USPCAS-W
Mehran University
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Jamshoro, Pakistan

Marble Sector

Brief Situation Analysis Report

Eco-Innovation for Sustainable Industrial Growth of Major Industrial Sectors in Special Economic Zones (SEZs) Under CPEC-75

(A Project funded by Higher Education Commission, HEC)

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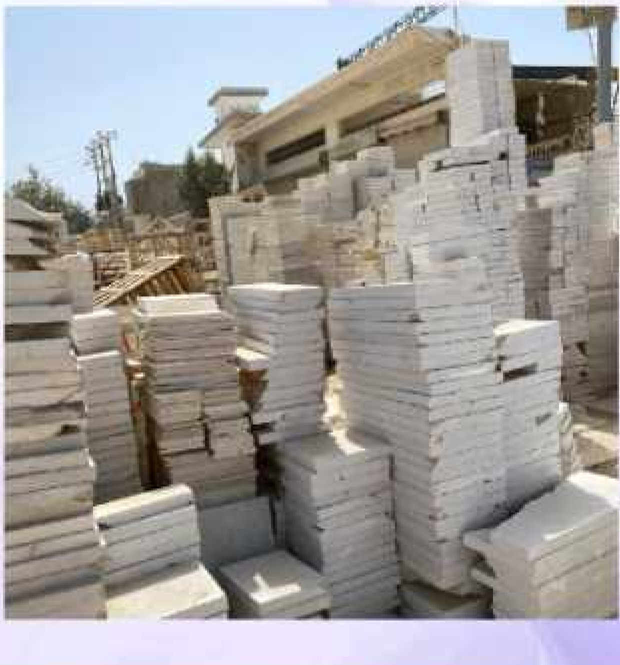
Context to the study

- Marble production and processing, water, energy consumption, disposal of marble waste and their cost estimation
- Marble slurry waste and wastewater assessment
- Identification of Eco-innovation option



Summary of findings

(1) This study shows that the marble industries consume high amounts of water and energy, required high cost for marble processing and it generates high amount of waste and wastewater. The average cutting of stone is 1307 tons per month, the average consumption of water per month is 50000 gallons/month and the average consumption of electricity is 19,389 units/month. The average number of tankers for disposal of marble sludge or slurry is 9/month.

(2) It also generates lot of wastewater and slurry waste which is then open dump in nearby areas of Mangho Pir.

(3) Many of the physio-chemical parameters of wastewater and slurry waste are not within the limits of NEQS when they were analyzed. This is due to the lack of proper policy and inefficient environmental laws. Another reason could be the lack of awareness, proper disposal, treatment and reuse of marble slurry waste and wastewater treatment and reuse facilities, financial resources, use of traditional technologies and high production cost.

(4) Considering the pollution caused, consumption of water and electricity and the disposal of marble waste and their cost, we have suggested some eco-innovation options such as use of automatic motors, PID controllers, VFDs, use of solar energy and instead of open dumping of marble slurry, it can be used as a calcium source for chicken feed. It can also be used for manufacturing of fired clay bricks.

(5) Following these options, they can save some cost and avoid environmental pollution.

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Introduction

Pakistan's mineral resources are abundant, and the country has enormous potential for economic growth and prosperity. According to study, Pakistan has around 600,000 square kilometres of outcrops land that has a diverse potential for mineral deposits (metallic as well as non-metallic) (Ahmad, 2019). When it comes to marble, Pakistan is having around 300 tons of reservoirs having more than around 30 different types of marbles. Most of such reservoirs are scattered in various areas of KPK, the tribal belt, and Baluchistan. In Pakistan, sandstone is used for structure rationale and development. In Pakistan, marble contributes to 0.008% to GDP and has been ranked as 5^{th} among all minerals (Ahmad, 2019). Considering these facts, marble industry can be perceived as having a great potential in Pakistan and this share can increase with time.

Marble factories heavily rely on water, as a significant amount is required to keep the blades of their machines wet during the stone crushing process (Arslan et al., 2005). To cut larger stones into smaller slabs, wet or dry cutter machines are used, with most marble factories in ManghoPir, Karachi, Sindh opting for wet cutter machines. However, due to the lack of a proper drainage system, these factories discharge their wastewater, which contains sediment and limestone, directly into the nearby open river. As a result, this is causing a significant amount of water pollution. Samples of both surface and groundwater in the area have been analysed and compared to the National Environmental Quality Standards (NEQS), with the results showing shockingly low levels in various physical and chemical parameters. Before the establishment of the marble industry, local people used the river for different purposes, such as washing clothes, bathing, watering animals, and even drinking. However, this practice is now having a detrimental impact on their health (Aukour & Al-Qinna, 2008).

