PRODUCTION TECHNOLOGIES OF DISINFECTANT AGENTS AND CLEANING PRODUCTS

RESEARCH PROJECT

CHEMICAL ENGINEERING

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1 ABSTRACT

Disinfecting agents have become very popular today due to the worldwide pandemic of COVID-19. In this final degree project, a study has been carried out on the different disinfectants for bacteria and fungi, but especially for viruses with a crown. Specifically, disinfectants based on potassium hydroxide (KOH) and sodium hydroxide (NaOH), having thoroughly analyzed the elements used, the methods, the technologies and the regulations that these disinfection elements must follow.

An example of the final product from a local company in Bydgoszcz, Poland is also shown. Emphasis has been placed on the regulations to be followed for these disinfecting agents due to the events that occur to us, since precautions must be taken, and these measures must be increased without exception so that the current situation worldwide does nothing but improve.

Keywords: disinfecting agents, production technologies, regulations for disinfecting agents, disinfectants based on sodium hydroxide, disinfectant based on potassium hydroxide.

RESUMEN

Los agentes desinfectantes han alcanzado gran notoriedad en la actualidad debido a la pandemia mundial sufrida a causa del COVID-19. En el presente trabajo de fin de grado se ha realizado un estudio a cerca de los diferentes desinfectantes tanto para bacterias y hongos, pero en especial para los virus con corona. Concretamente desinfectantes en base de hidróxido potásico (KOH) e hidróxido de sodio (NaOH), habiéndose analizado exhaustivamente los elementos utilizados, los métodos, las tecnologías y las normativas que deben seguir estos elementos de desinfección. También se muestra un ejemplo del producto final de una empresa local de Bydgoszcz, Polonia.

Se ha hecho hincapié en la normativa a seguir para dichos agentes desinfectantes con motivo de los hechos que nos acontecen, ya que se deben extremar las precauciones y aumentar dichas medidas sin excepción alguna para que la situación actual a nivel mundial no haga más que mejorar.

Palabras clave: agentes desinfectantes, tecnologías de producción, normativa de agentes desinfectantes, desinfectantes en base de hidróxido de sodio, desinfectante en base de hidróxido de potasio.

STRESZCZENIE

Środki dezynfekujące zyskały strategiczną ważność dla zdrowia i bezpieczeństwa ludzi ze względu na ogólnoświatową pandemię COVID-19. W ramach tego projektu dyplomowego przeanalizowano różne środki dezynfekujące bakteriobójcze i grzybobójcze, szczególną uwagę kładąc na wirusobójcze, przeciw koronowirusom. Skoncentrowano się na środkach dezynfekujących, powstających na bazie wodorotlenku potasu (KOH) i wodorotlenku sodu (NaOH), po dokładnej analizie możliwych do zastosowania reagentów w technologii wytwarzania mydeł, samych metod, technologii i przepisów, którym podlegają te środki dezynfekcji. Przedstawiono przykładowe produkty końcowe otrzymywane w lokalnej firmie w Bydgoszczy, w Polsce.

Szczególną uwagę zwrócono na przepisy, których należy przestrzegać w odniesieniu do środków dezynfekujących ze względu na światową pandemię, ponieważ należy podjąć środki ostrożności i ich przestrzegać, aby obecna sytuacja na świecie nie pogorszyła się.

Słowa kluczowe: środki dezynfekujące, technologie produkcji, przepisy dotyczące środków dezynfekujących, środki dezynfekujące na bazie wodorotlenku sodu, środki dezynfekujące na bazie wodorotlenku potasu.

2 INTRODUCTION

With the pandemic due to the Wuhan coronavirus outbreak that affects everyone, the importance of disinfecting agents to share or minimize its expansion has increased, even more so. The world health organization, WHO, recommends the use of these to avoid contagion, among other guidelines to follow. If these recommendations had been followed from the beginning, the current situation would probably not have been reached, especially in countries such as Italy and Spain. That is why, as citizens, we must be aware of the seriousness of the situation and make use of these disinfectants to prevent the pandemic from advancing so quickly.

The recommendations of the World Health Organization (WHO) include keeping the distance between people and avoiding crowds, washing hands frequently and avoiding touching the eyes, nose and mouth, since the hands touch surfaces that may be contaminated.

Viruses do not consider themselves organisms, because they need the cell of another living being to survive. When they enter the cell of an animal or a human being, they multiply and spread the infection throughout their body.

Although it seems a complex procedure, viruses have a very simple structure: a nucleus of genetic material that allows it to multiply, external proteins that allow it to hook onto the cells of the living being that it infects, and a protective fat envelope.

This is where soap comes in: its molecules can dissolve the fat membrane and affect the structure of the virus, which loses its ability to attach to and infect other cells.

3 THEORETICAL FRAMEWORK

Procedures and substances intended to reduce or eliminate infectious agents and contaminants have been in use for a long time. Pasteur and Koch laid the scientific foundations in the fight against microorganisms, but it was Scottish physician Lister who revolutionized surgery by advocating cleaning, antisepsis and disinfection techniques [1]. He advised the use of phenol (carbolic acid) for skin antisepsis (2.5%) and the instrumentation used (5%); It can be said, then, that Lister laid the foundations for what would later be defined as *sterilization*.

Antiseptics are substances used in living tissues, which prevent or impede the growth or action of microorganisms by inhibiting their activity or by destroying them.
Disinfectants are antimicrobial agents that are used only on inanimate objects or inert media. For the FDA (Food and Drug Administration), disinfectants are "chemical substances capable of destroying germs deposited on inert material in 10 or 15 minutes; they should alter the substrate on which they act as little as possible. It is desirable that they destroy all forms vegetative bacteria, as well as fungi and viruses." [2].
Alcohols (ethyl and isopropyl) are organic compounds in water, historically used in medicine as antiseptics for wound cleaning and disinfection. In addition to their antimicrobial activity, they are a good solvent for other products, such as many antiseptics and disinfectants, that enhance such activity. Commonly used alcohols are ethyl alcohol or ethanol and isopropyl alcohol. Concentrations vary between 70 and 96% for the first and between 70 and 100% for the second [3]. Although their applications are identical, ethanol is usually used as it is the least irritating. Alcohols act by destroying the cell membrane, by reducing its surface tension, and denaturing proteins. Its efficacy is based on the presence of water, since it thus penetrates cells and bacteria better, allowing damage to the membrane and rapid denaturation of proteins, with the consequent interference with metabolism and cell lysis. Its action is fast, even from 15 sec, mainly in concentrations of 70%, which allows its best penetration into the bacterial protoplasm. Its biological effects of microbial damage are mostly brief, but can remain for several hours [3].

