SUMMARY OF PRODUCT CHARACTERISTICS
1. **NAME OF THE MEDICINAL PRODUCT**

   Linezolid 600 mg Tablets

2. **QUALITATIVE AND QUANTITATIVE COMPOSITION**

   Each tablet contains 600 mg linezolid.
   Each tablet contains 139.6 mg of lactose monohydrate.
   For a full list of excipients see 6.1

3. **PHARMACEUTICAL FORM**

   White to off white, oval shaped, bevel edged, biconvex film coated tablets debossed with 'H' on one side with score line and 'L' and '8' separated by a score line on the other side.
   The tablets can be divided into equal halves.

4.1 **Therapeutic indications**

   Linezolid 600 mg Tablets is indicated in combination with other anti tuberculosis agents for the treatment of tuberculosis caused by *Mycobacterium tuberculosis* in adults and adolescents weighing ≥30 kg.
   Linezolid 600 mg Tablets is only indicated as a second-line antimycobacterial drug when use of first-line drugs is not appropriate due to resistance or intolerance (see sections 4.2, 4.4 and 5.1).
   Consideration should be given to official treatment guidelines for tuberculosis, e.g. those of WHO: [http://www.who.int/tb/MDRTBguidelines2016.pdf](http://www.who.int/tb/MDRTBguidelines2016.pdf)

4.2 **Posology and method of administration**

   **Posology**

   **Adults and adolescents aged 12 years and older and weighing ≥30 kg**
   The dose of Linezolid 600 mg Tablets is one 600 mg tablet once daily. The dose may be reduced to 400-300 mg/day if serious adverse effects develop (see sections 4.4 and 4.8).

   **Special populations**

   **Elderly**
   No dose adjustment is required (see section 5.2).

   **Renal Impairment**
   No dose adjustment is required, including in patients with severe renal impairment (CL\(_{\text{CR}}\) < 30 ml/min) (see sections 4.4 and 5.2). Due to the unknown clinical significance of higher exposure (up to 10 fold) to the two primary metabolites of linezolid in patients with severe renal insufficiency, linezolid should be used with special caution in these patients and only when the anticipated benefit is considered to outweigh the theoretical risk.
   As approximately 30% of a linezolid dose is removed during 3 hours of haemodialysis, linezolid should be given after dialysis in patients receiving such treatment. The primary metabolites of linezolid are removed to some extent by haemodialysis, but the concentrations of these metabolites are still very considerably higher following dialysis than those observed in patients with normal renal

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1 Trade names are not prequalified by WHO. This is the national medicines regulatory authority’s (NMRA) responsibility. Throughout this WHOPAR the proprietary name is given as an example only.
function or mild to moderate renal insufficiency. Linezolid should, therefore, be used with special caution in patients with severe renal insufficiency who are undergoing dialysis and only when the anticipated benefit is considered to outweigh the theoretical risk.

To date, there is no experience of linezolid administration to patients undergoing continuous ambulatory peritoneal dialysis (CAPD) or alternative treatments for renal failure (other than haemodialysis).

**Hepatic impairment**
Limited clinical data are available in patients with hepatic impairment. Linezolid should, therefore, be administered with caution to patients with liver dysfunction and only be used in such patients when the anticipated benefit is considered to outweigh the theoretical risk (see sections 4.4 and 5.2).

**Paediatric population**
Reduction in fertility of males was observed in animal studies (see sections 4.4, 4.6 and 5.3). The potential risk of reduced male fertility should be taken into account when treating adolescents.

Linezolid 600 mg Tablets is not recommended for use in children below the age of 12 years and with a body weight <30 kg. The recommended dose is 10 mg/kg, three times daily, which cannot be achieved with this formulation.

**Method of administration**
The recommended dose should be administered orally. Linezolid 600 mg Tablets may be taken with food or between meals.

### 4.3 Contraindications
Hypersensitivity to the active substance or to any of the excipients (see section 6.1).

Unless there are facilities available for close observation and monitoring of blood pressure, linezolid should not be administered to patients with the following underlying clinical conditions or on the following types of concomitant medications:

- Patients with uncontrolled hypertension, phaeochromocytoma, carcinoid, thyrotoxicosis, bipolar depression, schizoaffective disorder, acute confusional states.
- Patients taking pethidine, pseudoephedrine and phenylpropanolamine (see section 4.5).

Linezolid is contraindicated in women who are breastfeeding (see section 4.6).