The process of manufacturing marbles also involves cutting large stones into smaller slabs using a dry method, which generates significant air pollution (Arslan et al., 2005). The extent of pollution emitted depends on the size and operation of the equipment and machinery used. This pollution poses a health hazard to the workers in the factory as well as the people residing in nearby areas.

In Pakistan, many marble processing units dump their marble waste directly into streams, rivers, and fertile lowlands, which cover the soil pores because there is an absence of awareness and no law about the disposal of waste material (Khan et al., 2022). The population residing near marble factories is concerned over the hazardous and high-risk working environment at the factory that is allegedly putting their lives at risk daily. The marble industry is a big source of pollution as it uses low-quality scrap as raw materials and releases harmful particles into the air. Workers and residents inhaling dust particles from the marbles, which exposes them to Tuberculosis and Silicosis, a lung disease caused by a dust particle called crystalline silica (Khan et al., 2015). Marble dust contains particles of calcium carbonate and silica. The exposure to the latter causes silicosis, a lung disease also known as grinder's asthma. The marble factories dump waste in natural streams and empty plots nearby and none of these factories follow environmental laws to protect citizens. The dust of marble also destroys plants by covering their leaves and reducing exposure to sunlight. Physicians could be aware that silicosis is not a sporadic disease in the field of new "marble" materials and that some patients with simple silicosis could be symptomatic and undiagnosed for a lot of time (Shah & Mohammad, 2019).

Nowadays, the open disposal of the fine powder form of marble effluents into soil or water bodies is one of the leading environmental concerns throughout the globe. Moreover, the waste effluents of the marble industries, if properly utilized can produce new products, thus burden on the natural resources will be reduced, and eventually the harmful and devastating effects of marble industrial waste on the environment can be reduced (Karaşahin & Terzi, 2007). Utilization of industrial waste is a good process to control overload of pollution on environment (Hameed & Sekar, 2009), as cutting and sawing of marble results in large amount of marble slurry. This marble slurry disposed to open land area will cause land pollution and will be very harmful to land. In road construction, it can be used as substitute of fine aggregate. It has good binding property and gives enough strength to concrete (Hameed & Sekar, 2009). Therefore, the present study was conducted to assess various physicochemical parameters of marble wastewater and marble slurry waste from different industries.

Approach and Method

Pakistan. Due to many marble industries and related environmental issues, ManghoPir area was selected for study. It was estimated that there are around 400 marble industries in ManghoPir area. A total of 100 industries were visited during field surveys in this project. 33 marble industries among them agreed to fully participate in the data collection process. 28 of them were marble cutting industries and 5 of them were marble polishing industries. The survey employed a mixed data collection method:

- Interviews with industry experts and stakeholders
- Focused group meeting
- Online and in-person questionnaire survey
- Data collection of marble production process, raw material consumption water and energy consumption, waste generation and disposal and their cost required.
- Water and marble slurry waste sample collection from marble industries and their physio-chemical parameters analysis.

Research Findings

1. Marble cutting industries.

The average stone cutting of 30 industries is 1,307 tons/month. It was observed that the water supply is not available for the Marble factories in respective area, so they were using either the water tankers or ground water by boring. On average an industry uses 10 tankers per month with the tanker capacity of 5000 gallons. The maximum number of tankers used by an industry is 25 tankers/month and the minimum number of tankers used by an industry is 3 tankers/month. On average an industry is spending Rs. 47,696 per month on water. All the factories were using electricity supplied by K-Electricity and the factories pay the electricity cost of 698,014 per month. The factories are not only paying for fresh water, but they are also paying for the disposal of sludge generated from the processes, but the dilemma is that there is no proper dumping site for disposal purpose. On average an industry disposes off 9 tankers of sludge per month that cost around Rs. 40,893 monthly.

Due to the heavy charges of water tankers, despite having poor quality of ground water, 5 marble industries are using only ground water which is not good for their machinery because it causes corrosion and other faults. 17 marble industries are making conjunctive use of both tanker water and ground water to save money as well as their machinery, 6 industries are bearing the water tanker charges to run their operations and 5 industries use boring water.

The average cost of marble stone is 3000 PKR per Ton and the production cost of marble (13 soot per ton of stone is 42 PKR. However, the market price of marble of 13 soot is 100 PKR. The average cost of water tankers used is 36.49 PKR per ton of marble production, the average cost of electricity, sludge disposal tankers per ton of marble production is 534.05 PKR and 31.28 PKR. However, the total cost per ton of marble production is 616.55 PKR.

2. Marble Polishing industries

Apart from the stone-cutting industries, many marble polishing factories prepare the finished product for sale. Polishing machines and chemicals are used for this purpose. As compared to marble cutting process industries, the average consumption of water and sludge production and its disposal in the marble polishing industries is less, but in the marble polishing industries, the chemicals and polishing materials used are contributing to environmental pollution also (Iqbal et al., 2018). The average stone polishing is 222 tons/month, the number of water tankers per month required is 1 with the average cost of 4000 PKR. The average electricity consumption per month is 1934 units with the cost of 69560 PKR and the average sludge disposal tankers required per month is 1.86 with the average cost of 4300 PKR/tanker.