There is no antimicrobial chemical agent that is the "best" for each and every case, given the diversity of circumstances in which these agents can be used and the composition of the microbial cells on which they act. If the ideal microbial agent existed, it should have the properties detailed below [4]:

1. Antimicrobial activity even when is diluted.
2. Broad spectrum of action on gram-positive and gram-negative bacteria, acid-alcohol resistant bacteria, viruses and fungi.
3. Being a microbicide better than a microbiostat and causing the death of microorganisms gradually and in a short period of time (not exceeding 15min).
4. Be stable for a few months in your commercial preparation and be active.
5. Staying stable in the presence of organic matter.
6. Have a uniform homogenization in the diluent, was it water or alcohol, so that the active product has the same concentration in all its mass.

7. Its activity should occur as a reference in aqueous solutions, which will better penetrate exudates, pus, blood, etc., where there could be microorganisms.
8. Present a low surface tension for easy penetration.
9. Be compatible with other products that could be used before or simultaneously.
10. Not be toxic to human tissues. That it did not require the use of gloves or the immediate washing of living surfaces with which it had come into contact.
11. Not be corrosive to metals, wood, painted surfaces, etc., that is, it will not alter objects.
12. That its organoleptic properties were pleasant.
13. Should not fade tissues or surfaces.
14. It should not lose activity due to temperature or pH.

Table 3-1 Selective and non-selective antimicrobial chemical agents [4]

Compounds	*Scope*	*Use*
Antiseptics	Inhibits or kills microorganisms	Skin and mucosa
Disinfectants	Generally kills	Inanimate objects (toxicity)
Conservatives or Preservers	Prevents decomposition or putrefaction	Organic products (food)
Chemotherapy (medications)	Inhibits or kills	Systemic or local (living things)

It should be borne in mind that not only microorganisms and the chemical agent (disinfectant) participate in the disinfection process, but factors that affect their activity also intervene:

1. The type of microbial or infectious agent
2. Contact time
3. The death curve of the infectious agent
4. Temperature
5. Concentration
6. pH
7. Formulation or preparation time
8. The interference of substances in the environment that act as a barrier.

The virucidal action is not so defined. Iodine, chlorine, glutaraldehyde, and formaldehyde appear to be the most active agents for viruses. Organic solvents, such as chloroform and ether, are sometimes used to inactivate enveloped viruses. As for their sensitivity, naked viruses are less sensitive to chemical agents.

Alcohols are water soluble chemical compounds whose germicidal characteristics are often underestimated. These compounds usually act as rapid bactericides on vegetative forms of bacteria; they are fungicidal and virucidal but do not destroy bacterial spores. Their activity decreases markedly when diluted below 50%. Another drawback is that they evaporate quickly but adding another gel (Aloe Vera) prevents immediate evaporation.

The mechanism of action consists of protein denaturation by inhibiting the production of essential metabolites. This action is carried out in the presence of water and this explains why 70º alcohol is more effective than 95º [3].

Table 3-2 Qualities of alcohols

Advantage	*Disadvantage*
Low cost (ethanol)	Flammable
Low corrosive action	Evaporate quickly
Useful as vehicles for other chemical agents	Dehydrating agents
Leave no toxic residue	Harden plastics and rubbers

Methodologies for evaluating the virucidal efficacy of disinfectants exist internationally in the form of published guidelines and standards, although these differ dramatically. Among these methodologies, the two predominant methods for evaluating the virucidal efficacy of disinfectants are suspension and carrier tests. Suspension tests evaluate the virus as a liquid inoculum, while carrier tests evaluate the virus inoculated on various surfaces.

To better understand the approach of existing international guidelines or standards on virus disinfection, it is important to understand some of the differences between groups of viruses with regard to their reaction to chemical disinfection. Viruses are divided into several subgroups with respect to their resistance to disinfectants (*Table 3-3*), depending on the presence or absence of an envelope and the size of the virus particle. According to the Klein and Deforest [5] scheme for dividing viral groups, the least resistant to disinfectants are enveloped viruses (i.e. influenza, coronavirus), category A; those with moderate resistance are large, non-enveloped viruses (i.e. adenoviruses), category C; and those with the highest resistance are the small non-enveloped viruses (i.e. picornaviruses, parvoviruses), category B. Categories A and C are the least resistant, and disinfectants such as hypochlorite, alkalis, oxidizing agents, alcohols and aldehydes are very effective in relatively short contact times [6]. Category B viruses are the most resistant viruses and great care must be taken to ensure complete inactivation.

Table 3-3 Summary of National and International Virucidal Efficacy Standards

Agency/Organization	Test Tittle	Summary	Reference
US EPA	Efficacy Data Requirements: Virucides	Can be conducted as a suspension or surface test, minimum 10^4 test titer, must consider cytotoxicity	http://www.epa.gov [7]
ASTM	E1052-96 Efficacy of Antimicrobial Agents Against Viruses in Suspension	Method for evaluating efficacy of disinfectants against specific viruses in liquid suspension designed for cell culture host systems. Includes cell culture control, virus control, virucidal test, cytotoxicity control, and neutralization control.	http://www.astm.org [8]
ASTM	E1053-97 Efficacy of Virucidal Agents Intended for Inanimate Environmental Surfaces	Method for evaluating disinfectants as liquid, aerosol, or trigger spray on inanimate surfaces. Includes a cell culture control, virus control, virucidal test,	http://www.astm.org [8]

		cytotoxicity control, and a neutralization control.	
ASTM	E1482-04 Neutralization of Virucidal Agents in Virucidal Efficacy Evaluations	Method utilizes a gel filtration technology to separate the treated virus from the test disinfectant following the desired exposure duration.	http://www.astm.org [8]
ASTM	E2197-02 Standard Quantitative Disk Carrier Test Method for Determining the Bactericidal, Virucidal, Fungicidal, Mycobactericidal and Sporicidal Activities of Liquid Chemical Germicides	Method for evaluation liquid disinfectants for efficacy against various microbial targets in the presence of a soil load on disk carriers representing environmental surfaces or medical devices. Test viruses include Human adenovirus, hepatitis A, Canine parvovirus, human rhinovirus, and human rotavirus.	http://www.astm.org [8]
AFNOR	Association Francaise de Normalisation	Evaluates disinfectants at 2x concentration mixed to an	http://www.afnor.fr [9]

		equal volume of test virus (Polio 1*, Adenovirus, Vaccinia). Organic challenge is not used, and virus is recovered by host culture following dilution and washing to remove cytotoxicity. Efficacy claim must result in at least a 4 log_{10} reduction.	
DVV	Deutshe Verinigung zür Bekämpfung der Viruskrankheiten	Evaluates disinfectants at final use concentration and includes challenge with BSA or FCS (0.2-10%) against test virus (Polio 1*, Adenovirus, Vaccinia, SV40). Virus is recovered by host culture following dilution to remove cytotoxicity. Efficacy claim must result in at least a 4 log_{10} reduction.	Guidelines of Bundesgesundheit - samt [10]