### 4.4 Special warnings and special precautions for use
_Given the potentially serious adverse effects of linezolid – particularly anaemia, thrombocytopenia, lactic acidosis, peripheral neuropathy and optic neuropathy - the decision to use linezolid must balance its risks and benefits and the availability of other TB medicines. Due to the potential for severe and life threatening adverse events, close monitoring is strongly advised. Where this is not possible, linezolid is best reserved for MDR-TB patients who have additional drug resistance, or XDR-TB, or who are intolerant to other components of the core regimen._

**Myelosuppression**

Myelosuppression (including anaemia, leucopenia, pancytopenia and thrombocytopenia) has been reported in patients receiving linezolid. This can be severe and life threatening. These adverse effects were on some occasions reversible with lowering the dose of drug (usually from 600 mg daily to
300 mg daily). Haematologic toxicities are less common with current strategies of once-daily dosing. In cases where the outcome is known, when linezolid was discontinued, the affected haematologic parameters have risen toward pretreatment levels. The risk of these effects appears to be related to the duration of treatment. Elderly patients treated with linezolid may be at greater risk of experiencing blood dyscrasias than younger patients. Thrombocytopenia may occur more commonly in patients with severe renal insufficiency, whether or not on dialysis. Close monitoring of complete blood counts (including haemoglobin levels, platelets, and total and differentiated leucocyte counts) is recommended in patients who receive linezolid. This is even more important in patients who have pre-existing anaemia, granulocytopenia or thrombocytopenia; are receiving concomitant medications that may decrease haemoglobin levels, depress blood counts or adversely affect platelet count or function; or have severe renal insufficiency.

If significant myelosuppression occurs during linezolid therapy, treatment should be stopped unless it is considered absolutely necessary to continue therapy, in which case intensive monitoring of blood counts and appropriate management strategies should be implemented.

Post marketing reports and compassionate use studies showed a higher incidence of serious anaemia in patients receiving linezolid for longer than 28 days. These patients more often required blood transfusion.

Cases of sideroblastic anaemia have been reported post-marketing. Where time of onset was known, most patients had received linezolid therapy for more than 28 days. Most patients fully or partially recovered following discontinuation of linezolid with or without treatment for their anaemia.

**Lactic acidosis**

Lactic acidosis has been reported with the use of linezolid. Patients who develop signs and symptoms of metabolic acidosis including recurrent nausea or vomiting, abdominal pain, a low bicarbonate level, or hyperventilation while receiving linezolid should receive immediate medical attention. If lactic acidosis occurs, the benefits of continued use of linezolid should be weighed against the potential risks.

**Antibiotic-associated diarrhoea and colitis**

Antibiotic-associated diarrhoea and antibiotic-associated colitis, including pseudomembranous colitis and *Clostridium difficile*-associated diarrhoea, has been reported in association with the use of linezolid and may range in severity from mild diarrhoea to fatal colitis. Therefore, it is important to consider this diagnosis in patients who develop serious diarrhoea during or after the use of linezolid. If antibiotic-associated diarrhoea or antibiotic-associated colitis is suspected or confirmed, ongoing treatment with antibacterial agents, including linezolid, should be discontinued and adequate therapeutic measures should be initiated immediately. Drugs inhibiting peristalsis are contraindicated in this situation.

**Mitochondrial dysfunction**

Linezolid inhibits mitochondrial protein synthesis. Adverse events, such as lactic acidosis, anaemia and neuropathy (optic and peripheral), may occur as a result of this inhibition; these events are more common when the drug is used longer than 28 days.

**Serotonin syndrome**

There have been spontaneous reports of serotonin syndrome associated with the co-administration of linezolid and serotonergic agents, including antidepressants such as selective serotonin reuptake
inhibitors (SSRIs) (see section 4.5). Therefore, linezolid and serotonergic agents, such as serotonin re-uptake inhibitors, tricyclic antidepressants, serotonin 5-HT\textsubscript{1} receptor agonists (triptans), should not usually be co-administered, except where administration of linezolid and concomitant serotonergic agents is essential. In those cases patients should be closely observed for signs and symptoms of serotonin syndrome such as cognitive dysfunction, hyperpyrexia, hyperreflexia and incoordination. If signs or symptoms occur physicians should consider discontinuing either one or both agents; if the concomitant serotonergic agent is withdrawn, discontinuation symptoms can occur.

**Peripheral and optic neuropathy**

Peripheral neuropathy, as well as optic neuropathy and optic neuritis, sometimes progressing to loss of vision, have been reported in patients treated with linezolid; these reports have primarily been in patients treated for longer than 28 days. Peripheral neuropathy may or may not improve with cessation of drug. The outcome of optic neuropathy upon cessation of linezolid is less clear, and should be treated as a medical emergency.

If possible, patients’ visual function should be regularly monitored. Ophthalmologic examination should include tests for black-white/chromatic visual acuity (e.g. Sellen eye chart and 65-test) and ophthalmoscopy and should be repeated for any suspicion of change in acuity or colour vision. All patients should be advised to report symptoms of visual impairment, such as changes in visual acuity, changes in colour vision, blurred vision, or visual field defect. In such cases, prompt evaluation is recommended with referral to an ophthalmologist as necessary.