Water Quality Analysis

The samples were collected from different industrial streams and analysed in the laboratory. The results were then compared with Sindh Environmental Quality standards (SEQS).

The marble sector industry generates wastewater that has high turbidity and contains suspended solids. In the marble industry, water is mainly used to cool cutting blades. The effluent is then gathered in the sedimentation tanks, and suspended solids settle. The wastewater is reused several times before being discharged in semi-solid form (termed a slurry) for final disposal.

The wastewater samples from the outlets of sedimentation tanks of marble industries were collected and analyzed for physio-chemical and biological characteristics. A total of three samples from the different marble industrial units were collected, and the analysis reports are given in **Table 1 (see in annexure 1)**. It can be noticed that the TDS and turbidity values were very high. The reason is that the industry's influent water is already high in TDS, and the cutting process increases turbidity. High total suspended solids values verify it in all three samples. The chemical oxygen demand (COD) values were also over the limit set by Sind EPA. However, low BOD values indicated that the organic matter in the samples was mainly not biodegradable. Mercury was detected in one sample; the value was over the Sindh Environmental Quality Standards set by Sindh EPA. The mercury (Hg) source is unknown and found in only one sample. It may have originated from marble rocks in an isolated manner. All other parameters remained below the limits set by Sindh EPA.

Analysis of Marble slurry

The marble slurry waste was analysed in which the Molybdenum (Mo) was not detected, and Manganese (Mn) and Palladium (Pb) were detected below detection limit (BDL). However, the sodium (Na) was detected 301.4 mg per gram of marble slurry which is highest as compared to the other elements. The concentration of calcium (Ca) and Magnesium (Mg) in marble slurry were detected as 274.4 and 224.6 mg/g as shown in **Table 2 (see in annexure 1)**. The reason for the presence of sodium, calcium and magnesium in the marble slurry might be the presence of sodium, calcium and magnesium in original marble blocks or slabs, and it became concentrated in the marble slurry/dust during the cutting and polishing process (Khan et al., 2017). The other detected elements are shown in **Table 2 (see in annexure 1)**.

Analysis of major oxides in Marble slurry

In this study, the marble slurry waste was also analysed to know its characteristics. The analysis of major oxides in the marble slurry sample is given in Table 3 (see in annexure 1), in which the CaO

has a higher concentration of 42.3 % than all, LOI (Loss on Ignition) is 55%, and Humidity is 11.9%. These have a higher concentration in the marble slurry sample.

ECO-INNOVATION OPTIONS FOR MARBLE SECTOR

The major environmental issues marble sector industries face includes the generation of marble-powder slurry (semi-solid liquid), seepage of water from marble slurry in dumping areas, air-borne particulates generate upon drying of marble slurry in open dumping areas (marble dust), and high energy consumption for marble cuttings (Ahmad et al., 2021). The marble industry is energy-intensive and uses energy to cut large marble stones into small slabs of required sizes. Along with energy requirements, considerable water is needed to cool cutting blades. Marble dust, when dumped openly in the form of slurry, contributes to air pollution when it gets dried and threatens the area's ecology (Shah & Mohammad, 2019). The eco-innovation option identified for the marble sector industry is presented in **Table 4 (see in annexure 1).**

Conclusion

It has been concluded from this study that the marble industries consume high amounts of water and energy and generate lot of wastewater and slurry waste which is then open dump in nearby areas which poses serious threat to the environment. Many of the physio-chemical parameters were not within the limits of NEQS when they were analysed. This is due to the lack of proper policy and inefficient environmental laws. Another reason could be the lack of awareness, proper disposal, treatment and reuse of marble slurry waste and wastewater treatment and reuse facilities, financial resources, use of traditional technologies, high production cost.

Some eco-innovation options have been suggested to save processing cost water, energy and waste disposal costs. Instead of open dumping of marble slurry waste, the marble waste can be used in fired clay bricks which will improve the porosity and water absorption of bricks and the use of marble slurry will also reduce SO_2 emission and particulate matter. It can also be used as a calcium source for chicken feed which will improve the eggshell and egg production. The use of computer-integrated and automatic motors, PID controllers, VFDs and solar energy can be used as a substitute to reduce water and energy consumption and reduced unwanted water flow for blade cooling and saves energy.