Inactivation of a virus can be accomplished by degradation or disruption of the lipid envelope (if present), structural proteins such as capsid or surface receptors, and nucleic acid (DNA or RNA) [11]; or by all of them, depending on the chemistry of the disinfectant.
Several groups of chemical disinfectants have been shown to have virucidal activity. The classes of chemical disinfectants include the following groups: acids, alkalis, alcohols, surfactants, phenols, and oxidizing agents. The relative effectiveness of disinfectants depends on whether the target virus is involved or not.

In the acids group acetic acid is a common disinfectant that is effective against acid-sensitive organisms, probably due to the undissociated molecule, H^+ [12]. Citric acid [13] is described as a chelating agent that permeabilizes the outer membrane of lipophilic bacteria [14] and is likely to have virucidal activity against lipophilic (enveloped) viruses. Citric acid is frequently recommended for decontamination of clothing personnel and material [15]. Lactic acid is not as efficient as a liquid disinfectant, but it has been shown to be effective as an air disinfectant [12]. Peracetic acid (PAA) is rapidly becoming a popular disinfectant among the class of peroxygen disinfectants. This is a real action oxidizing agent that has been shown to be highly effective against bacteria, viruses, molds, yeasts, and bacterial spores [13, 14]. This compound is active at relatively low concentrations, remains effective in the presence of organic material, and can be deployed as a liquid or vapor. It is speculated that the active ingredient in PAA is the generation of organic radicals like CH_3CO_2 or CH_3CO, which have shown a greater longevity than the hydroxyl radical [16].

Regarding alkalis, the hydroxyl ion (OH^-) inhibits or kills most bacteria and viruses when the pH is greater than nine. Alkalis are effective against all organisms with the exception of non-enveloped viruses and bacterial spores. Sodium hydroxide (NaOH) is an alkali with strong disinfecting properties, unless aluminum is present [13]. Due to the high pH of this compound, it is quite caustic for the eyes, skin and mucous membranes [13] and must be handled with care and with the appropriate protective equipment. NaOH is very economical and highly effective against viral targets in the presence of organic material. Sodium carbonate (Na_2CO_3) is another alkaline disinfectant that is caustic to the eyes and skin and should also be handled with care. This disinfectant is described as highly effective, even in the presence of organic material [13,15]. Similarly, Na_2CO_3 is also relatively low cost.

Alcohols at 70% ethanol concentration, most enveloped viruses are easily inactivated, even in the presence of serum or other organic challenge. Unenveloped viruses, on the other hand, are very resistant to inactivation by it. The mechanism of inactivation by alcohol occurs by denaturing the protein structure and inducing conformational changes; however, the effects depend on the concentration [17].

As for oxidizing agents, the compounds of sodium hypochlorite (household bleach) and N-chlorine (organic chlorine) are oxidizing agents and are frequently used for disinfection. These are known for their wide range of applicability, low cost, and low toxicity to humans, but are nonetheless irritating and corrosive to

metals [13]. The stability of chlorine solutions depends on: concentration, presence of catalysts / reducing agents, pH, temperature, organic material and ultraviolet radiation [18]. Organic loading and pH reduce the effectiveness of chlorine disinfectants. The optimal pH range for hypochlorite disinfectants is a pH value of 6-9.
The mechanism of action of chlorine-based compounds begins with the dissociation of hypochlorous acid from chlorine in solution. Dissociated hypochlorous acid has been speculated to interact with cell membranes by altering metabolic processes, denaturing proteins and forming toxic complexes [18]. These compounds have also been shown to oxidize thiol groups of cysteine residues that are important in structuring protein determinants [17]. Chlorine disinfectants are affected by factors including pH, organic material, and light [19]. Chlorine is a corrosive disinfectant [19] and can lead to the production of disinfection by-products (DBP) including chloroform, bromodichloromethane, dibromochloromethane, and bromoform [18].
Hydrogen peroxide, another oxidizing agent, generates free hydroxyl radicals that can break down DNA and RNA structures [12]. Free hydroxyl radicals have been described as the strongest known oxidants and can attack membrane lipids, DNA and other essential cellular components [16]. These compounds have also been shown to oxidize thiol groups of cysteine residues that are important as structural determinants of proteins that in viruses likely cause disruption of the virus capsid structure [17]. The use of hydrogen peroxide has few environmental side effects, as it breaks down into oxygen and water [14].

Phenols bind to amino acid residues of cytoplasmic and membrane proteins that cause enzyme inhibition, membrane damage, and denaturation of cytoplasmic proteins [12, 20]. Phenols are highly toxic, have a strong odor, and are irritating to the skin and eyes [13]. This group of disinfectants is effective against a wide variety of bacteria and is often used as fungicides in the paper and cardboard industries. This group is not used in food processing. These groups of disinfectants are outdated and are not used as often in current disinfection practices, they are not very effective against viruses without envelopes [21]. Phenol has occupied a prominent place in the field of hospital disinfection since its initial use as a germicide by Lister in his pioneering work in antiseptic surgery, but in recent years more attention has been focused on derivatives of phenol and phenolic. Such derivatives originate when a functional group (e.g., alkyl, phenyl, benzyl, halogen) replaces one of the hydrogen atoms in the aromatic ring. The phenol derivatives most commonly found as components of hospital disinfectants are *ortho*-phenylphenol and *ortho*-benzyl-*para*-chlorophenol. Phenolics are absorbed by porous materials, and the residual disinfectant can irritate the tissue.