If peripheral or optic neuropathy occurs, the continued use of linezolid should be weighed against the potential risks.

**Convulsions**

Convulsions have been reported to occur in patients when treated with linezolid. In most of these cases, a history of seizures or risk factors for seizures was reported. Patients should be advised to inform their healthcare providers if they have a history of seizures.

**Monoamine oxidase inhibitors**

Linezolid is a reversible, non-selective inhibitor of monoamine oxidase (MAOI); however, at the doses used for antibacterial therapy, it does not exert an anti-depressive effect. There are very limited data from drug interaction studies and on the safety of linezolid when administered to patients with underlying conditions and/or on concomitant medications (e.g. phenelzine, isocarboxazid, selegiline, moclobemide) which might put them at risk from MAO inhibition. Therefore, linezolid should not be used in these circumstances unless close observation and monitoring is possible (see section 4.5).

**Use with tyramine-rich foods**

Patients should be advised against consuming large amounts of tyramine-rich foods (see section 4.5).

**Superinfection**

The effects of linezolid therapy on normal flora have not been evaluated in clinical trials.

The use of antibiotics may occasionally result in an overgrowth of non-susceptible organisms. For example, approximately 3% of patients receiving the recommended linezolid doses experienced drug-related candidiasis during clinical trials. Should superinfection occur during therapy, appropriate measures should be taken.
Special populations

Linezolid should be used with special caution in patients with severe renal insufficiency and only when the anticipated benefit is considered to outweigh the theoretical risk (see sections 4.2 and 5.2).

It is recommended that linezolid should be given to patients with severe hepatic insufficiency only when the perceived benefit outweighs the theoretical risk (see sections 4.2 and 5.2).

Impairment of fertility

Linezolid reversibly decreased fertility and induced abnormal sperm morphology in male rats at exposure levels approximately equal to those expected in humans; possible effects of linezolid on the human male reproductive system are not known (see sections 4.2, 4.6 and 5.3).

Potential interactions producing elevation of blood pressure

Linezolid can enhance increases in blood pressure caused by drugs with a vasopressive action (see section 4.5). Linezolid and drugs with vasopressive action should, therefore, not be co-administered, except when concomitant use of these drugs is essential.

Excipients

Each tablet contains 139.6 mg of lactose monohydrate. Patients with rare hereditary problems of galactose intolerance, the lapp lactase deficiency or glucose-galactose malabsorption may experience symptoms of intolerances.

4.5 Interaction with other medicinal products and other forms of interaction

Potential interactions producing elevation of blood pressure

In normotensive healthy volunteers, linezolid enhanced the increases in blood pressure caused by pseudoephedrine and phenylpropanolamine hydrochloride. Co-administration of linezolid with either pseudoephedrine or phenylpropanolamine resulted in mean increases in systolic blood pressure of the order of 30-40 mmHg, compared with 11-15 mmHg increases with linezolid alone, 14-18 mmHg with either pseudoephedrine or phenylpropanolamine alone and 8-11 mmHg with placebo. Similar studies in hypertensive subjects have not been conducted. Concomitant use of linezolid and pseudoephedrine or phenylpropanolamine is, therefore, contraindicated (see section 4.3). Linezolid should not be co-administered with other agents with a vasopressive action, unless concomitant use is essential. It is recommended that doses of directly and indirectly acting sympathomimetic agents (including adrenergic bronchodilators), vasopressive agents (e.g. epinephrine, norepinephrine), dopaminergic agents (e.g. dopamine, dobutamine), pethidine or buspirone, should be carefully titrated to achieve the desired response when co-administered with linezolid.

Potential serotonergic interactions

The potential drug-drug interaction with dextromethorphan was studied in healthy volunteers. Subjects were administered dextromethorphan (two 20 mg doses given 4 hours apart) with or without linezolid. No serotonin syndrome effects (confusion, delirium, restlessness, tremors, blushing, diaphoresis and hyperpyrexia) have been observed in normal subjects receiving linezolid and dextromethorphan.

Post marketing experience: there has been one report of a patient experiencing serotonin syndrome-like effects while taking linezolid and dextromethorphan which resolved on discontinuation of both medications.

During clinical use of linezolid with serotonergic agents, including antidepressants such as selective serotonin reuptake inhibitors (SSRIs), cases of serotonin syndrome have been reported. Therefore,
although linezolid and serotonergic agents, such as serotonin re-uptake inhibitors, tricyclic antidepressants, serotonin 5-HT\textsubscript{1} receptor agonists (triptans), should not usually be co-administered, management of patients for whom treatment with linezolid and serotonergic agents is essential, is described in section 4.4.

