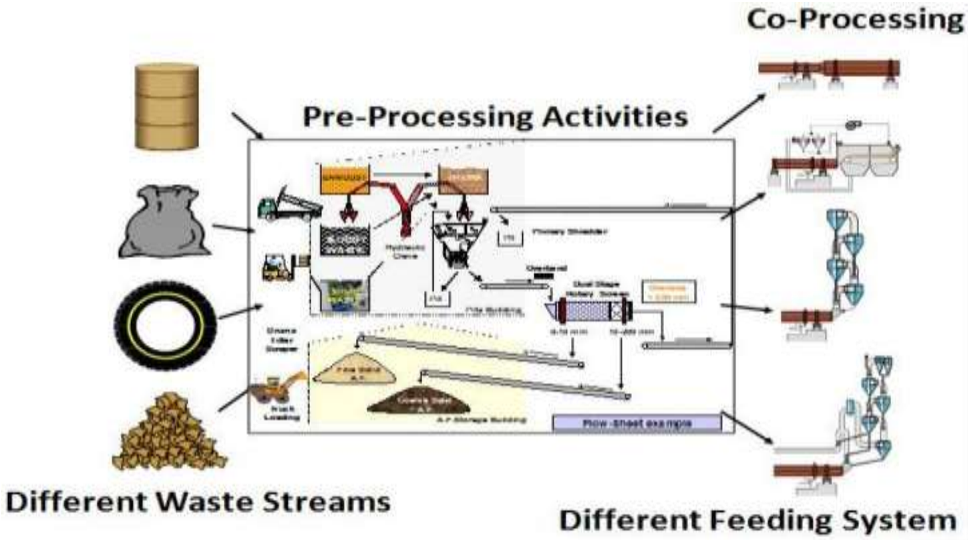

Figure 4. Schematic representation of Pre and Co-processing in Cement Kiln

8.1 Feeding of materials for Co-Processing

Different feed points can be used to insert the co-processing materials into the cement production process. The most common ones are:

- The main burner at the rotary kiln outlet end
- The rotary kiln inlet end
- The pre-calciner
- The mid kiln (for long dry and wet kilns

Appropriate feed points must be selected according to the physical, chemical, and toxicological characteristics of the substances, if relevant, used. Wastes of high calorific value must be always fed into the high temperature combustion zones of the kiln system. Such wastes containing stable toxic components should be fed to the main burner to ensure complete combustion in the high temperature and long retention time. Alternative raw materials containing components that can be volatilized at low temperatures (for example, hydrocarbons) must be fed into the high temperature zones of the kiln system. Feeding of alternative raw materials containing volatile (organic and inorganic) components to the kiln via the normal raw meal supply should be avoided unless it has been demonstrated by trial runs in the kiln that there is no undesired emission from the stack.

8.2 Suitability of Substances for co-processing

1. The decision on what type of substances can be used is based on the clinker production processes, the raw material and fuel compositions, the feeding points, the air pollution control devices and the given waste management problems. The Accept - Refuse Chart in Annexure-4 could be used by plant operators to help them in considering, which type of substance is suitable for co processing. As a basic rule, waste accepted must give an added – value for the cement kiln:

- Calorific value from the organic part
- Material value from the mineral part

2. Many substances, particularly those of low calorific value, contain a significant proportion of incombustible substance(s), while inorganic substances are used as a combination of high and low calorific value raw material.

3. In some cases, kilns can be used for the safe disposal of hazardous waste such as obsolete pesticides, PCB or out-dated pharmaceutical products, which may not have appropriate material or energy value as per the Annexure 4 but can be disposed in cement kiln without impacting the product quality. However, for this type of treatment, regulatory authorities and cement plant operators must come to individual agreements and standards on a case - by - case basis in consultation with CPCB.

4. The maximum concentration of various toxic parameters of waste, which may be considered for co-processing is termed as Acceptance criteria and appended as Annexure-5. This is evolved based on the following criteria.

- Emission standards.
- Pollutants in traditional raw materials.
- Treatment alternatives for the available waste.
- Trial run conducted in India.

8.3 Operating Conditions

1. Co-processing plants shall be designed, equipped, built and operated in such a way that the gas resulting from the co-processing is raised in a controlled and homogeneous fashion and even under the most unfavourable conditions, to a temperature of 950°C for two seconds. For hazardous wastes with a content of more than 1% halogenated organic substances (expressed as chlorine), the temperature has to be raised to 1100°C.

2. Co-processing plants shall have and operate an automatic system to prevent waste feed:

- at start up, until the temperature of 950°C or 1100°C as the case may be.
- Whenever the temperature of 950°C or 1100°C as the case may be is not maintained.
- Whenever emission monitoring show that any emission limits value is exceeded due to disturbances or failures of air pollution control devices.

3. Co-processing plants shall be designed, equipped, built and operated in such a way as to prevent emission into the air giving rise to significant ground level air pollution; in particular; exhaust gases shall be discharged in a controlled fashion and in conformity with ambient air quality standards (Annexure- 6) by means of a stack, the height of which is calculated in such a way as to safeguard human health and the environment.

