Melanins are structurally diverse high molecular weight pigments synthesized by oxidative polymerisation involving quinones (Liu and Nizet, 2009). They are the most common pigments produced in nature and distributed throughout the biological kingdom (Turick et al., 2010). Melanins are even found in very old fossils from dinosaurs, early birds, nonavian theropod species (Zhang et al., 2010; Wogelius et al., 2011) and primitive cephalopods. So they were considered to be distributed all over the living world as earlier as the time before life evolved, and can serve as a biomarker in evolutionary studies (Lindgren et al., 2012). There have been several definitions given to melanins in the last 50 years, but most of the proposed definitions appeared to be partial or incomplete due to the difficulty of defining something with such a wide diversity in composition, colour, size, occurrence, and functions. Simply put, we can say melanins are “heterogeneous polymer derived by the oxidation of phenols and subsequent polymerization of intermediate phenols and their resulting quinones” (Solano, 2014).

Although melanins are distributed throughout living forms and its role being mainly protection, but its type and function may also vary among different organisms. In plants melanin acts as cell wall strengtheners (Riley, 1997), while in humans it not only determines skin colour, but also plays a crucial role in protecting the skin against ultra violet light (Huang
and Chang, 2012). In the microbes, it acts as a protective agent against environmental stresses. For example making bacteria resistant to antibiotics (Lin et al., 2005), while melanins in fungi are involved in fungal pathogenesis (Butler and Day, 1998).

Dividing melanin into subtypes and distributing them between various forms of life is so difficult, as in most cases organisms produce one or a mixture with more than one type of melanin. Melanin produced by both prokaryotes and eukaryotes belongs to the following three main types. Eumelanins which are black or brown pigments produced in the course of oxidation of tyrosine (and/or phenylalanine) to o-dihydroxy phenylalanine (DOPA) and then to DOPAquinone, which further undergoes cyclization to 5,6-dihydroxyindole (DHI) or 5,6-dihydroxyindole-2-carboxylic acid (DHICA). Pheomelanins are yellow to red pigment which is also synthesized from tyrosine. Pheomelanin synthesis shares the same pathway with eumelanin up to DOPAquinone. Then DOPAquinone cysteinylation takes place to form cysteinylDOPA, which gets further polymerized to form pheomelanin. Allomelanins are the least studied and most heterogeneous group of melanins, formed by the polymerization of di (DHN) or tetrahydrofolate via pentaketide pathway, leading to formation of various colored polymers including DHN-melanin, homogentisic acid (pyomelanins), γ-glutaminyl-4-hydroxybenzene, catechols, as well as of 4-hydroxyphenylacetic acid (Plonka and Grabacka, 2006).

Bacterial melanins are usually considered to be allomelanin subtypes, although they produce considerable amounts of all other types of melanins. There is Klebsiella sp. which produces eumelanin (Sajjan et al., 2010) type utilizing tyrosinase mediated pathway. Pheomelanin producing Vibrio
cholerae can also be found in the bacterial world (Ivins and Holmes, 1981). Similar to plants, catecholic melanin are also produced by some bacteria. Azotobacter makes catecholic melanin to create high respiration rates necessary for protection of the nitrogenase system in nitrogen fixation (Shivprasad and Page, 1989). Some bacteria are also able to carry out the pentaketide biosynthetic pathway leading to DHN-melanin (Moore and Hopke, 2001). The large number of species utilizing melanin synthesis via homogentisic acid includes Pseudomonas aeruginosa (Yabuuchi and Ohyama, 1972), Vibrio cholerae (Ruzafa et al., 1995), Shewanella colweliana (Ruzafa et al., 1994) to name a few. Though there are several reports regarding melanin production by many bacterial species, bacterial melanin is the least explored compared to that of eukaryotic melanins.