**Monoamine oxidase inhibitors**

Linezolid is a reversible, non-selective inhibitor of monoamine oxidase (MAOI). There are very limited data from drug interaction studies and on the safety of linezolid when administered to patients on concomitant medications (e.g. phenelzine, isocarboxazid, selegiline, moclobemide) that might put them at risk from MAO inhibition. Therefore, linezolid is not recommended for use in these circumstances unless close observation and monitoring of the recipient is possible (see section 4.4).

**Use with tyramine-rich foods**

No significant pressor response was observed in subjects receiving both linezolid and less than 100 mg tyramine. This suggests that it is only necessary to avoid ingesting excessive amounts of food and beverages with a high tyramine content (e.g. mature cheese, yeast extracts, undistilled alcoholic beverages and fermented soya bean products such as soy sauce).

**Drugs metabolised by cytochrome P450**

Linezolid is not detectably metabolised by the cytochrome P450 (CYP) enzyme system and it does not inhibit any of the clinically significant human CYP isoforms (1A2, 2C9, 2C19, 2D6, 2E1, 3A4). Similarly, linezolid does not induce P450 isoenzymes in rats. Therefore, no CYP450-induced drug interactions are expected with linezolid.

**Rifampicin**

The effect of rifampicin on the pharmacokinetics of linezolid was studied in sixteen healthy adult male volunteers administered linezolid 600 mg twice daily for 2.5 days with and without rifampicin 600 mg once daily for 8 days. Rifampicin decreased the linezolid C\textsubscript{max} and AUC by a mean 21% [90% CI, 15, 27] and a mean 32% [90% CI, 27, 37], respectively. The mechanism of this interaction and its clinical significance are unknown.

**Warfarin**

When warfarin was added to linezolid therapy at steady-state, there was a 10% reduction in mean maximum INR on co-administration with a 5% reduction in AUC INR. There are insufficient data from patients who have received warfarin and linezolid to assess the clinical significance, if any, of these findings.

### 4.6 Fertility, pregnancy and lactation

**Pregnancy**

There are limited data from the use of linezolid in pregnant women. Studies in animals have shown reproductive toxicity (see section 5.3). A potential risk for humans exists.

Linezolid should not be used during pregnancy unless clearly necessary i.e. only if the potential benefit outweighs the possible risk.

**Breastfeeding**
Linezolid is excreted in human milk. A risk to the suckling child cannot be excluded. Breast-feeding should be discontinued during treatment with Linezolid 600 mg Tablets.

**Fertility**

In animal studies, linezolid caused a reduction in male fertility (see section 5.3). These effects were reversible in adult animals, but did not reverse in juvenile animals treated with linezolid for nearly the entire period of sexual maturation. The effect on fertility in humans is unknown, a risk of reduced fertility cannot be ruled out, specifically with long-term treatment in male adolescents (see section 4.2).

4.7 **Effects on ability to drive and use machines**

Patients should be warned about the potential for dizziness or symptoms of visual impairment (see sections 4.4 and 4.8) while taking linezolid and should be advised not to drive or operate machines if any of these symptoms occur.

4.8 **Undesirable effects**

Of note, the majority of available safety data on linezolid has been generated in patients with other conditions than tuberculosis in studies using higher doses of linezolid with a duration of less than four weeks.

**Adverse events**

The most commonly reported adverse reactions are diarrhoea, headache, nausea and vomiting. About 3% of patients discontinued treatment because they experienced a drug-related adverse event.

The following adverse reactions have been observed and reported during treatment with linezolid with the following frequencies: common (≥1/100 to <1/10); uncommon (≥1/1,000 to <1/100); rare (≥1/10,000 to <1/1,000); very rare (<1/10,000), not known (cannot be estimated from the available data).

