II. REVIEW OF LITERATURE

The literature reviewed here pertains to synthesis and characterization of nanoparticles, antibacterial activity of nanoparticles, lethal concentration of nanoparticles, impact of nanoparticles on biochemical changes in fish, haematological changes in fish, histopathological changes in fish and application of nanoparticles.

Synthesis and Characterization of Nanoparticles:

TC (Terminalia catappa) leaf extract. Joel Allen et al., (2010) studied the method of Ag Nps handling, sample preparation, advantages and disadvantages of different nano particle characterization techniques. Hanani Yazid et al., (2010) reported the synthesis and characterization of gold nanoparticles supported on zinc oxide via the deposition-precipitation method. Basic and elemental characterization of gold nano nanoparticles using X-ray diffraction (XRD), transmission electron microscopy (TEM), scanning electron microscopy (SEM), energy-dispersive X-rays (EDX), atomic absorption spectrometry (AAS), and ultraviolet-visible spectrophotometer (UV-Vis). Jannathul Firdhouse and Lalitha, (2013) reported the novel synthesis of silver nanoparticles using leaf ethanol extract of Pisonia grandis and reduction was carried out under room temperature, elevated temperatures and under sonication condition.

Javad Karimi et al., (2013) reported the rapid, green and eco-friendly biosynthesis of copper nanoparticles using flower extract of aloevera and eco-friendly synthetic approach to produce Cu nanoparticles through the reduction of Cu (CH₃COO)₂ H₂O solution. Monalisa Pattanayak and Nayak, (2013) reported for the first time the synthesis of green iron nanoparticles using the Azadirachta indica (Neem) leaf extract. Vasudev et al., (2013) studied the green synthesis of copper nanoparticles using Ocimum sanctum leaf extract and these biosynthesized Cu nanoparticles were characterized with the help of X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR). Arun et al., (2013) reported an eco-friendly approach of biosynthesis of nanoparticles using different methods such as chemical, physical and biogenic synthesis of nanoparticles and application.

Anuj Bhasker et al., (2014) reported the green synthesis of copper nanoparticles from the leaf extract of Ocimum sanctum and standardization of different parameters like metal ion concentration, reaction time, pH and ratio in different concentrations. Shobha et al., (2014) reported the biosynthesis of copper nanoparticles and its positive and negative impact on the
microorganism and plants. Remya Vijayan et al., (2014) reported the green synthesis of novel jasmine bud-shaped copper nanoparticles. Jayalakshmi and Yogamoorthi, (2014) reported the biosynthesis of copper oxide nanoparticles using water extract of flower of Cassia alata. The synthesized nanoparticles are characterized by SEM, EDX and XRD to the characteristics of the copper oxide nanoparticles which closely matched with JCPDS standard.

Gopinath et al., (2014) reported the synthesis of copper nanoparticles by reduction of copper sulphate and the aqueous leaf extract of Nerium oleander as a reducing agent and copper nanoparticles by using plant leaf extract of Vitis vinifera and confirmed by UV-visible spectrophotometer with a absorption peak at 384nm. Muralikrishna et al., (2014) reported the synthesis of gold nanoparticles using Aloe vera. Pattanayak et al., (2014) reported the green synthesis of gold nanoparticles using Daucus carota (Carrot) aqueous extract. The concentration of carrot root extract and metal ions plays a crucial role for the synthesis of gold nanoparticles of desired size with reaction conditions. Suresh et al., (2014) reported the green synthesis of tea decoction stabilized copper nanoparticles. Saranyaadevi et al., (2014) reported that the Capparis zeylanica leaf extract acts as both reducing and capping agent.

Raja Naika et al., (2015) reported the green synthesis of CuO Nps prepared by solution combustion method using Gloriosa superba extract as a fuel. The XRD patterns showed monoclinic phase and the UV–visible absorption spectrum indicates blue shift with increasing concentration of the plant extract in the reaction mixture during the synthesis. Kaliyaperumal Logaranjan et al., (2016) reported the biogenic synthesis of silver nanoparticles (Ag Nps) at room temperature using Aloe vera plant extract in the presence of ammonical silver nitrate as a metal salt precursor. The formation of Ag- NP was monitored by UV-visible spectroscopy. The shape and size of the synthesized particle were visualized by scanning electron microscopy (SEM) and transmission electron microscopy (TEM)
observations. These results were confirmed by X-ray powder diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR) analyses and further supported by surface-enhanced Raman spectroscopy/Raman scattering (SERS) study. Ayesha Khan et al., (2016) reported the fabrication of elemental copper nanoparticles by means of chemical reduction method.

