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Physio-Chemical and Heavy Metal Analysis of Waste Foundry Sand

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ABSTRACT

Foundries in Kolhapur and Pune dumps nearly 700-1000 tons of processed waste foundry sand annually in landfills causing severe land and water contamination. This practice is causing enormous pressure on foundries to look for an alternative option of reusing it in other applications. In this study we analyzed waste foundry samples from landfill and foundries for physical (clay, sand, and silt), moisture content, chemical properties (pH, CEC, and organic carbon) and heavy metals limits with an aim for using it in soil related applications. After analysis we found samples, texture is silt loamy with good moisture content, thus having a pH value ranging from 7.50-8.40 with an abundant organic carbon in the form sea charcoal added during casting process. In addition to this when we analyzed and compared 10 toxic heavy metals we found As, Hg, Be, Cd, Se, Ag, Mo are below detectable limits and mean values of metals Cr (10.45), Cu (19.94), Pb (7.74), Zn (18.35) and Ni (6.79) lower than USDA limits. Based on above studies we concluded that waste foundry samples are non-hazardous in nature with soil like properties, thus making it as an idle blending agent for soil related applications.

***Key word**: Waste Foundry Sand, Physio-chemical Properties, USDA, Heavy Metal Analysis*

Introduction

There are nearly 300 iron and steel foundries in Kolhapur and Pune accounting to nearly 7-8% of India's total casting production consuming large quantities of sand imported from different parts of costal India for mold and core preparation.

Sand is used because they absorb and transmit heat while allowing gasses generated during thermal degradation of binders to pass through the grains. After the casting process is completed, resin bound sand can be thermally reclaimed and reused in mold and core preparation, while green sand requires additional new bentonite clay and other carbonaceous compounds (Carey, 2002).

Foundry sand grains begin to break over time because of heat and mechanical abrasion, therefore new sand is added periodically to maintain process consistency for preventing defects.

When sand is no longer suitable for reusing due to its damaged grain size and poor process parameters foundries dispose nearly 700-1000 tons of processed foundry sand as spent or waste foundry sand in landfills (Solankhe, 2018) and allocated open dumping grounds, thereby altering soil profile impacting flora, fauna and soil pollution leading ground water contamination due to runoff from landfills.

This disposal method is costlier and requires large areas of land in local region which is becoming scarce and challenge for municipalities and foundries. In addition to this rising environmental and social awareness among public along with strict conditions to recycle and reuse waste with an emphasis on zero discharge is compelling foundries to look for alternative options like concrete, brick, and soil related applications. Basis of this study is collected waste foundry samples from foundries and landfills near Kolhapur and Pune with an objective to analyze physical, chemical, and metal concentration in them for determining its hazardous nature and suitability to reuse it soil related applications alike earlier work (EPA, 2006) and (Elizabeth and Dayton, 2010)

Materials and Methodology

Waste foundry sand

Waste foundry sand samples are mixture of core and mold sands made up of residual impurities of organic resins metal impurities are collected from piles using nominal capacity of scoop up to 1.5 kg from rear, center and front at a depth not less than 15 cm below surface of sand dumping grounds (ISI, 1984), at Shiroli (L1), Gokulshirgaon (L3), North Pune area L3) and foundries near Shiroli (L2), Gokulshirgaon (L4), Rajangaon MIDC (L6) in Kolhapur and Pune. After collection samples were dried and stored until analyzed in a plastic sample container.

Physical and chemical properties

Texture is a proportion of clay, sand and silt influencing every aspect of soil use. It is calculated using soil texture calculator (USDA United States Department of Agriculture, 2019). Bulk density is defined dry weight of soil per unit volume of soil signifying soil's ability to function for structural support, water and solute movement, and soil aeration is calculated, and moisture content is defined as the quantity of water it contains in soil are estimated (ISI, Methods of Physical Tests for Foundry Sands, 2003) by

$$Moisture\ Content\ (\%) = \left[10 - \frac{(W1 - Wg)}{10}\right] * 100$$

Where, Weight of Soil = 10g,
Weight of Silica Dish = Wg
Weight of Dish + oven dry Soil = W1
Weight of Dry oven Soil = (W1-Wg)
Weight of Moisture held by Soil = 10- (W1-Wg)

Organic carbon (OC), pH and cation exchange capacity (CEC) were calculated as per (ISI, 1997).