<table>
<thead>
<tr>
<th>System Organ Class</th>
<th>Common</th>
<th>Uncommon</th>
<th>Rare</th>
<th>Very Rare</th>
<th>Not known</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Infections and infestations</strong></td>
<td>candidiasis, oral candidiasis, vaginal candidiasis, fungal infections</td>
<td>vaginitis</td>
<td>antibiotic-associated colitis, including pseudomembranous colitis*</td>
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</tr>
<tr>
<td><strong>Blood and the lymphatic system disorders</strong></td>
<td>anaemia†</td>
<td>leukopenia*, neutropenia, thrombocytopenia*, eosinophilia</td>
<td>pancytopenia*</td>
<td></td>
<td>myelosuppression, sideroblastic anaemia†</td>
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<tr>
<td><strong>Immune system disorders</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>anaphylaxis</td>
</tr>
<tr>
<td><strong>Metabolic and nutrition disorders</strong></td>
<td>hyponatraemia</td>
<td></td>
<td></td>
<td></td>
<td>lactic acidosis*</td>
</tr>
<tr>
<td><strong>Psychiatric disorders</strong></td>
<td>insomnia</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nervous system disorders</strong></td>
<td>headache, taste perversion (metallic taste), dizziness</td>
<td>convulsions*, hypoaesthesia, paraesthesia</td>
<td>serotonin syndrome*, peripheral neuropathy*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Organ Class</td>
<td>Common</td>
<td>Uncommon</td>
<td>Rare</td>
<td>Very Rare</td>
<td>Not known</td>
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<tr>
<td><strong>Eye disorders</strong></td>
<td></td>
<td>blurred vision *</td>
<td>changes in visual field (defect) *</td>
<td>optic neuropathy *, optic neuritis *, loss of vision *, changes in visual acuity *, changes in colour vision</td>
<td></td>
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<tr>
<td><strong>Ear and labyrinth disorders</strong></td>
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<td>tinnitus</td>
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<tr>
<td><strong>Cardiac disorders</strong></td>
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<td>arrhythmia (tachycardia)</td>
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<tr>
<td><strong>Gastrointestinal disorders</strong></td>
<td>diarrhoea, nausea, vomiting, localized or general abdominal pain, constipation, dyspepsia</td>
<td>pancreatitis, gastritis, abdominal distention, dry mouth, glossitis, loose stools, stomatitis, tongue discoloration or disorder</td>
<td>superficial tooth discoloration</td>
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<tr>
<td><strong>Hepatobiliary disorders</strong></td>
<td>abnormal liver function test; increased AST, ALT or alkaline phophatase</td>
<td>increased total bilirubin</td>
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<td><strong>Skin and subcutaneous tissue disorders</strong></td>
<td>pruritus, rash</td>
<td>urticaria, dermatitis, diaphoresis</td>
<td></td>
<td>bulous disorders such as those described as Stevens-Johnson syndrome and toxic epidermal necrolysis, angioedema, alopecia</td>
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<tr>
<td><strong>Renal and urinary disorders</strong></td>
<td>increased BUN</td>
<td>renal failure, increased creatinine, polyuria</td>
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<tr>
<td><strong>Reproductive system and breast disorders</strong></td>
<td></td>
<td>vulvovaginal disorder</td>
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<tr>
<td><strong>General disorders and administration site conditions</strong></td>
<td>fever, localized pain</td>
<td>chills, fatigue, increased thirst</td>
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<tr>
<td><strong>investigations</strong></td>
<td>Chemistry Increased LDH, creatine kinase, lipase, amylase or non-fasting glucose. Decreased</td>
<td>Chemistry Increased sodium or calcium. Decreased non fasting glucose. Increased or decreased chloride.</td>
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<tr>
<td>System Organ Class</td>
<td>Common</td>
<td>Uncommon</td>
<td>Rare</td>
<td>Very Rare</td>
<td>Not known</td>
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<td></td>
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<td>total protein, albumin, sodium or calcium. Increased or decreased potassium or bicarbonate.</td>
<td>Haematology</td>
<td>Increased reticulocyte count. Decreased neutrophils.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Haematology</td>
<td>Increased neutrophils or eosinophils. Decreased haemoglobin, haematocrit or red blood cell count. Increased or decreased platelet or white blood cell counts.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* See section 4.4
** See sections 4.3 and 4.4
† See below

The following adverse reactions to linezolid were considered to be serious in rare cases: localised abdominal pain, transient ischaemic attacks and hypertension.

† In controlled clinical trials where linezolid was administered for up to 28 days, 2.0% of the patients reported anaemia. In a compassionate use program of patients with life-threatening infections and underlying co-morbidities, the percentage of patients who developed anaemia when receiving linezolid for ≤ 28 days was 2.5% (33/1326) as compared with 12.3% (53/430) when treated for >28 days. The proportion of cases reporting drug-related serious anaemia and requiring blood transfusion was 9% (3/33) in patients treated for ≤ 28 days and 15% (8/53) in those treated for >28 days.

Paediatric population
Safety data from clinical studies based on more than 500 paediatric patients (from birth to 17 years) do not indicate that the safety profile of linezolid for paediatric patients differs from that for adult patients.

Reporting of suspected adverse reactions
Reporting suspected adverse reactions after authorisation of the medicinal product is important. It allows continued monitoring of the benefit/risk balance of the medicinal product. Healthcare providers are asked to report any suspected adverse reactions to the marketing authorisation holder, or, if available, via the national reporting system.

4.9 Overdose

Symptoms

No cases of overdose have been reported. Signs of toxicity in rats following doses of 3000 mg/kg/day linezolid were decreased activity and ataxia whilst dogs treated with 2000 mg/kg/day experienced vomiting and tremors.
Treatment

No specific antidote is known.

Supportive care is advised together with maintenance of glomerular filtration. Approximately 30% of a linezolid dose is removed during 3 hours of haemodialysis, but no data are available for the removal of linezolid by peritoneal dialysis or haemoperfusion. The two primary metabolites of linezolid are also removed to some extent by haemodialysis.

