

Gadani Shipyard: Environmental Impacts on Maritime Pollution in Pakistan and China — A Legal and Policy Analysis

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ABSTRACT: The vessel recycling and in international trade play important role but it is also very danger for marine environment and human health. Pakistan is the largest country for breakdown facilities for Gadani Shipyard. The Pakistan Gadani shipyard criticized for marine pollution and danger hazards that it pollutes the marine environment. Similarly, China's ship recycling sector, while more regulated, still contributes to environmental degradation, particularly in coastal ecosystems. In this paper we are focusing on to examine the environmental impacts and legal laws and regulations also policy intervention of Gadani shipyard and China shipbreaking operation comparison to each other. My paper will show a clear image international convention, national policy and also show the gaps in regulations, challenges and alternative ways on the light of recent scholarly literatures. I will give recommendations on technologies and strengthen governance mechanism under the international standards. Also show the way to solve that problem which can damage the marine biodiversity, worker health and the community which living near the affected area. At last, give a recommendation to strengthen the national law under the international rules and regulation.

KEYWORDS: Environmental Law, Marine Pollution, Pakistan, China, Comparative Governance, Public Law.

1. INTRODUCTION

In the shipbreaking industry the valuable materials like steels and machinery are recover by dismantling of a vessel. Although the sector is economically significant, still it possesses severe environmental risks, such as oil spills, heavy metal contamination, and the release of harmful materials into marine and coastal ecosystems [1]. Pakistan's Gadani Shipyard and China's ship recycling industry distinctly different approaches to shipbreaking, making them a valuable case study in environmental management and policy compliance.

The largest shipbreaking yard is located in Pakistan in the coastal area of Balochistan. This shipbreaking industry dismantle hundreds of ships in one year. Many different papers discuss that the ecological damage occur due to inadequate poor management, unsanctioned waste disposal, and insufficient safety measures [2], [3]. Another hand, China has more advanced and good shipbreaking practices, now the all mitigation remains a challenge maritime pollution to put in danger [4].

My work focusses on:

1. The shipyard dismantling on marina Environmental in China and the shipbreaking in Gadani in Pakistan.
2. To discuss the international and national legal framework of ship dismantling.
3. The work main target is to give recommendation for comparative insights and also maritime practices.

2. LITERATURE REVIEW

The marine environmental harm is the main focusing part of my work. In shipbreaking industry, the worker safety risk has attracted considerable scholarly attention on economic benefits. The fresh studies show dismantling of obsolete vessels releases harmful substances like asbestos, PCBs, heavy metals like lead, cadmium as well as oil residue which is long-term risks to marine biodiversity and coastal environments [5], [6], [11]. The Gadani shipyard is a major part of marine pollution in Pakistan where the disposal practices frequent occur like oil spills and heavy metal buildup in surrounding sediments dangerous for fish and marine biodiversity and all the marine organisms was effected[12].My Comparative work is to reveals from China the mechanized ship recycling facilities have mitigated environmental contamination inadequate waste management at less semi-mechanized facilities still encounter persistent waste management leading to localized pollution [13], [14], [15].

The health is major and very important concern, with shipbreaking workers every day facing risks of injuries, chemical burns, inhalation of toxic fumes and chronic respiratory ailments [7], [16], [17]. The lack of modern protective equipment and less knowledge of safety and informal labor conditions that sometimes involve under eighteen workers in Gadani [18]. Conversely, The

Chinese have stronger safety protocols and also well-developed dismantling technologies, mandatory protective gear, inconsistent enforcement continues to result in occasional occupational hazards [19], [20].

The rules of law and good governance play a vital role in shaping the environmental occupational health outcomes of the shipbreaking industry. The Hong Kong International Convention and Environmentally Sound Recycling of Ships (2009) for safe ship dismantling sets international guidelines for dismantling and waste management [8]. Pakistan have insufficient tools and institutional weaknesses poor enforcement outdated ship recycling infrastructure continue to impede effective compliance [9], [21]. China upgrades Marine Environmental Protection Law (2017) due to legislation to enhanced regulatory oversight, and follow international standards and advancing the environmental sustainability of ship recycling activities [22], [23].