Many environmental factors, such as temperature, humidity, pH, and organic load, can have a major impact on the efficacy of disinfectants against viruses [6, 11, 19, 22-24]. Higher temperatures can increase the speed of the chemical reaction, but very high temperatures can affect the stability of the disinfecting agent. Low temperatures slow down chemical reactions, and very low temperatures can freeze liquid disinfectants. Reaction pH has the greatest impact on acid and alkaline based disinfectants. These disinfectants require specific pH ranges, acidic pH for acid-based disinfectants, and basic for alkaline compounds.

Chemical disinfectants have their own inherent stability properties, and the life of the disinfectant product can also be a major problem.

Coronaviruses belong to the family of RNA (ribonucleic acid) viruses. They are called coronaviruses because the viral particle shows a characteristic "corona" of specular proteins around the lipid envelope. This wrap makes them relatively sensitive to drying, heat, and alcoholic detergents or chlorinated disinfectants, which remove lipids and inactivate the virus.

In the available studies, a very high speed has been detected with the use of common disinfectants such as: hydrogen peroxide (hydrogen peroxide), alcohols, sodium hypochlorite or benzalkonium chloride, which are the sensors to inactivate the virus after five minutes of contact.

Alkaline agents, such as sodium or ammonium hydroxide, sodium carbonate, or calcium oxide, work by saponifying lipids within the envelopes of the microorganisms. The activity of the alkaline compounds is slow but can be increased by raising the temperature. Alkalis have good microbicidal properties but are highly corrosive agents and personal protection precautions must be observed. Sodium hydroxide (lye, caustic soda, soda ash) is a strong alkali used to disinfect buildings but is highly caustic. Protective clothing, rubber gloves, and safety glasses should be worn when mixing and applying the chemical. In early times, lye was obtained by leaching wood ash in water. The early product probably contained some potassium hydroxide (potash) and other contaminants found in impure soda ash. Pure sodium hydroxide is now commercially available in most countries, as it is commonly used in the chemical and paper industries, and as a septic line cleaner. Laboratory experiments show that 0.1 M sodium hydroxide is sufficient to inactivate the murine leukemia virus, a commonly used enveloped model virus [25]. More recently, Q-One Biotech Ltd. has released its data on the ability of sodium hydroxide to inactivate eight different viruses. Both 0.1M and 0.5M sodium hydroxide was tested and inactivation kinetics were reported (Table 3-4). It is worth noting that even highly resistant enveloped viruses, such as canine parvovirus and SV-40, were inactivated by sodium hydroxide. Furthermore, Creutzfeldt-Jakob disease (CJD) and its link to bovine spongiform encephalopathy (BSE) have raised new concerns about adventitious agents. Sodium hydroxide has been shown to be effective in inactivating the BSE agent, which is otherwise remarkably resistant to most treatments, including incineration at 360 °C for one hour [26, 27].

Table 3-4The inactivation of eight different viruses in 0.1 M and 0.5 M sodium hydroxide (italicized titer values indicate that no virus was detected in the sample and the values listed are theoretical minimum detectable titers)*

		HIV	BVDV	CPV	BHV	POL	SV-40	MLV	ADV
0.1M NaOH	Spike	$2.0*10^{6}$	$9.5*10^{6}$	$2.0*10^{9}$	$6.9*10^{9}$	$7.1*10^{8}$	$1.7*10^{8}$	$2.6*10^{5}$	$2.2*10^{8}$
	t=0min	$5.9*10^{2}$	$2.7*10^{7}$	$1.9*10^{3}$	$1.2*10^{2}$	$3.5*10^{4}$	$1.5*10^{5}$	$3.7*10^{1}$	$1.7*10^{2}$
	t=10min	$5.7*10^{2}$	$2.7*10^{5}$	$2.4*10^{3}$	$1.5*10^{1}$	$2.7*10^{3}$	$3.6*10^{5}$	$3.8*10^{1}$	$6.0*10^{1}$
	t=20min	$5.8*10^{2}$	$1.5*10^{4}$	$9.6*10^{2}$	$4.5*10^{1}$	$2.0*10^{4}$	$4.7*10^{4}$	$4.0*10^{1}$	$6.3*10^{1}$
	t=60min	$5.8*10^{2}$	$2.7*10^{4}$	$5.0*10^{3}$	$4.5*10^{1}$	$2.1*10^{3}$	$2.0*10^{4}$	$4.3*10^{1}$	$2.9*10^{1}$

	Inactivation (log_{10})	> 3.5	2.5	5.6	8.2	5.5	3.9	> 3.8	> 6.9
0.5M NaOH	Spike	$2.0*10^6$	$9.5*10^6$	$2.0*10^9$	$6.9*10^9$	$7.1*10^8$	$1.7*10^8$	$2.6*10^5$	$2.2*10^8$
	t=0min	$5.7*10^2$	$1.9*10^4$	$9.4*10^2$	$5.9*10^1$	$1.1*10^5$	$1.5*10^5$	$6.3*10^1$	$9.4*10^1$
	t=10min	$5.6*10^2$	$1.3*10^2$	$1.2*10^3$	$5.9*10^1$	$1.1*10^5$	$1.7*10^3$	$4.7*10^1$	$7.5*10^1$
	t=20min	$5.7*10^2$	$1.7*10^2$	$1.5*10^3$	$5.9*10^1$	$2.0*10^4$	$8.4*10^3$	$4.7*10^1$	$2.0*10^1$
	t=60min	$6.7*10^2$	$1.7*10^2$	$1.5*10^3$	$5.9*10^1$	$6.2*10^3$	$1.0*10^2$	$5.5*10^1$	$2.2*10^1$
	Inactivation (log_{10})	> 3.5	> 4.7	6.1	> 8.1	5.1	6.2	> 3.7	> 7.0

Where: Virus titers expressed in tissue culture infective dose ($TCID_{50}$) units for all viruses except BHV and MLV, which are expressed in plaque forming units (pfu).

Potassium hydroxide (KOH) and sodium hydroxide (NaOH) are alkali metal hydroxides. In the manufacture of soaps, both potassium hydroxide and sodium hydroxide are used in saponification, a process that turns fats into soap, and both are FDA approved as a thickening and stabilizing agent in processed foods.

Despite their similarities, there are some uses where you can't exchange one for the other. Potassium hydroxide is used as an electrolyte in alkaline batteries. Meanwhile, sodium hydroxide is used in water purification.
But to better understand when to choose one or the other, you must understand the similarities and differences between these alkali metals.