5. PHARMACOLOGICAL PROPERTIES

5.1 Pharmacodynamic properties

Pharmacotherapeutic group: Other antibacterials, ATC code: J01XX08.

Mode of action

Linezolid is a synthetic, antibacterial agent that belongs to the class of oxazolidinones. It has in vitro activity against aerobic Gram positive bacteria and anaerobic micro-organisms. Linezolid selectively inhibits bacterial protein synthesis by binding to a site on the bacterial ribosome (23S of the 50S subunit) and prevents the formation of a functional 70S initiation complex which is an essential component of the translation process.

The wild-type linezolid MIC distribution for clinical isolates of Mycobacterium Tuberculosis has been reported to range from 0.125 to 0.5 mg/ml, with a suggested epidemiological wild-type cut-off (ECOFF) of 0.5 mg/ml.

PK/PD relationship

In animal studies, the key pharmacodynamic parameter for efficacy was the time for which the linezolid plasma level exceeded the minimum inhibitory concentration (MIC) for the infecting organism. Target values of AUC/MIC ratio >100 and time above MIC >85% for linezolid in the treatment of infections caused by Gram-positive microorganisms in humans have been reported. The target values of these PK/PD indices for M. tuberculosis infection have not been established.

Mechanisms of resistance

Linezolid's mechanism of action differs from those of other antibiotic classes. In vitro studies with clinical isolates (including methicillin-resistant staphylococci, vancomycin-resistant enterococci, and penicillin- and erythromycin-resistant streptococci) indicate that linezolid is usually active against organisms which are resistant to one or more other classes of antimicrobial agents.

As documented with other antibiotics when used in patients with difficult to treat infections and/or for prolonged periods, emergent decreases in susceptibility have been observed with linezolid.

Resistance to linezolid, defined as MIC ≥ 1 µg/mL, ranging from 1.9% to 5.9% in clinical MDR M. tuberculosis isolates has been reported in several studies of over 500 clinical isolates from different geographic locations. Although the exact mechanisms of resistance are not completely known, resistance was found to be related to mutations in the 23S rRNA and mutation T460C in rplC, encoding the 50S ribosomal L3 protein. In addition, data are suggestive of a nonribosomal mechanism of resistance and possible involvement of efflux pumps.

Clinical experience

Limited data are available on the efficacy and safety of linezolid in the treatment of MDR-TB. In a randomized controlled trial in 65 patients with sputum-culture-positive extensively drug-resistant tuberculosis, patients received a 2-year, individually based chemotherapy regimen with or without linezolid (starting dose of 1200 mg/day for a period of 4–6 weeks followed by a dose of 300–600 mg/day). Treatment duration ranged from 6 to 24 months with an average of ~12 months. By 24 months, 78.8% of patients in the linezolid group and 37.6% of patients in the control group had
negative cultures (p<.001). Treatment success rates were 69.7% (23/33) and 34.4% (11/32) in the linezolid group and control group, respectively (p=0.004).

Another randomized controlled trial enrolled 41 patients with sputum-culture-positive extensively drug-resistant tuberculosis who did not respond to any available chemotherapeutic option during the previous 6 months. Patients received linezolid (600 mg/day), immediately or after 2 months in addition to their background regimen. After confirmed sputum-smear conversion or 4 months, patients were randomized to continued 600 mg/day or 300 mg/day linezolid therapy for at least an additional 18 months. By 4 months, 79% (15/19) of the patients in the immediate-start group and 35% (7/20) in the delayed-start group had culture conversion (p=0.001). One year after end of treatment, 71% (27/38) of patients who received linezolid had negative sputum cultures.

A systematic review reported a pooled sputum culture conversion rate of 88.45 % (95 % CI = 83.82–92.38 %) based on 507 patients from 23, mostly observational, studies. Linezolid doses were 300 to 1200 mg/day and treatment duration ranged from 1 to 36 months.

5.2 Pharmacokinetic properties

Absorption and bioavailability

After oral administration, linezolid is rapidly and extensively absorbed. Absolute oral bioavailability of linezolid is complete (approximately 100%) as compared to intravenous administration.

A bioequivalence study was performed, comparing bioavailability of Linezolid 600 mg Tablets with the reference formulation Zykvoxid (linezolid) 600 mg film coated tablets in 32 healthy participants. Following a single dose of Linezolid 600 mg Tablets, mean (SD) linezolid C\textsubscript{max} was 13.8 µg/ml (2.7 µg/ml) and the mean (SD) AUC\textsubscript{0\textendash}inf was 150.0 µg•hour/ml (37.0 µg•hour/ml). Mean (SD) t\textsubscript{max} (h) was 1.99 (1.07).

Steady state conditions are achieved by the second day of dosing. Oral absorption is not significantly affected by food intake.

