CAUSES OF MALFUNCTIONS WITH INSTALLATIONS FOR REFUSE DERIVED FUEL AND A NON-HAZARDOUS WASTE LANDFILL

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ABSTRACT. With the aim of avoiding future malfunctions and increasing the economic effect of installations for refuse derived fuel and of a non-hazardous waste landfill with an adjoining water-treatment plant for infiltrated water, a review is made of the failures and break-downs. The monitoring of the production process and the inspection carried out provide evidence of the observation of the adopted criteria for quality and faultless operation. Since the facilities have only operated for a short time since their inauguration and putting in service, the authors suggest an active monitoring, not reactive. After examining the faulty facilities on the territory of the plant, a classification is worked out for the various types of failure. The causes or the majority of faults and failures of the individual facilities are determined. Based on these, an analysis of the reasons for delays and interruptions of the working process is prepared. Recommendations are given. It has been established that there are constructional and technological errors that are impossible to correct. The mechanical problems are caused by the larger mass of the processed wastes. These problems can gradually be solved by replacing the driving equipment. As for the problems associated with the automation system, an adjustment of settings should be done that is connected with the power of the driving equipment and with the quality of the wastes recycled. Still, the reduction of the number of interruptions in the plant depends on the employees who need to be better educated and motivated by means of introducing clear criteria for career development. The authors believe that the introduction of the suggested measures for solving the problems that have arisen will help reduce production costs and will raise efficiency and the economic effect.

Keywords: accident, corrosion, electrical and mechanical damage failure, installation for refuse derived fuel

ПРИЧИНИ ЗА АВАРИИ ПРИ ИНСТАЛАЦИИТЕ ЗА МОДИФИЦИРАНО ГОРИВО И ДЕПО ЗА НЕОПАСНИ ОТПАДЪЦИ

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РЕЗЮМЕ. С цел предотвратяването на бъдещи аварии и повишаване на икономическия ефект е направен преглед на отказите и повредите на инсталациите за модифицирано гориво (RDF) и депо за неопасни отпадъци с прилежаща пречиствателна станция за инфилтратни води. Мониторингът и инспекцията предоставят доказателства за спазване на приетите критерии за качество и безаварийност на производствения процес. Тъй като предприятието е работило кратко време след пускането си в експлоатация, авторите препоръчват активен мониторинг, а не реактивен. След обследване на аварирали съоръжения на територията на завода е направена класификация на различните типове откази. Определени са причините за по-голямата част от авариите или отказите на отделни съоръжения. Въз основа на това е направен анализ на причините за забавяне или спиране на работния процес, дадени са препоръки. Установено е, че има конструктивни и технологични грешки, които не могат да бъдат променени. Механичните проблеми са причинени от по-голямата маса на преработваните отпадъци, които постепенно могат да се решат с подмяна на задвижващите съоръжения. Относно проблемите свързани със системата за автоматизация е необходима промяна на настройките съобразена с мощността на задвижващите съоръжения и с качествата на преработваните отпадъци. Все пак намаляването на броя на спиранията в завода зависят от персонала, който трябва да бъде по-добре обучен и мотивиран, чрез въвеждане на по-ясни критерии за кариерно израстване. Авторите вярват, че с внедряване на така предложените мерки за решаване на възникналите проблеми ще се намалят производствените разходи и ще повиши производителността и икономическия ефект.

Ключови думи: авария, корозия, електрически и механически повреди, инсталация за модифицирано гориво

Introduction

The rapidly evolving technologies, the high demands and the growing purchasing power of consumers are connected with the generation of more wastes, too. Natural resources are getting exhausted and this necessitates policies for a wiser management of wastes. These policies are associated with waste processing and re-use. With the development of the industry, an increasing number of enterprises is closing their work cycle in terms of generation and recovery of wastes. Therefore, waste management enterprises are in the service not only of the public but also of the industry to which they supply ready-made raw materials. Their own benefit is twofold - they work to minimise environmental pollution and produce resources for large processing companies, which is also associated with making profits. Effective waste management work requires the faultless operation of the working process and a low cost per unit of processing, which is achieved by meeting the criteria set in the technological cycle.

The purpose of this report is to examine malfunctions and to summarise the reasons for the necessity for early repairs in a newly-erected enterprise. The subject of the report is the premises and the adjoining facilities on the territory of a waste treatment plant.