Sodium hydroxide and potassium hydroxide are very strong and corrosive bases. Both are formed by ionically bonding an alkali metal to a hydroxide group. Of all the compounds belonging to the hydroxide group, these are the most chemically similar. Their great chemical similarity allows them to easily replace each other in a number of uses. Also, their chemical reactions are remarkably similar. Because potassium hydroxide and sodium hydroxide are strong bases, they react to water releasing heat, so both are highly exothermic. Its chemical similarity also coincides with its physical similarity. In solid form, both are white powder or flakes. When dissolved, each can be used as an aqueous solution.

Although these compounds are very similar, they are fundamentally different. Potassium and sodium each contribute a different number of protons. Sodium supplies 11 protons, while potassium donates 19. Likewise, the metal in sodium hydroxide is lighter than that of potassium hydroxide. This contributes to their very different atomic weights of 39,997 g/mol and 56,106 g/mol respectively.

But their differences actually start at the molecular level. Potassium hydroxide is somewhat smaller than sodium hydroxide, which means it cuts through oil molecules faster than sodium hydroxide. This makes potassium hydroxide an excellent choice for soaps that need to remove caked oil [27].

Their reactions are also slightly different. Both sodium hydroxide and potassium hydroxide release heat when they react with water. But the chemical composition of potassium hydroxide creates slightly less heat than sodium hydroxide when exposed to water.

Due to production costs, potassium hydroxide is generally more expensive than sodium hydroxide. Sodium hydroxide is produced with sodium chloride, also known as table salt. While potassium chloride, a more expensive compound, is used to produce potassium hydroxide [28].

4 PRODUCTION TECHNOLOGIES

For industrial soap production there are five essential steps:

Saponification

Soap washing or glycerol extraction

Fitting

Moulding

Drying

Although in some hard soaps, the steps can be classified into seven:

- Getting the right mixture of oil/fat and alkali, called “proving”.
- “Boiling down” – removing the unwanted water, and checking for “doneness”.
- Treating with salt to remove water, impurities, and glycerin a process called ‘graining’ this step makes a good solid soap for washing clothes.
- Adding coloring agents (colorants) and perfumes.
- Pouring into moulds, called “setting”.
- Breaking the “green” soap out of the mould and splitting it into finished sizes.
- Drying and airing the “green” soap.

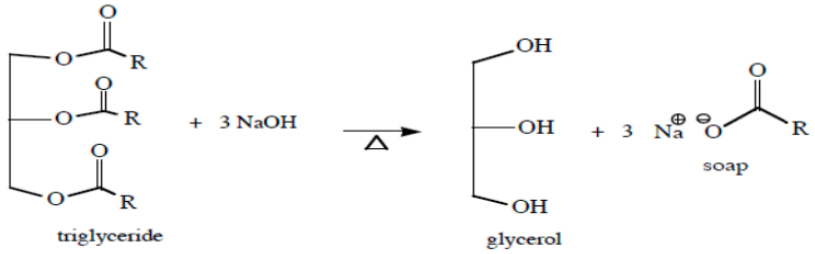


Figure 1-Saponification reaction. R is the long chain of carbon and hydrogen atoms

$$C_3H_5(OOCR)_3 + 3\ NaOH \rightarrow 3\ NaOOCR + C_3H_5OH \quad (1)$$

Or

$$C_3H_5(OOCR)_3 + 3\ KOH \rightarrow 3\ KOOCR + C_3H_5OH \quad (2)$$

Commercially, the fat is sourced from tallow, lard, palm oil, palm kernel oil. coconut oil, murine oil. etc. Potassium hydroxide is obtained from electrolysis of potassium chloride using a mercury cathodic cell. Sodium hydroxide is obtained from a similar electrolytic decomposition of sodium chloride [29].

In saponification reactions, the esters are divided into alcohols and carboxylic acid salts (
Figure 1). It could be said that the general reaction of triacylglycerol saponification occurs in two steps. The first is hydrolysis of the ester linkages to produce glycerol and three fatty acid molecules: Fat or oil + 3 H_2O → 3 fatty acids + glycerol. The second step involves a reaction between the fatty acid molecules and the base (usually NaOH) in the alkaline solution. This is an acid-base reaction that produces water plus salts: 3 fatty acids + 3 NaOH → 3 fatty acid salts + 3 H_2O.

For cold soap production, initially 200 g/dm^3 of NaOH solution is poured directly into the stainless-steel container containing the fat and oil in the ratio 1:1 (v/v). The fats/oil are then heated slightly and poured into the pot to make soap, followed by the alkaline solution to form an intimate mixture, and then shake frequently for 10 to 15 minutes with a wooden stirrer. Perfume and other ingredients can be added as additives before pouring the saponification mixture into the molds. After pouring, the soap is allowed to harden by air drying for 24 h to obtain the bars of soap (solid soap).

In molding and cutting the melted soap is poured into a molded mold so that it "sets" and hardens. Sometimes the soap is "broken" from the mold and "divided" with the wires to obtain the required sizes. Soaps are cut with a cutting machine that can be made locally in different designs and sizes.

In the stamping process a special seal (either electric or manual) and trademarks are used on the products (soap products).

In the drying process, the soap is normally moistened. Drying is required to reduce this soap water content to a carefully defined and controlled level, especially for bath soap bars. Control moisture containing soap will generally produce, after further processing, a stick of the required appearance. This cannot be accomplished until the soap has been ventilated for a required time or up to approximately 1 month for dry, hard soap that takes longer to consume.

Packaging is the use of special materials to package products for the market. The products are finally packed in cardboard boxes. Wrapping these soaps in nice paper or clean polyethylene can greatly increase their sales value and this cost associated with the packaging material is a major factor in the cost of production. The cost of packaging could be high for consumer products. Therefore, it is always important for a soap producer to calculate the cost of its packaging to account for its operating expenses that have a major impact on the sales premium and profit or gain.

Any soap making industry being it large or small scale should have documented information on safety categories and record keeping. The following parameters are some of the important references used.