Distribution

Volume of distribution at steady-state averages at about 40-50 litres in healthy adults and approximates to total body water. Plasma protein binding is about 31% and is not concentration dependent.

Linezolid concentrations have been determined in various fluids from a limited number of subjects in volunteer studies following multiple dosing. The ratio of linezolid in saliva and sweat relative to plasma was 1.2:1.0 and 0.55:1.0, respectively. The ratio for epithelial lining fluid and alveolar cells of the lung was 4.5:1.0 and 0.15:1.0, when measured at steady-state C\textsubscript{max}, respectively. In a small study of subjects with ventricular-peritoneal shunts and essentially non-inflamed meninges, the ratio of linezolid in cerebrospinal fluid to plasma at C\textsubscript{max} was 0.7:1.0 after multiple linezolid dosing.

Biotransformation

Linezolid is primarily metabolised by oxidation of the morpholine ring resulting mainly in the formation of two inactive open-ring carboxylic acid derivatives; the aminoethoxyacetic acid metabolite (PNU-142300) and the hydroxyethyl glycine metabolite (PNU-142586). The hydroxyethyl glycine metabolite (PNU-142586) is the predominant human metabolite and is believed to be formed by a non-enzymatic process. The aminoethoxyacetic acid metabolite (PNU-142300) is less abundant. Other minor, inactive metabolites have been characterised.

Elimination

Linezolid is primarily excreted under steady-state conditions in the urine as PNU-142586 (40%), parent drug (30%) and PNU-142300 (10%). Virtually no parent drug is found in the faeces whilst approximately 6% and 3% of each dose appears as PNU-142586 and PNU-142300, respectively. The elimination half-life of linezolid averages at about 5-7 hours.

Non-renal clearance accounts for approximately 65% of the total clearance of linezolid. A small degree of non-linearity in clearance is observed with increasing doses of linezolid. This appears to be due to lower renal and non-renal clearance at higher linezolid concentrations. However, the difference in clearance is small and is not reflected in the apparent elimination half-life.
Special populations

Renal impairment

Pharmacokinetics are not altered by mild to moderate renal impairment. After single doses of 600 mg, there was a 7-8 fold increase in exposure to the two primary metabolites of linezolid in the plasma of patients with severe renal insufficiency (i.e. creatinine clearance < 30 ml/min). However, there was no increase in AUC of parent drug. Although there is some removal of the major metabolites of linezolid by haemodialysis, metabolite plasma levels after single 600 mg doses were still considerably higher following dialysis than those observed in patients with normal renal function or mild to moderate renal insufficiency.

In 24 patients with severe renal insufficiency, 21 of whom were on regular haemodialysis, peak plasma concentrations of the two major metabolites after several days dosing were about 10 fold those seen in patients with normal renal function. Peak plasma levels of linezolid were not affected.

The clinical significance of these observations has not been established as limited safety data are currently available (see sections 4.2 and 4.4).

Hepatic impairment

Limited data indicate that the pharmacokinetics of linezolid, PNU-142300 and PNU-142586 are not altered in patients with mild to moderate hepatic insufficiency (i.e. Child-Pugh class A or B). The pharmacokinetics of linezolid in patients with severe hepatic insufficiency (i.e. Child-Pugh class C) have not been evaluated. However, as linezolid is metabolised by a non-enzymatic process, impairment of hepatic function would not be expected to significantly alter its metabolism (see sections 4.2 and 4.4).

Paediatric population (< 18 years old)

There are limited data on the safety and efficacy of linezolid in children and adolescents (< 18 years old). Pharmacokinetic studies indicate that after single and multiple doses in children (1 week to 12 years), linezolid clearance (based on kg body weight) was greater in paediatric patients than in adults, but decreased with increasing age.

In children 1 week to 12 years old, administration of 10 mg/kg every 8 hours daily gave exposure approximating to that achieved with 600 mg twice daily in adults.

In adolescents (12 to 17 years old), linezolid pharmacokinetics were similar to that in adults following a 600mg dose. Therefore, adolescents administered 600 mg every 12 hours daily will have similar exposure to that observed in adults receiving the same dosage.

In paediatric patients with ventriculoperitoneal shunts who were administered linezolid 10mg/kg either 12 hourly or 8 hourly, variable cerebrospinal fluid (CSF) linezolid concentrations were observed following either single or multiple dosing of linezolid. Therapeutic concentrations were not consistently achieved or maintained in the CSF.

Elderly

The pharmacokinetics of linezolid are not significantly altered in elderly patients aged 65 and over.
Female patients

Females have a slightly lower volume of distribution than males and the mean clearance is reduced by approximately 20% when corrected for body weight. Plasma concentrations are higher in females and this can partly be attributed to body weight differences. However, because the mean half-life of linezolid is not significantly different in males and females, plasma concentrations in females are not expected to substantially rise above those known to be well tolerated and, therefore, dose adjustments are not required.