Industrial development that the, regulatory effectiveness and technological integration are critical determinants of environmental performance is very important step in ship recycling. In Pakistan ship recycling facilities such as Gadani remain largely labor-driven on manually the method is very old, resulting in significant environmental pollution, ecological degrade [10], [24]. While in China, utilize modern technology and operate Strick rules and regulations for environment and robust enforcement mechanisms to reduced ecological impacts [25], [26]. In Pakistan the socio-economic pressures like job dependence and the demand for scrap steel often create conflicts between economic objectives environmental awareness and sustainability [27], [28].

The gap remains present because of such long-term monitoring of environmental pollution in Gadani, The weak evaluation of policy outcomes insufficient integration of socio-economic dimensions into environmental evaluations. This research seeks to bridge existing gaps study conducts an in-depth comparative evaluation of shipbreaking industries in Pakistan and China, focusing on policy, legal framework and environmental impact.

3. METHODOLOGY

Adopting a qualitative comparative research design this study analyzes the environmental and legal consequences of shipbreaking in Pakistan's Gadani Shipyard selected Chinese yards alongside an evaluation of their legal and policy structures. The secondary data review, legal evaluation, and cross-country comparison to understanding of the environmental and regulatory dimensions of shipbreaking.

3.1 Research Design

A qualitative approach was adopted to provide an in-depth understanding environmental, legal, and policy dimensions of shipbreaking, rather than to establish statistical correlations. Pakistan, where shipbreaking remains largely labor-intensive which is manual work and China, which is transitioning toward more mechanized and regulated recycling practices. The comparative framework the examination of both differences and similarities between two contrasting contexts a developing country Pakistan.

3.2 Data Collection

This study relied solely on secondary data to ensure the reliability and currency of information. The following types of sources:

1. **Scholarly articles (2019–2025):** I will Peer-reviewed journals papers examining maritime pollution, ship recycling practices, occupational protection, and environmental policy.
2. **Institutional reports:** The main Institutional Documents are IMO, UNEP, ILO national environmental institutions in Pakistan and China.
3. **Governmental legislation and policy documents:** The legislative documents like Pakistan's *Environmental Protection Act* (1997), *Pakistan Environmental Protection Agency (Pak-EPA) Guidelines*, China's *Marine Environmental Protection Law* (2017), other pertinent national regulatory instruments
4. **Media reports and case studies:** The social media reports and case studies which is verified repot industrial accidents, documented environmental violations in both contexts.

3.3 Data Analysis

The data analyzed through qualitative method:

- **Environmental impact assessment:** To evaluate the nature and assets, extent, and effects of pollution on marine soil toxicity and air pollution caused by shipbreaking.
- **Legal and policy evaluation:** To examine national legal framework enforcement capacity with Hong Kong International Convention for the protected Environmentally Sound Recycling of Ships (2009).
- **Comparative analysis:** How Pakistan and China differ to each other and align in environmental outcomes, governance quality, technological improvement, and socio-economic effects within the shipbreaking industry.

3.4 Comparative Framework

Using the following indicators:

1. **Pollution levels:** The reported concentrations of heavy metals hydrocarbons, airborne particulates marine pollutants like soil and atmospheric environments.

2. **Compliance and enforcement:** The programs, enforcement measures, conformity with national regulations and international standards, under the presence of environmental monitoring
3. **Technological practices:** Technological modernization, development of waste management infrastructure and use eco-efficient ship recycling techniques.

3.5 Limitations

This study based on secondary sources, there should be some limitations that are given below:

- **Lack of primary field data:** The study did not include direct field sampling on-site observations were not undertaken owing to logistical limitations.
- **Data gaps:** Certain environmental and occupational health data for the Gadani Shipyard small-scale Chinese shipyards remain limited incomplete, or inconsistent across sources.
- **Generalizability:** As the analysis focuses on Pakistan and China, its conclusions should be interpreted with care when extrapolating results to other national contexts.

While acknowledging these limitations the study's methodology provides a sound basis for analyzing environmental impacts the comparative performance of legal and policy frameworks in both countries.

4. ENVIRONMENTAL IMPACT ANALYSIS

The break down operation faced some challenges, one of largest part is marine pollution, The second one is soil and third is air contamination, these kinds of pollution disturb the ecological balance of costal line country and disrupt the ecological balance of costal line country. Although These operation like Gadani Shipyard and Chinese ship recycling operations affect the marine environmental operational method, technological sophistication advancement, and regulatory enforcement.

