# EVALUATION OF ENVIRONMENT FACTORS INFLUENCING ROBOTS IN GREENHOUSES

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**Abstract.** Chemical application of nutrients and pesticides is one of the most important processes in agricultural production, but also one of the most dangerous agricultural operations. To improve the chemical efficacy, reduce chemical and labour cost, minimize labour hazards and reduce the harmful environmental damage provided the motivation behind the development of the robots for greenhouse application. Corrosion of complex electronic equipment is an increasingly serious problem, causing expensive damage. Miniaturization of systems based on integrated circuits and small size components close component spacing, separable electrical contacts having lower voltages and contact forces than before have resulted in failures of electronic equipments due to the formation of small quantities of corrosion products. Sensors used in robots are impressible for many factors of the environment. Chemicals, moisture, airborne corrosives, impressed currents, etc. influence the occurrence of corrosion and cause sensor malfunction. Corrosion occurs throughout the entire life cycle during different stages of manufacturing, assembly, transport and storage of components and assemblies and during field operations of the equipment. Presence of moisture, chloride, sulphur dioxide, hydrogen sulphide and other airborne corrosives, meteorological parameters etc. influences the occurrence of corrosion. The present paper reviews the chemicals used in greenhouses, factors influencing corrosion in greenhouses and types of corrosion observed in electronics.

**Keywords:** greenhouse robots, sensors, fertilizers, plant protection.

## Introduction

The mobile robot developed to operate in greenhouses involves a synergetic integration of mechanical engineering with electronics and automatic control. From the first step of construction to the final tests in greenhouses, all the processes were supervised by a mechanical, electronic, and information technology combination [1; 2]. Autonomous control and operation of the mobile robot relies heavily on external sensor information. Therefore, the performance of the navigation and spraying controller will depend heavily on the installed sensors on the platform.

Electronic industry uses a number of metallic materials in various forms. Also new materials and technology are introduced all the time for increased performance. In recent years, corrosion of electronic systems has been a significant issue. Multiplicity of materials used is one reason limiting the corrosion reliability. However, the reduced spacing between components on a printed circuit board (PCB) due to miniaturization of the device is another factor that has made it easy for interaction of components in corrosive environments. Presently, the knowledge on corrosion issues of electronics is very limited [3].

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Corrosion of complex electronic equipment is an increasingly serious problem, causing expensive damage. Miniaturization of systems based on integrated circuits and small size components close component spacing, separable electrical contacts having lower voltages and contact forces than before have resulted in failures of electronic equipments due to the formation of small quantities of corrosion products. Sensors used in robots are impressible for many factors of the environment. Chemicals, moisture, airborne corrosives, impressed currents, etc. influence the occurrence of corrosion and cause sensor malfunction. Corrosion occurs throughout the entire life cycle during different stages of manufacturing, assembly, transport and storage of components and assemblies and during field operations of the equipment. Presence of moisture, chloride, sulphur dioxide, hydrogen sulphide and other airborne corrosives, meteorological parameters etc. influences the occurrence of corrosion.

## Materials and methods

There are various boundary surfaces of materials in electronics, for example on the circuit board, wiring patterns, connectors, switches and microcircuits. If the device is subjected to the corrosive substances present in air and to water and since water is always in contact with all the surfaces, at least to some extent, galvanic corrosion occurs always when two metals are in contact with one another. High temperature and humidity accelerate these reactions. The smallest risk for corrosion exists between two surfaces of the same metal. If the metals are different, the least corrosion occurs between the surfaces where the electric surface potentials are as close to one another as possible [4].

Corrosion resistance is formed of two entities:

- factors increasing the corrosion risk;
- protective measures, in other words methods preventing corrosion [4].

Causes for corrosion in electronic devices:

1. service of devices such as Integrated Circuits in which metallic lines are often biased electrically relative to nearby lines.
2. aggressive manufacturing processes.
3. exposure to corrosive range of uncontrolled environments such as temperature, humidity and contamination.
4. due to device miniaturization the width and separation of metal lines on integrated circuits(IC) devices have been cut in half approximately every 5 years and not less than 1 micron in the most advanced devices.
5. reactive gaseous agents –$NO_X$, $SO_X$, $O_3$, $H_2O_2$, $NH_3$, $H_2S$ plus volatile organic compounds.
6. suspended inorganic and organic acids ($H_2SO_4$ HCl, $HNO_3$), suspended submicron hygroscopic ionic particles ($NH_4HSO_4$, $NH_3NO_4$, $(NH_4)_2$ $SO_4$ plus others).
7. other inorganic compounds and metals –NaCl, Fe, Al, Mg, Ca, K suspended in the air.