Devan Elumalai et al., (2017) reported the biosynthesis of silver nanoparticles from leaf extracts of *Leucas aspera* and *Hyptis suaveolens* as reducing agent and investigated the larvicidal activity of synthesized silver nanoparticles. Paolo Bollella et al., (2017) reported a facile, cost effective and environmental friendly green synthesis of gold and silver nanoparticles (Nps) by plant extracts using as reducing agent. The obtained Nps were characterized by transmission electron microscopy (TEM), energy dispersive spectroscopy (EDS), dynamic light scattering (DLS) and UV-Vis spectroscopy and parameters such as pH, ionic strength and temperature, effectively affecting shape and size of Nps, have been carefully studied and optimized.

Mina Sorbiun et al., (2018) reported that copper oxide nanoparticles synthesized by using extract of oak fruit hull (Jaft) are environmentally benign and cost-effective when compared to chemical/physical method of CuO Nps synthesis. Pulicherla Yugandhar et al., (2018) reported that the copper oxide nanoparticles synthesized from fruit extract showed a color change pattern from brown to green color at the time of synthesis and the UV–Vis analysis of nanoparticles resulted as a small peak at 541 nm and a large peak at 285 nm proves the formation of CuO Nps.

**Antibacterial Activity of Nanoparticles:**

Ivan Sondi and Branka Salopek - Sondi, (2004) reported that *E. coli* as a model for gram negative bacteria and silver nanoparticles have excellent antibacterial activity against *E. Coli*. Ki Young Yoon et al., (2007) reported that the reaction of copper nanoparticles of 100 nm with *B. subtilus* showed the highest susceptibility (Z=0.0734 mL/µg) whereas the
reaction of silver nanoparticles of 40 nm with *E. coli* showed the lowest one ($Z=0.0236$ mL/μg). Azom et al., (2012) reported that the gold nanoparticles are high antibacterial activity against *E. Coli* with average diameter of about 1-22 mm. Antibacterial activity of gold nanoparticles reveals that the zone of inhibition (22 mm) was almost similar to two types of gold nanoparticles used. Soo-Hwan et al., (2011) reported that the *S. aureus* and *E. coli* were substantially inhibited by Ag-Nps, and the antibacterial activity of Ag-Nps did not fluctuate with temperature or pH and these results suggest that Ag-Nps could be used as an effective antibacterial material. Jeyaraman Ramyadevi et al., (2012) reported the synthesis and antimicrobial activity of copper nanoparticles and showed more inhibitory activity in bacteria than the fungus and it also showed more zone of inhibition in *E.coli* (26 mm) than *C. albicans* (23 mm).

Sudhanshu Shekhar Behera et al., (2012) reported the antibacterial effect of iron oxide nanoparticles and was evaluated against ten pathogenic bacteria and also showed that the nanoparticles have moderate antibacterial activity against both Gram positive and Gram negative pathogenic bacterial strains and retains potential application in pharmaceutical and biomedical industries. Usman et al.,(2013) reported that the antibacterial as well as antifungal activity of the nanoparticles using several microorganisms of interest, including methicillin-resistant *Staphylococcus aureus, Bacillus subtilis, Pseudomonas aeruginosa, Salmonella choleraesuis* and *Candida albicans*. Chinnaperumal Kamaraj et al., (2014) reported that the antibacterial activity of SnO$_2$ against *Escherichia coli*. SnO$_2$ nanoparticles showed high potential antibacterial property.

Chatterjee Arijit Kumar et al., (2014) reported that the synthesized silver and gold nanoparticles using aqueous seed extract of recalcitrant seeded *Protorhus longifolia* and confirmed the antibacterial activity of resultant nanoparticles. Swarnali Maiti et al., (2014) reported that the nanoparticles are bacteriostatic at low concentration and bactericidal at high
concentration and these nanoparticles are believed to act as preventive bacterial contamination. Khushboo Singh et al., (2014) reported that the antibacterial activity of silver nanoparticles from *Tinospora cordifolia* against multidrug strains and determined by agar well diffusion assay and Minimum Inhibitory Concentration (MIC) was estimated by qualitative experimentation by reassuring based micro broth dilution method.