The breakdown start it release many kinds of dangerous substance like notably asbestos, polychlorinated biphenyls (PCBs), toxic heavy metals like lead, cadmium, and mercury residual petroleum compounds. In Gadani the dismantling is manual and used unregulated breaking techniques it causes recurrent oil spills, toxic sludge discharge, causing significant heavy metal contamination along the Arabian Sea coastline. The observational worker report shows, that total petroleum hydrocarbons TPH levels in the coastal area near Gadani often increase **3,500 µg/L**, and damage the environmental level [29]. On another way damage the sediments exhibit elevated cadmium, lead, and the level of mercury concentrations increased that harm through the marine food chain produced long-term public health problem. [30], [31] when this continuous discharge of untreated and chemical and oil are occurred it damage mangrove life and it is very danger for fish and marine organism [12].

In China shipyards in Guangdong and Shanghai have modernized operations through mechanization, effluent treatment, and oil recovery systems regulation in reducing marine pollution. [32], [33]. Environmental progress remains uneven small-scale and semi-mechanized shipbreaking operations remain sources of untreated effluents revealing gaps in regulatory enforcement and ongoing localized ecological damage [34].

The soil contamination continues to pose environmental concern in shipbreaking areas. At Gadani the infiltration of heavy metals infiltrate coastal soils led to the loss of vegetation and also harmful for groundwater quality [35]. Soil cadmium levels near the shipyard is reach up to 12 mg/kg, this level is above global coastal averages [36]. The mechanized shipyards have minimized soil contamination in China by utilizing lined storage waste containment facilities to challenge full environmental restoration. [37].

Shipbreaking operations generate air pollution including particulate matter volatile organic compounds (VOCs). To open-air cutting and the uncontrolled burning of cables and insulation release dioxins [3]. The levels **150 µg/m³** during WHO, Chinese shipyards utilize emission control protective ventilation systems that significantly reduce atmospheric pollutants, though VOC emissions from welding and paint stripping remain a concern [40], [41].

The combined impact of these contaminants has accelerated degradation of the surrounding ecosystems. The mangrove ecosystems surrounding Gadani have suffered due to physical disturbances and chemical contamination declines in biodiversity, especially within mollusk and crustacean communities [42], [43]. Chinese shipyards have adopted environmental monitoring coastal restoration programs aimed at preserving marine flora and fauna showcasing a more sustainable model despite ongoing issues in small-scale yards [44].

My work shows quality and advance variety of technology to regulate the effectiveness, on the all-operational process of recycling activities. The breakdown of ship in Gadani machinimas is very old and weak regulatory system make caused environmental damage. While the Chinese legal enforcement and the equipment are advanced and the break down are also advance its mitigation environment is strong impact [45], [46].

For the economic stability and also for the supply of recyclable materials need good and advance toll to protect the marine environmental balance. The toll is insufficient on effective waste management and the worker training is also poor and need good regulatory monitoring. China's have balance and modern technology which can reduced the bad impact on marine environment and also reduce need Mitigating these impacts requires mechanized dismantling.

5. LEGAL AND POLICY FRAMEWORK

The stronger regulatory system of ship breaking industry make safe marine ecosystem and reduce marine environmental pollution. Both are the party of international convention and bindable to make their own domestic legal frame work under the international standard, the enforcement and implementation is very important between these two states.

In Pakistan have the laws about to protect marine environment, pollution and waste management the act is **Pakistan Environmental Protection Act (1997)**. In Pakistan have another legal body to deal industrial activities, environmental activities and issuing environmental clearance and enforce international compliance that is Pakistan Environmental Protection Agency (Pak-EPA). But these legal body are present the Gadani shipyard regularly faces challenges because of insufficient monitoring bad infrastructure and the main is weak enforcement [47]. The main is there is no strong rule regulation to control dangerous waste in ship dismantling that is treat to marine biodiversity.

The Factory Act 1934 play important role in labor health and safety regulation it is mandatory for safety measure. The issue is that this Act is not strongly enforceable, due to no enforcement resulting in widespread exposure of workers to chemical hazards, physical injuries, and toxic fumes [48], [49]. The ILO means international Labor Organization is international organization but the enforcement is weak the organization having no effect in the sector.