The occurrence of malfunctions in the situation under consideration is a casual process despite the experience gained in the construction of such types of enterprise in other countries. This report aims at tracking the work of the structural units and analysing the trend of facility failures; both will lead to taking timely actions to ensure the uninterrupted production process. Based on the problems identified and on the analysis of the causes, and following the generation of a sufficient amount of data, a risk assessment report can be produced for upcoming periods of time. Unfortunately, the experience of other authors can not be referred to since the conditions in every specific enterprise are individual and non-characteristic.

After a new plant has been constructed and commissioned, it is supposed to function flawlessly during the first years and no repairs are expected to be needed. Each plant like this has a specific structure and the adjoining facilities have a different operating period that depends on the construction and the functions they perform. In the course of the operation, each waste treatment facility is subjected to mechanical and physico-chemical peak loads.

Major structural units in a waste treatment plant

Non-hazardous waste landfill. The landfill is divided into two functional areas: first waste disposal area and a second waste pre-treatment area that incorporates a plant for mechanical and biological treatment. The block diagram of the non-hazardous waste landfill is presented in Figure 1.

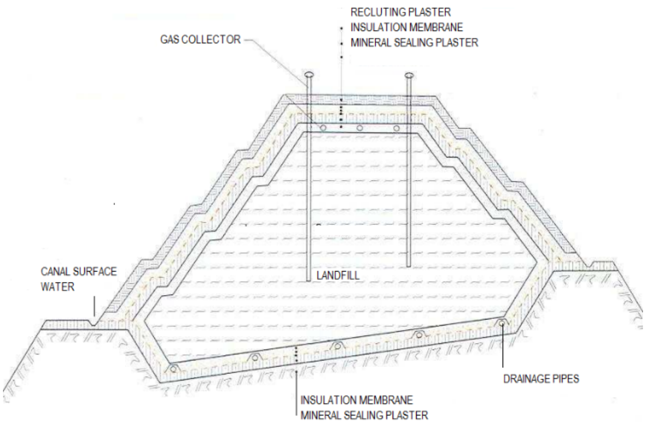

Fig. 1. Structure of the non-hazardous waste landfill

The landfill is constructed with an insulating screen at the bottom - to protect the soil and groundwater; collection and treatment of the infiltrate in a waste water treatment plant (WWTP) - to protect groundwater from pollution; biogas management - to prevent uncontrolled emissions into the atmosphere; placing wastes in cells - for operational control and reducing rainwater penetration; waste compacting - to limit pest access, to reduce the risk of fire, and to help stabilise the body of the landfill; daily and intermediate covering; final sealing.

Plant for mechanical and biological treatment (MBT) of wastes with the production of RDF fuel

The plant for mechanical and biological treatment is adjacent to a non-hazardous waste landfill. The plant processes household waste (except for the bio waste and the green waste that are collected separately). The process of mechanical and biological treatment includes the following steps: mechanical/manual separation and sorting, biological treatment of organic waste, and the production of refuse derived fuel (RDF)l. The origin of waste is: domestic waste (waste from households) and waste generated by shops, warehouses, offices, and factories (industrial waste). The MBT facility consists of:

• Classification line for recyclable materials separated from specific suitable waste streams, such as paper, cardboard, plastics and metals.

• An RDF generating plant where high-calory fractions of bio-waste (some sorts of paper, cardboard, and mostly plastic) are released in the form of RDF. RDF is mainly released after drying the waste to a certain extent. Bio-waste drying is carried out as a combination of the stages of biological drying and thermal drying. The duration and the combination of processes take a minimum of 6 weeks, depending on the requirements posed to the products.

The article studies the individual processing units in a waste management plant. Each of these is analysed in terms of the problems that have arisen. The technology in the plant is given in the diagram in Fig. 2.

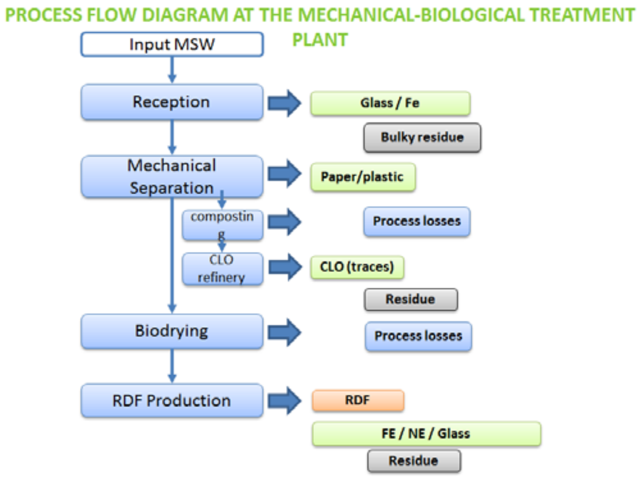

Fig. 2. Flowchart of the waste management process

The malfunction analysis involves exploring the causes of their occurrence. As a summary of the various problems, we offer the following groups:
- technological problems;
- constructive;
- building;
- mechanical - erosion, friction, pressure, vibration;
- chemical - corrosion;
- electrical;
- the human factor.