The service related residues are the residues introduced during exposure to service environments. They can be aggressive ions like chlorides, $SO_2$(g), $NO_2$(g), or other types of chemically aggressive ions. Presence of such substances triggers corrosion to a large extent under humid conditions. The dust particle is another issue, which can act as a moisture trapping agent. Formation of a water layer is easy on a dusted surface compared to the clean one. Therefore, corrosion is possible even at relatively low humidity such as 50 – 70 %. If the surface of the electronic components is not contaminated, corrosion will not be a large issue. However, in practise significant levels of contamination could be detected on printed circuit boards and components [5].

A water layer or a tiny water drop-let sitting on the surface of a PCB can generate the micro galvanic cell by electrically connecting the two metallic parts. Within the micro-galvanic cell, cathodic reaction takes place on the noble electrode (e.g., graphite, gold, silver, copper or a negatively charged part under applied potential), while the anodic reaction occurs on the active electrode by metal dissolution. However, due to the large ohmic drop experienced in the thin film solution, anodic reaction often takes place on a close by cathodic part. It is important to notice that the electrical charge is transported by electrons in the metallic material and by ions in the liquid. The transfer of charge from the metal surface (electronic conductor) to solution (ionic conductor) interface occurs by an electrochemical reaction, namely oxidation or reduction.

Several materials are used in electronic industry and new materials are emerging all the time. However, the material combinations together with the demand for miniaturization and large spread in user environment have introduced significant corrosion problems. Presence of process and service related residues on the electronic component is an important factor in dictating the corrosion problem, hence cleanness plays a big role in corrosion control. New testing methods and standards have to be developed, although the localised detection methods such as micro electrochemical technique and localised residue analysing systems are very much useful.

External connectors and wirings of electronic devices are one of the problematic sections in the control of problems caused by corrosion. Periodic cut-offs are very common failures in external connectors. The usual reason for these is the gradual corrosion or dirtying of the contact coatings, wear of the contacts and fatigue of the springs. The contacts that are opened in use must tolerate repeated mechanical stress, they should be watertight and the contact coatings should tolerate humidity and mechanical wear caused by changes in the external temperature. In addition, the adhesion of the wires to the connector frame must be ensured against jerks by suitable clamps. In devices operated outdoors, the prevention of the corrosion risk can be improved by mechanically supporting the wiring, by conducting the wires to the inside under the device to prevent draining of water directly on the contacts and by choosing the materials so that the wiring can take bending, changes in the temperature and the continuous presence of water [4].

The standard guideline BS 7195 (1989) Prevention of corrosion of metals caused by vapours from organic materials gives a fairly detailed list of emissions of corrosive elements from organic substances and guidelines on how various metal surfaces should be protected against such emissions. The BS 7195 divides metals into the following categories according to their sensitivity to the corroding emissions of organic substances (Table 1). The classification was not drawn up with regard to the corrosion sensitivity of electronics but it can be considered a guideline at least when evaluating the corrosion sensitivity of case and support materials.

Table 1

**Sensitivity to corrosion of metals from the emissions of organic substances**

| Sensitivity | Materials |
|---|---|
| Serious corrosion sensitivity | Carbon steels, lead and lead alloys, zinc, zinc alloys, magnesium, magnesium alloys and cadmium (the use of cadmium is nowadays prohibited) |
| Moderate corrosion sensitivity | Copper and copper alloys |
| Slight corrosion sensitivity | Aluminium and aluminium alloys, nickel and nickel alloys |
| Durable materials | Austenitic stainless steel, chromium, gold, molybdenum, silver, tin, titanium and titanium compounds |

Also silver has been categorised in the most durable group although it is not recommended for contact surfaces in electronics, if the operation is in small signal conditions with voltages less than a few volts and there are sulphuric compounds in the air, which is usually the case. Silver is suitable for contacts with high currents and voltages for instance in switches and relays since it is resistant to sparking (arc flame erosion) in opening/closing switches [4].

The greenhouse microclimate parameters were assessed to determine their effects on the robot sensors and electronic components. Greenhouse microclimate is controlled so that it would be most favourable for the plants. The optimum temperature for plant growth of 25 ºC – 28 ºC, humidity 60 – 80 %, carbon dioxide content ranging from 5 to 10 $g \cdot m^{-3}$ and the necessary lighting from 4000 to 6000 lux, but each of these parameters may vary depending on the vegetable crops.

In order to evaluate the robot parts of the resistance to environmental effects the analytical hierarchy process method was used. A comparison was made of construction materials, mechanics, contacts, electronics, and inductive, optical and ultrasonic sensors, depending on the effects of the factors: the greenhouse microclimate, plant protection and plant fertilizers. The analysis process compares pairs and evaluates the problems of elements of interaction strength in the hierarchy. These comparative conclusions are expressed numerically. The problem solving is the process of progressive priorities. The first step is definitely the most important elements of the problem and the hierarchy. The second compares, reviews and evaluates the elements. The third developed a method to implement the decision and evaluate its quality [6].