Heavy metal analysis

In this study we analyzed metals Mercury (Hg), Arsenic (As), Barium (Ba), Berellium (Be), Chromium (Cr), Cadmium (Cd), Copper (Cu), Lead (Pb), Antimony (Sb), Cobalt (Co), Selenium (Se), Silver (Ag), Aluminum (Al), Iron (Fe), Manganese (Mn), Zinc (Zn), Nickle (Ni), and Molybdenum (Mo) as per EPA, (1996).

Samples were digested with conc. HNO_3 + conc. HCL and estimated using ICP-OES (Inductively Coupled Plasma-Optical Emission Spectroscopy) made by Teledyne Leeman Labs with aliquots of standard solution (1000 mgl^{-1}) was used in preparation of calibration solutions. Working standard solutions were prepared by dilution of the stock standard solutions to desired concentration in 5% concentric nitric acid.

The range of calibration curves (0.05, 0.1, 0.2, 0.5, 1 ppm) respectively were selected to match the expected concentration for all elements of the samples studied by ICP-OES with correlation coefficient obtained for all cases was 0.999. Detection limits of an instrument for metals with BDL are arsenic (5 mg kg^{-1}), beryllium (3 mg kg^{-1}), cadmium (2 mg kg^{-1}), mercury (0.02 mg kg^{-1}), molybdenum (5 mg kg^{-1}), selenium (5 mg kg^{-1}) and silver (2 mg kg^{-1}). Descriptive statistical analysis, maximum, minimum, mean and median was calculated using MINITAB 18.

Results and Discussion

Foundries adopt different techniques and methods based on cost but use green sand as a raw material for preparing core and molds in casting process due to its natural composition of silica, clay (bentonite), water and anthracite in combination with in organic chemical binders like phenol-formaldehyde resins and charcoal.

Molten metal with high metal impurities is poured in between core and mold at high temperature leading to off gassing of organic vapors causing thermal degradation of silica grains that tend to explode to form sub-micron sized particles, thus impacting grain size of the natural sand. After casting is prepared processed green sand is again recycled and reused in combination with fresh sand till it loses it grain size and no longer suitable for reusing and finally disposed as spent sand or waste foundry sand in open dump.

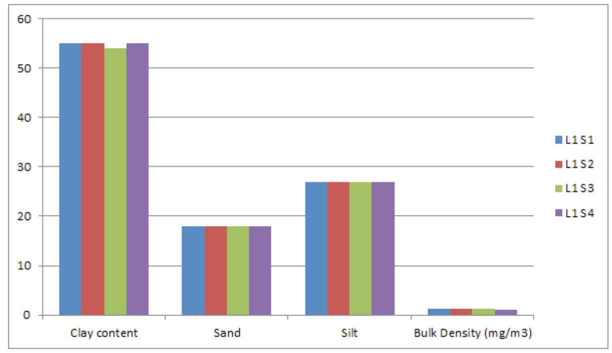
For using any material as a co-product with soil it should demonstrate soil like properties. Therefore 24 waste foundry samples analyzed in this study were collected from foundries using different treatment methods and from dumping grounds after processed sand is disposed in bulk from various foundries resulting in variations in physical and chemical properties of waste foundry sand samples as represented at various locations in bar graphs.

Texture is a relative content of clay (finely grained soil or natural rock that combines with possible traces of silica, organic matter and metal oxides), sand (granular material composed of finely divided rock and mineral particles) and silt (granular material whose mineral origin is feldspar and quartz and having size in between sand and clay). Clay content is from 21-55 with mean of 41, sand ranging from 5-18 with a mean of 10.22 and silt varying from 27-63 with a mean of 48.50 making waste foundry sand samples texture silt loam and having bulk density (dry weight of soil per unit volume of soil) range from minimum 0.87-1.45 mg/m^3 maximum with a mean of 1.11 mg/m^3.