4. The management of the co- processing plant shall be in the hands of a skilled person, competent to manage the hazardous waste in an environmentally sound manner.

8.4 Air Pollution Control

The dust emission is the main pollutant as far as pollution from cement industry is concerned. The dust emission is unlikely to change when cement plant is processing hazardous and other substances. Generally, cement kilns are equipped with Electro Static Precipitator (ESP) or Bag House to control the particulate matter emission. Any acid gases formed during co-processing are likely to be scrubbed by the raw material being of an alkaline nature and are incorporated into the cement clinker. However, cement industry has to ensure that they meet the particulate matter emission standards during co-processing as prescribed under the consent order issued by SPCB/PCC.

9. Case Study

Tar balls are generally deposited on the Goan coast during the pre-monsoon and southwest monsoon seasons. Tar balls of 100–300-mm size was observed. The width of the shoreline plays a significant role in tar-ball deposition on the seashore. Beaches such as Dona Paula, Miramar, Singuerim, Candolim, and Chalanguate have reduced foreshore and backshore width, compared with the Arambol beach. By contrast, the latter beach has a less inclined slope and considerably wider foreshore and backshore. Because both sides of the seashore are wider, the monthly high tide covers a noticeably longer distance than at other beaches. Each wave of seawater deposits more tar balls on the seashore. Volatile and low-density hydrocarbons are readily evaporated at increased environmental temperatures, but heavy and long-chain hydrocarbons evaporate slowly. The tar balls are dispersed at increasing temperatures and in turn percolate deeply in the sand. The back-and-forth movement of sea waves stains the sand, thereby changing the natural color of the sand to blackish oil-slicked sand (Rekadwad & Khobragade, 2015).

In one such event, we observed tar ball deposits along the Goa coast during August 2010, April 2011 and May 2011 when no oil spill was reported in the Arabian Sea. The only source for the formation of tar balls could be the spill/tanker-wash from the tankers passing through the international tanker routes across the Arabian Sea. Assuming this, an attempt has been made to simulate surface winds, currents and tar ball trajectories for August 2010 using hydrodynamics and particle tracking models. Tar ball particles were released numerically at eight locations in the Arabian Sea, and five of them reached the Goa coast, matching reasonably well with the observations. (Suneel, Vethamony, Kumar, et al., 2013)

The winds, waves, and turbulence at sea surface cause the emulsion to break into smaller pieces, which eventually become tar balls. Oceanic convergence plays a major role in the formation of tar balls since the convergence zones trap the floating organic and inorganic objects, which act as nuclei around the oil slicks/emulsions and form the tar ball (Suneel, Vethamony, Kumar, et al., 2013). The cyclonic eddy produces the convergence in the ocean while the divergence is due to an anticyclonic eddy. According to the Sand theory, when oil encounters sediment, sand and other shoreline materials, they may adhere together forming tar balls.

9.1 Re-use of tar balls

As per news article published in 2015, the Goa State Pollution Control Board Chairman, Jose Manuel Noronha, stated that tests on the tar balls have indicated that tar balls have a calorific value between 4000-6000 kCal/kg.(Tar Balls Have Been a Nuisance for Goa For, n.d.)

So, according to the CPCB Standard Operating Procedure (SOP), published in February 2010 “Guidelines on Coprocessing in Cement/Power/Steel Industry” states that if the hazardous waste is having calorific value above 2500 kCal/kg means it can be used as an energy source. Following this SOP tar balls can be used as an energy source in cement industries. (Guidelines on Co-Processing in Cement/Power/Steel Industry Central Pollution Control Board, 2010)

10. Conclusion

Offshore oil pollution along the West Coast of India is a serious problem as is evident by the seasonal occurrence of tar ball deposition on its beaches. When large spills occur due to collision or grounding of ships/tankers or accidents at oil platforms, they are considered as significant, and oil spill containing measures are immediately put into action by policymakers and stakeholders to protect the marine environment before the spills reach the coast. However, when small spills occur routinely in the sea far from the coast, they go unidentified and unreported, and no precautionary measures are taken to rectify the damage caused by such oil spills.

Effective policies on managing oil spills are warranted to restore beaches damaged by oil spills and tar-ball deposition. It is known that deposition of tar balls is a serious concern in most places as they float on the sea surface and get transported to the coast under the influence of winds, currents, tides and waves. The deposition of tar balls along the beaches of Goa during pre-monsoon and South West monsoon seasons, more or less regularly. Now it is necessary to collect it in a proper way with its significant reuse to conserve the marine ecosystem.

Based on the Goa reports of fingerprint analysis of tar balls in year 2015, the tar balls have a significant calorific value which can be further used as a source of energy in cement industries as pre and co-processing. This approach not only addresses the challenges of hazardous waste disposal but also promotes sustainable practices. The paper advocates for the implementation of effective policies for oil spill management and tar ball reuse, aiming to restore affected beaches, conserve marine ecosystems, and support sustainable development.

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