## Results and discussion

One of the benefits of growing crops in a greenhouse is the ability to control all aspects of the production environment. One of the major factors influencing the crop growth is the temperature. Different crop species have different optimum growing temperatures and these optimum temperatures can be different for the root and the photosynthesis environment and for the different growth stages during the life of the crop. Since we are usually interested in rapid crop growth and development, we need to provide these optimum temperatures throughout the entire cropping cycle [7].

Healthy plants can transpire a lot of water, resulting in an increase in the humidity of the greenhouse air. A high relative humidity (above 80 – 85 %) should be avoided because it can increase the incidence of disease and reduce plant transpiration. To reduce the temperature and humidity, greenhouses can be mechanically or naturally ventilated. When the regular ventilation system is unable to provide sufficient cooling for greenhouse temperature control, additional cooling is needed. Two cooling systems, the pad-and-fan and the fog system, are commonly used in greenhouses and both make use of the cooling effect resulting from the evaporation of water [7].

Table 2

**Plant Protection Products Classification and Evaluation**

| Nr. | Name | The active substance | Use form | Potential corrosion activity |
|---|---|---|---|---|
| | | INSECTICIDES AND ACARICIDES | | |
| 1 | Aktara 25 | Thiamethoxam | solution | Active for PCB, contaminate the optical sensors |
| 2 | Fastaks 50 | Alpha-cypermethrin | emulsion | Active for PCB, contaminate the optical sensors |
| 3 | Fitoekols IF | Pine and spruce needle extracts in a mixture | solution | Active for PCB, contaminate the optical sensors |
| 4 | Potash soap | Fatty acid potassium salt | solution | Active for PCB, contaminate the optical sensors |
| 5 | Karatē Zeons 5 | Lambda-cyhalothrin | solution | Active for PCB, contaminate the optical sensors |
| 6 | Kestaks 50 | Cypermethrin | emulsion | Active for PCB, contaminate the optical sensors |
| 7 | Mačs 50 | Lufenuron | emulsion | Active for PCB, contaminate the optical sensors |
| 8 | Nīmazals | Azadirachtin-A | emulsion | Active for PCB, contaminate the optical sensors |
| 9 | Sulphur | Sulphur | powder | Active for PCB, contaminate the optical sensors |
| 10 | Sumi-alfa 5 | Esfenvalerate | emulsion | Active for PCB, contaminate the optical sensors |
| 11 | Tiovits 80 | Sulphur | powder | Active for PCB, contaminate the optical sensors |
| 12 | Vertimeks 018 | Abamectin | emulsion | Active for PCB, contaminate the optical sensors |
| | | FUNGICIDES | | |
| 1 | Amistārs 250 | Azoxystrobin | suspension | Active for PCB, contaminate the optical sensors |
| 2 | Bordeaux mixture | Copper vitriol + calcium | suspension | Active for PCB, contaminate the optical sensors |
| 3 | Bravo 500 | Chlorothalonil | suspension | Active for PCB, contaminate the optical sensors |
| 4 | Ēempions 50 | Copper hydroxide | suspension | Active for PCB, contaminate the optical sensors |
| 5 | Ditāns NT | Mancozeb | solution | Active for PCB, contaminate the optical sensors |
| 6 | Euparens M | Tolylfluanid | solution | Active for PCB, contaminate the optical sensors |
| 7 | Infinito 687.5 | Propamocarb + Propamocarb hydrochloride + Fluopicolide | suspension | Active for PCB, contaminate the optical sensors |
| 8 | Litagra Previkurs | Propamocarb | solution | Active for PCB, contaminate the optical sensors |
| 9 | Timorekss | Australian tea tree oil | solution | Active for PCB, contaminate the optical sensors |
| 10 | Topāzs 100 | Penconazole | emulsion | Active for PCB, contaminate the optical sensors |
| | | HERBICIDES | | |
| 1 | 2.4-D Nufarm | 2.4–D | solution | Active for PCB, contaminate the optical sensors |
| 2 | Barbarian Biograde 360 | Glyphosate | solution | Active for PCB, contaminate the optical sensors |
| 3 | Lentagrāns 45 | Pyridate | suspension | Active for PCB, contaminate the optical sensors |
| | | MICROBIOLOGICAL HERBAL REMEDIES | | |
| More than 10 plant protection products containing a variety of microorganisms | | | | The low-level exposure to PCBs. There may be some contamination of optical elements |
| | | PLANT PROTECTION PRODUCTS CONTAINING LIVING ORGANISMS | | |
| More than 10 plant protection products containing a variety of living organisms (*Aphidoletes aphidimyza, Aphidius colemani, Amblyseius cucumeris*, etc.) | | | | No significant effect on the electronics and optical elements of the operation. |

During the cooling, sprays of water droplets cover the electronic parts and robot sensors. Along with the dust they form electrolytes, which can cause the PCB of electrochemical corrosion.