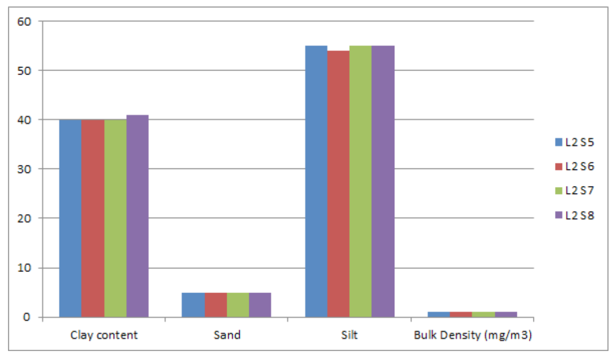
It reflects waste foundry sand's ability to function for water and solute movement in addition to soil aeration. With good texture and bulk density waste foundry sand demonstrate ability to hold and solute movement with a good moisture content ranging from 0.15-2.15% with a mean of 0.60%.

pH value refers to the amount of potential of concentration of hydrogenion present in a solution. pH of waste foundry sand is ranging from 7.50-8.40 with a mean of 8.13 indicating slightly alkaline with a capacity to act as a buffer when mixed with acidic soils and its ability to influence cation exchange capacity.

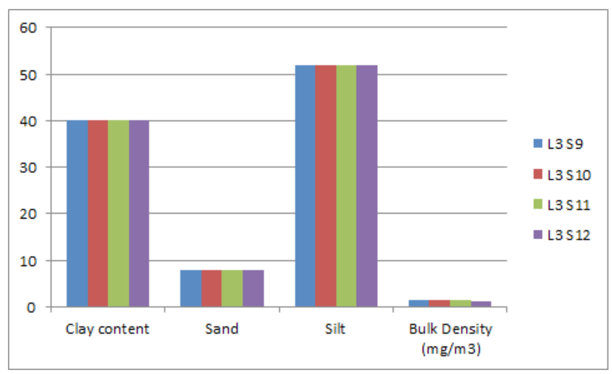
In principle relative proportion of acidic and alkaline or basic ions on the exchange site determines a soil's pH value thus directly establishing a correlation between CEC (total soil capacity to hold exchangeable cations) and pH. In table we observe CEC values range from 6.70-10.40 meq/100 g with a mean of 7.85 thus directly establishing a correlation with pH values. Organic carbon (is an amount of carbon stored in soil) range from 3.41-7.34% with a mean of 5.55% is due to addition charcoal in casting process as discussed above, thus providing a rich source of carbon for soil fertility.