Material Safety Data Sheets (MSDS) are a reference that contains relevant information related to the following safety categories for specific material:

manufacturer or seller information, chemical composition, hazards and possible health effects, first aid measures, firefighting measures, spill measures, handling and storage, exposure and protection, physical and chemical properties, stability and reactivity, toxicological information, environmental information, disposal considerations, transport information and regulatory information. MSDSs are generally available through the chemical manufacturer, a commercial source, or a private library developed by the chemical plant. The industrial hygienist or safety professional should interpret the physical and toxicological properties to determine the hazards associated with a chemical. These properties are also used to develop a strategy for proper control and handling of these chemicals [30].

A safe workplace means having ingredients properly labeled and stored, maintaining a clean, tidy, well-lit, and well-ventilated work area for making soap restricting the access of not qualified personal to storage and work areas, having easy access to personal protective equipment: a telephone, a fire extinguisher, and running water.

The batch code is a numbered record of each batch of soap. The batch code sheet lists the manufacturing company, the name of the soap factory(s), the date of manufacture, the ingredients, the weight numbers, any variations from the normal soap manufacturing procedure, the cure date or "do not use before" date, expiration date and any additional comments.

Also, a list of measures to improve the quality of soaps could be mentioning, such as the use of glycerin. The presence of various OH polar groups strongly attracts it to water, a feature that makes glycerin useful as a skin softener in products such as lotions, cosmetics, shaving creams, and liquid soaps. Also, the use of sequestrants. Many manufacturers use chelating molecules in their commercial soap products, EDTA derivatives are often used to help bind with any calcium or magnesium free ion to prevent soap suds (a process called sequestration). These also help reduce fragrance loss, discoloration, and rancidity. Control of the pH of the soap is necessary not only to improve the quality of the soaps, but also to regulate the pH level that will not contribute to the hardness of the hands and skin. In order to protect public health, high pH levels in the range of 9 to 11 or low levels in the range of 3 to 5 are considered harmful to the skin, with the optimal pH being 5.5-6. This is in accordance with NAFDAC (*National Agency for Food and Drug Administration and Control*) regulatory requirements for cosmetics, soaps, and detergents [31]. The use of silicates, such as sodium silicate [$Na_4(SiO_4)$], is an example of a large family of silicates that is used commercially in detergents, where it maintains a constant pH and can degrade fats by hydrolysis [32]. Sodium metasilicate is a basic salt used in detergent, partly as a basic buffer and also to prevent dirt from depositing back on the fabric [33]. SiO_3^{2-} ions are attached to dirt particles, which gives the particles a negative charge and thus prevents them from merging with each other into larger, more insoluble particles. When the soap last melts before you pour it into molds, it can be colored and scented. It is preferable not to do this earlier during the method, as the bleach water could damage the perfume or the coloration. And, finally, to determine the industrial value of a particular oil or fat that depends on the composition and purity, a series of chemical tests are carried out to have a quality control on the

fats and oils used as raw materials for the production of soaps, whose parameters are:

1) Saponification value;
2) Iodine value;
3) Acid value.

The manufacture of soap took place in the saponification reaction stage to obtain a neat soap. 2172ml of the ashed plantain peel extract containing 28.5g potassium hydroxide was concentrated to 50% KOH by heating and evaporation in a saponification pot (reactor). The amount of KOH in the extract was calculated from the equation:

$$V_{KOH} = \frac{FW_{KOH} \cdot M_{KOH} \cdot V_{ex}}{100ml}$$

V_{KOH}= Amount of KOH in a given volume of extract
FW_{KOH}= Formula weight of KOH
M_{KOH}= molarity of KOH
V_{ex}= Volume of extract ml

Thus, assuming as a first approximation that all the extract is KOH; then for 2172ml, amount of KOH in the extract is 28.5g of KOH.

If the extract is assumed however to comprise 82% KOH and 16% NaOH and no other alkalis (Table4-1), then the ratio by weight of the two alkalis is 84:16 KOH to NaOH.

Table4-1 Percentage Composition Of Metals In The Plantain Peel Ash Extract

METAL	CONCENTRATION (ppm)	% COMPOSITION
K	126.1	81.98
Na	24.4	15.86
Ca	1.04	0.68
Mg	N.D*	-
Al	N.D	-
Zn	0.33	0.21
Fe	0.07	0.05
Pd	0.79	0.51
Cu	N.D	-
Ag	N.D	-
Cr	0.18	0.12
B	0.50	0.33
Ni	0.41	0.27
TOTAL	153.82	100.0

**n.d. not detectable.*

If W_2 is the weight of KOH and W_3 is the weight of NaOH in the same 2172ml of extract, then,

$$W_2 + W_3 = W_1$$

$$\frac{W_2}{W_3} = \frac{84}{16} = 5.25$$

Also,

$$\frac{W_2}{57} + \frac{W_3}{40} = \frac{W_1}{Formula\ wt\ of\ combined\ alkali}$$

$$\frac{5.25W_3}{57} + \frac{W_3}{40} = \frac{6.25W_3}{Formula\ wt\ of\ combined\ alkali}$$

From equation the above formula weight of combined alkali is 53.37g/gmoles; and the amount of combined alkali in the extract is 26.7g.

The higher value has been retained in this work because in soap making a slight excess of alkali is usually recommended in order to ensure that all the fat is saponified and also because of the antibacterial effect of alkalis [34]. The concentrated extract was heated to 80ºC and 134.3g of bleached oil blend (the amount of oil blend that completely saponified 28.5g of the potassium hydroxide; as determined by the saponification value of the oil blend) was gradually charged into the pot. The temperature was maintained at 80ºC and 5ml of distilled water was added intermittently while the mixture was continuously stirred.

Saponification continued until the solution become creamy. This took approximately forty minutes. About 50ml of sodium chloride brine was charged into the saponification pot and the soap was completely homogenized and maintained at the temperature of 70ºC for 30 minutes. The crude soap mass was separated by allowing the pot and its contents to cool. The soap formed a cake on the surface of the pot while lye (solution of glycerol and brine) was below. The lye was removed by piercing the soap mass and pouring out the solution, this is the salting out process. Thereafter the soap was fitted by heating it to 90ºC with the addition of 5ml of the distilled water and maintaining the temperature for twenty minutes. The saponification pot and its contents were then put in an oven and maintaining at 90ºC for 30 hours. The essence was to wash off excess brine, lye and nigre (partially formed soap). The neat soap, which separated out on the surface, was cooled and removed.