Monitoring and inspection

Monitoring and inspection provide evidence for the work performed in accordance with the adopted criteria. Concurrently, it allows for improvements to be made. Two types of inspection are possible to use - active and reactive monitoring (Brouwer, 1998). Based on the active monitoring, the risk for the system is predicted, feedback is provided related to the process management, and malfunctions are avoided. Reactive monitoring includes a “post-failure” record, reviews, repair incidents, and other evidences of the lack of adequate management. When managing a waste treatment plant, it is necessary to ensure the efficient operation of the facilities. For the prevention of emergency situations, it is appropriate to apply active monitoring, which will determine the subsequent accumulation of a significant database. The subsequent analysis will result in the outlining of appropriate management policies and measures that aim at achieving the safety of both the installation and, as a leading requirement, the staff .

Technological problems / causes

The major problems in the plant are related to the project morphology of the waste, which differs from that of the currently incoming waste in the plant. Namely, the waste is of a higher humidity (up to 45% higher) and of a higher percentage of sand, dust, soil, building materials, and other inert materials. Over the heating period, an increased content of cinder and ash is observed, by up to 9%. The high content of dust, ash, and inert materials brings about clogging of the moving floors and heavier dust-loading in the buildings.

Trommel screening with a diameter of 200 mm is technologically inappropriate, since a significant proportion of PET bottles and other plastic materials that are of high cost if recycled fall out. Those do not go through manual separation; instead, they pass directly into the cells for bio-drying, which makes them impossible to be the objects of the recycling process, thus the recycling targets are not achieved. In bio-drying, there are 26 cells operating on a 7-day technological period of drying. Upon completion, the dried waste has a humidity of up to 20%. There is a tendency for a steady rise in humidity to 32-33%, with cells where humidity soars to 36-37%. This t is indicative of the fact that the technological scheme and the software do not allow for the waste to be dried in compliance with the requirements of the contracting authority. Adding to the problems of the heavy dust-loading, the poor performance of the taps, and the high incidences of cell fan failures, there is a clear indication as to the connectivity among electrical, mechanical and technological problems. The insufficiently dried material goes to the RDF (waste fuel) building. Excessive humidity and the high content of non-combustible inert materials in the incoming material lead to the wear of the vibration screens, the tear of the elastic membranes, congestion of the densitometric tables, blocking-up of other technological sieves. All of these result in ceasing of the operation of the production area for a long period of time in order to recover the electrical and mechanical systems.

Structural problems / reasons

In the present case, by a structural problem, we mean the design of the plant's processing lines. The RDF plant is designed after the model of enterprises with a similar object abroad. A special feature in this case is the presence of a sloping terrain that the designers have not taken into consideration because the processing line of the material goes from a lower to a higher point. This is related to the raising and movement of large masses of materials (recyclable raw materials), which is associated with economic losses. On the one hand, the introduction of engines and equipment for the lifting of these raw materials is required, and on the other hand, a huge amount of electricity is used for their operation. The economic effect would greater be if the production line moved from a higher to a lower level, whereby the materials would move by their own mass.

The manual classification lines are mounted at a higher level which poses difficulties for the workers and, similarly, makes attendance of the entire belt difficult. It is necessary to adjust the height of the floor from the manual sorting position. Another problem that violates the ergonomics of the working environment is the poor sealing of the windows in the control room, as a result of which polluted air from the hall penetrates into the manual sorting area.

We have also established the lack of shutters that open easily for access to various service premises. Besides, there are no rubber muffs on the ears through which the lighting cables pass and no railings along the bio-basins. To a large extent, these deficiencies incur risks for the employees of the enterprise. It is also imperative to put warning notices and information boards in Bulgarian.