The China's have legal framework which is highly good regulation and enforcement. The Marine Environmental Protection Law (2017), along with the Solid Waste Pollution Prevention and Control Law, These Act give a clear view about the control of pollution which is cause to ship breaking operations. China authorized and make a mechanism for separation of waste which is harmful for marine ecosystem and also enforce the rules on the basis of regular checks, licensing, and fines [50], [51]. The Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (2009) is the main draft for China to make their domestic law under the international standard, ensuring stricter adherence to environmental and occupational safety standards [8].

The Hong Kong Convention (2009) seeks to minimize the environmental and health impacts of ship, it is international standard to recycling by requiring an inventory of dangerous materials, environmentally sound breaking down process, and safety for labor practices. In Pakistan it still not properly enforces and leaving gap for dangerous substance in waste and to protect the workers [9], [52]. China, followed the convention strictly and make and also update their domestic law under the international conventions by shipyard operation [53].

The success of laws depends on stronger institution to strong enforcement and use modern technology. Pakistan's have weak regulation and intensive labor and socio-economic pressure, and hinder compliance. The China's highly strong enforcement and highly centralized mechanization enable greater adherence to international environmental and labor standards [54], [55].

6. COMPARATIVE DISCUSSION

A comparison of two state to ship dismantling process have a clear difference how China and Pakistan can handle and follow the international rules and also technology, and affect people's lives and jobs. This comparison will show the differences and give a lesson for ship recycling and marine environmental pollution control.

The Gadani Shipyard in Pakistan is high level of marine pollution creator like soil, and air contamination among South Asian shipbreaking facilities. The uncontrol dangerous substance Oil spills, toxic waste, and heavy metals damage the marine environment and destroy the marine life like mangrove forests [29], [31], [42]. The breakdown and recycling of a ship in open air caused and contribute in respiratory illnesses among the labor and the community as well [38], [39]. Conversely In Chinese shipyards, the main places like Guangdong and Shanghai minimize and show lower pollution levels, the follow and adoption of effluent treatment systems, the recovery of oil and controlled breakdown process [32], [33], [40]. The China have advanced technology of recycling but it still harmful to local environment proving that technology by itself can't stop all pollution [34].

The effectiveness of Legal framework plays a vital role in environmental ecosystem and put a strong outcome. The law enforcement is very important Pakistan have the laws but enforcement is weak and no monitoring, inadequate sector-specific regulations [47], [48]. Pakistan is the party of Hong Kong Convention weak enforcement the ship breaking at Gadani have no control over hazardous waste management and worker safety [9], [52]. China followed the international standard in the own national legal framework and enhance licenses, fines, and environmental checks [50], [51], [53]. The comparative study focusses on good governance and good institution control the harmful effect in shipbreaking.

The technology used for safety in these two state like Pakistan and China. In Pakistan at Gadani remains labor-intensive, cutting is manual, minimal mechanization, and inadequate waste management infrastructure [29], [35]. This kind of working caused pollution lasting marine environmental harm and damages. In China use machine to cut the ship his focus on to reduce the marine environment and make the work safe [32], [40]. The main difference in law enforcement is different in both state that have reasonable outcome and enforcement show the China have better environmentally than Pakistan.

The ship breaking show the state Socio-economic considerations of a state. The Gadani Shipyard produced many jobs for local people and also give economic support to civilian, creating a tension **between** economic needs and environmental sustainability [27], [28]. In China the technology reduces the need of worker the people of China face a lot of problem and pressure but it is easy

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to follow the environmental law [25], [26]. This study shows that how the balance of economic growth and protect the environmental integrity human health is important.

In short we can say that the comparison highlights that environmental harm in ship breaking does not happen its depend on how the law are enforced and what kind of technology used and how the industries managed, In Pakistan the Gadani indicate the red light of danger due to poor regulation and dependence on manual method while China have strict monitoring and laws and using machines and follow the law and rule regulation according to international standard it will reduce the environmental and recycling bad impact. For better and suitable policies need, improved technology, and global cooperation.