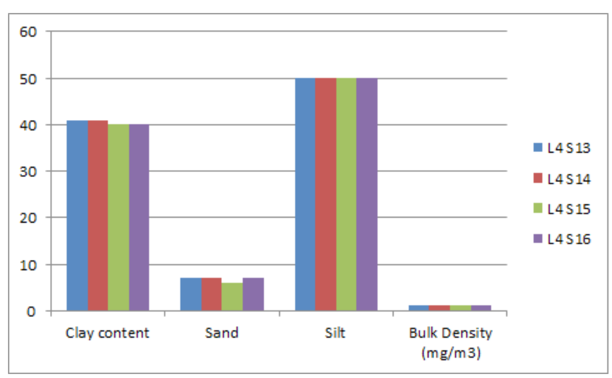
a. Location L1



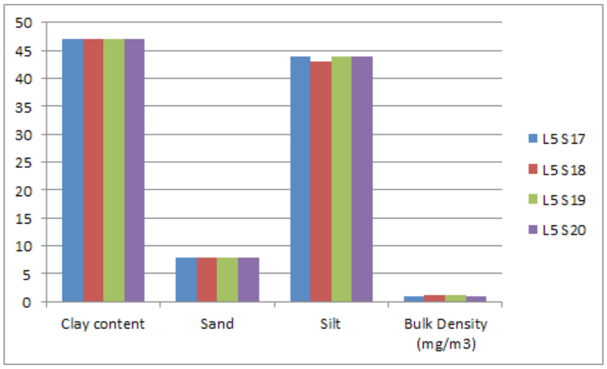
b. Location L2



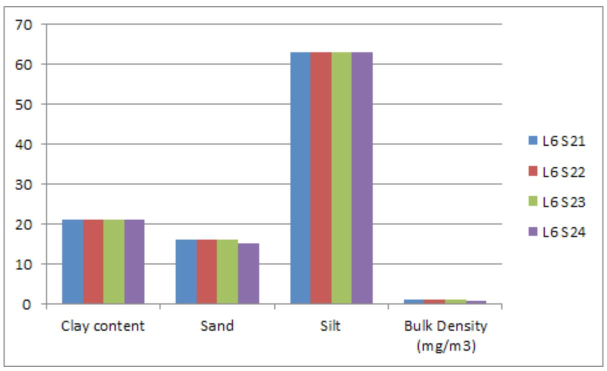
c. Location L3



d. Location L4



d. Location L5



f. Location L6

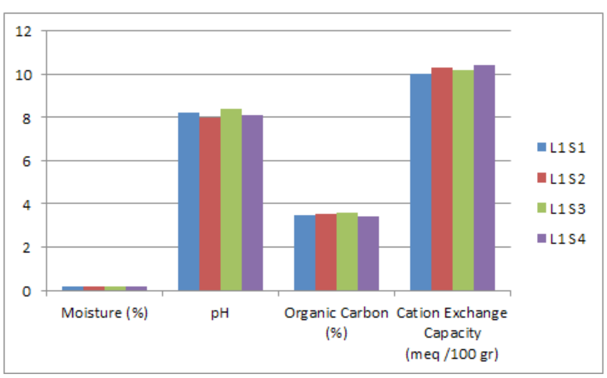
Physical Properties of Waste Foundry Sand (a-f)

Chemical Properties of Waste Foundry Sand (A-F)

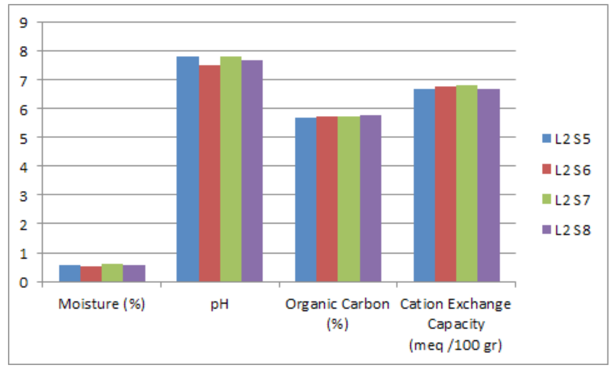
Maximum, Minimum and Mean values of constituents of waste foundry sand are shown in Fig. 1.

Total metal analysis of waste foundry sample

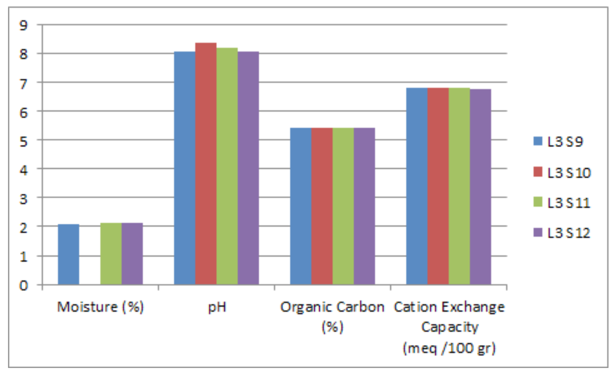
Iron and steel foundry process sand is contaminated with organic resins and metal impurities added from iron related scrap and chromium as an addi-