Raja Naika et al., (2015) reported the methonolic extract of *Ocimum teniflorum* posses antimicrobial potential against both gram positive and negative bacteria. It contains medicinally important bioactive compounds and this justifies the use of plant species as traditional medicine for treatment of various diseases. Hoda Erjaee et al., (2017) reported that the synthesized silver nanoparticles using *Chamaemelum nobile* exhibit a pronounced antibacterial activity against different microorganisms. Mohammed et al., (2018) reported that the bacterial pathogens *B. cereus* was highly susceptible (25.3 mm) to biosynthesized CuO Nps.

**Lethal Concentration of Nanoparticles:**

Michiel et al., (1994) reported that the relation between short -term and long -term toxicities of different nanoparticles (Cu, Zn, Pb and Cd). Robert J.Griffitt et al., (2009) reported that the acute toxicity of copper nanoparticle suspensions were examined in zebra fish, demonstrate that nano copper is acutely toxic to zebra fish with a 48 h LC$_{50}$ concentration of 1.5 mg/L. HAO Linhua et al., (2009) reported that the TiO$_2$-Nps have adverse influence on carps, lethal to the carps with exposure to 10–200 mg/L TiO$_2$-Nps and abnormal physiological and behavioural changes. Ya-Nan Chang et al., (2012) reported the toxic effects and mechanisms of CuO and ZnO Nanoparticles. Iman et al.,(2012) reported that LC$_{50}$ values decreased with time and about 50% of all mortalities occurred in Black fish (*Capoeta fusca*) at the first 24 hrs, the environmental contamination with this metal can represent a great threat for the serious problem for aquaculture. Hedayati et al., (2013)
reported that the LC$_{50}$ in goldfish (0.53 ppm) was higher than that of silver carps (0.34 ppm) exposed to silver nanoparticles (Ag-Nps) and also suggests that Ag-Nps could accumulate in aquatic environments and seriously disturb the development of fish species and toxic action of platinum Nps on aquatic animals during acute and sublethal toxicity leads to mortality. During acute treatment of platinum Nps, the fish *Cirrhinus mrigala* showed behavioural changes such as loss of balance, restlessness and abnormal swimming. During sublethal treatment of platinum Nps, showed the changes such as the gulping of air, opercular movement and erratic jumping.

Shaluei *et al.*, (2013) reported the acute toxicity and evaluated the sub acute concentrations of Ag-NPs on hematological and plasma biochemical indices of silver carp. Shine *et al.*, (2014) reported the impact of biogenic gold nanoparticles and its oral administration on *Oreochromis mossambicus*. Amina Dedeh *et al.*, (2014) studied the impact of contaminated sediment containing 14-nm gold nanoparticles (AuNps) and reported that the zebrafish *Danio rerio* was exposed for 20 days to two concentrations, 16 and 55 mg/g dry weight. John Thomas *et al.*, (2014) studied that the magnesium oxide bulk particle was found to be more toxic when compared to nano particle. Fernando *et al.*, (2014) reported that the manufactured CuO Nps can trigger sub-lethal responses associated with oxidative stress in *Mozambique tilapia*. Rossbach M. Lisa *et al.*, (2017) reported that mortality of *Carcinus maenas* exposed to both 1 mg L-1 Cu Nps and Cu (as CuSO$_4$) treatments. The metal salt was more acutely toxic with 50 % mortality (LC$_{50}$) reached after 6.5 days, compared to only 21 % mortality in 1 mg L-1 Cu Nps after 7 days. Muhammad Saleem Khan *et al.*, (2017) reported that the damage increases when the dose or time interval of the exposure of Ag-NPs increases and these findings are mainly focused on the toxicological effects in fresh water fish *Labeo rohita*. 
Impact of Nanoparticles on Biochemical Changes in Fish:

Daowen Xiong et al., (2011) reported the exposure of 5 mg/L ZnO NPs and bulk ZnO suspension induced oxidative stress in the liver and decreased protein level on zebra fish. Kawade and Khillare., (2012) reported that the estimated protein level in tissues, gills, liver, kidney, ovary and testis were found to be reduced when the exposed to CuO Nps, maximum reduction in protein level in freshwater fish Channa gachua at 96 h. Monfared Ali Louei and Soltani Salman, (2013) reported that the total protein was decreased to exposure of silver nanoparticles on rainbow trout (Oncorhynchus mykiss). Abdel-Tawwab Mohsen et al., (2013) reported the changes in biochemical status of common carp (Cyprinus carpio) exposed to water-born zinc for different periods.