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Annexure 1

Table 1: Water Quality Analysis of 3 random Marble Industries

S. No.	Parameters	Units	Marble-1	Marble-2	Marble-3	NEQS Limits
1	pH	-	8.5	8.2	8.5	6.0-8.5
2	Total Dissolved Solids (TDS)	mg/L	773 ± 3	1230 ± 4	1348 ± 3	500
3	Turbidity	NTU	570 ± 1	1070 ± 2	1021 ± 3	5
4	Chemical Oxygen Demand (COD)	mg/L	562 ± 1	211 ± 1	386 ± 3	400
5	Biological Oxygen Demand	mg/L	10 ± 1	32 ± 1	19 ± 1	80
6	Total Suspended Solids (TSS)	mg/L	32869 ± 2	5408 ± 3	16745 ± 2	500
7	Volatile Suspended Solids (VSS)	mg/L	31893 ± 1	486 ± 1	11 ± 2	
8	Hardness	mg/L	500 ± 1	261 ± 1	259 ± 1	---
9	Alkalinity	mg/L	830 ± 1	503 ± 3	739 ± 1	---
10	Total Nitrogen (TN)	mg/L	2	5	3	---
11	Mercury (Hg)	µg/L	0.5	BDL	BDL	0.01
12	Magnesium (Mg)	mg/L	22	13	8	60*

13	Sodium (Na)	mg/L	23	20	21	200*
14	Potassium (K)	mg/L	10	10	4	---
15	Calcium (Ca)	mg/L	56	75	21	200

Manganese (Mn), Molybdenum (Mo), Arsenic (As), Copper (Cu), Chromium (Cr), Barium (Ba), Zinc (Zn), Ferrous (Fe), Nickel (Ni), Serium (Se), Cadmium (Cd) were below detection limits or not detected, BDL: Below detection limit.

Table 2: Elemental Composition of Marble Slurry

Elements	Symbols	Marble Slurry (mg/g)
Manganese	Mn	BDL
Copper	Cu	2
Molybdenum	Mo	ND
Palladium	Pd	BDL
Cobalt	Co	2
Chromium	Cr	5
Zinc	Zn	11
Nickle	Ni	15
Boron	B	29
Potassium	K	45
Ferric	Fe	72.5
Sodium	Na	301.4
Magnesium	Mg	224.6
Calcium	Ca	274.4
Experimental method: Inductive Coupled Plasma Mass Spectrometry. BDL: Below Detection Limit ND: Not Detected		

Table 3: Analysis of major Oxides of Marble Slurry

Oxides	Symbols	Content (%)
Calcium Oxide	CaO	42.3
Aluminum Oxide	Al_2O_3	0.16
Ferric Oxide	Fe_2O_3	0.028
Magnesium Oxide	MgO	0.93
Sulfur trioxide	SO_3	0.73
Sodium Oxide	Na_2O_3	0.027
Potassium Oxide	K_2O	0.036
Phosphorus pentoxide	P_2O_5	0.013
Chlorine monoxide	Cl^-	0.039
Strontium oxide	SrO	0.018

Loss On Ignition	LOI	55.1
Water content	(w)	0.73
Humidity	---	11.9

Table 4: Eco-Innovation Options for Marble Sector

S#	Industry Type	Eco-Innovation options	Description
Environmental Issues: Water /slurry			
01	Marble Cutting and Polishing industry	Use Marble slurry in Fired clay bricks as an alternative source to reduce flue gases from the brick kilns.	• Marble slurry can be used in fired clay bricks. It will increase the porosity of bricks, improve water absorption. • Used of marble slurry will also reduce SO_2 emission and particulate matter in flue gases by 43-65%.
02	Marble Cutting and Polishing industry	Use marble slurry as a limestone (calcium) source in chicken feed production.	• Treated marble slurry is used as an alternate source of calcium in chicken feed production, strengthening the eggshell and increasing egg production.
Environmental Issues: Energy			
03	Marble Cutting industry	Use of Automatic Motor Controllers (PID controllers and VFDs)	• The use of computer-integrated programming motor controllers will reduce water and energy consumption. • Reduced unwanted water flow for blade cooling saves energy.
Environmental Issues: Energy			
04	Marble Cutting and Polishing industry	Use of Solar Energy	• Installing solar energy systems can reduce energy costs and associated emissions. • The payback period is estimated at two years.

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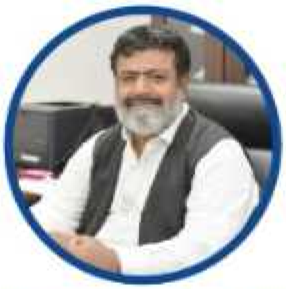

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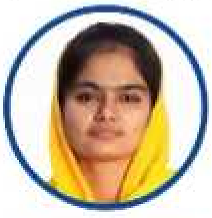

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The proposed research aims to develop a policy framework for adopting the eco-innovation approach. The objectives of the research are:
(1) To examine existing environmental measures in major industrial sectors.
(2) To develop new eco-innovation options.
(3) To develop a plan for the management of underlying factors creating challenges in the adoption of eco-innovation strategies.

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