Building problems

During the erection of the building, the contractor has overlooked some mistakes made, e.g. the concrete flooring around an expansion joint (between the concrete flooring and the asphalt pavement) at the exit from the mechanical and biological treatment plant was damaged; the cover of the W&S manhole in front of the electric substation 110/20 kV did not close tightly; there were no restrictive lines; the pavement around the transformer building was unfinished; newly formed cracks in the reinforced concrete pavement around switchboards were visible; the flooring in the pedestrian areas was missing or unfinished. All these problems have been resolved after a signal from the responsible bodies at the plant. In connection with the poor quality of the building work or with the fact that it was incomplete, the conclusion can be drawn that a number of rules and regulations related to the safety technique were violated, such as ORDINANCE № 5 of 21st May 2001, ORDINANCE № 8121z – 647 of the 1st October 2014, ORDINANCE № RD-07/8 of 20th December 2008, technical safety measures of the Safety and Health Regulations for the Operation of Eelectrical Equipment with Voltages of up to 1000V of 2014, requirements for safe use and operation of buildings, etc.

Mechanical problems

Mechanical problems have been found in all the buildings of the enterprise. Due to the poorly executed project in the reception building, material falls out on either side of the moving floor with a separating drum. This leads to the clogging of the bunker under the dosing drum. Cleaning itself is very labor-consuming and requires the participation of several workers. When belt conveyors were designed, no side guards and canvases were provided which is considered to be a disadvantage since part of the material falls out. A possible solution to the problem is to place a device to collect the pieces and take them aside. Due to the established structural peculiarities and the presence of raw materials to be processed that are heavier than the technologically set, a problem appears in various facilities mostly related to the leakages of oil in the following: the compressors; the chain conveyor with a de-compacting block where oozing of oil out of the gear box is seen; the feeding conveyor to the baling press. Overheating of some items of equipment has also been registered (for instance, the front bearing of the sleeve filter fan motor from the reception area gets excessively heated).

Another purely mechanical problem is the high level of dust in the RDF-production building which is the result of non-efficient operation of the dedusting system in the building. This poses considerable risks for the formation of explosive air-dust mixtures. The problem can be solved with the implementation of more powerful fans.

Also, non-efficient separation of glass from fraction 30-60 mm has been established which necessitates the installation of a separator functioning along a different principle.

Corrosion problems

Corrosion of the metal and concrete surfaces is a registered problem and at present the corrosion processes of the various facilities are monitored. The reasons are: the ill-painted protective coating on the metal elements and damages inflicted on them, the heavy mechanical loads they sustain, and, most of all, the aggressive environment

On the territory of the infiltrated water treatment plant, the most serious corrosion damage is the initiated corrosion of the drainage pipes. As a result of the analysis, it was established that a failure can occur due only to the advancement of corrosion processes, but not due to mechanical stress. The installed plant facilities are also subject to corrosion due to evaporation of infiltrated waters. With these facilities, faults can also occur due to mechanical reasons - friction of moving parts, erosion of the deposition of solids in the fluid, fluid pressure at the pumps. After analysing the infiltrated water and of the atmosphere around the equipment, it may be generalised that the causes of the corrosion are: the corrosive action of the agents in the environment (ammonium nitrogen (NH4-N), organic carbon, sulfates, chloride and oxygen), depolarisers from the air, temperature amplitudes due to seasonal changes, and an atmosphere rich in chlorine ions. These factors create conditions for accelerating the processes of oxidation and for the occurrence of oxide covering layer with weak protective properties that disintegrates under the action of chlorine ions. Consequently, uniform corrosion and pitting corrosion occur, and, due to the presence of anaerobic bacteria, microbiological corrosion is also possible.

To prevent the processes leading to failures, the following measures are recommended: the choice of a material suitable for the construction of the facilities and the pipes, the construction of protective gearboxes, placing the appropriate insulating coatings of the pipes, surface treatment of the equipment.

For facilities subjected to atmospheric corrosion, the suitable alloying elements are Sn, Cu, Ni, and some rare earth elements. Nitrogenation (doping with nitrogen) is suitable only for these facilities because it prevents the development of cracks. For the pipes, the recommended alloying elements are Cr, Si, Ni, and Mo or the so-called chromium-nickel steels or chromium-nickel-molybdenum steels. For all facilities on the territory of the WWTP, it is necessary to use a material with fine-grained structure, e.g. austenitic steel, and to avoid martensite (coarse-grained) structures. The following brands of steel can be recommended: 10H14G14N4T, 10H14AG15, and 07H13AG20 which are substitutes for steel type H18N10T in environments with relatively low aggressiveness.