Deepa Rani et al., (2016) reported that the effect of biochemical constituents such as total protein, carbohydrate and lipid levels drastically decreased when exposed to cadmium nanoparticle (CdNps) which denotes the energy demand in mud crab, Scylla olivacea organism. Mahdi Banaee et al., (2016) reported that alterations in blood biochemical parameters in fish exposed to TiO$_2$-NPs under light photoperiod conditions were more acute than fish exposed to TiO$_2$-NPs under dark conditions. Keerthika et al., (2017) reported that the total protein, carbohydrate and lipid were consequently decreased in Fe$_3$O$_4$ nanoparticles treated fish Labeo rohita when compared with control. Nasrin Akter et al., (2018) reported that the metallic iron nanoparticles (Fe-NPs) as a fish additive in growth and physiological stimulation of Bagridae catfish Clarias batrachus. Significantly higher total protein and lipid content of fish muscle were also found at 40 mg/kg feed of Fe-NPs.

Impact of Nanoparticles on Haematological Changes in Fish:

Asharani et al., (2008) reported that the impact of silver nanoparticles on Zebra fish by concentration dependent, typified by phenotypes that had abnormal body, slow blood flow, pericardial edema and cardiac arrhythmia. Vignesh Venkatasamy et al., (2013) reported the
colloidal AgNPs on hematological and biochemical functions of freshwater fish *Labeo rohita*. The experiments revealed that the amount of hemoglobin and total count of blood cells were considerably increased. Khabbazi Mahboobe *et al.*, (2014) reported that the CuO Nps affected hematological parameters such as counts of white blood cells, lymphocytes, eosinophils, neutrophils, hematocrits, MCH, MCHC and MCV and also any effects on monocytes and hemoglobin. Rajkumar *et al.*, (2015) reported the toxicity assessment of silver nanoparticles exposed to freshwater fish *Labeo rohita* on haematology alterations. Deshmukh, (2015) reported that the parameters such as RBC and Hb were decreased whereas WBC in blood cell in fresh fish *Channa striatus*.

Jahanbakhshi *et al.*, (2015) reported the *Rutilus rutilus* sensitivity to CuO-NPs and changes in blood parameters, such as RBC count, Hb and Hct values significantly decreased and in the WBC numbers, MCH, MCHC and MCV significantly increased. Carrillo *et al.*, (2015) reported that the exposure Ag nanoparticles may cause significant protein and lipid oxidative damage in Zebra fish. Suganthi *et al.*, (2015) reported the acute toxicity, behavioural and haematomietalological effects of ZnO NPs on freshwater fish *Oreochromis mossambicus*. Also reported significant decrease in the number of total Red cell count (RBC), haemaglobin (Hb) and Haematocrit (Ht) reflects changes in red blood indices such as MCV, MCH, MCHC and oxygen carrying capacity. Decreased leucocytes and differential count differences observed in ZnO NPs exposed groups. Alkaladi Ali *et al.*, (2015) studied the effect of zinc oxide nanoparticles (ZnO Nps) on *Oreochromis niloticus* and reported the effect of hematological alterations induced by two sublethal concentrations. Leukocytosis, heterophilia, lymphopenia and monocytopenia were recorded on the 7th day in all treated groups compared with control. Ostaszewska Teresa *et al.*, (2016) reported the effects of silver (AgNPs) and copper (CuNPs) nanoparticles on larval Siberian sturgeon (*Acipenser baerii*) after 21 days of exposure. Servet Duran and Cahit Erdem, (2016) studied that Hematocrit
level showed an increase under the effect of metal mixture after 96-h expose to fresh water fish *Oreochromis niloticus* while erythrocytes number increased compared to control.

Hamid Salari Joo *et al.*, (2018) reported the concentration dependently increased thrombocyte, monocyte, and large lymphocyte and decreased neutrophil and small lymphocyte and also reported that the white blood cell count and Red blood cell volume significantly increased in all the experimental groups exposed to higher Ag-NP concentration on rainbow trout (*Oncorhynchus mykiss*). Roodsari Mina Tavassoli *et al.*, (2018) reported the impact of Ag-NPs on the hematological parameters of Rainbow trout, *Oncorhynchus mykiss juvenile*. Hematological toxicities of Ag-NPs to rainbow trout juveniles were assessed and showed that the values of white blood cells (WBCs) were higher in all treatments than those in the control group and the red blood cells (RBCs) reduced in the high concentration of AgNPs.