Table 1: Pakistan and China Comparative Environmental Impacts of Shipbreaking

Parameter	Gadani Shipyard, Pakistan	Chinese Shipyards
Marine pollution (heavy metals, oil)	High	Moderate to low
Soil contamination	High	Moderate
Air pollution (particulates, toxic fumes)	High	Low
Waste management (hazardous materials)	Poor	Advanced
Occupational hazards	High	Low to moderate (mechanized, PPE)
Regulatory enforcement	Weak	Strong
Technology adoption	Manual / labor-intensive	Mechanized / automated

Table 2: Legal & Policy Framework Comparison

Aspect	Pakistan (Gadani)	China
National environmental laws	Pakistan Environmental Protection Act, 1997	Marine Environmental Protection Law, Solid Waste Pollution Prevention & Control Law
International conventions	Signatory to Hong Kong Convention (not fully implemented)	Fully integrated Hong Kong Convention
Occupational health & safety laws	Factories Act 1934, limited enforcement	Strict labor and safety regulations, enforced inspections
Monitoring & compliance	Minimal inspections, weak enforcement	Regular inspections, licensing, penalties
Waste handling & recycling standards	Poor, informal handling	Advanced treatment, mechanized recycling

7. RECOMMENDATION AND CONCLUSION

For global maritime trade the ship breaking industry play a vital role to recycle the materials. However, The Gadani shipyard in Pakistan and the China ship recycling facilities face a big environmental, social and health challenge. These challenges need to solve a advance technology, policy intervention to promote a good practice to balance economic needs.

7.1 Recommendations

- Strengthen Regulatory Frameworks:** Pakistan should need to develop shipbreaking-specific regulations and take the convention as a standard Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (2009). It will assessment of environmental impact, make a clear rule for hazardous waste management protocols, and enforcement mechanisms to ensure compliance [9], [52].
- Enhance Institutional Capacity:** The Pakistan Environmental Protection Agency (Pak-EPA) need technical skill, monitoring tools and properly supervise recycling process, regularly review and inspection and those who violate the rules they have a strict penalty to improve the compliance.
- Promote Mechanization and Cleaner Technologies:** The replacement of Labor-intensive methods, dismantling, oil recovery systems, and waste containment facilities should be reduced. Learn from China to used modern technology for reducing pollution and protect the working place [32], [40], [44].

4. **Occupational Health and Safety Measures:** At Gadani the training make mandatory and make a clear rules and regulation for safety to prevent injuries and reduce chemical exposure [48], [49]. Provide Awareness programs and teach him development skill it will be helpful for worker it will a part of regulatory system.
5. **Environmental Monitoring and Reporting:** For both state need monitoring system to check regularly water, soil, and air quality, making the reports and it will increase public transference supports long-term ecosystem recovery.
6. **International Cooperation and Funding:** Pakistan need help in financial and technical support from international organizations, such as the IMO, UNEP, and ILO, to upgrade infrastructure, train personnel, and implement sustainable ship recycling practices [8], [50]. When Pakistan work on international project it will reach the Pakistan to global standard and the environmental risk should be low.
7. **Socio-Economic Balancing:** Balance environmental protection need effective policies with live hood of workers economic importance of the shipbreaking industry. environmental rules do not harm vulnerable workers, formal employment channels can ensure training programs, new job opportunities [27], [28].

7.2 Conclusion

Comparing these two-state ship breaking yard it does not have to cause pollution it depends on how we can apply the rules, technology and to manage all activities. Gadani Shipyard still faces the big problem that is environmental pollution included soil and water contain heavy metals, oil is often spilled, and the air is dirty this issue causes due to manual method, second is facilities are poor and the main is rules and regulation are not fully enforced. These kinds of problem put the marine life endanger, harm the local people and make the industries further uncertain.

The Chinese shipyards used the machines, strong monitoring of environment strictly follow the national and international rules regulation like the Hong Kong International Convention to protect the marine environment and safe ship recycling also to reduce the bad impact of ship breaking. The practices of China show that modern technology with strong governance can safeguard the Marine environment also protect worker health and maintain economic standard.

For sustainable recycling of a ship, in Pakistan and other developing countries, need complete and balanced plan. It should need to make stronger law and rules regulation to protect the marine environment, need modern machinery to break the ship, improve safety of worker and need help to technical and financial support from other countries. For economic growth while reducing environmental and health risks adopting the strategy the country can goes on good ways.

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