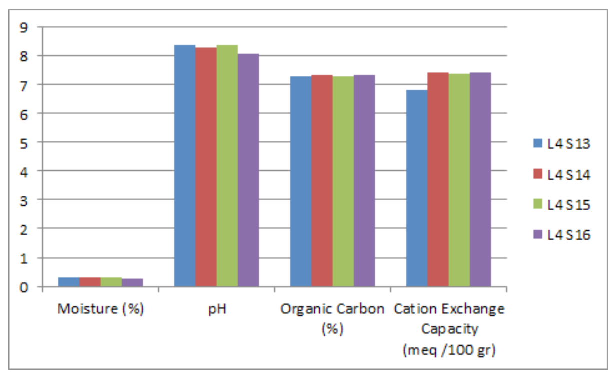
A. Location L1



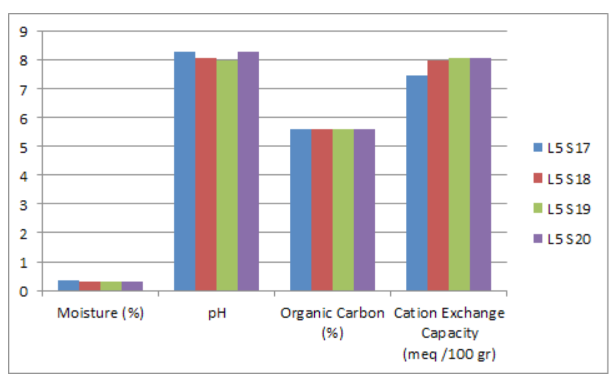
B. Location L2



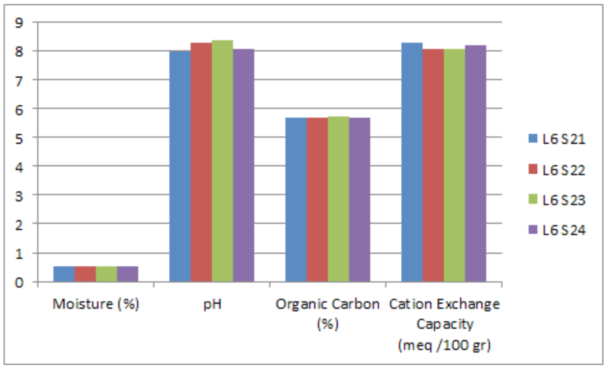
C. Location L3



D. Location L4



E. Location L5



F. Location L6

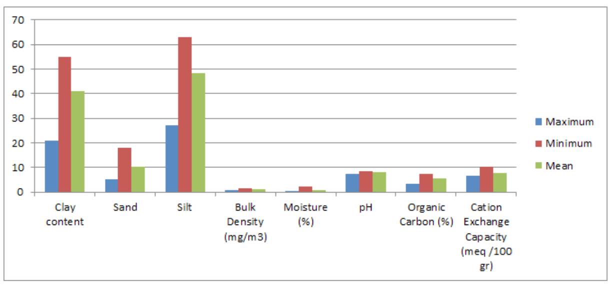


Fig. 1.

tive into castings to increase anti corrosiveness and improve quality (Deng, 2009). During this, thermally degraded chemically bind core and mold contains organic residual binder during casting process resulting in formation of volatile and semi volatile organic compound (Alves, 2014), but their concentration is found to be relatively low (Dungan and Reeves, 2005).

Heavy metal residues are carried over into waste foundry samples causing potential land contamination and ground water pollution if disposed on open ground without engineering controls. In this proposed paper we estimated 18 heavy metals and considered only 10 metallic elements Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Molybdenum, Nickle, Selenium and Zinc on the basis of heavy metals limits applied to soil ((USDA, Heavy Metal Soil Contamination, 2000) for determining hazardous nature of waste foundry samples and its limitations to use in soil applications.

As, Hg, Be, Cd, Se, Ag, Mo are below detectable limits and mean values of metals Cr (10.45), Cu (19.94), Pb (7.74), Zn (18.35) and Ni (6.79) are lower than USDA soil limits and when compared analyzed metals with published data in Table 2 (Elizabeth A. Dayton, 2010) we found results lower making waste foundry samples non-hazardous in nature.

Heavy metal analysis of waste foundry samples from dump yards and industries is shown in Fig. 2.

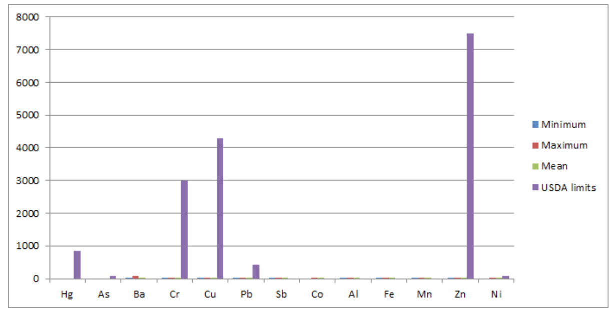


Fig. 2.

Conclusion

Waste foundry samples analyzed in this study for their texture silt loamy based on clay, sand silt show bulk density range (0.87-1.45 mg/m^3) show its ability for solute movement with a good moisture content (0.15-2.15%). pH value average of 8.13 and an organic carbon range (6.70-7.40%) in waste foundry sand makes it a good buffering agent with essential organic nutrients. When analyzed for heavy metals As, Hg, Be, Cd, Se, Ag, Mo we found values below detectable limits and mean values of metals Cr (10.45), Cu (19.94), Pb (7.74), Zn (18.35) and Ni (6.79) are lower than USDA soil limits making waste foundry sand non-hazardous in nature. Therefore, based on above study we infer and conclude that waste foundry sand samples collected from Kolhapur and Pune are non-hazardous and demonstrate soil like properties making it an idle blending agent for soil related applications.

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