For plant nutrition and protection against pests and diseases a variety of chemicals in aqueous solution are used. Usually these substances are sprayed on plants. The robot working parts and electronic components are also exposed to the spray exposure. This leads to corrosion of the PCB. Chemical solutions cover the sensor optical elements and reduce the light transmission.

Various agricultural chemicals affect the robot components with different intensities. Plant protection product and fertilizer evaluation was conducted to determine the possible effects of corrosion on the robots. As follows from Table 2, for plant protection chemical compounds, micro-organisms and living organisms are used.

Chemical compounds are used in water solutions, emulsions and suspensions. In the spraying process small droplets are formed in the air. These droplets cover the parts of robots, sensors and open parts of electronic devices. After drying the surface of the equipment stays covered with a small layer of the active substance. Considering that the greenhouse humidity is increased, for PCBs, contacts, etc. formed electrolyte that leads to electrochemical corrosion.

Inorganic fertilizers in greenhouses are routinely used in aqueous solutions and used to spray on plants or soil. The drops of the chemicals cover the sensors and robotic components like plant protection products and create corrosion. Given that the fertilizer solution contains active ions, the effect on the robot parts is more important than the impact of the plant protection means provided. We conclude that the fertilizer effect on the robot parts has to be evaluated first.

The optical sensor and the camera lens should be covered with a light-dissipating layer that reduces the light transmission and resolution.

To continue further experiments sensitivity to the environmental factors should be established for the parts and sensors of the horticultural robots. A comparison was done using the Analytic Hierarchy reference method. As a result of the comparison comparative sensitivity of the basic parts of the robot and frequently used sensors was obtained, Fig. 1.

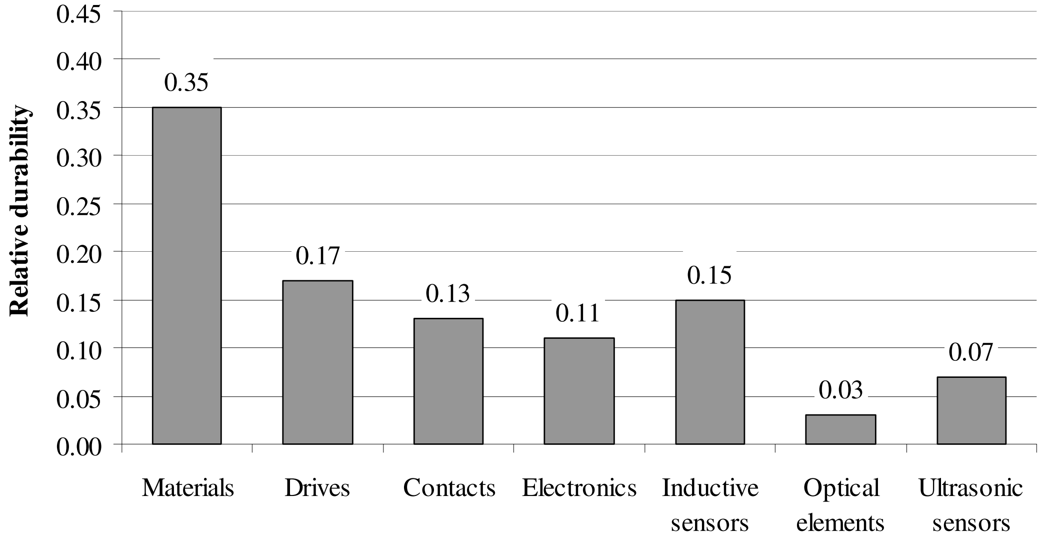


Fig. 1. **Relative durability of the frequently used parts of robots**

Optical sensors and other optical devices such as camcorders are most sensitive to the greenhouse effect present environment. Optical elements are sensitive to the soluble chemicals that cover the surface of the translucent components and decrease the light permeability and distinction ability.

Future research will focus primarily on environmental impact evaluation of robotic optical components. The result of the research will be developed protection methods of optical components against environmental influences.

## Conclusions

1. Soluble fertilizers and plant protection products used in greenhouses are the major risk factors for the operation of the robot in the greenhouse.
2. Optical sensors and other optical elements are most sensitive to aggressive environmental effects.

3. The relative durability between the assessed elements has been 0.03.
4. Future research should focus first on the optical sensor protection methods and circuit corrosion risk aversion.

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