**Impact of Nanoparticles on Histopathological Changes in Fish:**

Federici *et al.*, (2007) reported that the histopathological changes of gills are observed in TiO$_2$ NPs exposed to rainbow trout. Robert J. Griffitt *et al.*, (2009) studied the comparison of molecular and histological changes in zebra fish gills exposed to metallic nanoparticles. Byoungcheun Lee (2012) reported that the acute toxicity and oxidative stress caused by silver nanoparticles (Ag-NPs) on *Cyprinus carpio*, its observed histological abnormalities in different tissues (i.e., liver, gills and brain).

Govindasamy Rajakumar and Abdul Rahuman Abdul, (2012) reported the liver tissues of fish *Oreochromis mossambicus* exposed to Ag NPs at 50mg/L showed cloudy swelling of hepatocytes, congestion, vacuolar degeneration, karyolysis, karyohexis, dilation of sinusoids, nuclear hypertrophy, fusion of primary lamellae in gill and marked hyperplasia of the branchial arch at 25mg/L concentration. The muscle tissue exhibited dystrophic changes with
thickening and separation of muscle bundles in oedema. Yousefian Mahdi and Payam Banafsheh, (2012) studies the effect of nanoparticles on some histological parameters of fish.

Mahboobe Khabbazi et al., (2014) reported the effects of water-born CuO Nps (Copper (II) oxide) on the rainbow trout (Oncorhynchus mykiss) gill tissue to establish asuitable biomarker for copper in water resources. Chidambaram Jayaseelan et al., (2014) reported that the main alterations of irregular shaped nuclei, nuclear hypertrophy (NH), cytoplasmic vacuolation (CV), nuclear degeneration (ND), pyknotic nucleus(PN) and necrosis(NC) in the liver of Ni Nps exposed Oreochromis mossambicus. Subashkumar and Selvanayagan, (2014) reported that the ZnO nanoparticles induced hypertrophy of hepatocytes, nuclear degeneration, focal necrosis, pyknotic nuclei, kupffer cells, dilated sinusoids, narrowing of sinusoids, fatty degeneration, irregular shaped nucleus and cytoplasmic degeneration.

Selvaraj Kunjiappan et al.,(2015) reported that phytochemically synthesized gold Nps in liver against oxidative damage, tissue damaging and hepatic damage in fresh water fish common carp Cyprinus carpio L. Rajkumar et al., (2015) reported the histological changes caused by chemically synthesized Ag Nps and demonstrated the damages in the tissues, primary lamella and blood vessels of Labeo rohita. Sugantri et al., (2015) reported the abnormalities of gills, muscle, brain, intestine and ovariy tissues of Oreochromis mossambicus exposed to ZnO Nps, thus their physiological, secretory and absorption, endocrine and reproductive activities are disturbed. Amr et al., (2016) reported that the histological effects of nano-CuO and bulk CuO on a common freshwater fish Oreochromis niloticus. CuO NPs had more efficiency to internalize fish tissues (liver, kidneys, gills, skin and muscle), histopathological analysis shows various alterations that varied between adaptation responses and permanent tissue damage. Kanwal Zakia et al., (2016) reported that the effect of cobalt oxide nanoparticles on freshwater fish Labeo rohita. Co$_2$O$_4$ NPs particles
treated fish were observed to be adversely affect organs and erythrocytes clumping and shape change was also observed in Co$_2$O$_4$ NPs treated fish. Lustosa do Carmo Talita Laurie et al., (2018) reported that after exposure to TiO$_2$Nps, histopathological changes in the gills were more frequent but less severe than those in the kidneys.

**Application of nanoparticles:**

Athanassiou et al., (2006) reported that the carbon layer protected the copper nanoparticles from oxidation in air. Bulk pills of pressed copper nanoparticles displayed a highly pressure and temperature dependent electrical conductivity with sensitivity comparable to commercial materials. These properties suggest the use of thin copper nanocomposites as novel, low-cost sensor materials and a metal-based alternative of currently used brittle oxide spinels. Ping Jianfeng et al., (2010) reported the fabrication of novel H$_2$O$_2$ sensing electrode by mixing the graphite powder, ionic liquid OPPF6, and CuO Nps. Due to the combination of good conductivity of ionic liquid and excellent catalytic activity of CuO Nps, the developed electrode showed very attractively analytical performance in the determination of H$_2$O$_2$. Xue Wang et al., (2010) reported the synthesis CuO flowers and nanorods for the first time by the composite hydroxide mediated and the composite-molten salt method, respectively, with advantages of one step, ambient pressure, low temperature, template free and low cost. Both nanostructures have been applied to modify the graphite substrates for non enzymatic glucose detection compared with bare graphite electrode, the new electrodes exhibit excellent catalysis to direct glucose oxidation.