Various laser and ultrasonic techniques are used to treat the pipe surfaces. Those lead to the removal of local dislocations, the hardening of materials, and the like. For example, laser decontamination or pre-treatment at high temperature or under high pressure contributes to the stability of the micro-grained structure of the steel, and in this case is recommended for both equipment and pipes. The formation of a passive layer under the influence of dynamic polarisation between hydrogen and oxygen, the exposure to UV light, or electropolishing, results in reduced development of local destruction. The materials used are argon, sodium nitrate or phosphate.

As a lining material for the walls of new pipes, in view of the composition of the corrosive environment, polystyrene, fiberglass, epoxy polymers, laminated fabric, silicone rubber, rubber with inhibiting substances in its composition, etc. are offered. As the facilities are operative and their premature replacement is economically unprofitable, in order to extend their operating life, it is recommended to cover them with boxes equipped with blowing fans. The same materials that were listed for pipe insulations, without the rubber, can be used for the boxes.

The use of an inhibitor in this case is inappropriate. On the one hand, there is a large flow of water along the tubes, and the inhibitors can only act in a limited volume. In addition, there are anaerobically active bacteria in the pipes that can also be affected, with the resulting negative effect produced on the production process. Devices operating in the workshop and above it can be treated with the compound 0.5 mM $SnCl_2$ (Kamimura, 2012), but there are chlorine ions in the medium, and further research is needed to determine the concentration and its effectiveness.

All these recommendations can be carried out after replacing the facilities. At this stage, the main tools for process control and for failure prevention remain the continuous inspection and the additional processing. Running facilities can be laser-cleaned: laser melting (LSM), laser alloying, or laser annealing. Laser Peening (Hackel, Rankin) is suitable for the processing of blades, fans, motors, and other moving parts, thus the risk of crack formation will be diminished. With respect to friction, laser transformation hardening needs to be carried out with moving parts for improving the wear resistance (Brown, 2010). Laser beating (Peyre, 2000) increases resistance to pitting corrosion that is obvious in all units in the shop.

Another important measure is building of additional monitoring systems. For this purpose, sensors operating on a resistive principle were installed in the infiltration tube section and the SBRs section to monitor the corrosion growth. The sensors measure levels of 1 mm, 2 mm, 4 mm, and 5 mm (Stefanov, Hristova, 2009). The material for making the sensors and the measured thicknesses are consistent with the material and thickness of the tubes. At present, corrosion growth has been reported in bio-basins and in SBRs, and none the infiltrated water section. Ultrasonic measurement is another suitable method for the non-destructive tracking of corrosion damage and cracks in the depth of the monitored objects. The level of corrosion in the equipment and in the pipes was inspected by means of the OLYMPUS company ultrasound thickness gauge 45 MG. The model provides options for recording previous measurements.

Electrical problems and such associated with the controlling and measurement equipment and automation

At the reception building, failures of the SCADA system for controlling and measurement equipment and automation are more serious. The system does not take into account the data from the scale integrators. There is a problem with their setup as the instruction is incomplete. For the time being, it is recommended to train the staff for: working with the software for setting-up the integrators, and monitoring for disconnected electrical cables that might lead to possible failures.

In the mechanical separation building, part of the material falls out of the2nd rotary drum and under the floor. The problem is not mechanical, but is also related to the SCADA system. It is recommended to change the settings of the SCADA automatic system for the performance of the feeding conveyor in such a manner that the sieve is not overfilled. Naturally, a change of setting in the system for controlling and measurement equipment and automation goes with the requirement for new data. For instance, in the mechanical separation building, this necessitates the installation of a sensor that monitors the level of feeding the containers with recyclable materials.

Problems have been identified that are due to poor connection between electrical wires, or a problem in the software of the SCADA control system: e.g. there is no visualisation of the electric power in Transformer substation 1, Transformer substation 3, and Transformer substation 4 in electrical sub-station 110/20 kV.

Because of unfinished or incomplete setup of the SCADA control system, other serious problems have been identified as well. Some of them are as follows:

- in the reception building, some of the integrators are not connected to the SCADA system;
- in the reception building and in the bio-drying building, the unfinished adjustment of the SCADA control system causes problems to the function of the Valtorta bridge cranes, with all consequences for the operation of the above in automatic mode; besides, the Valtorta command console system is not translated into the Bulgarian language, thus hindering staff operation;
- in the reception building, communication errors between the entrance weighbridge and the SCADA system have been registered that impose manual operation; this leads to delays in the technological process;
- in the mechanical separation building, no information in SCADA is available as to the feeding of the reception bunker;
- in the mechanical separation building, upon starting the process line, the shredder indicates an error;
- in the mechanical separation building, the information is not entered in MOTION SCADA; troubles in the whole system have been established;
- in the biological drying building, the information from MOTION SCADA does not read the real periods of time set by the operator, thus restricting the opportunities to check the quantities of incoming and outgoing material to/from the building;
- when changing the direction of the belt conveyor (reversible) that feeds ferrous metals to two containers, the SCADA system makes it possible to change the direction only from container 2 to container 1, but not from container 1 to container 2.
- in the biological drying building, while the crane operates in manual mode, it is not possible to record the quantity of the material that is being fed to the cells and from the cells to the movable floors;
- in the RDF-production building, interruptions are frequent due to activation of the overload protection of the belt conveyor; the problem may as well be mechanical because of the heavier material;
- there is a problem with the automatic switching and adjustment of the belt conveyor (collective for PVC); a new control system for the engine revolutions is needed.

There are also a number of problems that result from sensor malfunctioning. For example, in the bio-drying building, the water level sensor in the tub of the cooling tower is mounted but does not work properly. Baling presses cause incessant interruptions of the technological process due to problems with the sensors for the waste level in the bunkers, as well as to problems with the devices for the wire tightening. To solve these problems, calibration of the sensors measuring various indicators is advisable to be carried out and the required documents to be presented by the manufacturing company.

Problems have been identified that relate to the presence of higher current and voltage harmonics, as well as to losses in transformers. Variable active filters to suppress harmonics are installed to improve network characteristics, as well as a variable anti-resonant harmonic filter. Those are connected in parallel to the respective modules and are controlled by a controller. Theoretically, when introducing them, electrical energy savings should be reported, along with an increase in the reserve and the power capacity charge of the electrical installation, and hence a reduction in maintenance costs. In practice, however, the realisation of the estimated benefits has not been proven.

To achieve an efficient and fault-free process, it is necessary to install such automation tools as:

- emergency stop buttons on the magnetic separators;
- an emergency stop button for the movable floors in the reception hall; this might speed up the operators' reaction in an emergency situation (e.g. if waste that has is not intended for the mechanical and biological treatment (MBT) plant falls on the movable floor.

It can be seen that the major problems are related to the automatic control system that does not always work properly. A conclusion can be drawn that the problems found are three - interrupted cables, sensors that are out of order, or inappropriate SCADA settings. Therefore, it is necessary to introduce wireless data transmission.

Problems associated with the human factor

A complete documentation is provided to change the settings of the control system. It is imperative that the personnel who handle the individual modules be well-trained to work properly with the software that is currently causing problems. Inscriptions in the Bulgarian language should be placed on for various objects. Besides, clear criteria for career prospects must be introduced that will bring about self-training initiatives.

This, in turn, will optimise the process of working with the SCADA system.

To sum up:

Only after the problems have been classified is it possible to take differential measures to solve them. It is clear that constructive features can not be changed. What matters in this case is that this problem should be taken into account by constructors when building similar plants on other premises. Construction waste and unfinished objects have been removed. Mechanical problems are caused by the larger mass of the processed waste. Those can gradually be resolved by replacing the driving equipment. For the time being, each separate engine requires inspection by a specialist who can offer adequate solutions.

Problems related to the automation system are the result of the waste morphology and of the presence of mechanical problems. To fix them, it is necessary to change the settings in accordance with the power of the drive equipment and the quality of the waste processed. Because of the distributed structure of the enterprise, a modular system for measurement and control is appropriate. Modules in all workshops must be compatible with the overall system and be capable of wireless data transmission. According to the significance of the measured value, data can be transmitted on a continuous basis, once a day, or when a value has been measured whose magnitude deviates from the standard value. Continuous data submission is required for all engines, pumps, and dispensers. With corrosion monitoring, switching on is only necessary when deviation has been measured.

Conclusion

It can be concluded that the problems in the enterprise are caused by the incorrect design of the facilities, the morphology of the waste generated by the respective region, and the lack of well-trained staff. This also generates the deficiencies in the automatic control system and brings about machine failures. The measures recommended are prompted by the expertise of the specialiststhat has been gained as a result of the inspections carried out and measurements made. The human factor, supported by an adequate monitoring system, is essential for the prevention of malfunctions. In this manner, unnecessary repairs are avoided and the outcome is a better economic result. No risk assessment has been performed which is due to the lack of accumulated data on the failures of the various facilities and systems. In order to achieve the quality of management of the production process and to reduce the risk of malfunctions, after accumulating data about accidents and subsequent repairs, the reliability theory can be applied for each site on the premises of the enterprise.

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