5.3 Preclinical safety data

Linezolid decreased fertility and reproductive performance of male rats at exposure levels approximately equal to those in humans. In sexually mature animals these effects were reversible. However, these effects did not reverse in juvenile animals treated with linezolid for nearly the entire period of sexual maturation. Abnormal sperm morphology in testis of adult male rats, and epithelial cell hypertrophy and hyperplasia in the epididymis were noted. Linezolid appeared to affect the maturation of rat spermatozoa. Supplementation of testosterone had no effect on linezolid-mediated fertility effects. Epididymal hypertrophy was not observed in dogs treated for 1 month, although changes in the weights of prostate, testes and epididymis were apparent.

Reproductive toxicity studies in mice and rats showed no evidence of a teratogenic effect at exposure levels 4 times or equivalent, respectively, to those in humans. The same linezolid concentrations caused maternal toxicity in mice and were related to increased embryo death including total litter loss, decreased foetal body weight and an exacerbation of the normal genetic predisposition to sternal variations in the strain of mice. In rats, slight maternal toxicity was noted at exposures lower than clinical exposures. Mild foetal toxicity, manifested as decreased foetal body weights, reduced ossification of sternebrae, reduced pup survival and mild maturational delays were noted. When mated, these same pups showed evidence of a reversible dose-related increase in pre-implantation loss with a corresponding decrease in fertility. In rabbits, reduced foetal body weight occurred only in the presence of maternal toxicity (clinical signs, reduced body weight gain and food consumption) at low exposure levels 0.06 times compared to the expected human exposure based on AUCs. The species is known to be sensitive to the effects of antibiotics.

Linezolid and its metabolites are excreted into the milk of lactating rats and the concentrations observed were higher than those in maternal plasma.

Linezolid produced reversible myelosuppression in rats and dogs.

In rats administered linezolid orally for 6 months, non-reversible, minimal to mild axonal degeneration of sciatic nerves was observed at 80 mg/kg/day; minimal degeneration of the sciatic nerve was also observed in 1 male at this dose level at a 3-month interim necropsy. Minimal to moderate optic nerve degeneration was evident in 2 of 3 male rats after 6 months of dosing, but the direct relationship to drug was equivocal because of the acute nature of the finding and its asymmetrical distribution. The optic nerve degeneration observed was microscopically comparable to spontaneous unilateral optic nerve degeneration reported in aging rats and may be an exacerbation of common background change.

Preclinical data, based on conventional studies of repeated-dose toxicity and genotoxicity, revealed no further special hazard for humans. Carcinogenicity / oncogenicity studies have not been conducted.

6. Pharmaceutical particulars

6.1 List of excipients

Core tablet:
Lactose monohydrate
Maize starch
Hydroxypropyl cellulose  
Sodium starch glycolate  
Magnesium stearate  

Film coat:  
Hypermellose  
Titanium dioxide  
Macrogol  
Carnauba wax  

6.2 Incompatibilities  
Not applicable.  

6.3 Shelf life  
24 months  

6.4 Special precautions for storage  
Store in the original bottle. Do not store above 30°C. Protect from moisture.  

6.5 Nature and contents of container  
HDPE bottle with Child Resistant plastic caps (Outer cap White opaque polypropylene and Inner cap Translucent child resistant plastic cap) with pulp liner. The bottle pack includes a canister containing silica gel desiccant.  
Pack size: 20 tablets and 100 tablets  

Alu-Alu Blister:  
Lidding foil: 0.025 X 139 mm, plain aluminium foil (hard tempered) with 7 GSM HSL coating on bright side.  
Forming foil: Cold form foil 139 mm (60 microns PVC/ 45 microns aluminium foil / 25 microns OPA)  
Pack size: 10 x 10’s Alu-Alu blister  

6.6 Instructions for use and handling and disposal  
No special requirements.  
Any unused medicinal product or waste material should be disposed of in accordance with local requirements.  

7. SUPPLIER  
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Fax: 0091- 40 – 23704035, 23813359
8. **WHO REFERENCE NUMBER (PREQUALIFICATION PROGRAMME)**

TB 299

9. **DATE OF FIRST PREQUALIFICATION**

11 July 2016

10. **DATE OF REVISION OF THE TEXT**

February 2017

Detailed information on this medicinal product is available on the website of the WHO Prequalification Programme [https://extranet.who.int/prequal/](https://extranet.who.int/prequal/)

**Reference list**

This text is primarily based on the SmPC for Zyvox 600 mg Film-Coated Tablets, available at: [http://www.medicines.org.uk/emc/medicine/9857](http://www.medicines.org.uk/emc/medicine/9857)


Further references relevant to sections of the SmPC include:

**Section 5.1**