Sathish Reddy et al., (2012) reported that the prepared CuO nanoparticles were used for the preparation of modified carbon paste electrodes (MCPE) for the electrochemical detection of dopamine (DA) at pH 6.0. The MCPE prepared from flake shaped CuO nanoparticles exhibited an enhanced current response for DA (Dopamine). Hong - Ying Yu et al., (2013) reported the chemiluminescent cholesterol sensor with good selectivity and
enhanced sensitivity was constructed based upon the peroxidase activity of cupric oxide nanoparticles. \( \text{H}_2\text{O}_2 \) could be generated by the reaction between cholesterol and oxygen in the presence of ChOx. Then luminol reacted with \( \text{H}_2\text{O}_2 \) under the catalysis of CuO nanoparticles and detection of cholesterol in milk powder or human serum. Fugang Xu et al., (2013) reported that the non enzymatic \( \text{H}_2\text{O}_2 \) sensor was fabricated based on the Cu\(_2\)O–rGOpa composite, which display higher sensitivity, much wider linear responsive range and better stability than that of Cu\(_2\)O based sensor.

Ahamed Maqsood et al., (2014) reported that the CuO Nps have potential for external uses as antibacterial agents in surface coatings on various substrates to prevent microorganisms from attaching, colonizing, spreading, and forming bio films in dwelling medical devices. Gao Peng and Liu Dawei, (2014) reported that different CuO nanostructures were prepared through simple hydrothermal reactions without using any additives and their electrochemical properties were investigated systematically. Microstructure characterization demonstrated that the morphological change of CuO nanostructures was mainly dependent on initial amount of Cu (NO\(_3\))\(_2\). Ai-Ling Hu et al., (2014) reported the development of novel fluorescent hydrogen peroxide sensor based on the peroxide as like activity of cupric oxide nanoparticles. Cupric oxide nanoparticle effectively catalyzed the decomposition of hydrogen peroxide into hydroxyl radicals.

Tadayon and Sepehri, (2015) reported that nanocomposites based on nitrogen–dopped graphene nanosheets/ CuCo\(_2\)O\(_4\) nanoparticles was prepared and used as an electrode material for simultaneous determination of dopamine, melatonin and tryptophan. Zhang Jing et al., (2015) reported the non enzymatic glucose sensor based on the CuO Nps-CSs modified electrode. The highly dispersed CuO Nps on CSs results in that CuO Nps-CSs modified electrode has an excellent electro catalytic activity towards the electro oxidation of glucose. The CuO Nps-CSs based sensor for glucose possesses good analytical performance,
such as wide linear range ($5.0 \times 10^{-7}$ to $2.3 \times 10^{-3}$ M), high sensitivity ($2981 \, \mu$A mM$^{-1}$ cm$^{-2}$), low detection limit (0.1 μM), excellent reproducibility and stability, and good selectivity to glucose determination. Tiana Ye et al., (2015) reported the electrochemical measurements and showed that CuO/SG exhibited a better electro catalytic activity for glucose oxidation than CuO Nps and CuO/r GO, which could be attributed to the synergetic effects between CuO and SG, including the large CuO surface areas, good conductivity of SG, and enhanced electron donor ability of the CuO Nps interaction.

Pino et al., (2016) reported that CuO Nps can be used to produce a simple and reliable sensor system with an improved analytical performance that would be useful as an alternative to enzyme-based inhibition sensors. The high reproducibility and sensitivity obtained for the detection of different phenolic compounds below the threshold values make the developed device a promising system for environmental monitoring. Maaoui Houcem et al., (2016) reported the Cu$_2$O-modified GC electrodes for sensing. The electro catalytic activity of the material allowed for the detection of glucose in a non-enzymatic manner under basic conditions, while the obtained limit of detection is comparable to other carbon-based/Cu nanoparticles, the CQDs/Cu$_2$O matrix shows enhanced sensitivity and offers a facile and low-cost material for glucose sensor.