The most well characterized bacterial melanins are from Streptomyces species, as they have been actively pursued in the search for antibiotics (Mencher and Heim, 1962). In fact, melanin formation was proposed as an appropriate technique for the classification of Streptomyces (Arai and Mikami, 1972). These species had been good models for the study of the enzyme tyrosinase, its structure, mechanism of catalysis, and regulation of its expression, rather than for the study of the final melanin product. In S. antibioticus or S. lividans, the pigment is a undesirable product, since its formation hinders the isolation of antibiotics from these species (Lerch and Ettlinger, 1972). Molecular mechanisms involved in melanin production is most characterized in Streptomyces sp., while for other bacteria it still remains at the initial stages.

The peculiar properties of melanin can be utilized for many useful applications which make the study of bacterial melanins important.
Besides, melanin production was reportedly increased in pathogenic bacteria. This reflects a close relationship between virulence, melanin production and the survival of the pathogen (Shivprasad and Page, 1989). Thus, studying bacterial melanins can also help in development of effective antibacterial drugs.

The well-known and most commercialized application of melanin is its use in cosmetic formulations, such as sunscreen lotions where it acts as a photo protective component due to its UV-protective and free radicals scavenging properties (Riley, 1997). Melanins are used as UV-protective agent in the bioinsecticide preparation like the *Bacillus thuringenesis* (Bt) insecticidal crystals (Wan *et al*., 2007; Zhang *et al*., 2007). The melanin producing organism can also be used in bioremediation of radioactive waste such as uranium (Turick *et al*., 2008). Extensive melanized fungal growth was observed on the walls and other building constructions in the inner parts of the shelter of the damaged fourth unit of the Chernobyl Nuclear Power Plant in 1997–98 (Zhdanova *et al*., 2000). The radio-protective nature of melanin needs to be addressed further due to its significance in present times. The genes responsible for the melanin synthesis from bacteria can also be utilized as a reporter gene to screen for recombinants (Tseng *et al*., 1990; Adham *et al*., 2003).

The therapeutic applications includes anti-HIV (Human Immunodeficiency Virus) property of melanin, as soluble melanin was shown to be inhibit replication of HIV *in vitro* (Montefiori and Zhou, 1991). Due to its radio-protective nature as discussed, melanin-covered nanoparticles can be used for the protection of bone marrow during radiation therapy of cancer (Schweitzer *et al*., 2010). A novel bio-inspired
functional material was produced by the hybridization of TiO$_2$/DHICA-melanin nanoparticles which can be utilized in wide number of applications ranging from organo-electronics to bioactive compounds (Pezzella et al., 2013).

Due to its diverse applications not restricted to any particular field, makes study of melanin a demand of the hour. Animal sources of melanin will be usually contaminated with proteins, while plant sources produce large quantities of melanin which are too complicated to separate from the other phenolics produced by the plant. Besides plant melamins are subject to batch variations. Most purified melanin without any batch variations can be obtained from bacterial sources (Tarangini and Mishra, 2014). So this makes the study of bacterial melanin important.

The present study explored the novel bacterial sources for effective melanin production and looked at developing efficient methods to improve melanin production. The work also involved characterization of the melanin using physical and chemical methods, and its various applications.
Marine bacteria are less explored with respect to its ability to produce melanins. There were only few reports regarding marine melanin producers like *Vibrio cholerae*, *Shewanella colwelliana*, *Streptomyces* sp. and *Alteromonas nigrificiens* are some among them (Soliev et al., 2011). As majority of the marine microflora is still unexplored, the present study focused on investigating marine bacteria and their ability to produce melanin.

The aim of the study was the identification and characterization of melanin producing bacteria and their melanins; to evaluate the various physical and chemical characteristics of bacterial melanins which are little investigated. In addition it included the selection of suitable high yielding strain for melanin production, production optimization, followed by utilizing the unusual characteristics and properties of melanin for effective applications.

The specific objectives of the study include

1. **Screening for melanin producing bacteria from marine water and sediments and segregation of high yielding strains.**

2. **Purification and characterization of melanin from selected bacterial strains.**