The reactor where the saponification is carried out is a discontinuous reactor. This type of reactor is characteristic of liquid phase reactions. It is a stirred tank reactor so that it can be assumed that the mixture is perfect, and therefore, the concentration and temperature are uniform throughout the contents of the tank. In most cases, the operation consists of introducing the reagents into the container and increasing the temperature to the desired level (through the outer jacket) so that the reaction occurs.

Given that it is a small-scale production and that the total volume in each production charge is 2,172L, a 5L stirred tank batch reactor will be taken as a reference. The reactor measurements are shown in the following Table 4-2:

Table 4-2 Reactor measurements

Reactor measurements	
Product volume in each load, L	2,172
Internal volume of the reactor, L	5
Radio, m	0.056
Height, m	0.5
Reactor jacket width, m	0.01
Total radius of the reactor, m	0.066
Total height of the reactor, m	0.6
Total reactor volume	8.21

Figure 2 Continuous stirred tank reactor where saponification occurs

The plans for said reactor are shown in the Reactor plans.

Regarding the final product, two soaps produced in Bydgoszcz by the Polish company *Stara Mydlarnia* [45] are shown below. This company is local to Bydgoszcz and the soaps attached below are respectively sodium hydroxide (Figure 3) and potassium hydroxide (Figure 4).

Figure 3 Sodium Hydroxide Soap

Figure 4 Potassium Hydroxide Soap

5 LEGAL FRAMEWORK FOR THE USE OF DISINFECTANTS IN THE CONTEXT OF THE COVID-19 PANDEMIC

The current COVID-19 pandemic that is being suffered worldwide caused by the SARS-CoV-2 coronavirus, has caused a strong increase in the demand for products, technologies and procedures for the decontamination of all types of surfaces and environments related to the presence of people: hospitals, industries, means of transport, work centers, etc.

From different health authorities, headed by the Ministry of Health of all affected countries, emergency procedures and exemptions to the placing on the market of raw materials and disinfectant products have been enabled. This has been done in order to respond to this demand and to facilitate access to these types of products to the professionals who need them most, mainly hospitals and health care establishments, as well as other sectors considered critical, such as the food industries. The measures taken to facilitate the availability of disinfectant products do not imply the free commercialization of products by any supplier, but rather have the additional objective of ensuring that the new products placed on the market meet the same technical and efficacy requirements that are usually required.

For this reason, this publication aims to summarize the legal requirements that both existing disinfectants and new products that are placed on the market on an exceptional basis must continue to meet to cope with the COVID-19 pandemic and companies that manufacture or supply them.

GENERAL APPLICATION REGULATIONS FOR BIOCIDAL PRODUCTS

Biocidal products are regulated by Regulation (EU) No. 528/2012 (Biocidal Products Regulation, BPR), which defines the active substances authorized for use in biocidal products and the requirements for the authorization of such products. These active substances are gradually being authorized and, for those biocides based on active substances that are not yet authorized by the Regulation, the current regulations in each country apply. In the case of Spain, this is Royal Decree 3349/83 [35]. All biocidal products marketed in Spain must be authorized according to this regulation. Likewise, the companies that manufacture or store biocidal products must be duly authorized according to the type of biocides that they commercialize [36]:

- TP1: Biocides for human hygiene.
- TP2: Disinfectants and algaecides not intended for direct application to people or animals.
- TP3: Biocidas para la higiene veterinaria.

- TP4: Disinfectants for equipment, containers, utensils and surfaces that are in contact with food and feed.
- TP5: Disinfectants used in the disinfection of drinking water.

Thus, hand sanitizers are within the TP1 group, and must be authorized by the Ministry of Health (biocides included in BPR) or the Spanish Agency of Medicines and Health Products (AEMPS), in the case of biocides not yet included in BPR. Disinfectants used in food industries belong to group TP4, regulated by the Ministry of Health, while disinfectants used in other types of facilities (hospitals, offices, textiles, etc.) belong to group TP2, also called environmental use and are regulated by the Ministry of Health except in the case of products for the hospital environment, competence of the AEMPS.

To authorize the placing on the market of disinfectants, there are a series of requirements that these must meet regarding their physico-chemical and toxicological properties and, in particular, their biocidal efficacy against different microorganisms. To demonstrate biocidal efficacy, products must pass tests according to different EN standards, depending on the type of biocide. In general, surface or hand disinfectant products must demonstrate, at least, bactericidal and levuricidal efficacy (with some exceptions), being optional for product authorization to demonstrate fungicidal efficacy and against other microorganisms such as viruses, spores, mycobacteria, etc.

Currently there are no biocidal products tested against SARS-CoV-2. There are different sources of information that allow us to guarantee the effectiveness of a certain formulated against this virus:

- Virucidal efficacy tests according to the EN14476 standard, against encapsulated viruses (Vaccinia) or against the viruses required by the standard (general virucidal activity).
- Recommendations of health authorities, such as the Ministry of Health [37] or the European Center for Disease Prevention and Control [38].
- Information available in the scientific literature on the activity of different substances against coronavirus [39].

Additionally, there are a series of legal requirements for manufacturers or marketers of disinfectants and for suppliers of biocidal active substances that are used in disinfectants. In the case of manufacturers of TP2 biocides (except for healthcare), TP3 and TP4, they must be registered in the corresponding Official Registry of Biocidal Establishments and Services [40]. In the case of manufacturers or marketers of hand sanitizers (biocides PT1) and biocides TP2 for the health field, they must have authorization for the manufacture or storage of these products, for which they require a series of technical requirements in the facilities (clean room) and controls in the production process and finished product.

For the manufacture of disinfectants, only biocidal active substances contemplated by the Biocidal Products Regulation can be used. Article 95 of the BPR contains a list of the suppliers that have defended the active substances

according to the Regulation and, therefore, the active substances that can be used in the manufacture of biocides on European territory [41].

In summary, the products that are put on the market for the purpose of disinfection or elimination of microorganisms must:

- Be authorized by the competent body and within the group corresponding to its use.
- Be manufactured by companies that have all the relevant authorizations, such as the registration in the ROESB for surface disinfectants and the activity license for personal hygiene products.
- Contain active substances identified in the Regulation of Biocidal Products and obtained through authorized suppliers (Article 95 List).

ADDITIONAL MEASURES TAKEN IN SPAIN

The recent exceptional measures adopted in Spain by the Ministry of Health make the terms for some of these procedures more flexible and shorter, but they do not imply a relaxation of the technical or regulatory requirements. These measures are the following:

- Application of Article 55.1 of the Biocidal Products Regulation, which allows the authorization of new suppliers of the active substances propan-1-ol and propan-2-ol for product types 1, 2 and 4 [42], quaternary ammoniums for product types 2 and 4 [43] and sodium hypochlorite for product types 2 and 4 [44]. These new suppliers are additional to those identified in the list of Article 95 of the Biocidal Products Regulation and must ensure the technical quality of the substances produced, previously informing the Ministry of Health.
- Temporary authorization of the use of bioethanol for the manufacture of surface disinfectants (TP2). It allows this substance to be used for ethanol-based and previously registered products.
- Temporary authorization of new TP1 products (hand sanitizers), issued by the AEMPS, with a duration of 3 months and for products based on ethanol and destined for the healthcare field. These products must be manufactured in a manufacturing license facility for that product and must be documented with AEMPS prior to authorization.

In conclusion, there is a broad regulatory framework applicable to products with biocidal properties, the manufacturers and marketers of such products, and the manufacturers and suppliers of the active substances they contain. This regulation aims to ensure the technical quality and effectiveness of these products, so that users have complete confidence in their use and performance. In the current pandemic situation due to COVID-19, exceptional measures have been taken to facilitate the availability of disinfectants, but always maintaining the legal requirements for products, manufacturers and suppliers that ensure their quality.

Lastly, it should be noted that the implementation of procedures for the decontamination of SARS-CoV-2 on surfaces is not exclusive of carrying out the usual cleaning and disinfection tasks, especially in the food industry. The hygiene procedures in the food industries, within its HACCP plan, must be designed for the elimination of contaminants that can affect the quality and safety of food and, among them, microorganisms such as viruses.

6 CONCLUSION

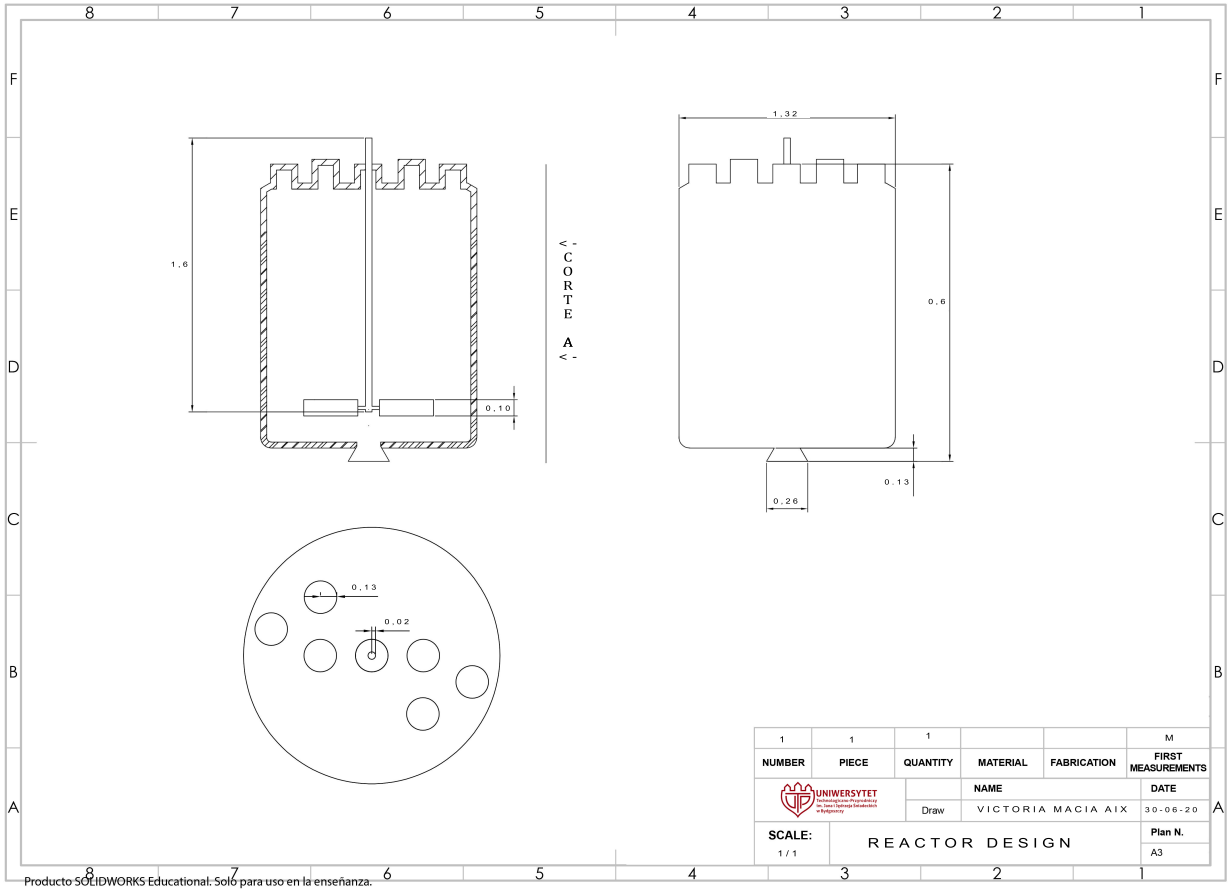
Soap has been produced that meets the standards for alkali potassium-based soaps derived from banana ash. The soap is suitable for uses previously listed for potassium-based soaps. Recent estimates show that substantial amounts of KOH can be obtained from ash from plant matter. In particular, plant matter presents a potentially viable material resource that, if not properly used, could actually harm the environment. Therefore, it is recommended that potassium hydroxide and sodium hydroxide produced from ash from plant matter be used to replace important ones in soap production. The soap made from alkali derived from the banana peels reported in this work was milky hydroxide alkaline soap and pure sodium hydroxide alkaline soap, made as controls, using the same mixture of bleached palm oil and palm kernel oil.

Discontinuous reactors often give problems at an industrial level, so it is advisable to be updated with control technologies such as pH, temperature and pressure sensors.

The benefits of a cheap and readily available alkali source for a cash-strapped development firm like the described production are truly enormous. Efficient designs in the operations of the soap manufacturing process units, as well as in the saponification reaction stage, show excellent results. And finally, the importance of the regulations that govern such production must be taken into account, especially in these times when there is a global pandemic due to COVID-19.

7 ANNEX

7.1 Reactor plans



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